FM Approvals®

Member of the FM Global Group

Approval Standard for Foam Extinguishing Systems

Class Number 5130

December 2014

Foreword

The FM Approvals certification mark is intended to verify that the products described will meet FM Approvals' stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of Approval Standards is to present the criteria for FM Approval of various types of products, as guidance for FM Approvals personnel, manufacturers, users and authorities having jurisdiction.

Products submitted for certification by FM Approvals shall demonstrate that they meet the intent of the Approval Standard, and that quality control in manufacturing shall ensure a consistently uniform and reliable product. Approval Standards strive to be performance-oriented. They are intended to facilitate technological development.

For examining equipment, and materials, Approval Standards:

a) must be useful to the ends of property conservation by preventing, limiting or not causing damage under the conditions stated by the Approval listing; and

b) must be readily identifiable.

Continuance of Approval and listing depends on compliance with the Approval Agreement, satisfactory performance in the field, on successful re-examinations of equipment, and materials, as appropriate, and on periodic follow-up audits of the manufacturing facility.

FM Approvals LLC reserves the right in its sole judgment to change or revise its standards, criteria, methods, or procedures.

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1. INTRODUCTION

1.1 Purpose

1.1.1 This standard describes requirements for fixed fire extinguishing systems that use an aqueous foam as the extinguishant.

1.1.2 FM Approvals criteria may include, but are not limited to, performance requirements, marking requirements, examination of manufacturing facilities, audit of quality assurance procedures, and a follow-up program.

1.2 Scope

1.2.1 Foam fire extinguishing systems are classed in three general categories according to foam concentrate type, low, medium, and high expansion. All may be designed for manual or automatic control and are most often used to extinguish Class B fires. At present, FM Global does not specify any applications for medium expansion foam systems, nor for protection of Class A combustibles with high expansion foam systems.

1.2.2 A basic foam extinguishing system comprises a concentrate, a device to proportion the concentrate in the proper ratio into water, and a discharge device to deliver the foam to a burning liquid surface. A discharge device may assume the entire task of expanding the foam, or function primarily to distribute foam which has been partially or completely expanded by an upstream device, such as a foam maker. Compatible FM Approved detectors and detection and release controls are required for automatic operation of these systems, but are not included in the scope of this standard.

1.2.3 This standard requires the examination of complete systems. Complete systems shall be submitted along with design, installation, operation, and maintenance instructions for Approval. However, the manufacturer may, at any time, submit additional separate component parts or auxiliary equipment for use on his system. Purchased devices such as pumps, tanks, control valves, and sprinklers must also be submitted by the system manufacturer for evaluation as a part of his system, even though such devices may already be FM Approved and listed by FM Approvals. At minimum, a system shall consist of those component parts and auxiliary equipment considered necessary by FM Approvals for the system to operate satisfactorily. Incomplete systems shall not be FM Approved.

1.2.4 This standard sets performance requirements for foam extinguishing systems in product categories that are identified by the following class numbers.

Table 1.2.4 Product Categories and Class Numbers

Class	***Product Category***
5130	Extinguishing Systems, Fixed Foam
5133	Foam Water Sprinkler Systems
5135	Low Expansion Foam Systems
5136	Compressed Air Foam (CAF) Systems
5137	High Expansion Foam Systems

1.3 Basis for Requirements

1.3.1 The requirements of this standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions and/or loss control specialists has also been considered.

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of foam fire extinguishing systems (hereinafter referred to as “systems”) for the purpose of obtaining Approval. Systems having characteristics not anticipated by this standard may be FM Approved if performance equal, or superior, to that required by this standard is demonstrated, or if the intent of the standard is met.

Alternatively, systems that meet all of the requirements identified in this standard may not be FM Approved if other conditions which adversely affect performance exist or if the intent of this standard is not met.

1.4 Basis for Approval

Approval is based upon satisfactory evaluation of the product and the manufacturer in the following major areas:

1.4.1 Examination and tests on production samples shall be performed to evaluate

- The suitability of the product
- The performance of the product as specified by the manufacturer and required by FM Approvals; and as far as practical,
- The durability and reliability of the product.

1.4.2 An examination of the facilities and audit of quality control procedures is made to evaluate the manufacturer's ability to produce the product that was examined and tested, and the marking procedures used to identify the product. These examinations are repeated as part of FM Approvals product follow-up program.

1.5 Basis for Continued Approval

Continued Approval is based upon:

- Production or availability of the product as currently FM Approved;
- The continued use of acceptable quality assurance procedures;
- Satisfactory field experience;
- Compliance with the terms stipulated in the Master Agreement;
- Satisfactory re-examination of production samples for continued conformity to requirements;
- Satisfactory Surveillance Audits conducted as part of FM Approvals product follow-up program.

Also, as a condition of retaining Approval, manufacturers may not change a product without prior authorization by FM Approvals.

1.6 Effective Date

The effective date of an Approval standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that standard. Products FM Approved under a previous edition shall comply with the new version by the effective date or forfeit Approval.

The effective date of this standard is 31 December 2015 for full compliance with all requirements.

1.7 System of Units

Units of measurement used in this standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Appendix A lists the selected units and conversions to SI units for measures appearing in this standard. Conversion of U.S. customary units is in accordance with the Institute of Electrical and Electronics Engineers (IEEE)/ American Society for Testing and Materials (ASTM) SI 10 - 2010, *American National Standard for Use of the International System of Units (SI): The Modern Metric System*. Two units (liter and bar), outside of but recognized by SI, are commonly used in international fire protection and are used in this standard.

1.8 Applicable Documents

This standard is used in conjunction with the following standards, test methods, and practices as referenced in this standard:

ASTM B 117 – 11 (2011), *Standard Practice for Operating Salt Spray (Fog) Apparatus*

ASTM D 412, 06ae2 (2013), *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension*

ASTM D 1141 – 98 (2013), *Standard Practice for the Preparation of Substitute Ocean Water*

ASTM D 1331-11 (2011), *Standard Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents*

ASTM D 5798-13a (2013), *Standard Specification for Ethanol Fuel Blends for Automotive Flexible-Fuel Automotive Spark-Ignition Engines*.

ASTM E 729 - 96 (2007), *Standard Guide for Conducting Acute Toxicity Tests on Test Materials with Fishes, Macroinvertebrates, and Amphibians*

FM Approvals, Approval Standard 2000, *Automatic Control Mode Sprinklers for Fire Protection*, March 2006.

FM Approvals, Requirements for Class 3010, *Fire Alarm Systems,* December 2010

FM Approvals, Approval Standard Class 3810, *Electrical and Electronic Test, Measuring, and Process Control Equipment,* January 2005

FM Approvals, Assessment Standard 5138, Assessment Standard for Proportioning Testing, April 2011

FM Global Property Loss Prevention Data Sheet 3-7, *Fire Protection Pumps,* April 2012

FM Global Property Loss Prevention Data Sheet 4-0, *Special Protection Systems*, April 2012

FM Global Property Loss Prevention Data Sheet 4-3N, *Medium- and High-Expansion Foam Systems,* September 2010

FM Global Property Loss Prevention Data Sheet 4-7N, *Low Expansion Foam Systems,* January 2013

FM Global Property Loss Prevention Data Sheet 7-93N, *Aircraft Hangars,* September 2004

FM Global Property Loss Prevention Data Sheet 4-12, *Foam-Water Sprinkler Systems,* January 2013

FM Global Property Loss Prevention Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers,* April 2012

FM Global Property Loss Prevention Data Sheet 7-32, *Ignitable Liquid Operations,* April 2012

IEEE/ASTM SI10 - 2010, *Standard for Use of the International System of Units (SI): The Modern Metric System*.

National Electrical Manufacturers' Association (NEMA) 250 - 2008, Enclosures for Electrical Equipment (1000 Volts Maximum)

National Fire Protection Association (NFPA) 11, *Standard for Low-, Medium-, and High Expansion Foam*, 2010 Edition

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, 2011 Edition

NFPA 20, *Standard for the Installation of Stationary Fire Pumps for Fire Protection,* 2013 Edition

NFPA 72, *National Fire Alarm and Signaling Code*, 2013 Edition

NFPA 409, *Standard on Aircraft Hangars*, 2011 Edition

United States Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances (EPA OPPTS) 850.175, *Fish Acute Toxicity Test, Freshwater and Marine*

US EPA OPPTS 870.1100, *Acute Oral Toxicity*
US EPA OPPTS 870.1200, *Acute Dermal Toxicity*
US EPA OPPTS 870.2400, *Acute Eye Irritation*
US EPA OPPTS 870.2500, *Acute Dermal Irritation*

1.9 Definitions

For purposes of this standard, the following terms shall apply:

Accepted

This term refers to installations acceptable to the authority enforcing the applicable installation rules. When the authority is FM Global, such locations are termed "FM Global Accepted." Acceptance is based upon an overall evaluation of the installation. Factors other than the use of FM Approved equipment impact upon the decision to accept, or not to accept. Acceptance is not a characteristic of a product. It is installation specific. A product accepted for one installation may not be acceptable elsewhere. (Contrast with FM Approved.)

Air-Aspirating Discharge Device

A discharge device which mixes air into a foam solution to create a controlled expansion of the foam at the point of discharge.

Alcohol-Resistant Foam (AR)

A foam produced from a synthetic or protein foam concentrate that resists being dissolved in liquids normally miscible with water, and that can also be used to protect liquids immiscible in water.

Application Rate

The ratio of quantity of foam discharged to the discharge time measured within ± 1 second divided by the area covered by the discharge. When a minimum application rate is indicated, reference is made to the minimum quantity of foam solution discharged and the time measured within ± 1 second per unit area of surface covered. Application rate is expressed in units of gal/min/ft^2 (L/min/m^2, which equals mm/min). The volume used to calculate application rate is that of the foam solution prior to expansion into foam for consistency among foams of different expansion ratios.

Aqueous Film-Forming Foam (AFFF)

A foam produced from a synthetic concentrate and that forms an aqueous vapor barrier film on the surface of liquids immiscible in water, and is measured to have a spreading coefficient greater than zero when tested as described in Section 4.5.

Area of Coverage

The maximum area which can be protected by a foam discharge device, based upon the minimum effective application rate for the hazard, the maximum application rate which will not cause substantial differences in the foam quality from that producing successful extinguishment in tests, and the maximum distance from the application device to the burning surface which will also not significantly effect foam quality.

Around the Pump Proportioner

See Pump Proportioner.

Aspirating High Expansion Foam Generator

A high expansion foam generator in which airflow is induced by the spraying of the concentrate solution.

Automatic Control

A device or arrangement of devices for initiating foam discharge including a panel which monitors fire detectors and releases the agent when pre-established conditions have been met, without requiring human intervention.

Automatic Foam Concentrate Control Valve

A valve controlling the flow of foam concentrate to the proportioner. The valve is automatically actuated by either hydraulic, pneumatic, or electrical power and incorporates means to supervise its position.

Automatic Sprinkler

A discharge device that is actually an FM Approved fire protection sprinkler designed for use with plain water, and that does not aspirate air into the water discharge.

Balanced Pressure Bladder Tank

A foam concentrate supply tank fitted with an internal bladder to separate water from the concentrate. Water pressure on the outside of the bladder pressurizes the concentrate inside and drives it through a modified venturi type Proportioner into the water stream at the Specified rate, based upon the pressure differential created by the venturi.

Balanced Pressure Pump-Type Proportioning

Foam proportioning using a foam concentrate pump and an automatic pressure balancing valve that is operated by water supply pressure and is located in the concentrate bypass line to the pump to balance concentrate and water pressures to a modified venturi-type proportioner.

Blower Type High Expansion Foam Generator

A high expansion foam generator in which airflow is produced by a blower driven by an electric motor, water jet, or turbine, or other device powering the blower's fan blades

CAF

See Compressed Air Foam

CAFS

See Compressed Air Foam System

CAF Nozzle

The discharge device for a CAF system that is designed to distribute the pre-expanded CAF over a specified area with minimal destruction of bubbles.

Calm Air

Wind conditions of 0 – 8.0 miles/hour (0 – 3.6 m/s)

Cannon

See Monitor

Class A Fires

Fires in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics.

Class B Fires

Fires in ignitable liquids, petroleum greases, tars, oils, oil-based paints, solvents, lacquers, alcohols, and flammable gases.

Class C Fires

Fires in which the ignition source is energized electrical equipment.

Compressed Air Foam

Foam produced by combining a low expansion foam solution with compressed air or an inert gas in a mixing device and typically having a very small and uniform bubble size.

Compressed Air Foam System

A foam generation and delivery system that consists of a pressurized air or inert gas source, a source of foam solution (water pump and proportioner), and a means to apply the foam. In a CAF system, the distribution piping carries already expanded foam and the discharge device only distributes the foam without further expansion. CAF systems have unique hydraulic considerations which must be addressed by the manufacturer to ensure delivery of an effective foam to the discharge device. These systems may be pre-engineered or engineered designs.

Concentration

The volume percent of a foam concentrate in water.

Concentration Ratio

See Concentration.

Control

See definition for *Fire Control Time*

Discharge Device

A nozzle or other device that is used to distribute the extinguishing foam uniformly over or into a specific area, within a specific volume, or both.

Discharge Outlet

A discharge device that is permanently affixed to an ignitable liquid containment vessel or other structure to protect a defined hazard.

Discharge Duration

The time interval between the first appearance of foam at the discharge device and the time at which the foam concentrate primary supply is depleted.

Direct Injection Variable Pump Output Proportioning

Proportioning using flowmeters for both concentrate and water supply and a control system to vary foam concentrate pump flow in proportion to water supply flow.

E85

A blend of nominal 85 percent ethanol and 15 percent hydrocarbons and other additives, as defined by ASTM D 5798 and that may contain as much as 30 percent non-ethanol constituents, depending on the volatility class specified for a particular geographical region and season.

E85 Test Fuel

A blend of 70 percent ethanol and 30 percent normal heptane used as a conservative representative test fuel to qualify the fire extinguishment capabilities of foam.

Eductor

A device that uses the Bernoulli pressure reduction caused by the flow of water through a venturi to allow atmospheric pressure to drive foam concentrate into the water stream to produce a mixture of the specified concentration.

Engineered System

A fire extinguishing system design in which friction loss of piping, nozzles, and other components, and an analysis of the piping configuration, are used in hydraulic calculations to predict flows and pressures at individual nozzles.

Expansion Ratio

The ratio of the volume of expanded foam to that of the same weight of the foam solution.

Film-Forming Fluoroprotein Foam (FFFP)

A foam produced from a fluoroprotein concentrate that includes a fluorinated surfactant to form a vapor barrier film on the surface of liquids immiscible in water.

Fire Control Time

Fire Control time is the elapsed time from the beginning of foam application until the average radiative heat flux levels, 1 ½ pool widths from the pool center measured in the crosswind direction, have reached 10 percent of the initial steady-state uncontrolled values

Fluoroprotein Foam

A foam similar to protein foam, but which also includes a fluorinated surfactant.

FM Approvals Certification Mark

The FM Approvals Certification Marks are detailed in Appendix B. Their use is mandatory on all units of FM Approved products. These registered marks cannot be used except as authorized by FM Approvals via the granting of Approval to a specific product.

FM Approved

This term refers to products FM Approved by FM Approvals. Such products are listed in the Approval Guide, an on-line resource of FM Approvals. All products so listed have been successfully examined by FM Approvals, and their manufacturers have signed and returned a Master Agreement to FM Approvals. This agreement obligates the manufacturer to allow re-examination of the product and audit of facilities and procedures at the discretion of FM Approvals. It further requires the manufacturer not to deviate from the as FM Approved configuration of the product without review by and agreement of FM Approvals. Approval is manufacturing site and product specific.

Foam

A stable aggregation of bubbles produced from an aqueous solution of foam concentrate that has a sufficiently low density and sufficient fluidity to allow it to float on top of and form a blanket on the surface of a liquid being protected.

Foam Chamber

A Type I or II discharge outlet normally installed along the perimeter of an ignitable liquid storage vessel or containment structure to ensure delivery of foam to the contents, when required.

Foam Concentrate

A concentrated aqueous liquid formulated to produce firefighting foam when mixed in the proper concentration with water and in which air can be entrained to reach the specified Expansion Ratio.

Foam Generator

A device used with high expansion foam concentrates to produce foam by spraying the concentrate solution onto a screen and forcing air through the screen.

Foam Maker

A device that generates foam and that is intended to be installed between the supply piping of foam solution and piping leading to discharge outlets.

Foam-Water Sprinkler

A discharge device that is an air-aspirating, usually-open fire protection sprinkler designed to create foam, as well as providing effective water discharge upon depletion of the foam concentrate supply.

Foam-Water Sprinkler System

A modified sprinkler system that is pipe connected to a source of foam concentrate and to a water supply. The system is equipped with appropriate discharge devices for foam-water solution discharge and for distribution over the area to be protected. Upon opening of the water control valve, water flows through the piping system and foam concentrate is proportioned and injected into the water, and the resulting solution discharges through devices that generate and distribute the foam. Upon exhaustion of the foam concentrate supply, water continues to discharge until shut off manually. These systems can be of wet pipe, dry pipe, deluge, or preaction designs, paralleling the design and using most of the components of the equivalent water-only sprinkler systems. They differ primarily in the addition of foam concentrate proportioning equipment or pre-priming of the sprinkler piping with foam-water solution. The introduction of the foam concentrate may be controlled by a detection system and can precede or follow the water-only discharge.

Foam Solution

A solution of foam concentrate in water that is named by the concentrate's name and the specified concentration.

High Expansion Foam

A foam that is produced in foam generators and has an expansion ratio greater than 200:1.

Ignitable Liquid

For the purposes of this standard, an ignitable liquid is simply a liquid that will burn. While some other organizations use different terms to identify liquids that burn, we believe that our approach is consistent with the hazard that is created by these liquids. Liquids that burn create challenging fire hazards and those hazards are not defined by the closed cup flash point of the liquid. The hazard is driven by the simple fact that the liquid burns (i.e., has a fire point).

Inductor

See Eductor.

In-Line Balanced Pressure Proportioning

Balanced foam proportioning using a concentrate pressure which is greater than the water supply working pressure under all operating conditions. Automatic pressure balancing valves operated by the water supply pressure to the proportioner are used to regulate the concentrate pressure individually to each proportioner. Concentrate pressure may be created by either a bladder tank or a concentrate pump.

Inline Eductor

An eductor that is installed upstream of the discharge device and which uses a foam concentrate supply at atmospheric pressure.

Local Application System

A fire extinguishing system designed to protect a defined area by the direct discharge of foam onto burning materials.

Lock-Out Valve

A lockable manually operated valve which can be used to isolate the foam supply from the rest of the system during maintenance and service.

Low Expansion Foam

A foam having an expansion ratio less than 20:1 and that may be produced by various devices.

Manual Control

A device or arrangement of devices for initiating system discharge that requires action by a human to release the agent.

Maximum Working Pressure

The pressure in a foam extinguishing system at the maximum available pressure of the water and foam concentrate supplies.

Minimum Working Pressure

The pressure in a foam extinguishing system below which it will not produce foam of acceptable quality.

Mixture Strength or Ratio

See Concentration.

Monitor

A fixed or portable device that is mounted on a supporting structure and delivers a large foam stream from a nozzle that may be aimed over a variety of vertical and horizontal angles.

Non-Air-Aspirating Discharge Device

A discharge device, such as a fire protection sprinkler, which delivers unexpanded foam concentrate solution to the hazard and relies on subsequent turbulence to entrain the air required for expansion.

Nozzle

A discharge device that may be either hand held or mounted on a monitor, is designed to expand the foam solution, and is capable of directing a stream of foam into a narrow targeted area.

Operable Pressure Range

The pressure range corresponding to the pressures in the water supply at the specified minimum and maximum flow rates at which the system is intended to be operable.

Operating Pressure

See Working Pressure.

Oscillating Monitor

A monitor that can be set to move the direction of its stream automatically and continuously over a range of horizontal angles by means of a water pressure driven or electrically powered device.

Polar Solvent

An ignitable liquid such as an alcohol or ketone that is miscible in water and that tends to dissolve foams and thereby reduce their fire extinguishing effectiveness.

Pre-Engineered System

A fire extinguishing system design in which a predetermined range of piping and nozzle characteristics and configurations are used to predict individual nozzle flow rates.

Premixed Foam Solution

A foam solution produced by introducing a measured amount of foam concentrate into a known amount of water in a storage vessel.

Pressure Proportioning Tank

A bladderless foam concentrate supply tank that uses water flow through a port located high in the tank to displace the concentrate in the tank through a low mounted port with an orifice. Since buoyancy is the only mechanism separating the concentrate from the water, this method is only suitable for concentrates with a minimum specific gravity of 1.15. The concentrate orifice controls its flow rate into the water stream to approximate the specified concentration in the combined stream.

Proportioner

A device similar in function to an inline eductor, except that it uses a foam concentrate supply at a pressure higher than atmospheric.

Proportioning

The continuous introduction of foam concentrate at the specified ratio into the water stream to form foam solution.

Protein Foam

A foam produced from concentrate consisting primarily of products from a protein hydrolysate, plus stabilizing additives and inhibitors to protect against freezing, to prevent corrosion of equipment and containers, to resist bacterial decomposition, to control viscosity, and to otherwise ensure readiness for use.

Proportioning Testing Service Provider

A commercial entity that has been successfully evaluated for competency to test installed foam systems using the test liquid or water equivalency proportioning methods.

Pump Proportioner

A system using a venturi eductor installed in a bypass line between the discharge and suction lines of a water supply pump and suitable orifices or a metering valve to control the amount of concentrate supplied in proportion to pump discharge (system water supply) pressure.

Salt Water

Manufactured artificial sea water, as defined by ASTM D 1141 – 98 (2013), *Standard Practice for the Preparation of Substitute Ocean Water*

Self-Educting Nozzle

A nozzle that includes a venturi to draw foam concentrate into the water stream through a short length of flexible tubing connected to a supply container, effectively incorporating a nozzle and an eductor in one device.

Semisubsurface Foam Injection

Discharge of foam at the liquid surface within an ignitable liquid storage tank from a floating hose that rises from a piped connector near the tank bottom upon system actuation.

Specified

The value of a design parameter set by the manufacturer.

Spray Nozzle

A discharge device that may be an open automatic sprinkler or specially designed nozzle attached to fixed piping and discharges water or foam in a fixed spray pattern.

Subsurface Foam Injection

Discharge of foam from an outlet near the bottom of an ignitable liquid storage tank. The foam then rises to the liquid surface due to buoyancy.

Synthetic Foam

A foam produced from concentrate consisting of foaming agents other than hydrolyzed protein.

Synthetic Seawater

See Salt Water.

System Water Supply

In most cases, the water flow and pressure available to the foam system after the point of foam concentrate introduction. For systems using a premixed foam solution it is the flow and pressure available at the connection to the discharge piping, downstream of any pump or other pressure source.

Test Liquid

A non-foaming liquid that replicates the viscosity, specific gravity, and other relevant properties of the actual foam concentrate used in a system and that is used to test the accuracy of proportioners and similar devices in an installed system.

Test Liquid Proportioning Testing

A method of evaluating the proportioning accuracy of an installed foam fire extinguishing system using a test liquid in lieu of the concentrate to minimize the difficulties in disposing of the required discharge in the annual retesting of a foam system.

Topside Discharge Device

A discharge device such as a foam chamber that applies foam to the surface of a burning liquid from above.

Total Flooding System

A high expansion foam extinguishing system designed to protect an enclosed hazard area by discharging foam to reach and maintain a minimum level 1.1 times the maximum height of or 2 ft (0.61 m) above all protected contents, whichever is greater, throughout the enclosed area sufficiently quickly and of sufficient duration to extinguish a fire. For a given foam, parameters of required depth of submergence, discharge rate, and duration must be determined by test because they are dependent upon the construction of the building, the nature of the contents, and the storage configuration.

Type I Discharge Outlet

A discharge outlet designed to deliver the extinguishing foam gently onto a liquid surface with no submergence or agitation.

Type II Discharge Outlet

A discharge outlet designed to deliver the extinguishing foam onto a liquid surface with minimal submergence or agitation.

Type III Discharge Outlet

A discharge outlet designed to deliver the extinguishing foam onto a liquid surface with significant submergence or agitation.

Vapor Seal

Frangible component designed to prevent tank contents vapors from entering the atmosphere through the foam chamber while allowing foam to flow into the tank during system operation.

Water Equivalency Proportioning Testing

A method of evaluating the proportioning accuracy of an installed foam fire extinguishing system using water in lieu of the concentrate to minimize the difficulties in disposing of the required discharge in the annual retesting of a foam system.

Wood Crib

A square stack of alternate layers of kiln-dried spruce or fir in nominal 2x4 inch trade size and equal lengths placed at right angles to the preceding layer and spaced to allow air flow between the members. Each layer consists of the same number of evenly spaced members placed on edge, except for the top layer, which has fewer evenly spaced members placed on their sides. The outer members of all layers are placed flush with the ends of the members of the adjacent layers. All members are carefully nailed in place to avoid splitting the wood. Wood cribs are a standard test fuel for Class A fire tests. For the purposes of this standard, the high expansion foam Class A fire extinguishment test wood crib shall consist of members 87.125 in. (2213 mm) long arranged in 10 layers of 21 on edge, with a top layer of 14 on side.

Working Pressure

The water supply pressure to a foam extinguishing system at a condition of zero flow.

2. GENERAL INFORMATION

2.1 Approval Application Requirements

To apply for an Approval examination the manufacturer, or its authorized representative, should submit a request to:

Manager of Fire Protection
FM Approvals, Hydraulics Laboratory
743A Reynolds Road
West Glocester, RI 02814 U.S.A.

The manufacturer shall provide the following preliminary information with any request for Approval consideration:

- A complete list of all models, types, sizes, and options for the products being submitted for Approval consideration;
- Assembly drawings, component drawings, materials list, anticipated marking format, nameplate format, brochures, sales literature, specification sheets, installation, operation and maintenance procedures;
- The number and location of manufacturing facilities;
- All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level; and
- All documents shall be provided with English translation.

2.2 Requirements for Samples for Examination

2.2.1 Following authorization of an Approval examination, the manufacturer shall submit samples for examination and testing based on a determination by FM Approvals following review of the preliminary information.

2.2.2 Requirements for samples may vary depending on design features, results of prior or similar testing, and results of any foregoing tests.

2.2.3 The manufacturer shall submit samples representative of production. Any decision to use data generated utilizing prototypes is at the discretion of FM Approvals.

2.2.4 It is the manufacturer's responsibility to either provide or have available for witness testing at their facility any necessary test fixtures, such as those that may be required to evaluate the system.

3. GENERAL REQUIREMENTS

3.1 Review of Documentation

During the initial investigation and prior to physical testing, the manufacturer's specifications and details shall be reviewed to assess the ease and practicality of installation and use. The Approval test program requirements shall define the limits of the Approval investigation.

3.2 Physical or Structural Construction Features

3.2.1 Components versus Systems

Foam concentrates are the central component of foam extinguishing systems. Approval of a system is based upon its ability to proportion a concentrate accurately into water and to produce and deliver a foam from the resulting foam solution, the quality of which is within the limits of expansion ratio and 25 percent drainage time of foams demonstrating successful performance in fire extinguishing tests. Foam concentrate fire extinguishing performance shall be tested for each concentrate at all concentration ratios specified by the manufacturer. These tests shall be conducted at the minimum specified application rate and on heptane fires to qualify for general hydrocarbon liquid protection, as well as on any specific polar solvent liquids specified by the manufacturer. Further, unless the manufacturer specifies that a concentrate is suitable for use with fresh water only, then extinguishment tests shall be performed with foam produced from both salt and fresh water.

Foam concentrate component FM Approvals are granted only for use in FM Approved foam extinguishing systems that have been performance tested specifically with that concentrate. FM Approvals for systems using FM Approved concentrates are granted separately, subsequent to the component Approval of the concentrate. Component FM Approved concentrates need only be listed separately from the systems with which they are FM Approved if the concentrate and system manufacturer are different corporate entities, or if the concentrate manufacturer so specifically requests.

Foam concentrates shall only be FM Approved at the nominal concentration ratio(s) at which they are fire tested.

Similarly, mechanical components for foam systems shall only be component FM Approved for use in FM Approved systems with which they have been performance tested.

Systems shall only be listed for use with concentrates and at concentration ratio(s) with which they were fire tested.

The manufacturer of a system to be FM Approved must have effective control over the configuration and manufacture of the components and the formulation of the concentrate to be included to ensure that all systems produced under the Approval will offer essentially the same performance as that originally tested.

This can be accomplished in two ways:

1. The manufacturer can be the manufacturer of all components and the concentrate and demonstrate effective quality control, or the manufacturer can enter into written agreements with component or concentrate manufacturers to control the designs and formulations per the Master Agreement, and FM Approvals shall be permitted to periodically audit this “outside” manufacturer (either on behalf of the manufacturer or as a result of component listing of the outsourced items), or

2. The manufacturer can demonstrate sufficient quality control of the critical characteristics of the outsourced components as to ensure system performance. Generally, this will include a minimum of some performance testing. System configuration and application shall be prescribed by appropriate design, installation, and operation information to be provided by the manufacturer. FM Approvals will review such

information to verify completeness and conformance to FM Global loss prevention recommendations and the limits of the Approval to be granted.

A first Audit shall be conducted at each manufacturing site for the concentrate and system components.

3.2.2 Operating Range

All system components shall operate within the temperature ranges of 35 F to 120 F (1.7 C to 49 C). If the manufacturer specifies a lower minimum or higher maximum installation temperature, system and component evaluations will be based upon the resulting greater range.

3.2.3 Materials

3.2.3.1 All components shall be made of corrosion resistant materials suitable for their intended use.

3.2.3.2 Elastomeric Components – Elastomeric components used in the system shall be compatible with the concentrate. Compatibility shall be determined by successful performance at maximum and minimum installation temperatures while exposed to the agent. At minimum, tensile strength, ultimate elongation, and hardness of samples of un-reinforced materials shall not be changed by more than 15 percent from new condition by a 60 day exposure to the agent at the maximum storage temperature.

3.2.4 Control

3.2.4.1 For normal operation, a system shall be either automatically controlled or operable from a manual control that is easily accessible to the hazard, or both. If the normal manual means of actuation utilizes electric power, the source of that power shall be completely independent of any electric power source used for automatic operation. Alternatively, a power source used for both normal manual and automatic operation shall be provided with an independent back-up, such as a battery. Whether normally operated automatically or manually, all systems shall also be provided with an alternate means of fully mechanical manual emergency control. Fully mechanical manual emergency controls shall not require an electric power source but may make use of water supply pressure to operate the release. These emergency controls shall be located at or near the device being controlled.

3.2.4.2 Control panels shall comply with NFPA Standard 72, *National Fire Alarm Code,* and FM Approvals requirements for Classes 3010, *Fire Alarm Systems*, Classes 1321 and 1323, *Controllers for Electric Motor Driven and Diesel Engine Driven Fire Pumps* and 3810, *Electrical and Electronic Test, Measuring, and Process Control Equipment.* Control panels need not be submitted as a part of a system. However, system design shall be such that the system is operable by at least one FM Approved detection and release panel.

3.2.5 Strength

All component parts subject to full system operating pressure shall be designed for a minimum working pressure of 175 psi (12 bar). Components protected from exposure to full system operating pressure by a pressure relief device may be designed for the reduced pressure, subject to satisfactory evaluation of the protection device or system.

3.2.6 Pressure Vessels

Bladder tanks and other pressurized containers shall conform to the appropriate regulations for the installation location. In the U.S.A., DOT regulations are appropriate for cylinders which are shipped pressurized and the ASME unfired pressure vessel code for cylinders filled after installation. The following documents shall be submitted for each diameter of each cylinder design to demonstrate compliance with the relevant design standard:

- Calculation of wall thicknesses per the method specified in the standard, with appropriate supporting references, as necessary.
- Certificate of chemical analysis of materials.
- Certificate of physical properties of materials.

3.2.7 Valves

The pressure versus rate of flow through system valves shall be measured to allow accurate calculations for system design. Automatic concentrate control valves, water supply valves, and water alarm check valves shall be equipped with electrical supervision of operating position to allow remote monitoring and annunciation and a position indicator. Additionally automatic concentrate control valves must be equipped with an emergency manual operator, and a strainer in the actuation line and means to flush that line, if hydraulically operated. All automatic concentrate control valves shall be provided with a local manual reset. All valves equipped with electrical supervision shall be provided with a minimum NEMA Type 1 or IP-10 housing or enclosure if electrically operated by a solenoid. Automatic valve actuators shall be provided with tamper resistant construction to restrict access to components and protection to vents or orifices to prevent tampering or clogging that would render the valve inoperable.

3.2.8 Manifolds and Piping

Manifolds of proprietary designs used in place of standard pipe and fittings shall have minimum internal cross sectional areas no less than that of their corresponding pipe sizes. All foam concentrate and foam solution pipe shall be designed and installed in accordance with the piping section of NFPA 11 and/or FM Global Property Loss Prevention Data Sheet 4-12, Foam-Water Sprinkler Systems.

3.2.9 Protective Covering

All valves and control devices with exterior movable parts that are vulnerable to obstruction or physical damage shall be protected by paneled enclosures or cages. This requirement shall not apply to levers, pushbuttons, and other operators requiring manual access for their function to the extent necessary to provide such access. Conduit shall be used for cables, tubing, or wires outside the enclosures. Heat detection tubing, in the areas being monitored by the tubing, shall not be installed in conduits, but shall be routed and supported in such a manner as to protect it from mechanical damage.

3.2.10 Discharge Devices

Discharge devices shall be evaluated for the intended use, including flow characteristics and area of coverage. Nozzles and other discharge devices shall he made of corrosion resistant materials that will not be deformed or otherwise be damaged by fire exposure. Fire exposure resistance shall not be required for hand-held devices or other components normally located outside of the fire area.

3.2.11 Auxiliary Equipment

Auxiliary equipment includes those devices required in a system to protect against a specific hazard. The need for these devices shall be determined by FM Approvals according to the nature of the hazard. Some of the devices listed below or others may be required for the system to earn Approval for specific applications.

3.2.11.1 Pressure Operated Switches

Pressure operated switches may be used to shut down fans, conveyors, or other electrical equipment in the protected area, and activate alarm and indicator circuits. These switches shall operate at a maximum water supply pressure of 50 psi (3.5 bar) and not release water from the system. They may have a means for alternate, manual control and shall be designed for manual resetting only.

3.2.11.2 Alarms

Alarms and/or indicators shall be provided to show that the system is operating, warn personnel of the forthcoming discharge of foam and signal the failure of any supervised equipment. Indicators which show that the system has been used and must be serviced shall operate upon actuation of the system and require manual resetting.

3.2.12 High Expansion System Configuration Requirements

3.2.12.1 Pressure Operated Release

A pressure operated release shall be provided on all doors, windows, and other openings below the intended flooding level in the protected hazard area. The release shall operate at a maximum pressure of 50 psi (3.5 bar) system water pressure. The release shall not permit the escape of water from the system. It shall automatically reset and may have a control for manual operation.

3.2.12.2 Time Delays

A delay device shall be installed on systems when safety dictates the evacuation of personnel from the hazard area. This device may either delay the operation of the system, or delay the discharge of foam after the system has been actuated. In the first arrangement, the actual discharge shall be manually controlled. A manual override shall be provided in the second arrangement to allow instant discharge.

3.2.12.3 Automatic Venting

High expansion foam systems shall use air from outside the protected space for foam generation. Air must be vented from the protected space at the same rate of flow to allow the foam generators to operate at their specified capacities. Air intake and venting devices for air movement into the foam generators and out of the protected volume shall be automatically operated at system actuation and protected from mechanical damage, corrosion, and freezing.

3.2.12.4 Watertight Electrical Equipment

Electrical equipment below the design level of flooding shall be designed for submerged operation to eliminate the risks of short circuiting of controls and shocking to personnel.

3.2.13 High Expansion Foam Stability under Sprinkler Discharge

Foam breakdown testing shall be conducted with the full range of foam concentrates, concentrations, and application rates submitted for Approval to determine the breakdown coefficient. Tests shall be conducted as described in Section 4.10, *High Expansion Foam Breakdown Due to Sprinkler Discharge*.

3.2.14 Foam Concentrates

3.2.14.1 Environmental Considerations

Foam concentrates shall not be considered for Approval if they contain materials regulated by the U.S. Environmental Protection Agency (EPA) or equivalent local authorities, except within the permitted usages of those materials. The foam concentrate industry has committed itself to a voluntary stewardship program to eliminate the use of fluorosurfactants of orders of C8 or higher (greater than eight-carbon chain molecules). In support of this effort, FM Approvals will not consider foam concentrates violating this constraint for Approval.

3.2.14.2 Foam Concentrate Piping

Manufacturers of FM Approved Foam Extinguishing Systems shall specify that the Approval of their Foam Extinguishing System is contingent upon piping designed and installed in accordance with NFPA 11 and/or FM Global Property Loss Prevention Data Sheet 4-12, Foam-Water Sprinkler Systems.

3.2.14.3 Foam Concentrate Viscosity

Foam Concentrate manufacturers seeking Approval as part of an FM Approved Foam Extinguishing System shall publish the nominal viscosity of the concentrate along with the method utilized for determining the viscosity; normally the spindle number used and the spindle RPM. The viscosity shall be stated at the standard temperature of 77 F (25 C) and at the minimum use temperature specified by the manufacturer.

Manufacturers shall also publish a viscosity range that will be considered acceptable by the manufacturer when samples of concentrate are sent to the manufacturer or qualified laboratory for quality condition testing. At the discretion of FM Approvals, examinations may be specified in accordance with Section 4 for concentrates at the limits of this viscosity range.

3.2.15 Proportioners

3.2.15.1 Required Literature

Manufacturers of proportioners as part of an FM Approved Foam Extinguishing System shall publish the following information (at minimum):

- Nominal pipe size corresponding to each proportioner model designation
- Concentrate(s) that have been specifically tested and FM Approved for use with each proportioner
- In the case of foam concentrate pump proportioners driven by a water motor; concentrate viscosity ranges that have been specifically tested and FM Approved for use with the subject proportioner
- Minimum inlet pressure associated with Approval and specific concentrate(s)
- Maximum inlet pressure associated with Approval and specific concentrate(s)
- Inlet Pressure vs. Foam Solution Flow representation throughout FM Approved ranges
- Friction Loss vs. Foam Solution Flow representation throughout FM Approved ranges
- Description of test and installation criteria in accordance with FM Global Property Loss Prevention Datasheet 4-12 with the minimum as follows:
    - Provide a length of either (a) a minimum of five pipe diameters, or (b) the manufacturer’s recommended amount of straight, unobstructed pipe on the inlet and discharge side of the proportioner.
- For proportioners with moving parts specifically designed to operate over wide flow ranges, manufacturers must state piping configuration limitations:

- In the case where proportioners with moving parts are specified in installations where there are one or more downstream pipes of smaller pipe diameter than the proportioner nominal pipe diameter; manufacturers must state the minimum straight pipe length between the proportioner and the reduction or tee. Manufacturers must also make it known in product literature that utilizing this style of proportioner in the described configuration could lead to a condition where the time necessary to achieve the nominal proportioning ratio at low flow rates may be influenced by the large volume of water required to be evacuated in the proportioner nominal diameter piping on the inlet and discharge side of the proportioner.

3.2.15.2 Proportioners for use with Dry Systems

Proportioner components used in dry valve configurations shall include special procedures addressing flushing of foam concentrate after inspection and operations. In addition, examinations by FM Approvals may be administered to proportioning system components used in dry systems.

3.2.16 Foam Chambers and Foam Makers

3.2.16.1 Tank Penetration

Manufacturers of Foam Chambers and Foam Makers consisting of an outlet leading to a tank penetration shall define acceptable methods for connecting the Foam Chamber or Foam Maker to the deflector or pourer on the inside of the tank.

3.2.16.2 External Tank Protection

Manufacturers of Foam Makers consisting of an outlet leading to a dike shall define acceptable methods for mounting the Foam Maker to the deflector or pourer on the side of the dike.

3.2.16.3 High Back Pressure Devices

Foam Makers may not be Approved for use with “high back pressure” configurations unless explicitly tested and FM Approved for the maximum rated back pressure.

3.3 Markings

3.3.1 A conspicuously mounted nameplate shall be affixed to the proportioning device or the main concentrate supply container, or a combination of both, and shall display the following markings, at minimum. Any additional markings required by the authority having jurisdiction shall also be provided.

- Manufacturer's name and address
- System type
- The FM Approvals Certification mark
- Concentrate identification
- Specified concentration ratio
- Allowable ambient storage temperature range
- Year of manufacture
- Location of manufacture if different from manufacturer’s address
- Reference to NFPA 11, *Standard for Low-, Medium-, and High Expansion Foam*, or other relevant local standard and the manufacturer’s design, installation, operation, and maintenance instructions.
- Volume of main and back-up concentrate supplies
- Inspection requirements

3.3.2 Combination instruction and identification plates shall be mounted on or next to all control devices. All significant component parts or assemblies shall also bear an identification mark, such as a part, catalog, or pattern number.

3.3.3 Discharge devices shall be marked with a model or other identifying number to allow determination of capacity, throw, and other information required to verify appropriateness for the application.

3.3.4 Proportioning devices and foam generators shall be marked with a model or other identifying number to allow determination of capacity, and other information required to verify appropriateness for the application.

3.3.5 Valves, proportioners, and other devices requiring installation providing the correct direction of flow for proper operation shall be marked with the specified flow direction.

3.3.6 Proportioners shall be marked with the orifice size or other configuration details, as required by the design to set the specified proportioning ratio for the installation.

3.3.7 All marking plates shall be made of materials which will not corrode or otherwise become illegible from the action of system liquids or vapors, or normal, local conditions. All markings shall be legible and durable.

3.3.8 When hazard warnings are needed, the markings should be universally recognizable.

3.3.9 The model or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the product as FM Approved. The manufacturer shall not place this model or type identification on any other product unless covered by a separate agreement.

3.3.10 The FM Approvals Certification Mark (see Appendix B) shall be displayed visibly and permanently on the product and/or packaging as appropriate. The manufacturer shall not use this Mark on any other product unless such product is covered by separate agreement with FM Approvals.

3.3.11 Foam Concentrates that complete successful examination as part of an FM Approved Foam Extinguishing System may be marked with the FM Approvals Certification Mark in accordance with Appendix B. However the marking must be accompanied by a statement indicating that: “This concentrate is only FM Approved in conjunction with the specific proportioning and discharge devices as shown in the Approval Guide (www.ApprovalGuide.com)”

3.4 Manufacturer's Installation and Operation Instructions

3.4.1 The manufacturer shall provide complete instructions and any assistance required to properly design, install, operate, and maintain the system for acceptance and annual retesting of a foam system. These instructions shall be submitted to FM Approvals as a prerequisite to the examination of a system. Further direction for the construction of a complete Design, Installation, Operation, and Maintenance Manual can be found in Section 5.6, *Design, Installation, Operation, and Maintenance Manual*. Alternate proportioning test methods are to be assessed in accordance with FM Approvals' Assessment Standard 5138, Proportioning Testing Assessment, April 2011.

3.4.2 Design requirements for FM Approved systems are contained in NFPA 11, *Standard for Low-, Medium-, and High Expansion Foam*, and in other standards required by the authority having jurisdiction (AHJ) in the intended market(s) for the system. The manufacturer’s design instructions for a system submitted for Approval shall be evaluated based upon FM Global requirements and the relevant standard(s) recognized by the AHJ(s) for the manufacturer’s specified market(s).

3.5 Calibration

All equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage of the equipment. For testing conducted at locations other than FM Approvals, a copy of the calibration certificate for each piece of test equipment is required for FM Approvals' records that indicate that the calibration was performed to standards traceable to the National Institute of Standards and Technology (NIST) or to other acceptable reference standards by an accredited ISO 17025 calibration laboratory. The test equipment must be clearly identified by label or sticker showing the last date of the calibration and the next due date. In addition, a copy of the ISO 17025 accreditation certificate for the calibration laboratory is required for FM Approvals records.

The calibration of recently purchased new equipment is also required. Documentation indicating either the date of purchase or date of shipment, equipment description, model and serial number is required for identification. The period from the time the equipment was put into service to the date of testing must be within an interval that does not require the equipment to be calibrated as determined on the basis of the parameters mentioned above.

4. PERFORMANCE REQUIREMENTS

4.1 Low Expansion Foam Concentrate Extinguishing Performance

4.1.1 Requirement

Low expansion foam concentrates shall demonstrate extinguishing performance in Class B fire tests. Fires shall be extinguished by the end of the allowable discharge time and shall not reignite during the post extinguishment observation period.

4.1.2 Tests/Verification

4.1.2.1 The fire test, see Figure D-2, pan shall be square and fabricated of steel with a minimum thickness of 1/4 in. (4.8 mm). The inside dimensions shall be 85 in. (2.16 m) square by a minimum of 12 in. (305 mm) deep. All surfaces shall meet at 90º angles and shall be joined by continuous, liquid tight welds. The upper edge of the pan shall be reinforced by an externally attached 1-1/2 in. (38 mm) steel angle of 1/4 in. (4.8 mm) minimum thickness. The angle shall be attached to the pan by continuously welding its outside corner to the top edge of the pan, so that the upper surface of one leg of the angle is flush with the top of the pan and the other leg of the angle is tight against the outside wall of the pan. The lower leg of the angle shall be attached to the pan by approximately 1/2 in. (12 mm) long tack welds spaced approximately every 2 in. (50 mm). The pan may be fitted with a drain connection and lifting lugs below the reinforcing angle, if desired. Other, equivalent construction shall be allowed, provided that minimum section thicknesses are met or exceeded.

4.1.2.2 The fire test shall be conducted with the pan resting on a flat surface or elevated no more than a 12 in. (305 mm) above that surface.

4.1.2.3 At minimum, the concentrate shall be tested with normal heptane for the test fuel. After the pan has been leveled, heptane shall be added to a minimum depth of 2 in. (50 mm). Then water shall be added to raise the heptane level to provide a minimum freeboard of 8 in. (203 mm). Additional freeboard shall be allowed as necessary if high application rates and/or highly expanded foam would cause foam to flow over the top of the pan. If extinguishing capability with other class B fuels is to be FM Approved, tests using those fuels shall also be conducted. For water-miscible fuels, water cannot be used to adjust the fuel level in the pan. Therefore, a shallower pan may be used if the manufacturer does not wish to test with a freeboard greater than 8 in. (203 mm).

4.1.2.4 Tests shall be conducted under conditions of calm air, no precipitation, premix and fuel temperatures between 50 F and 90 F (10 C and 32 C).

4.1.2.5 Foam solution shall be prepared by mixing the specified amount of concentrate with water, either in a premixed solution or continuously by use of suitable proportioning equipment. Volume measuring, weighing, or flow measuring equipment shall be of sufficient accuracy to assure that concentration is within ± 5 percent of the specified value. If conductivity measurements are to be used as a proxy for direct measurements of volume, weight, or flow to determine concentration, the procedure of Appendix G shall be used to validate the correlation of conductivity to concentration. Refractivity measurements are generally not sufficiently accurate for AFFF and AR foams. Use of refractometry to measure concentration shall be evaluated for applicability to a particular foam solution prior to its use in Approval evaluations. If refractometry is used, a properly calibrated digital refractometer shall be used. No refractometer using an analogue display shall be acceptable. If refractometry is employed, the testing shall be conducted as described in Appendix G with regard to the development of and evaluation using base calibration curves.

4.1.2.6 The discharge device and application rate to be used in test shall be selected by the manufacturer and configured as specified in Appendix E. Appendix E describes the required test configurations and locations for various types of discharge devices in relation to the pan's location.

4.1.2.6.1 For Automatic Sprinkler and Air Aspirating Foam Water Sprinkler fire tests; the application rate used in accordance with Appendix E shall define the minimum rate to be FM Approved for the concentrate and sprinkler combination.

4.1.2.6.2 For all foam concentrates; Type I, II or III tests as described in Appendix E must be completed at the specified minimum application rates. Application rates may vary among polar groups, above the minimum, as specified by the manufacturer. Foam Qualities attained during this test can later be utilized for qualifying discharge devices per the criteria of FM 5130 Section 4.4 Qualification of Other Low Expansion Discharge Devices.

4.1.2.7 Authorities having jurisdiction may mandate higher application rates for specific hazards than the FM Approved minimums.

4.1.2.8 For each new or modified foam concentrate submitted to FM Approvals as part of an FM Approved Foam Extinguishing System; testing in accordance with 4.1.2.6.2 is required to prove extinguishment at a verified Foam Quality. Successful completion of the foam water sprinkler fire test protocol by itself shall not qualify a foam concentrate for FM Approval.

4.1.2.9 Extinguishment

The test fuel shall be ignited and allowed to burn for the preburn time indicated in Appendix F prior to the application of foam. Foam application shall continue for the duration indicated in Appendix F. The fuel surface shall be completely covered by the foam blanket and the fire completely extinguished by the end of foam discharge. For all discharge devices, Appendices E and F shall be followed.

4.1.2.9.1 Extinguishment – Air Aspirating Foam Water Sprinklers and Automatic Sprinklers

If the discharge device is an Air Aspirating Foam Water Sprinkler or Automatic Sprinkler , or a device which may be installed under a building fire protection system, then water-only discharge shall continue for an additional five minutes to verify that the foam blanket cannot be easily degraded by subsequent water discharge. The water application rate shall be the same as used for the foam for a foam water sprinkler except that the minimum foam solution application rate shall be 0.2 gal/min/ft^2 (8.1 mm/min) for FM Approval (Reference Appendix E). A subsequent maximum water application rate for foam breakdown, as specified by the manufacturer shall be tested for FM Approval. This maximum application rate may be selected by the manufacturer from 0.3 gal/min/ft^2 (12.2 mm/min) to the application rate at the associated maximum sprinkler pressure at even steps of 0.1 gal/min/ft^2 (4.1 mm/min). The fuel surface shall be completely covered by the foam blanket by the end of water discharge.

If the test fuel is water miscible the water-only discharge will not be used for that fuel, because the mixing of water with the fuel will prejudice the reigniton and sealing evaluations. All concentrates and concentrations submitted for use on water miscible fuels shall also be tested on heptane fuel with subsequent water-only discharge.

4.1.2.9.2 Extinguishment –Topside Discharge Devices

For Type II application, the nozzle is to be positioned in front of and above the test pan, fixed in position by mechanical means and centered on the near side of the pan. The nozzle is to be positioned so that foam is directed across the pan and strike a flat steel backboard on the opposite side of the pan throughout the duration of the foam application. In no case is the nozzle to extend over any part of the test pan.

For Type III application, the nozzle is to be positioned in front of and above the test pan. The nozzle position must remain unchanged until control is attained; all foam application is to be from behind one side of the test pan and discharged directly onto the fuel surface. After control, foam application may be from the front and one adjacent side and may be directed onto the inside of the test pan and the fuel surface. The nozzle may be moved beyond the adjacent side extensions. In no case is the nozzle to extend over any part of the test pan.

If a discharge device is capable of being installed under a fire protection sprinkler system, such as a low level discharge device for under wing protection in an aircraft hangar; then the instructions of Appendix F, Note 1 shall be followed.

If the discharge device is intended never to be installed under a fire protection sprinkler system, the additional water-only discharge is not required. Appendices E and F shall be followed.

4.1.2.10 Reigniton Resistance

After the completion of discharge, the foam blanket shall remain undisturbed for an observation period, as indicated in Appendix F. During this time, the fuel shall not reignite when a lighted torch is passed within 1 in. (25 mm) of the surface of the foam blanket. Reignition attempts shall be made within 1 minute after the end of discharge and within one minute before the end of the observation period. Reignition attempts shall be 1 minute in duration, during which time the torch shall be passed within approximately 1 in. (25 mm) over the entire surface of the blanket, including the corners. The torch shall consist of an approximately 4 in. (100 mm) diameter by 4 in. (100 mm) long tightly wrapped roll of heptane-soaked cotton cloth at the end of a steel rod approximately 4 ft (1.2 m) long. Alternatively, a propane torch can be used for this purpose if provided with a non air-aspirating tip at the end of a minimum length 4 ft (1.2 m) wand and adjusted to produce a yellow flame a minimum of 4 in. (100 mm) long. The propane container shall be at the operator end of the wand and shall not be extended over the pan surface. Other torch configurations may be utilized if found to be comparable to the above configurations.

Exception: Candling, flaming or flashover that self-extinguishes is acceptable provided that the phenomenon does not remain in one area for more than 30 seconds.

4.1.2.11 Burnback Resistance

At the end of the observation period, the foam blanket shall be deliberately broken and the fuel shall be reignited in the rift. The rift shall be created by placing a vertical pipe in the pan, removing the foam blanket from within the pipe, reigniting the fuel within the pipe, and slowly removing the pipe. The pipe shall be fabricated from steel sheet of 0.015 in. to 0.048 in. (0.38 mm to 1.23 mm) thickness and a minimum of 12 in. (305 mm) inside diameter and approximately 14 in. (355 mm) long. The pipe shall be placed with its outer surface approximately 2.5 ft (0.76 m) from both walls of the pan in the corner where the foam blanket appears to be weakest. If a determination cannot be made where the foam blanket appears to be the weakest, the rift shall be created by placing the pipe in the corner where the fire was observed last. The foam blanket captured within the pipe shall be removed as thoroughly as possible without agitating the surface of the fuel. The fire within the pipe shall be allowed to burn for one minute prior to removing the pipe. Subsequently, the burning rift shall either re-close or not enlarge beyond 10 ft^2 (0.9 m^2) over a 5 minute observation period. During this observation period; fire originating from the rift and passing over the surface of the foam blanket shall be allowed as long as the flame height stays below 2 ft (.6 m) and does not remain in one place other than the original rift area for more than thirty seconds. The total area involved in flames in any one area must remain less than 10 ft^2 (0.9 m^2) at all times during the observation period.

4.1.2.12 Appendix F provides a tabular chronology of the schedule of events for this test.

4.1.3 A foam sample shall be captured under the same discharge conditions as used for this test. Quality measurements shall be taken from this sample, as described in Section 4.2. These values shall be used to verify that discharge devices submitted for Approval with this concentrate can produce foam sufficiently similar to that used in the successful fire tests. Accurate foam quality measurements may not be possible with extremely low expansion ratios and rapid drainage times, such as is frequently the case with conventional sprinklers used for foam water service. In such circumstances, FM Approvals may waive quality testing, at its sole discretion. When there is no quality data obtained in an extinguishment test, that test cannot be used to qualify equipment other than that actually used in the test.

4.2 Low Expansion Foam Quality Measurements

4.2.1. Requirements

The expansion ratio and 25 percent drainage time for foam produced from a concentrate at a specified concentration ratio that has been successfully fire tested shall be measured to establish benchmark values for use in evaluation of the effectiveness of any discharge devices proposed for use with that foam.

4.2.2 Tests/Verification

4.2.2.1 A foam slider shall be used to collect foam samples for determining foam quality. A typical “slider” is illustrated in Figure D-1 and consists of a sheet of smooth metal, plastic, or wood held on a frame at an angle of 45 degrees to the floor. Foam reaching the “slider” surface shall be guided into a foam sample container placed at the bottom of the sheet. Excessive overflowing of foam solution shall be avoided to prevent foam agitation in the container.

4.2.2.2 Two collection containers shall be used. The containers shall be graduate cylinders of 1600 to 2000 ml capacity. Each container shall be weighed prior to the test to the nearest gram and these tare weights shall be recorded. The specific size of the containers used is not critical, as long as the volume is accurately measured and the gradations are a maximum of 0.1 times the liquid volume for 25 percent drainage.

4.2.2.3 The foam discharge shall be stabilized at the desired concentration and flow rate. The foam shall be running freely down the slider, presenting a uniform, steady-state appearance at the time of sample collection.

4.2.2.4 Each container shall be filled with foam from the sample collector. Timers shall be started at the completion of filling.

4.2.2.5 Observations of the liquid level at the bottom of each container shall be recorded at 15 second intervals. Data recording shall continue for a minimum of 30 seconds after the liquid quantity exceeds 1/10 of the graduate cylinder’s volume, or all foam has been liquefied, whichever first occurs. Data recording intervals may be increased to 30 seconds if the 25 percent drainage times exceed 5 minutes.

4.2.2.6 The foam container external surfaces shall be thoroughly wiped off and each container reweighed. Net weights shall be calculated for each container by subtracting its tare weight from the final weight.

4.2.2.7 Each container shall be thoroughly rinsed out with water and refilled with foam solution, at the same concentration as used to generate the foam samples. The refilled containers shall be reweighed and the net weights of the solution shall then be calculated by subtracting the tare weights. Alternatively, the weight of foam solution may be calculated from the specific gravity of the solution and the container volume, if the solution specific gravity has been determined to a level of accuracy acceptable to FM Approvals.

4.2.2.8 Expansion ratio shall be calculated by dividing the total of the net weights of the solution from both containers by the total of the net weights of the foam samples from each.

4.2.2.9 25 percent drainage time shall be determined by fitting the best line to the time versus collection data for each container and calculating the time for drainage of 25 percent of the container volume. This process shall be automated using an electronic spreadsheet program such as Microsoft Excel. The data for the time of collection (in seconds) shall be plotted as a function of the volume of solution collected (in grams) using the spreadsheet software. The spreadsheet shall also be used to fit the best line to the data and obtain the equation of that line, as well as its R^2 correlation coefficient. If the correlation coefficient is 0.95, or higher, then the equation for that line shall be used to calculate the time to collect liquid solution equivalent to 0.25 of the graduate cylinder's foam weight. This shall be termed the "25 percent drainage time" for the sample. If the correlation coefficient is less than 0.95, the test shall be repeated until data is obtained which will generate a curve fit of acceptable accuracy. The value for the two containers shall be averaged and recorded. This shall determine the 25 percent drainage time to be used for future comparisons.

4.2.2.10 Other methods of measuring foam expansion ratio and 25 percent drainage time may be employed if judged by FM Approvals to be sufficiently accurate. Such alternate methods may be desirable for particularly fast or slow draining foams. Appendix I describes one alternative method.

4.3 Qualification of Other Low Expansion Foam Discharge Devices

4.3.1 Requirement

A discharge device shall either be used to create foam used in a successful fire test, as described in Section 4.1, or shall produce foam of approximately equivalent quality to that undergoing a successful fire test, when tested using a solution of the same concentrate at the same concentration ratio.

4.3.2 Tests/Verification

4.3.2.1 Testing of discharge devices shall be conducted as described in Section 4.1 to demonstrate -their ability to produce foam capable of extinguishing the Class B pan fire.

4.3.2.2 Fire extinguishment testing may be waived if the discharge device is of the same type as one used in a successful fire extinguishment test and demonstrates the ability to produce foam of essentially equivalent quality, when tested as described in Section 4.2. Table 4.3.2.2 lists the acceptable quality limits.

Table 4.3.2.2 - *Quality Equivalency Limits*

Parameter	***Minimum below Fire Extinguishment Foam***	***Maximum above Fire Extinguishment Foam***	***Remarks***
Expansion Ratio	-10 percent, or -1 expansion ratio unit, whichever is greater	+ 20 percent, or + 2 expansion ratio units, whichever is greater	A ratio of 3:1 denotes three expansion ratio units, 5:1 denotes five, et cetera
25 percent Drain Time	-10 percent, or -1 minute, whichever is greater	+ 20 percent, or +2 minutes, whichever is greater	25 percent drain time also shall never be less than 30 seconds

4.3.3 In the event that two successful fire extinguishment tests in accordance with 4.1.2.9.2 are completed with the same foam concentrate at the nominal percentage; discharge device foam qualities falling between the minimum and maximum fire extinguishment foam qualities, with tolerances as applied above, are acceptable.

4.3.4 The operation of non-air aspirating fire sprinklers makes the collection of valid foam samples for quality testing difficult. Therefore, such devices shall always require fire extinguishment testing for Approval.

4.4 Proportioning Tests

4.4.1 Requirement

Proportioning devices shall meter foam concentrate into water with acceptable accuracy throughout their specified ranges of installation orientation, system type, flow, pressure, and concentration ratios. Proportioners utilizing a pump as part of their assembly must also demonstrate acceptable accuracy throughout their specified viscosity range.

4.4.2 Tests/Verification

4.4.2.1 The device shall be installed and adjusted per the manufacturer's specifications and operated at maximum, midrange, and minimum flow rates. At each flow rate, it shall be operated at maximum and minimum specified inlet pressures; proportioners that are not dependent on inlet pressure, such as balanced pressure proportioners, are not subjected to be evaluated at the minimum and maximum pressure at each flow rate. At each flow condition, it shall be tested at the specified minimum and maximum proportioning rate with each specified foam concentrate. Proportioners with automatically variable geometry shall be evaluated in each orientation (e.g. horizontal and vertical) to be included in the Approval listing. Permanent changes in the proportioning ratio are not allowed in excess of the requirements outlined in Section 4.4.2.2 below.

4.4.2.2 Proportioning ratio measured in test shall match the specified ratio within a tolerance of -0 to +30 percent.

4.4.2.3 Tests shall be conducted at concentrate temperatures within a range of 60 F to 80 F (15 C to 27 C). Additionally, the test condition showing least accuracy of proportioning shall be repeated with the concentrate supply chilled to 35 F (1.1 C), or the manufacturer's minimum specified temperature, whichever is less. The actual foam concentrate shall be used for this test, rather than a test liquid. Foam concentrate shall be proportioned at a rate no less than 0.85 of the test at the standard temperature. Proportioning devices operating at a positive pressure of the concentrate supply above the water pressure at the mixing point are not required to be tested at minimum temperature, provided that the concentrate selected has been successfully tested at minimum temperature with the use of a minimum of one vacuum induction proportioning device.

4.4.2.4 Proportioners having moving parts shall be subjected to a 500 cycle durability test similar to that described in Section 4.12.5, except that the cycling shall be from 0 to maximum flow rate or by mechanical movement of all moving parts simulating 0 to maximum specified flow, prior to being tested for proportioning accuracy, as described above. This test may be conducted with water substituted for the concentrate to minimize unnecessary production of solution. At the conclusion of the test, proportioning accuracy can be determined with concentrate or test liquid.

4.4.2.5 Proportioners utilizing springs shall be subjected to a 5000 spring cycle durability test. The spring shall be removed from the assembly and shall be cycled from its zero position to the maximum compressed position as it would be compressed at the maximum flow rate associated with the proportioner assembly, at a rate of no more than 10 cycles per minute. The spring shall then be installed into the proportioner and tested for proportioning accuracy, as described above. Measured proportioning ratios shall not exceed 10 percent variation from the pre-tested condition, and must remain within the tolerance as outlined in Section 4.4.2.2 above.

4.4.2.6 Proportioners specified for use in dry sprinkler systems and having moving parts shall be subjected to 10 additional cycles of operation from an initially dry condition before being tested for accuracy.

4.4.2.7 Proportioners with moving parts in the path of extinguishing water and/or foam solution shall be subjected to a flow endurance test of one hour at the maximum flow rate and associated maximum inlet pressure. Deformation or degradation of any components or features that would significantly alter the function of the device shall not be allowed. At the conclusion of this test the proportioner shall be tested for proportioning accuracy, as described above. Measured proportioning ratios shall not exceed 10 percent variation from the pre-tested condition, and must remain within the tolerance as outlined in Section 4.4.2.2 above. Further post-testing may be specified at the discretion of FM Approvals; including but not limited to Section 4.16 Equivalent Length Determination, Section 4.11 Hydrostatic Integrity and the cycle test described in Section 4.4.2.4 above.

4.4.2.8 Proportioners utilizing a pump as part of their assembly shall be evaluated in accordance with the requirements of this section, and additionally be subjected to the requirements of Section 4.18. The requirements of Section 4.4.2.2 shall be met throughout the manufacturer stated flow range when tested at the minimum and maximum viscosity range of foam concentrates with which it will be considered for Approval.

4.5 Film Forming Test

4.5.1 Requirement

A film forming foam liquid concentrate shall have a spreading coefficient greater than zero when tested as described in Section 4.5.2.

4.5.2 Test/Verification

4.5.2.1 The surface tension of the foam solution and the interfacial tension of the foam solution and cyclohexane shall be determined using a tensiometer as described in ASTM D 1331, *Standard Test Methods for Surface and Interfacial Tension of Solutions of Surface-Active Agents.*

4.5.2.2 The surface tension of the foam solution shall be determined on samples of the foam liquid concentrate mixed with both distilled water and synthetic sea water in the concentration recommended by the manufacturer. The determinations shall be conducted with the samples conditioned at 70 F ± 5 F (21 C ± 3 C).

4.5.2.3 The interfacial tension of the foam solution and cyclohexane shall be determined as described for surface tension except that after immersion of the tensiometer ring in the foam solution, a layer of reagent grade (not less than 99 percent) cyclohexane shall be carefully added on top of the foam solution. Contact between the tensiometer ring and the cyclohexane should be avoided. After waiting 5 minutes, the interfacial tension shall be determined.

4.5.2.4 The spreading coefficient of the foam liquid concentrate shall be calculated as follows:

$$SC = S_c - S_f - S_{cf}$$

Where:

SC = Spreading coefficient, dynes/cm
S_c = Surface tension of cyc1ohexane, dynes/cm
S_f = Surface tension of foam solution, dynes/cm
S_{cf} =Interfacial tension of the foam solution and cyclohexane, dynes/cm

4.6 High Expansion Foam Fire Extinguishment

4.6.1 Requirement

Foam concentrates and generators shall demonstrate effective fire extinguishment, when tested per Section 4.6.2. A minimum of one successful Class A and one successful Class B fire test are required.

At present, FM Global does not have any allowable Class A applications for high expansion foam and will not list this product for that application, irrespective of fire test performance. However, to receive Approval for Class B applications, successful Class A extinguishment is also required.

4.6.2 Test/Verification

4.6.2.1 Foam solution shall be prepared by mixing the specified amount of concentrate with water, either in a premixed solution or continuously by use of suitable proportioning equipment. Volume measuring, weighing, or flow measuring equipment shall be of sufficient accuracy to assure that concentration is within -0/+30 percent of the specified value. If conductivity measurements are to be used as a proxy for direct measurements of volume, weight, or flow to determine concentration, the procedure of Appendix G shall be used to validate the correlation of conductivity to concentration. Use of refractometry to measure concentration shall be evaluated for applicability to a particular foam solution prior to its use in Approval evaluations. If refractometry is used, a properly calibrated digital refractometer shall be used. No refractometer using an analogue display shall be acceptable. If refractometry is employed, the testing shall be conducted as described in Appendix G with regard to the development of and evaluation using base calibration curves.

4.6.2.2 Tests shall be conducted under conditions of calm air, no precipitation, and at ambient temperatures between 50 F and 90 F (10 C and 32 C).

4.6.2.3 Class B Fire - A minimum of one generator of each type shall be tested with each concentrate and at each concentration submitted for Approval. At minimum, the concentrate shall be tested with normal heptane for the test fuel. If extinguishing capability with other class B fuels is to be FM Approved, tests using those fuels shall also be conducted. For water-miscible fuels, water cannot be used to adjust the fuel level in the pan. Therefore, sufficient fuel shall be used to achieve the required freeboard.

4.6.2.3.1 The size of the test enclosure shall be determined by the specified generation rate for the generator used. Test enclosures shall be a minimum of 20 ft (6.1 m) or 1/100 of the generator capacity, whichever is greater, wide and 10 ft (3.0 m) high. Enclosure length shall be a minimum of 10 ft (3.0 m) + 0.75 times the generator capacity divided by the enclosure width, see Figure D-3. The following equations describe the relationship among the enclosure dimensions in terms of generator capacity.

$$W = R/100,\ 20\ ft\ (6.1\ m),\ minimum.$$

$$L = (0.75 \times R/W) + 10\ ft\ (3.0\ m)$$

Where,

W is the width of the enclosure,
L is the Length of the enclosure, and
R is the foam discharge rate in compatible unit (feet or meters) length and width cubed per minute.

These relationships are based upon the assumption that the advancing foam front will reach the full 10 ft (3.0 m) height of the test enclosure and the requirements that the fire test fuel array be located a minimum of 10 ft (3.0 m) away from the wall of the enclosure farthest from the generator and that the transit time for the foam front to reach the top leading edge of the fuel array shall be a minimum of 7.5 minutes. The 7.5 minute requirement is based upon 1.5 times the 5 minute maximum design submergence time for ignitable liquids specified in NFPA 11, *Standard for Low-, Medium-, and High Expansion Foam*. FM Approvals may allow other test enclosure sizes as long as the minimum transit time requirement is met.

4.6.2.3.2 The foam generator shall be mounted at one end of the enclosure, at a height above intended depth of submersion to prevent discharge from being impeded by backpressure created by submergence. The fuel array shall be positioned 10 ft (3.0 m) away from the center of the opposite wall. There shall be sufficient free height above the anticipated maximum foam level to avoid interference with discharge from the generator. The foam shall not contact the ceiling of the enclosure during the test.

4.6.2.3.3 A test without a fire shall be conducted to verify the 7.5 minute minimum transit time and to determine the location of the unimpeded foam front 1 minute prior to its reaching the fuel array. This will determine the point at which the fuel can be ignited to ensure a minimum of a 1 minute preburn. If the height of the foam front is less than 10 ft (3.0 m), the movement of the foam front shall be evaluated to determine the suitability of the enclosure. If the required preburn time has been completed and the foam front has reached a stable configuration and rate of advance before reaching the test fuel, the enclosure may be accepted for the test, at the sole discretion of FM Approvals. Otherwise, the length or width of the enclosure shall be increased to provide the minimum 7.5 minute transit time

4.6.2.3.4 The fuel array for the Class B test shall be the same as that described in Section 4.1.2. However, the fuel level or overall tank height shall be adjusted to provide a freeboard of approximately 6 in. (150 mm).

4.6.2.3.5 The generator shall be operated for a maximum of 15 minutes. The fire shall be extinguished within 12 minutes and so remain through the end of foam discharge.

4.6.2.4 Class A Fire – The test arrangement and criteria for success shall be the same as for the Class B fire, with the following exceptions:

A. The minimum transit time shall be 12 minutes, based upon 1.5 times the maximum design submergence time of 8 minutes for Class A combustibles specified in NFPA 11, *Standard for Low-, Medium-, and High Expansion Foam*. This requires the substitution of 1.2 for the factor of 0.75 in the above equation for length of enclosure. Transit time is the total time from the start of generation to the time when the top leading edge of the foam front reaches the fuel array.

B. The ignition time shall be adjusted to allow a minimum preburn time of 3 minutes.

C. The fuel array shall consist of a wood crib, with a moisture content between 9 and 13 percent. The crib shall be suspended a maximum of 2 ft (0.61 m) above the floor on noncombustible supports. A 76 in. square by 12 in. high (1930 mm square by 305 mm high) pan containing

10 gallons (38 L) of heptane floating on water shall be placed approximately 1 ft (0.3 m) below the bottom of the crib and used to ignite the array.

D. The foam generator shall be run for a maximum of 30 minutes. The fire shall be extinguished by the end of foam discharge and not reignite while submerged in the foam for an additional 15 minute observation period.

4.6.3 Foam quality measurements per Section 4.7 shall be made to establish benchmark values for evaluation of other sizes of foam generators of similar design.

4.7 High Expansion Foam Quality Measurement

4.7.1 Requirement

The expansion ratio for foam produced from a concentrate at a specified concentration ratio that has been successfully fire tested shall be measured to establish benchmark values for use in evaluation additional sizes of foam generators of similar design that are also proposed for use with that foam.

4.7.2 Tests/Verification

4.7.2.1 The collection container shall be weighed prior to the test to the nearest 0.1 pound (0.045 kg) and the tare weight shall be recorded.

4.7.2.2 The foam discharge shall be stabilized at the desired concentration and flow rate. The foam shall be discharging freely, presenting a uniform, steady-state appearance at the time of sample collection. Foam samples shall be collected directly from the generator's discharge opening in a container placed approximately 2 ft (0.61) below and centered on the discharge outlet.

4.7.2.3 The collection container shall be a specially designed tank approximating the dimensions of a standard 55 gallon nominal capacity drum. The modification shall consist of a wheeled support stand to elevate the drum above the floor and a central drain connection centered on the bottom of the drum. The bottom of the tank shall be tapered toward the drain. The drain shall be approximately 1/2 in. (12.5 mm) in diameter and shall be connected to a full diameter ball quarter-turn shutoff valve. An alternate configuration collection container may be used, as long as it is configured to collect foam without the formation of voids. Sizing of the container shall be such that the duration of collection does not exceed one minute to avoid errors in expansion ratio calculation due to breakdown of the foam during collection.

4.7.2.4 The collection container shall be moved into the foam discharge stream. The drain valve shall remain open until collection is complete to remove any liquid that may form due to foam breakdown to improve accuracy of expansion ratio calculation. The container shall be withdrawn from the discharge stream, the drain valve closed after any liquid discharge ceases, and the foam doctored off flush with its top. The outside of the container shall be rinsed with water to remove any clinging foam and dried off before any weights are taken.

4.7.2.5 The foam collection container external surfaces shall be thoroughly wiped off and the container reweighed. Net weights shall be calculated for the container by subtracting its tare weight from the final weight.

4.7.2.6 The container shall be filled with water and reweighed. The net weight of the solution shall then be calculated by subtracting the tare weight and multiplying that weight by the specific gravity of the foam solution.

4.7.2.7 Expansion ratio shall be calculated by dividing the calculated net weight of the solution from the container by the net weight of the foam sample.

4.7.2.8 Expansion ratio may alternately be determined by discharging into a known area and measuring the average height of the foam, and calculating the volume of expanded foam. The ratio of the total volume of expanded foam to the total solution flow over the duration of discharge is an acceptable expression of the expansion ratio.

4.8 Qualification of High Expansion Foam Generators

4.8.1 Requirement

A foam generator shall either be used to create foam used in a successful fire test, as described in Section 4.6, or shall produce foam of approximately equivalent expansion ratio to that undergoing a successful fire test, when tested using a solution of the same concentrate at the same concentration ratio.

4.8.2 Tests/Verification

4.8.2.1 Testing of foam generators shall be conducted as described in Section 4.6 to demonstrate their ability to produce foam capable of extinguishing the required Class B pan fire.

4.8.2.2 Fire extinguishment testing may be waived if the foam generator is of the same type as one used in a successful fire extinguishment test and demonstrates the ability to produce foam of essentially equivalent quality, when tested as described in Section 4.2. Table 4.8.2.2 lists the acceptable quality limits. To qualify as being of the same type, a generator shall be of essentially the same configuration and differ only in size or materials from the generator which produced the foam that demonstrated successful extinguishment performance. If foam of more than one quality has been successfully fire tested, a generator need only produce foam which replicates the expansion ratio for it to be qualified. This is intended to allow a manufacturer to produce generators for different quality foams to address specific hazard scenarios which have been shown to respond better to a drier or wetter foam.

Table 4.8.2.2 - Quality Equivalency Limits

Parameter	***Minimum below Fire Extinguishment Foam***	***Maximum above Fire Extinguishment Foam***	***Remarks***
Expansion Ratio	-10 percent, or -50 expansion ratio units, whichever is greater	+ 20 percent, or + 200 expansion ratio units, whichever is greater	A ratio of 300:1 denotes three hundred expansion ratio units, 500:1 denotes five hundred, et cetera

4.9 High Expansion Foam Generator Capacity

4.9.1 Requirement

Foam generators shall produce their specified capacities with each concentrate and at each concentration ratio for which they are FM Approved.

4.9.2 Tests/Verification

4.9.2.1 Tests shall be conducted with all combinations of concentrate, concentration ratio, and with fresh or salt water within the manufacturer's specification.

4.9.2.1.1 Expansion ratio testing for comparison of fresh water to salt water may be conducted on small scale test equipment.

4.9.2.2 The collection container shall be a minimum of 10 x 10 ft (3.05 x 3.05m) in area and of a height sufficient to contain a minimum of 30 seconds of foam discharge at the specified rate.

4.9.2.3 The generator shall be operated at a steady state. The discharge shall be directed into the collection container and timing shall begin. When the foam overflows the top of the container, the timer shall be stopped and the time recorded.

4.9.2.4 Measured discharge rate shall be calculated by dividing the collected volume by the time for collection.

4.9.2.5 Measured discharge rate shall be equivalent to the specified rate, within a tolerance of ± 15 percent.

4.10 High Expansion Foam Breakdown Due to Sprinkler Discharge

4.10.1 Requirement

High expansion foams shall not be degraded by sprinkler discharge beyond the manufacturer's specified breakdown rate.

4.10.2 Test/Verification

The high expansion foam generator capacity test of Section 4.9 shall be repeated while under sprinkler discharge.

A 10 x 10 ft (3.05 x 3.05 m) hydraulically balanced sprinkler grid shall be centered at a minimum height of 6 ft (1.83 m) over the collection container. Four FM Approved K5.6 pendent design open fire sprinklers shall be installed.

A maximum water application rate for foam breakdown, as specified by the manufacturer shall be tested for Approval. This maximum application rate may be selected by the manufacturer from 0.3 gal/min/ft^2 to 1.0 gal/min/ft^2 (12.2 mm/min to 40.8 mm/min) at even steps of 0.1 gal/min/ft^2 (4.1 mm/min).

Foam discharge shall commence after sprinkler discharge is established.

Time to fill the container during sprinkler discharge shall be measured at both the maximum and minimum generation rates for the generator used.

The foam breakdown rate in volume of foam lost per minute per rate of sprinkler discharge per minute per unit area shall be determined as follows:

$$S = (Q - G_s)/D$$

Where,

- S is the breakdown rate in ft^5/gal (m^3/mm),
- Q is the total sprinkler water flow in gal/min (L/min),
- G_s is the generation rate of foam under sprinkler discharge, calculated the same way as G and is expressed in the same units, and
- D is the sprinkler discharge rate per unit area and is expressed in gal/min/ft^2 (mm/min).

S shall be calculated for each foam generation rate. The highest value so calculated shall not exceed the manufacturer's specified rate.

Where generation rates are high enough to require an enclosure of larger area, the sprinkler grid shall be expanded in multiples of the 10 x 10 ft (3.05 x 3.05 m) spacing and the total water flow rate and calculations adjusted to provide the same specified discharge rates.

4.11 Hydrostatic Integrity

4.11.1 Requirement

All components of the foam system shall be capable of withstanding the maximum specified system pressure.

4.11.2 Tests/Verification

All components shall be hydrostatically tested as follows.

4.11.2.1 The device shall be closed by means of its normal connections to the system. Means shall be provided for the introduction of water and the venting of any trapped air. After filling and venting, the device shall be pressurized to 80 percent of the required pressure and the pressure raised the remaining 20 percent at a rate not to exceed 100 psi (6.9 bar) per minute.

4.11.2.2 Required test pressure shall be four times the specified rated operating pressure, or 700 psi (48.3 bar), whichever is greater.

4.11.2.3 The required test pressure shall be held for one minute.

4.11.2.4 No cracking, excessive distortion, or visible leakage shall result. Any distortion which would impair function shall be termed "excessive distortion".

4.11.2.5 Devices which do not incorporate a means for trapping system pressure shall be exempt from hydrostatic test.

4.11.2.6 All valves shall be tested in new condition, as supplied by the manufacturer. Additional samples previously subjected to the cycle operation test shall remain within the acceptable limits of leakage when tested at the normal working pressure.

The inlet of the valve shall be pressurized and the outlet shall remain open.

Valves shall not leak more than 1 fluid ounce (0.008 ml) per second when held at twice the specified system pressure for five minutes.

Check valves shall be subjected to hydrostatic test both with the disc open to pressurize the entire body and in a separate test with the pressure applied through the outlet connection against the disc while the inlet connection is open to atmosphere.

No cracking, fracture, or failure to retain the test pressure shall be allowed.

4.11.2.7 If the authority having jurisdiction requires that the cylinder manufacture be under recognized third party surveillance, hydrostatic testing shall not require witnessing by FM Approvals. Instead, certifications of tests witnessed by the recognized third party shall be reviewed by FM Approvals for compliance with this requirement. Acceptable third parties shall include those granted reciprocity for boiler and pressure vessel inspection to the ASME (American Society of Mechanical Engineers) code.

4.12 Automatic Concentrate Control Valve Operation

4.12.1 Pressure Operated Valves

4.12.1.1 Requirement

Concentrate control valves shall operate under the most adverse normal pressure (maximum system pressure and minimum actuator pressure) when conditioned to the maximum and minimum specified installation temperatures. The range of installation temperatures specified shall include at minimum, 35 F to 120 F (1.7 C to 48.9 C).

4.12.1.2 Tests/Verification

A minimum of one sample of each device shall be conditioned to the minimum specified installation temperature for 16 hours. While still at that temperature, the device shall be operated and shall display no detectable hesitation, partial operation, or other failure. Devices motivated by pressure shall be tested at maximum or minimum normal system pressures, whichever is more adverse for the design of the specific component. If which condition is the most adverse is not readily discernable, the device shall be operated at both extremes of pressure.

A minimum of one sample of each device shall be conditioned at the maximum specified installation temperature for 16 hours and the same evaluations shall be conducted.

4.12.2 Electrically Operated Valves

4.12.2.1 Requirement

Electrically operated valves shall also operate properly at 85 and 110 percent of rated voltage while at maximum and minimum specified installation temperatures.

4.12.2.2 Tests/Verification

A minimum of one sample of each valve shall be tested. The tests of Section 4.12.1.2 shall be conducted on a device powered at 85 percent of rated voltage and again at 110 percent of rated voltage. No deterioration in operation shall be allowed.

4.12.3 Leakage

4.12.3.1 Requirement

Valves shall not leak throughout the full range of specified inlet water pressures.

4.12.3.2 Tests/Verification

The outlet of the valve shall be open to atmosphere and the inlet suitably closed. The inlet closure shall be provided with pressurization and venting connections.

After venting any trapped air, the valve shall be pressurized to 30 psi, 100 psi, and 175 psi (2.0 bar, 6.90 bar, and 12.0 bar) in successive trials. Additionally, a fourth trial shall be run at the rated pressure if that pressure is greater than 175 psi (12.0 bar).

Each trial shall be 5 minutes in duration.

No visible leakage shall be allowed on the outlet side in any trial.

4.12.4 Actuator Gland Leakage

4.12.4.1 Requirement

Valves having glands or seals to prevent internal pressure from leaking past moving or rotating connections to external operators shall demonstrate the effectiveness of those components.

4.12.4.2 Tests/Verification

The tests of Section 4.12.3.2 shall be repeated with the valve outlet plugged. During the five-minute observation period, the valve shall be operated once per minute. The actuator sealing locations shall be observed. No visible leakage shall be allowed.

4.12.5 Durability

4.12.5.1 Requirement

Excessive wear shall not occur as a result of operation of a valve 500 times at pressure.

4.12.5.2 Tests/Verification

A representative size of valve shall be tested. If differing designs are used, a minimum of one valve of each design shall be tested.

The valve shall be cycled from full open to closed 500 times with the outlet open to atmosphere and the inlet pressurized with water from a supply with a static pressure equal to the valve's rated pressure, 175 psi (12.1 bar), minimum.

Cycling rate shall be approximately 4 cycles per minute.

Subsequent to this cycling, the valve shall be subjected to the evaluations of Sections 4.12.3.2 and 4.12.4.2 with no failures.

4.12.6 Pressure Actuator Integrity

4.12.6.1 Requirement

Actuators of valves operated by pressure shall withstand hydrostatic pressure equal to twice the valve's rated pressure with no failure.

4.12.6.2 Tests/Verification

With the valve inlet and outlet connections open to atmosphere, the connection to the actuator shall be pressurized with water to twice the valve's rated pressure, 350 psi (24.1 bar) minimum, for five minutes. If an actuator is rated at a lower pressure and equipped with a pressure relief, it shall be tested at twice its rated pressure or a minimum of 1.1 times the setting of the pressure relief, whichever is greater. Pressure relief devices shall be appropriately tested to verify reliability.

No failure or visible leakage shall be allowed.

Subsequently, the valve shall demonstrate unimpeded operation.

4.13 Dielectric Withstand

4.13.1 Requirement

Electrical components shall withstand application of twice their rated voltage plus 1000 V between all terminals provided for external connections and ground. Devices rated at 60 V, or less, shall be tested at 500V.

4.13.2 Tests/Verification

Voltage shall be applied, in turn, between each terminal and ground. For devices rated at 60 V, or less, the test voltage shall be 500 V. Components subjected to the Dielectric Withstand test shall continue to function normally subsequent to this test.

4.14 Salt Fog Corrosion

4.14.1 Requirement

System components shall withstand a 240 hour exposure to a 20 percent salt in water (laboratory grade sodium chloride in demineralized water) fog without incurring damage which would impair function.

4.14.2 Tests/Verification

Test samples shall be selected to represent all material combinations and configurations.

The test shall be conducted in conformance to ASTM B117, *Standard Practice for Operating Salt Spray (Fog) Apparatus*.

Tested samples shall remain fully functional and exhibit no corrosion, galvanic action, loss of legibility of markings, or separation of protective coatings which would impair future functionality. Superficial discoloration with no substantial attack of the underlying material shall be acceptable.

4.15 Individual Component Functionality

4.15.1 General

4.15.1.1 Requirement

FM Approved devices need not be tested for inclusion within a foam extinguishing system if they are used in conformance to their FM Approvals listed ratings and applications. Otherwise, components shall be evaluated by FM Approvals to determine suitability for the intended use. Such evaluations shall address all relevant FM Approvals requirements for the type of device.

4.15.1.2 Tests/Verification

Pressure operated devices shall be tested to verify that they operate at the minimum required pressures.

Devices for which there are no established Approval requirements shall be evaluated to confirm function as required for system operation and integrity at the extremes of the anticipated service conditions. Such ad hoc evaluations shall be structured based upon the engineering judgment of FM Approvals. Wherever possible, established standard evaluation methods shall be used. While manufacturer advice and counsel is welcomed, the evaluation protocols selected shall be at the discretion of FM Approvals.

4.15.2 Stress Corrosion

4.15.2.1 Requirement

Devices manufactured of copper alloys containing greater than 15 percent zinc shall exhibit resistance to stress corrosion susceptibility, when tested as described in Section 4.15.2.2 for 10 days.

4.15.2.2 Test/Verification

The openings of each sample shall be filled with deionized water and sealed with a non-reactive material (e.g., plastic cap) so as to prevent the introduction of the ammonia atmosphere into the interior of the component. The samples to be tested shall be free from any non-permanent protective coating and, if necessary, shall be degreased. If a permanent coating is an inherent part of the design, such coating shall be subjected to tests as deemed necessary by FM Approvals to evaluate its protective integrity. The samples shall be tested in their intended orientation.

There shall be provisions in the test chamber to prevent droplets of condensation from falling from the top of the enclosure directly onto the samples. Such shield or other means shall be constructed of glass or other non-reactive materials.

The samples shall be exposed to the moist ammonia-air mixture maintained in a glass chamber with a volume of 0.73 ± 0.34 ft^3 (0.02 ± 0.01 m^3).

Aqueous ammonia having a density of $5.86x10^{-5}$ lb/ft^3 (0.94 g/cm^3) shall be maintained in the bottom of the chamber, approximately 1.5 in. (40 mm) below the bottom of the samples. A volume of aqueous ammonia equal to 0.075 gal/ft^3 (10 L/m^3) of the test chamber volume results in approximately the following atmospheric concentrations: 35 percent ammonia, 5 percent water vapor, and 60 percent air. Prior to beginning the exposure, the chamber shall be conditioned to a temperature of 93 F ± 4 F (34 C ± 2 C) for a period of not less than one hour, and shall be maintained as such throughout the exposure period. The moist ammonia-air mixture shall be maintained at essentially atmospheric pressure. Provision shall be made for venting the chamber, such as by the use of a capillary tube, to avoid buildup of pressure.

The test duration shall be 10 days.

Upon removal, samples shall be rinsed in potable water and air dried. Following a two- to four-day drying period, visual examination of the samples shall be made. Following exposure, the samples shall not show evidence of cracking, delamination, or degradation.

4.15.3 Thermal Shock

4.15.3.1 Requirement

Components such as high expansion foam generators, monitors, nozzles, and other discharge devices, which are exposed to the protected space, shall remain functional if heated by a fire prior to the system discharge. Functionality shall be defined as appropriate for the specific component.

4.15.3.2 Test/Verification

The component shall be connected to a 175 psi (12.1 bar) water supply, or, in the case of a high expansion foam generator, to a foam solution supply.

The component shall be placed on the edge of the fire test pan described in Section 4.1, arranged as it would be to protect the pan. High expansion foam generators shall be located 10 ft (3.05 m) above the pan. Heptane fuel shall be provided in sufficient depth to last six minutes.

Components other than high expansion foam generators shall be dry for the first minute of fire exposure. Then water shall be flowed for an additional 5 minutes. High expansion foam generators shall remain dry for 5 minutes and shall then be supplied with foam solution at the same rate as used for the fire extinguishment test of Section 4.1.

After this test, the component shall exhibit normal operation. Normal operation for a high expansion foam generator shall include the ability prior to cooling to immediately produce foam with an expansion ratio identical to that produced prior to exposure within ± 15 percent. The pan and generator shall be separated by distance or an appropriate barrier prior to conducting this test to avoid exposure of the test personnel to the hot pan.

After being allowed to return to room temperature, the sample shall be inspected for damage. No damage which would impair function shall be allowed.

Small assemblies such as CAFS Nozzles and aspirating foam water nozzles may be tested to FM 2000 Section 4.23 *High Temperature Exposure* in lieu of the Thermal Shock test, at the discretion of FM Approvals.

4.16 Equivalent Length Determination

4.16.1 Requirement

The friction loss of all components in the system flow path shall be determined to allow system design calculation.

4.16.2 Tests/Verification

A minimum of four tests at different flow rates over the specified range of operation for the device shall be performed. The test medium shall be water. Flow rate and pressure differential shall be measured and the data used to perform a regression analysis to justify the equivalent length figure used in system design. Equivalent length shall be calculated on the basis of the discharge outlet nominal pipe size, using a Hazen-Williams coefficient of 120. This test shall be conducted for each different component design.

All concentrate control valves, check valves, and other non-standard components in the flow path shall be tested to determine equivalent length.

4.17 Bladder Materials

4.17.1 Tensile Strength and Elongation

4.17.1.1 Requirement

Unreinforced materials shall have a tensile strength of not less than 500 psi (3.45 MPa) and at least 100 percent ultimate elongation to ensure adequate toughness for service in bladder tanks. Reinforced materials shall have a tensile strength not less than 2000 psi (13.80 MPa) and are not subject to an initial minimum elongation requirement.

4.17.1.2 Tests/Verification

Tensile strength and ultimate elongation shall be determined in accordance with ASTM D 412, *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension, Method A.* If either the measured tensile strength or ultimate elongation of the specimen is less than the required value, an additional specimen shall be tested, and those results shall be considered final. Results of tests for specimens that break in the curved portion just outside the benchmarks shall be permitted to be accepted if the measured strength and elongation values are within the minimum requirements. A minimum of three samples shall be tested and the results shall be averaged.

4.17.2 Air Oven Aging

4.17.2.1 Requirement

Materials used for bladders and their bonded seams shall be resistant to aging in air.

4.17.2.2 Tests/Verification

Three samples of each material shall be subjected to air-oven aging for 60 days at 158 F (70 C), and then allowed to cool at least 24 hours in air at 74 F (23 C), at 50 percent relative humidity. At the conclusion of this test the samples shall be inspected for cracking and crazing. There shall be no cracking or crazing as a result of this test. An additional three samples cut perpendicular to a centrally located bonded seam shall also be tested. No separation of the seam shall result from this exposure.

Tensile strength and elongation shall then be measured per Section 4.17.1.2. For unreinforced materials, neither shall average less than 0.85 of the average values obtained from new samples of the same material. Reinforced materials shall instead be limited to a 2000 psi (13.90 MPa) minimum tensile strength and a minimum of 0.5 of their original elongation after this exposure. Bonded seam samples shall not fail at the seam.

4.17.3 Compatibility with Foam Concentrate

4.17.3.1 Requirement

Bladder materials and their bonded seams shall be resistant to aging while immersed in concentrate.

4.17.3.2 Tests/Verification

Three samples of each material shall be immersed in each foam concentrate and subjected to aging for 60 days at 158 F (70 C). Subsequently, the samples shall be rinsed off in water and allowed to dry at least 24 hours in air at 74 F (23 C), at 50 percent relative humidity. At the conclusion of this test, the samples shall be inspected for cracking and crazing. There shall be no cracking or crazing as a result of this test. An additional three samples cut perpendicular to a centrally located bonded seam shall also be tested. No separation of the seam shall result from this exposure.

Tensile strength and elongation shall then be measured per Section 4.17.1.2. For unreinforced materials, neither shall average less than 0.85 of the average values obtained from new samples of the same material. Reinforced materials shall instead be limited to a 2000 psi (13.90 MPa) minimum tensile strength and a minimum of 0.5 of their original elongation after this exposure. Bonded seam samples shall not fail at the seam.

4.18 Foam Concentrate and Water Pumps

Foam concentrate and water pumps shall be evaluated per Approval Standard 1313, Positive Displacement Rotary Fire Pumps. If designs other than positive displacement rotary gear pumps are to be used, additional or alternative evaluations and tests may be required, at the discretion of FM Approvals.

4.19 Monitors for use with Foam and CAFS

Monitors and associated Nozzles for use with foam shall be evaluated per Approval Standard 1421, Monitor Assembly, and Approval Standard 5511, Approval Standard for Firefighting Nozzles for Use with Hose, Monitor Assemblies and other Firefighting Equipment.

Foam Monitors and CAFS Monitors and Nozzles for Low-Level Foam Protection systems shall be evaluated per the applicable sections of Approval Standard 1421, Monitor Assembly, and Approval Standard 5511, Approval Standard for Firefighting Nozzles for Use with Hose, Monitor Assemblies and other Firefighting Equipment, as determined by FM Approvals.

Additionally, Electrically Operated Monitors shall be evaluated per Approval Standard 3611, Nonincendive Electrical Equipment for Use In Class I and II, Div. 2 & Class III, Divisions 1 & 2 Hazardous (Classified) Locations and Approval Standard 3810, Electrical and Electronic Test, Measuring and Process Control Equipment.

In addition, the following requirements are to be met:

4.19.1 Coverage

4.19.1.1 Requirement

Oscillating Foam Monitors and CAFS Monitors for Low-Level Foam Protection Systems shall deliver foam or CAF at the specified application rate over the specified area within the specified range. It is up to the manufacturer to define the area of coverage at specified nozzle vertical orientations (where applicable), for Approval. All possible configurations of vertical nozzle adjustment are subject to the requirements of this Section for the purpose of Approval.

4.19.1.2 Tests/Verification

Each monitor, nozzle, concentrate, and concentration shall be tested.

Monitors for Low-Level Foam Protection Systems shall be operated at maximum flow rate and range while traversing the specified maximum horizontal angle. The test shall be repeated at the minimum flow rate and range with the same criteria for success. At all flow rates and areas of coverage; monitors must satisfy a minimum application rate of 0.1 gal/min/ft^2. Foam samples shall be collected during this test and their quality determined per Section 4.2.

For Monitors for Low-Level Foam Protection with a nozzle angle above a parallel plane with the floor surface; collection pans of known area shall be placed within the specified area of coverage in locations where coverage appears weakest. Collection and area of coverage over a three minute period shall be measured.

For Monitors for Low-Level Foam Protection with a nozzle angle at or below a parallel plane with the floor surface; the monitor shall be operated and the area of coverage over a three minute period shall be measured.

For Monitors and associated Nozzles for use with foam where no area of coverage claim is made by the manufacturer; each device shall be exercised throughout all of its possible configurations with each specific concentrate for which Approval is sought. Spray Character, Reach and Discharge vs. Pressure measured in accordance with FM 5511 Section 4.6 shall be required for each Monitor and associated Nozzle configuration.

In all cases above, foam quality shall match that obtained during successful fire tests of the same concentrate at the same concentration. Monitors for use with Foam and CAFS are to meet the foam quality specifications of Table 4.3.2.2 - *Quality Equivalency Limits*.

4.19.2 Durability

4.19.2.1 Requirement

Monitors for use with Foam and CAFS shall withstand continuous operation without failure.

4.19.2.2 Tests/Verification

A monitor shall be operated throughout the maximum specified range of horizontal angles while elevated to the elevation which creates the most adverse condition for the oscillating mechanism and while flowing water at the maximum specified rate for one hour or 500 cycles, whichever is longer.

The monitor shall then be lowered to the minimum specified vertical angle and the test repeated.

Subsequent to these tests, the monitor shall continue to exhibit normal operation and no visible leakage.

4.19.3 Thermal Shock

Monitors for use with Foam and CAFS shall be subject to the thermal shock requirements of Section 4.15.3.

4.20 Foam Water Sprinklers

Conventional automatic fire sprinklers designed for use with water shall be FM Approved per Approval Standard 2000, Automatic Control Mode Sprinklers for Fire Protection, as a prerequisite for consideration for use in foam water extinguishing systems. In addition, such sprinklers shall exhibit effective fire extinguishing performance when evaluated as described in Section 4.1 and Appendix E of this standard.

Air Aspirating Foam Water Sprinklers and Foam Water Spray Nozzles shall be allowed to be tested and FM Approved as foam discharge devices. Such devices shall be subjected to the applicable sections of Approval Standard 2000, Automatic Control Mode Sprinklers for Fire Protection, at the discretion of FM Approvals. In addition, such devices shall exhibit effective fire extinguishing performance when evaluated as described in Section 4.1 and Appendix E of this standard.

FM Loss Prevention Data Sheet 4-12, *Foam Water Sprinkler Systems*, and NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*, is also referenced with regard to general information about the acceptable configurations and applications of these systems. However, the improved effectiveness of foam-water sprinkler systems over conventional water-only systems is highly dependent upon the commodities and configurations being protected, as well as the specifics of the system design. As a result, it will be necessary to conduct full-scale fire tests to Approve a foam water sprinkler system which deviates from the established design criteria for water-only fire sprinkler systems.

4.21 Subsurface and SemiSubsurface Distribution Devices

4.21.1 Requirement

Subsurface and semisubsurface distribution devices shall demonstrate fire extinguishment effectiveness with each specified concentrate and at each specified concentration.

4.21.2 Tests/Verification

4.21.2.1 The test arrangement shall comprise a vertical, open-topped steel tank of 15 ft (4.6 m) minimum diameter and 13 ft (4 m) minimum height. The tank shall contain a minimum 10 ft (3 m) depth of fuel. If non-polar solvent fuel is used, the fuel may be supported on a maximum 1 ft (0.3 m) layer of water. Freeboard shall be no less than 3 ft (0.9 m) nor greater than 4 ft (1.2 m).

4.21.2.2 Fuel shall be commercial grade normal heptane, unless otherwise specified.

4.21.2.3 The device under test shall be installed no higher than 2ft (0.61 m) above the bottom of the tank.

4.21.2.4 Tests shall be conducted under conditions of calm air, no precipitation, and at ambient temperatures between 50 F and 90 F (10 C and 32 C).

4.21.2.5 A 10 minute preburn shall be followed by 10 minutes of foam discharge at the manufacturer's specified application rate.

4.21.2.6 Foam shall completely cover the surface and all fire shall be extinguished within 15 minutes of the start of discharge. In addition, semi-subsurface devices shall exhibit normal specified operation, including full deployment of the hose to the surface.

4.22 Compressed Air Foam Systems

CAF systems may include pressurized air or nitrogen cylinders and related control components, specialized nozzles, and other devices not normally included in low expansion foam systems. Accordingly evaluations germane to the specific configuration may be required. Depending upon hazard selection and system design, a CAF system may also require nonstandard fire extinguishment tests to evaluate the manufacturer's specified uses. In all cases, FM Approved CAF Systems must be able to be configured to supply a 20 minute duration of CAF application to the hazard area.

4.22.1 CAF Fire Extinguishment

CAF fire extinguishment tests are similar to those described in Section 4.1 for low expansion foam concentrates. Appendix E provides the specifics of the required configurations and Appendix F provides the test chronology. Because CAF systems use specialized discharge devices and spacing, it is necessary to iterate to the required test configurations as follows.

Extinguishment tests shall be conducted using four nozzles installed on the manufacturer's maximum specified square spacing and at the manufacturer's minimum recommended foam application rate. Nozzle height shall be the manufacturer's specified minimum. A second set of tests shall be conducted using the manufacturer's maximum area of coverage asymmetry; if other than square spacing is specified for the system. After review of the test results, the worst performing combinations of concentrates, hardware, and installation geometries shall also be tested at the manufacturer's maximum recommended installation height.

Tests shall be conducted with each concentrate submitted for Approval and at the manufacturer's specified concentration(s).

Discharge duration shall be 5 minutes with 5 minutes of subsequent water discharge. Since CAF discharge devices are typically not sprinklers, this will require overlaying of the CAF piping grid with a second sprinkler grid. The sprinkler grid shall be as described for high expansion foam breakdown testing in Section 4.10.2 with a minimum water application rate of 0.3 gal/min/ft^2 (12.2 mm/min). A maximum water application rate for foam breakdown as specified by the manufacturer shall be tested for Approval. The maximum water application rate may be selected by the manufacturer from 0.3 gal/min/ft^2 to 1.0 gal/min/ft^2 (12.2 mm/min to 40.8 mm/min) at even 0.1 gal/min/ft^2 (4.1 mm/min) steps. The timing for reignition attempts and the burnback resistance evaluation shall be as specified for foam water sprinklers and the type of concentrate, as shown in Appendix E.

For water miscible fuels, discharge duration shall be 5 minutes with no subsequent water discharge. The timing for re-ignition attempts and the burnback resistance evaluation shall be as specified for foam water sprinklers and the type of concentrate, as shown in Appendix E.

If a premixed solution is not used, concentration shall be verified by appropriate instrumentation to measure water and concentrate flow rates or weight or volume changes.

A second set of tests shall be conducted using the manufacturer's maximum area of coverage asymmetry, if other than square spacings are specified for the system.

Foam quality measurements shall be made, as described in Section 4.2, *Low Expansion Foam Quality Measurements*, for comparison with foam quality produced by other mixing devices.

4.22.2 CAF Generation and Proportioning

Generation rates shall be measured for all sizes of mixing devices, with each specified concentrate, and at minimum and maximum specified water pressures.

When the mixing devices also perform the proportioning function, all sizes shall be tested to verify accuracy of proportioning of all concentrates over the manufacturer's specified range of supply pressures. Tests shall be repeated using concentrate supplies at the manufacturer's minimum specified temperature, but no higher than 35 F (1.7 C).

The quality (expansion ratio and 25 percent drainage time) of the foam produced in each test shall be measured as described in Section 4.2, *Low Expansion Foam Quality Measurements*, and shall conform to the limits specified in Table 4.3.2.2, when compared to the relevant CAF used in successful extinguishment tests.

The foam generation rates measured in these tests shall meet or exceed the manufacturer's specified capacities for each size of mixing device.

4.22.3 CAF Area of Coverage

Areas of effective coverage for each nozzle design shall be measured by foam collection at the specified flow rate, in known size pans throughout the specified coverage area. These tests shall be conducted using both the most highly and least highly expanded foams identified in the CAF generation tests and at the minimum specified nozzle height, or worst case height as determined by FM Approvals. The minimum specified application rate shall be achieved over the entire specified areas of coverage.

4.22.4 CAF Hydraulics

Because CAF systems transport foam from the generator to the discharge device in a fully expanded state, the manufacturer shall demonstrate the ability to predict flow rates at the discharge device either by testing the most restrictive specified balanced piping arrangements, or by conducting tests at the specified limits of design methodology for unbalanced systems. In these tests, discharge rates and foam quality shall be measured for all discharge points and compared to the predicted rates and the quality of the foam applied in the successful extinguishment tests.

Foam quality matching shall be evaluated against the criteria of Table 4.22.4.

Table 4.22.4 – CAF Quality Equivalency Limits

Parameter	***Minimum below Fire Extinguishment Foam***	***Maximum above Fire Extinguishment Foam***	***Remarks***
Expansion Ratio	-10 percent, or -1 expansion ratio unit, whichever is greater	+ 20 percent, or + 2 expansion ratio units, whichever is greater	A ratio of 3:1 denotes three expansion ratio units, 5:1 denotes five, et cetera
25 percent Drain Time	-10 percent, or -5 minutes, whichever is greater	+ 20 percent, or +10 minutes, whichever is greater	25 percent drain time also shall never be less than 30 seconds

Foam discharge rates shall match within ± 10 percent among all discharge points.

4.22.5 Suitability and Durability

The system shall be exercised through all its operating modes and shall operate as specified by the manufacturer. All possible combinations of inputs shall be applied and responses shall be as specified. A minimum of three trials shall be conducted for each combination with successful results. Components shall operate normally at the maximum and minimum installation temperatures, water pressures, air pressures and other extremes of specified operating ranges.

4.22.6 Gas Pressure Containing Components

All components subject to gas pressure that are intended to be shipped pressurized shall meet the relevant U.S. Department of Transportation or Transport Canada requirements or equivalent relative standard for the jurisdiction of installation. Cylinder construction shall be verified to be in compliance to the standards to which they are designed. This will require design calculations per the appropriate standards, chemical and physical data for the materials, and drawings illustrating the relevant construction details, such as wall thickness and materials. All components subject to gas pressure shall not leak at the proof test pressure and shall not be damaged when subjected to 5/3 that pressure, or twice the pressure relief setting, whichever is greater. For pressure vessels, that will be transported while pressurized, permanent volume expansion resulting from a 30 second application of the proof pressure shall not exceed 10 percent of the total expansion.

4.22.7 Durability

All operating devices shall not fail, leak, or significantly change their operating characteristics after being cycled 500 times at rated conditions.

4.22.8 Nozzle Materials

Nozzles shall not exhibit corrosion which would compromise their hydraulic or mechanical performance after being subjected to salt fog testing per Section 4.14, *Salt Fog Corrosion*.

Any nozzle incorporating moving parts showing increased resistance to motion after this test shall be retested at the lowest foam delivery pressure to ensure that it can still maintain its specified coverage area.

4.22.9 Nozzle Impact Resistance

Nozzles shall withstand a drop of 30 in. onto a concrete surface in various impact orientations with no adverse effect on hydraulic or mechanical performance.

Any nozzle incorporating moving parts showing increased resistance to motion after this test shall be retested at the lowest foam delivery pressure to ensure that it can still maintain its specified coverage area.

4.22.10 Nozzle Vibration Resistance

Nozzles shall withstand 25 hours of vibration with no failure to retain all parts or loss of ability of moving parts to move freely.

Testing shall be in accordance with FM Approvals Standard 2000, Section 4.21. Any nozzle showing increased resistance to motion of moving parts or any other symptom of impaired operation after this test shall be retested at the lowest foam delivery pressure to ensure that it can still maintain its specified coverage area.

4.23 High Expansion Foam Air Inlet and Outlet Vents

4.23.1 Vent Sizing

4.23.1.1 Requirement

High expansion foam generators require adequate venting to ensure movement of air from outside the protected space into the generator and displacement of air from the space to the outside to prevent back-pressurizing the generator. The manufacturer shall specify the allowable back pressure on his generators and shall provide sizing calculations for the required venting.

4.23.1.2 Tests/Verification

FM Approvals shall review the vent sizing calculations and may, at its discretion, require a demonstration of foam capacity per Section 4.9, while the specified maximum backpressure is applied to the generator.

4.23.2 Vent Durability

4.23.2.1 Requirement

Vents shall operate reliably over 60 cycles of operation while supplied with the minimum driving force (voltage, pressure, as applicable).

4.23.2.2 Tests/Verification

A sample vent of each design and size shall be operated 60 times as quickly as the mechanism allows while supplied with the minimum driving force. If electrically operated, this test shall be conducted at 0.85 of the rated voltage. If hydraulically operated, the minimum specified pressure shall be used. The vent shall not fail to fully open within 30 seconds of initiation of the actuation sequence.

4.23.3 Vent Resistance to Wind Loading

4.23.3.1 Requirement

A vent shall operate while subjected to wind loading.

4.23.3.2 Tests/Verification

The durability test of Section 4.23.2 shall be repeated for 3 cycles while a uniform force of 2 lb/ft^2 (96 N/m^2) is applied to its exterior surface. For this test, the vent shall be mounted in a horizontal position with its exterior face upward. Force shall be applied by means of a 1/2 in. nominal thickness sheet of plywood with additional loose weights applied, as necessary. The vent shall fully open in each trial while so loaded.

4.23.4 Vent Resistance to Snow Loading

4.23.4.1 Requirement

A roof mounted vent shall operate while subjected to snow loading.

4.23.4.2 Tests/Verification

The test of 4.23.3.2 shall be repeated with the uniform weight increased to 10 lb/ft^2 (478 N/m^2). No failure to operate in three trials shall be allowed. Vents with shields to prevent snow loading on moving parts shall be tested to verify that the shields will support the snow load.

4.23.5 Vent Operation under Icing Conditions

4.23.5.1 Requirement

A vent shall remain fully functional under icing conditions.

4.23.5.2 Tests/Verification

A vent shall be mounted in its normal installation orientation. If designed for both vertical and horizontal mounting, one sample shall be tested in each orientation. The icing exposure shall be applied to the surfaces normally exposed to the weather after a normal installation on a building wall or roof. Those areas protected by the building shall not be subject to water spray. However the entire assembly shall be subjected to the lowered temperatures. The test shall be conducted per NEMA 250, *Enclosures for Electrical Equipment (1000 Volts Maximum)*, Section 5.6.1, *External Icing Test Method*. At the end of the exposure and formation of the full 3/4 in. (20 mm) ice layer, and while still between 20 F and 27 F (-7 C and -3 C), the vent shall be operated with the minimum operating force. It shall fully open within 60 seconds of initiation of operation.

4.24 Foam Concentrate Stability

4.24.1 Requirement

All foam concentrates shall remain homogeneous solutions when stored at the maximum and minimum specified temperatures.

4.24.2 Tests/Verification

An approximately 0.16 gallon (600 ml) sample of concentrate shall be placed in a transparent closed container and stored at the manufacturer's minimum specified temperature, but no higher than 35 F (1.1 C) and a second, similar sample at the manufacturer's maximum specified temperature, but no less than 120 F (49 C). Both samples shall remain undisturbed for 90 days. At 30 days, 60 days, and 90 days the samples shall be examined for separation or stratification. No such separation or stratification shall be visible. Visible evidence of separation or stratification shall include the development of two or more distinct layers or the precipitation of any solids. Cloudiness or other changes in appearance without loss of homogeneity shall be acceptable.

4.25 Concentrate Identification Benchmarking

4.25.1 Requirement

Concentrates shall be subjected to a viscosity measurement and Fourier transform infrared spectroscopy (FTIR) analysis to obtain a benchmark profile for future reexamination reference.

4.25.2 Test/Verification

A 0.25 gal (1 L) minimum sample of each concentrate submitted for Approval shall be provided for viscosity measurement and FTIR analysis. The FTIR analysis shall be conducted in the FM Global Research Laboratory or at another competent laboratory with witnessing by an FM Approvals representative. The resulting spectrum shall be retained by FM Approvals for use in identifying deviations from the as-Approved composition, either through formulation changes, production process faults, or contamination of installed systems. Viscosity measurement shall be performed as described in Appendix J.

4.26 Additional Tests

4.26.1 Additional tests may be required, at the discretion of FM Approvals, depending on design features and results of any foregoing tests.

4.26.2 A re-test following a failure shall be acceptable only at the discretion of FM Approvals and with a technical justification of the conditions or reasons for failure.

4.27 United States Coast Guard Requirements

The USCG mandates additional requirements for Systems used in marine applications, as listed in Appendix H. Conformance to all the requirements of this standard are a prerequisite for the evaluations described in Appendix H.

4.28 Foam Chamber Vapor Seal Requirements

4.28.1 Requirement

Burst Discs for use in Foam Chamber Assemblies shall demonstrate repeatable functionality at inlet pressures below the lowest rated operating pressure of the associated Foam Chamber Assembly.

The minimum allowable hydrostatic burst pressure for any vapor seal shall be 10 psi (0.7 bar).

The maximum allowable hydrostatic burst pressure for any vapor seal shall be 25 psi (1.7 bar).

4.28.2 Test/Verification

Each configuration of Foam Chamber body size and style, configured with the smallest, mid-range, and largest orifice plates shall be fitted with representative samples of the manufacturer's specified vapor seal as it would be arranged in service.

Water shall be introduced to the Foam Chamber Assembly through the inlet at a minimal pressure as measured by a gauge installed near the flange inlet. Water pressure shall be increased at a continuous rate not exceeding 15 psi (1.0 bar) per minute until the vapor seal ruptures. The pressure at the time of rupture is to be recorded.

Three trials per each body size, orifice plate, and vapor seal combination shall be completed with acceptable results per Section 4.28.1.

5. OPERATIONS REQUIREMENTS

A quality assurance program is required to assure that subsequent systems produced by the manufacturer shall present the same quality and reliability as the specific system(s) examined. Design quality, conformance to design, and performance are the areas of primary concern.

- Design quality is determined during the examination and tests, and is documented in the Approval Report.
- Continued conformance to this standard is verified by the Surveillance Audits.
- Quality of performance is determined by field performance and as necessary by periodic re-examination and testing.

5.1 Demonstrated Quality Control Program

5.1.1 The manufacturer shall demonstrate a quality assurance program which specifies controls for at least the following areas:

- Existence of corporate quality assurance guidelines
- Incoming quality assurance, including testing
- In-process quality assurance, including testing
- Final inspection and tests
- Equipment calibration
- Drawing and change control
- Packaging and shipping
- Handling and disposition of discrepant materials

5.1.2 Documentation/Manual

There should be an authoritative collection of procedures/policies. It should provide an accurate description of the quality management system while serving as a permanent reference for implementation and maintenance of that system. The system should require that sufficient records are maintained to demonstrate achievement of the required quality and verify operation of the quality system.

5.1.3 Records

To assure adequate traceability of materials and products, the manufacturer shall maintain a record of all quality assurance tests performed, and shall maintain this record for a minimum period of two years from the date of manufacture rendered.

5.1.4 Drawing and Change Control

- The manufacturer shall establish a system of product configuration control that shall allow no unauthorized changes to the product. Changes to critical documents, identified in the Approval Report, must be reported to, and authorized by, FM Approvals prior to implementation for production.
- The manufacturer shall assign an appropriate person or group to be responsible for, and require that, proposed changes to FM Approved or Listed products be reported to FM Approvals before implementation. The manufacturer shall notify FM Approvals of changes in the product or of persons responsible for keeping FM Approvals advised by means of FM Approvals Form 797, Approved Product Revision Report or Address/ Contact Change Notice.
- Records of all revisions to all FM Approved products shall be maintained.

5.2 Surveillance Audit

5.2.1 An audit of the manufacturing facility is part of the Approval investigation to verify implementation of the quality assurance program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to insure a uniform product consistent with that which was tested and FM Approved.

5.2.2 These audits shall be conducted quarterly by FM Approvals or its representatives or more frequently dependent on jurisdictional requirements.

5.2.3 FM Approved products shall be produced or provided at or from the location(s) audited by FM Approvals and as specified in the Approval Report. Manufacture of products bearing the FM Approvals Certification Mark is not permitted at any other location without prior written authorization by FM Approvals.

5.3 Installation Inspections

Field inspections may be conducted to review an installation. The inspections are conducted to assess ease of application, and conformance to written specifications. When more than one application technique is used, one or all may be inspected at the discretion of FM Approvals.

5.4 Manufacturer's Responsibilities

The manufacturer shall provide complete instructions for the recharge and usage of systems. The instructions shall provide specific quality assurance procedures on the usage of calibrated equipment, such as scales, pressure gauges, and other necessary critical equipment, in the recharging a system.

5.5 Manufacturing and Production

5.5.1 The manufacturer shall only specify design criteria for systems which does not conflict with NFPA 11, *Standard for Low-, Medium-, and High Expansion Foam,* or any other standard specifically referenced in the Approval report and listing.

5.5.2 The manufacturer shall fabricate and test pressure cylinders in accordance with the standard(s) referenced in the Approval report and listing.

5.6 Design, Installation, Operation, and Maintenance Manual

5.6.1 Design, installation, operation, and maintenance instruction manual(s) shall be submitted for review. An English version of this manual shall be submitted to FM Approvals

The review by FM Approvals and FM Global Engineering Standards shall verify compliance to the requirements outlined by applicable FM Global Property Loss Prevention Data Sheets and the requirements of this Standard. The manual(s) should also reflect those requirements that are applicable to foam fire extinguishing systems, as outlined below:

- The manual(s) shall provide a description and operating details of all equipment associated with the fire protection system by part and/or model number
- The manual(s) shall specify the size, schedule, supporting method, and material for all piping, tubing, and fittings, as well as allowable shapes.
- The installation instructions shall be clear and concise and specify all limitations and restrictions. Diagrams of typical system installations shall be included for typical hazards.

- Any variations of the system(s) shall be discussed in detail, including the limitations and restrictions of each system. The manual(s) shall clearly identify which configurations are FM Approved by FM Approvals.
- The manual(s) shall specify all discharge devices performance criteria.
- The manual(s) shall clearly identify all requirements for detection and actuation, where applicable.
- The manual(s) shall state if the fire protection systems can be interconnected. If the systems can be interconnected, the manual(s) shall clearly indicate how the system interconnections are accomplished.
- The manual(s) shall state the ambient operating temperature range of the fire protection system.
- The minimum and maximum operating pressures of the system(s) and sub-systems shall be clearly specified at ambient 70 F (21 C) conditions, and at the minimum and maximum operating temperatures.
- The manual(s) shall specify the required acceptance and commissioning procedures.
- The manual(s) shall specify the required inspection and maintenance for the system. In addition, the manual(s) shall specify the frequency and method of inspections and maintenance.
- The manual(s) shall contain detailed instructions for restoring the complete system to full operation after a complete or partial discharge. In addition, the manual(s) shall specify the estimated time to return the system to operation.
- The manual(s) shall identify a date or revision to the manual, as well as a designation number, and shall be provided with a means by which the user can readily identify if the manual(s) are of the current revision. These items are to be identified on each page of the manual.
- The manual(s) shall identify the manufacturer or private labeler, address, contact, and service information.
- The manual(s) shall identify and outline procedures and training of personnel for testing of foam concentrate pumps as part of an ILBP or other foam systems.
- If there are references to other manuals, these publications should be included or summarized so that information needed for proper installation is available.
- The manual shall provide criteria for the installation of proportioners in accordance with Section 3.2.15

APPENDIX A: Units of Measurement

AREA:	in^2 - "square inches"; (mm^2 - "square millimeters") $mm^2 = in^2 \times 6.4516 \times 10^2$ ft^2 - "square feet"; (m^2 - "square meters") $m^2 = ft^2 \times 0.0929$
FLOW RATE:	gal/min - "gallon per minute"; (L/min - "liters per minute") L/min = gal/min x 3.785
FORCE:	lb - "pounds", (N - "newtons") N = lb x 4.448
HEAT:	Btu - "British thermal units"; (J - "joules") $J = Btu \times 1.0551 \times 10^3$
HEAT RELEASE RATE:	Btu/min - "British thermal units per minute"; (kW - "kilowatts") kW = Btu/min x 0.0176
LENGTH:	in. - "inches"; (mm - "millimeters") mm = in. x 25.4 ft - "feet"; (m - "meters") m = ft x 0.3048
LIQUID:	gal - "gallons"; (L - "liter") l = gal x 3.785
MASS:	lb - "pounds"; (kg - "kilograms") kg = lb x 0.454
PRESSURE:	psi - "pounds per square inch"; (bar - "bar") kPa = psi x 6.895 bar = psi x 0.06895
TEMPERATURE:	F - "Fahrenheit"; (C - "Celsius") C = (F - 32) x 0.556

APPENDIX B: FM APPROVALS CERTIFICATION MARKS

FM APPROVED mark:
Authorized by FM Approvals as a certification mark for any product that has been FM Approved. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable and shall be permanent. The mark should be produced in black on a light background, or in reverse on a dark background.

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Authorized by FM Approvals as a certification mark for any product that has been evaluated by FM Approvals in accordance with Canada codes and standards. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable and shall be permanent. The mark should be produced in black on a light background, or in reverse on a dark background.

FM APPROVED mark with ‘‘C’’ and ‘‘US’’:
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FM Approvals Certification Marks

Usage Guidelines

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- FM Approvals customers often have legitimate FM Approval for products being advertised and sold by others, including online trading platforms, drop-ship companies, web-based advertisers, distributors, suppliers and other legitimate business entities. The FM Approvals customer may not transfer the right to use FM Approvals certification marks or the use of the term "FM Approved" when dealing with any advertisers or marketers of these products.
- In order for the advertiser or marketer to depict the FM Approvals certification mark, the FM Approvals customer (owner) must be clearly identified in the advertisement or marketing literature. Otherwise, a Private Labeler Agreement (PLA) must exist among the two parties and FM Approvals..

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- FM Approvals certification marks shall appear on all products or packaging materials of FM Approved products in accordance with the FM Approval requirements for those products. Any similar products that are not marketed as FM Approved shall be uniquely identified and distinctive from the FM Approved product(s).

- FM Approvals certification marks are strictly limited to use in association with those products that have attained FM Approval. Use of FM Approvals certification marks in advertisements, catalogs, news releases, websites or email marketing is not a substitute for use of the complete FM Approvals certification mark on FM Approved products and/or product packaging.

  When an FM Approvals certification mark is used in advertising material, website display, electronic imaging, and quick reader scanner code or on product packaging, all material must reflect the specific circumstances under which the product was FM Approved. The material must clearly differentiate between products that are FM Approved and those that are not, and may not, in any way, imply a more substantial relationship with FM Approvals.

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- No FM Approvals certification mark or aspect thereof may be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. This includes both design aspects (the FM Approvals "diamond", etc.) and word aspects ("FM,"

  "FM Approved," etc.) The use of any FM Approvals certification mark as a trademark is strictly prohibited.
- The Approval Standard number or class number may not be incorporated as part of a business name, Internet domain name or brand name/trademark for products/product lines. For example, a company may not say "ABC Company's 4100 Fire Door is FM Approved"; the proper terminology is, "ABC Company's Fire Door is FM Approved per Approval Standard 4100."

FM Approvals Certification Marks

- FM Approvals certification marks, except for the FM Approvals Quality System Registration mark, may not be used on business stationery/cards/signage, because this could mischaracterize the relationship with FM Approvals. Additionally, these items should not reference any FM Approvals certification mark.

- FM Approvals certification marks may not be used in a 'general' context on websites or other online trading platforms. The certification mark must be used in conjunction with the actual product which is FM Approved and if being advertised by an entity other than the Original Equipment Manufacturer (OEM) the FM Approved manufacturer's name must be evident.

- Products or services may not be marketed under any mark or name similar to "FM Global," "FM Approvals" or any of the FM Approvals certification marks. Further, products or services may not be marketed to imply a relationship beyond the scope of any Approval made by FM Approvals.

- A company may not reference the intent to submit a product for Approval or the expectation that a company will have a certain product FM Approved in the future. For example, a company may not state "Approval by FM Approvals pending" or "Approval by FM Approvals applied for."

- FM Approvals certification marks should not be preceded or followed by a qualifier that indicates a degree of certification or acceptability. For example, "exceeds," "first" or "only" may not be used to qualify any FM Approvals certification mark.

Proper Appearance of FM Approvals Certification Marks

- Only original artwork issued by FM Approvals should be used. The FM Approvals certification marks should not be altered in any way other than to resize the artwork proportionately. Unacceptable uses of the marks include, but are not limited to, adding/deleting wording or artwork, reducing the artwork to an illegible size, animation or distortion.
- The text of the FM Approvals certification marks may not be translated into any language other than English.
- FM Approvals certification marks must appear in a size and location that is readily identifiable, but less prominent than the name of the owner of the certification or manufacturer/seller/distributor of the certified products.

Examples of Misuse of FM Approvals Brand Identity

- Factory Mutual Approved;
- FM Global Approved;
- Factory Mutual Research Corporation tested and certified;
- Third party tested by FM;
- Accepted for use by FM Global;
- Approved for use in Factory Mutual insured facilities;
- Factory Mutual System Approved

APPENDIX C: Component Examination Guide

Evaluation	*Component(s)*	*Section References*	*Remarks*
Extinguishing Performance	Low expansion foam concentrates	4.1	At all concentrations and with both fresh and salt water
Extinguishing Performance	High expansion foam concentrates	4.6	At all concentrations and with both fresh and salt water
Foam Quality Measurements	Low expansion foam concentrates	4.2, 4.3	All concentrates at all concentrations for extinguishment tests and for discharge devices not requiring extinguishing tests
Foam Quality Measurements	High expansion foam concentrates	4.7, 4.8	All concentrates at all concentrations for extinguishment tests and for generators not requiring extinguishing tests
Film-Forming	AFFF & FFFP concentrates	4.5	All AFFF & FFFP concentrates
Foam Concentrate Stability	All concentrates	4.24	All concentrates
Concentrate Identification Benchmarking	All concentrates and test liquids	4.25	For traceability and monitoring of future changes
Foam Generator Capacity	Foam Generators	4.9	All generators with all concentrates at all concentrations
Hydrostatic Integrity	All components capable of pressurization	4.11	Includes all devices subject to water or concentrate pressure. Special requirements for valves. Pressure vessel requirements are dependent upon the code to which they are designed. CAF systems use components subject to elevated air pressure, which shall determine test pressures for those devices.
Leakage	Valves	4.12.3, 4.12.4, 4.12.6	Both through seats and external
Operation at Minimum Temperature	Concentrate control valves, pressure switches, hydraulic actuators, proportioners	4.12.1	All components that have moving parts that could experience increased resistance due to thermal contraction, viscosity increases, stiffening of polymers, et cetera.
Operation at voltage extremes	All electrically operated devices	4.12.2	While at minimum and maximum temperatures
Functional	All mechanical, electrical, and hydraulically operated devices	4.15	Separate protocols to verify operation of all devices under most adverse normal conditions
Dielectric Withstand	All electrically powered devices	4.13	Across all combinations of two externally accessible terminals and ground.
Salt Fog Corrosion	Discharge devices, valves, and other representative components.	4.14	All materials and material combinations exposed to atmosphere with function vulnerable to corrosion.
Bladder Material Suitability	Bladder tank materials	4.17	Air-oven aging, concentrate compatibility
Foam Concentrate Pumps	All pumps	Approval Standard 1313	Performance and durability

Evaluation	*Component(s)*	*Section References*	*Remarks*
Monitors	Manual & Oscillating	4.19 and Approval Standard 1421	Performance and durability
Foam Water Sprinklers	Air aspirating and water sprinklers	4.20 and Approval Standard 2000	Fire extinguishment per Section 4.1
Subsurface and Semisubsurface Injection	Subsurface and semisubsurface discharge devices	4.21	Fire extinguishment
Compressed Air Foam Systems	Components not normally included in foam systems	4.22	Most tests for low expansion foam concentrates and components are applicable. Special conditions and additional tests are specified in this section.
Sizing, Durability, Wind Loading, Snow Loading, Icing Resistance	High Expansion System Inlet and Outlet Vents	4.23.1 through 4.23.5	Vent performance is critical to proper operation of foam generators.
Design Review	Manuals, drawings, markings	3.1 through 3.4	Configurations shall be compatible with FM Global loss prevention recommendations.

APPENDIX D: Figures

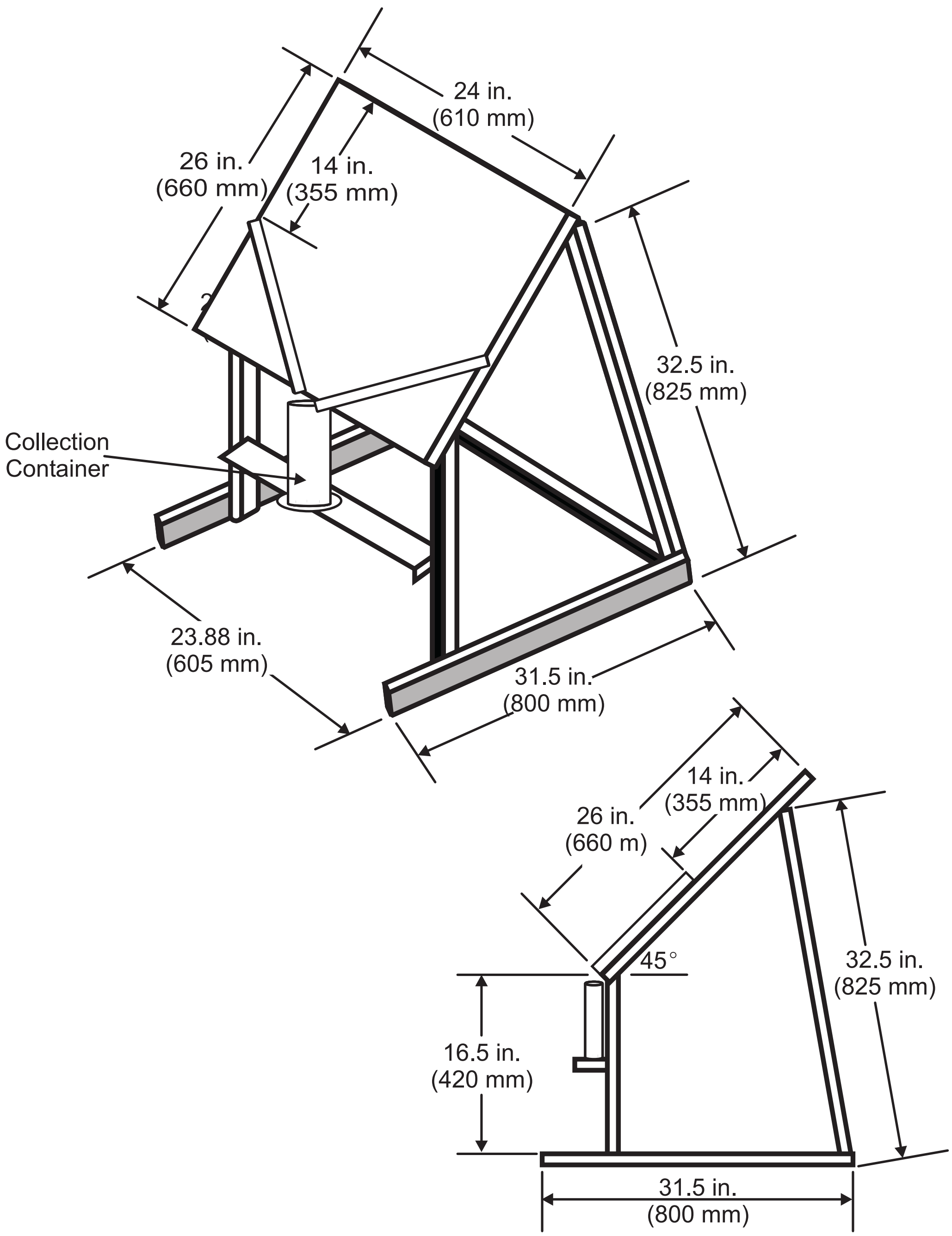

Figure D-1 *Typical Foam Slider*

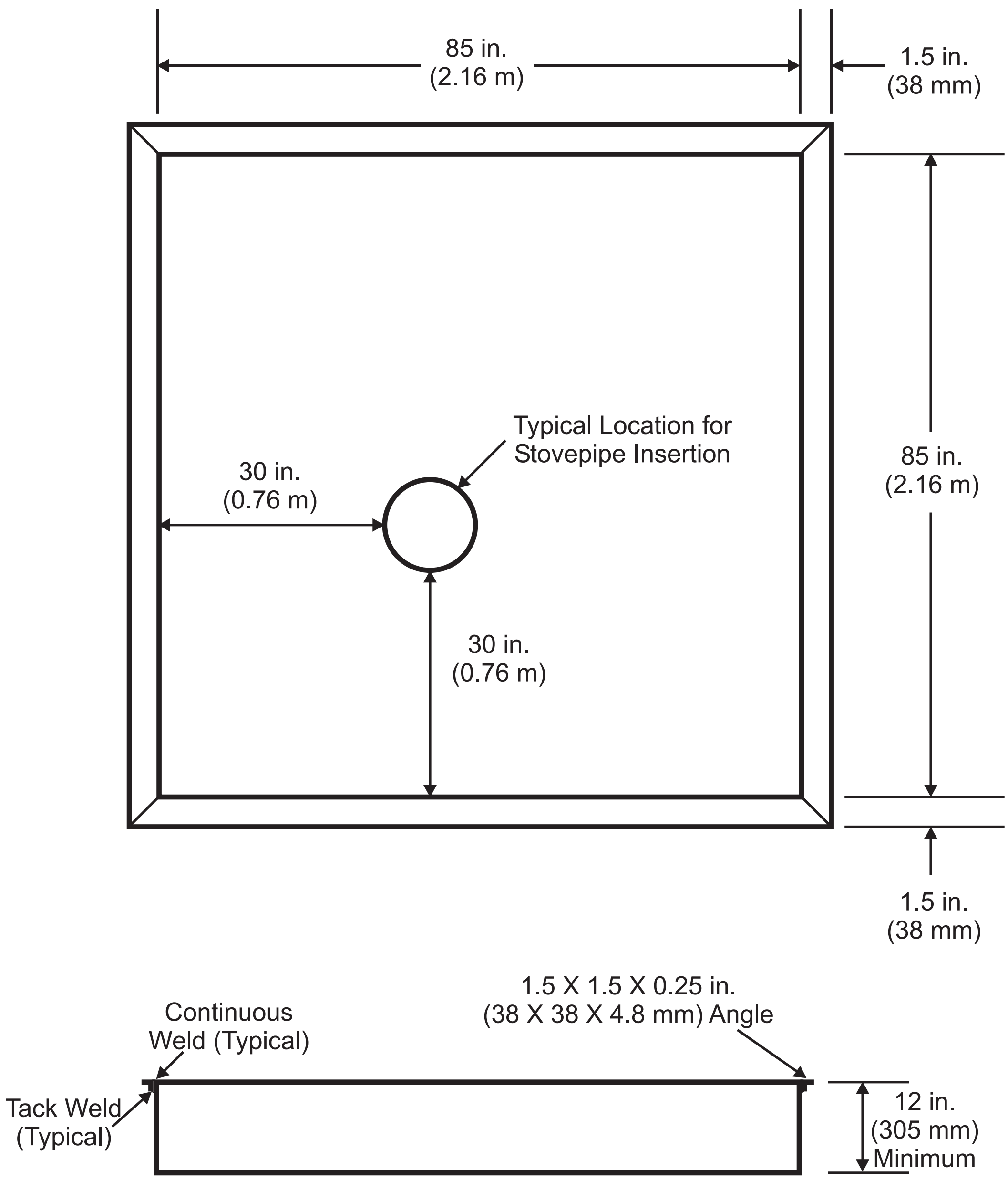

Figure D-2 *Low Expansion Fire Test Pan*

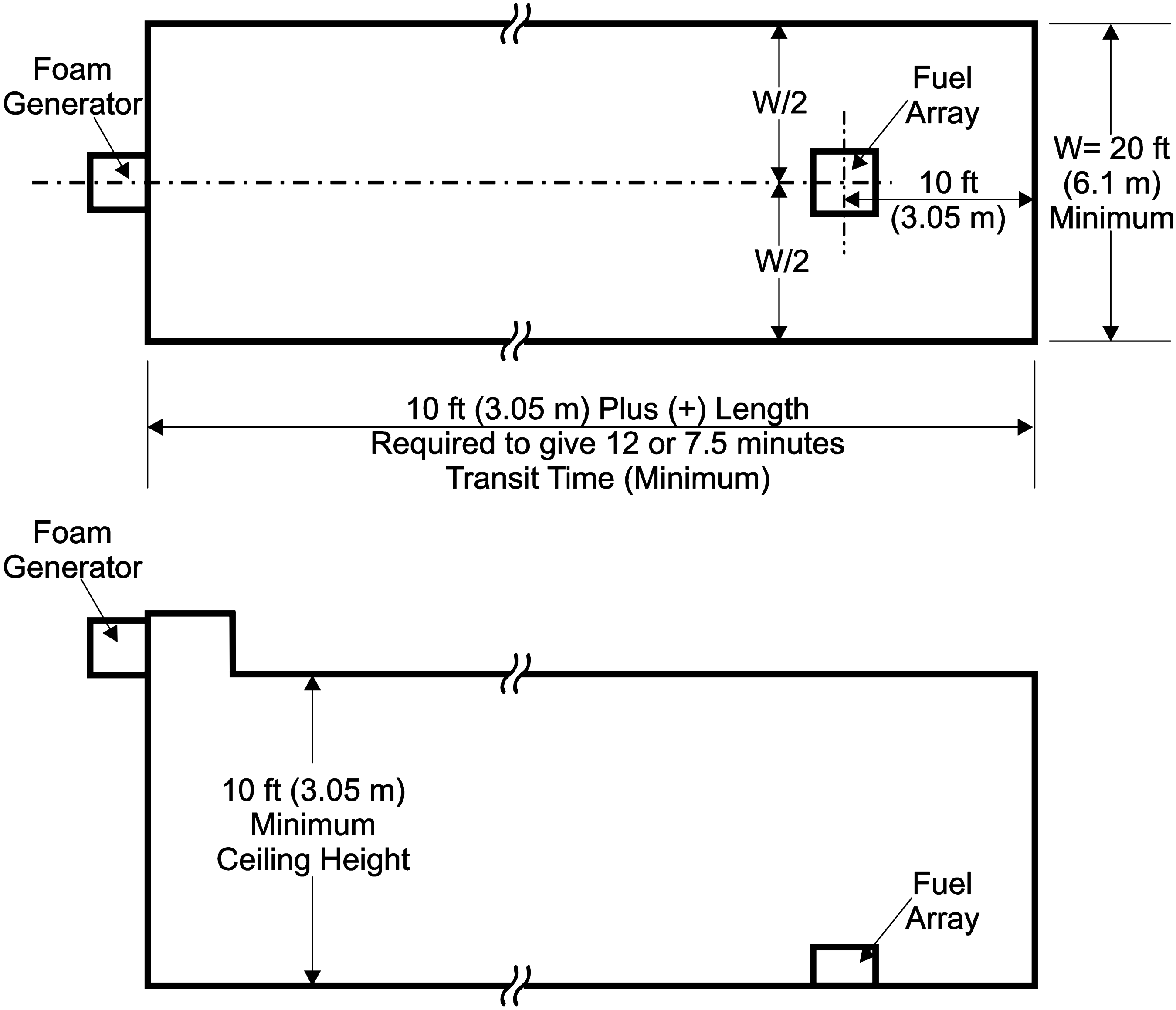

Figure D-3 *High Expansion Foam Fire Test Enclosure*

APPENDIX E: Low Expansion Foam Fire Test Configurations

Fire Test Configuration

Application Type	*Concentrate Type[1]*	*Fuel Group*	*Discharge Device Location Relative to Pan*	*Discharge Device Elevation Above Pan ft (m)*	*Minimum Test Application Rate gal/min/ft² (mm/min)*	*Remarks*
Type I	P, FP, S, FFFP (alt)	Hydrocarobon	Centered on near side	Bottom at elevation of top of pan	0.06 (2.45)	Device in fixed position
Type I	AFFF, FFFP	Hydrocarbon	Centered on near side	Bottom at elevation of top of pan	0.04 (1.63)	Device in fixed position
Type II	P, FP, S, FFFP, (alt)	Hydrocarbon	Centered on near side with no overhang	2 ft (0.61 m) above top of pan	0.06 (2.45)	Nozzle in fixed position. Foam to strike backboard above far side.
Type II	AFFF, FFFP	Hydrocarbon	Centered on near side with no overhang	2 ft (0.61 m) above top of pan	0.04 (1.63)	Nozzle in fixed position. Foam to strike backboard above far side.
Type II	Alcohol Resistant	Polar	Centered on near side with no overhang	2 ft (0.61 m) above top of pan	0.06 (2.45) Higher minimum rates may be selected as specified by the manufacturer	Nozzle in fixed position. Foam to strike backboard above far side.
Type III	P, FP, S, FFFP (alt)	Hydrocarbon	Same as for Type II or may be moved to any non-overhanging position. Cannot move from near side until Fire Control Time has been established.	Any elevation above top of pan.	0.06 (2.45)	Foam discharge to strike fuel surface until Fire Control Time has been established. Subsequently, discharge may also be directed at wall.
Type III	AFFF, FFFP	Hydrocarbon	Same as for Type II or may be moved to any non-overhanging position. Cannot move from near side until Fire Control Time has been established.	Any elevation above top of pan.	0.04 (1.63)	Foam discharge to strike fuel surface until Fire Control Time has been established. Subsequently, discharge may also be directed at wall.

Application Type	*Concentrate Type*[1]	*Fuel Group*	*Discharge Device Location Relative to Pan*	*Discharge Device Elevation Above Pan ft (m)*	*Minimum Test Application Rate gal/min/ft^2 (mm/min)*	*Remarks*
Type III	Alcohol Resistant	Hydrocarbon	Same as for Type II or may be moved to any non-overhanging position. Cannot move from near side until Fire Control Time has been established.	Any elevation above top of pan.	0.04 (1.63)	Foam discharge to strike fuel surface until Fire Control Time has been established. Subsequently, discharge may also be directed at wall.
Air Aspirating Foam Water Sprinklers, Automatic Sprinklers[2,4]	All Low Expansion	Hydrocarbon and Polar	10 x 10 ft (3.04 x 3.04 m) spacing 4 sprinkler array centered on pan.	Manufacturer's specified minimum and maximum heights above floor[4]	0.20[2] (8.2)	Five minutes of foam discharge are to be followed by five minutes of water only discharge at a minimum rate of 0.3 gal/min/ft2 (12.2 mm/min), for tests using fuels other than polar solvents
Automatic Sprinklers K= or >5.6[2,4]	All Low Expansion	Hydrocarbon and Polar	10 x 10 ft (3.04 x 3.04 m) spacing 4 sprinkler array centered on pan	Manufacturer's specified minimum and maximum heights above floor[4]	0.20[2] (8.2)	
Overhead CAF Nozzles	All Low Expansion	Hydrocarbon and Polar	Widest and most eccentric spacing specified	Manufacturer's specified minimum and maximum height above floor.[4]	Minimum specified	See Note 5

Notes:

1 P=Protein; FP=Fluoroprotein; S=Synthetic; FFFP=Film-Forming Fluoroprotein; AFFF= Aqueous Film-Forming Foam; (alt) = reserved for new or innovative concentrate technologies

2 Minimum application rate is based upon the assumption that the Air Aspirating Foam Water Sprinklers or Automatic Sprinklers will be tested, Approved and installed on a 10 ft x 10 ft (3.04 m x 3.04 m) spacing. Typical K factors and the corresponding application rates are shown in Table E-1. Sprinklers may be tested at lower application rates but can only be Approved at the application rates of Table E-1; sprinklers may not be tested at nozzle pressures below the manufacturer's specified minimum.

3 If worst case scenarios for extinguishment (combinations of concentrate, concentration, application rate, subsequent sprinkler water application rate, and fuels giving longest extinguishment times and least burnback resistance) can be identified for the lowest specified installation heights, then FM Approvals may limit the number of tests required at the maximum specified installation heights.

4 The minimum allowable test and installation height for Air Aspirating Foam Water Sprinklers is 36 in (0.91 m). The minimum allowable test and installation height for Automatic Sprinklers is 72 in (1.82 m).

5 Uniformity of coverage to be separately evaluated, in non-fire distribution tests. Spacing and application rate shall be limited by minimum application rate successfully tested. Five minutes of foam discharge are to be followed by five minutes of water only discharge at a minimum rate of 0.3 gal/min/ft2 (12.2 mm/min), for tests using fuels other than polar solvents. Water discharge shall be from an overlaid sprinkler system utilizing either 5.6 K Factor or 8.0 K Factor, pendent FM Approved sprinklers

All heptane fires shall be extinguished at the minimum application rates tabulated. Polar solvent fires may be extinguished at higher rates if so specified by the manufacturer.

Where alternate (alt) application rate minimums are offered, a concentrate will only be listed based upon the lowest rate at which it was successfully tested

Table E-1 Minimum Application Rates for Sprinklers

Discharge Coefficient or K Factor	***Minimum Application Rate gal/min/ft^2 (mm/min)***
5.6	0.2 (8.2)
8.0	0.3 (12.2)
11.2	0.3 (12.2)
16.8	0.5 (20.4)

APPENDIX F: Low Expansion Foam Fire Test Chronology

Event	Target Time from Ignition, min:s			
	Sprinklers & CAF Nozzles ***Reference Sections 4.1.2.6.1 and 4.1.2.9.1***		**Topside Discharge *Devices*[1]** ***Reference Sections 4.1.2.6.2 and 4.1.2.9.2***	
	Hydrocarbon Fuels	***Polar Solvent Fuels***	***AFFF & FFFP[2] with Hydrocarbon Fuels***	P, FP, S, FFFP and (alt) foams ***with Hydrocarbon Fuels and Alcohol Resistant Foams with Polar Solvent Fuels***
Ignition Preburn Starts	00:00	00:00	00:00	00:00
Foam Application Starts Preburn Ends	00:15	00:15	01:00	01:00
Fire Control Time	Not Applicable	Not Applicable	Record actual time	Record actual time
Fire Out	Record actual time[3]	Record actual time[3]	Record actual time[3]	Record actual time[3]
Foam Application Ends	05:15	05:15	04:00	06:00
Water Application Starts	05:15	Not applicable	Not applicable	Not applicable
Water Application Ends	10:15	Not applicable	Not applicable	Not applicable
First Torch Pass	11:15	06:15	05:00 (or 10:00[2])	07:00
Second Torch Pass	17:15	17:15	11:00 (or 16:00[2])	18:00
Stovepipe Insertion	18:15	18:15	12:00 (or 17:00[2])	19:00
Stovepipe Ignition	19:15	19:15	13:00 (or 18:00[2])	20:00
Stovepipe Removal	20:15	20:15	14:00 (or 19:00[2])	21:00
Rift Fire Extinguished	Record actual time[4]	Record actual time[4]	Record actual time[4]	Record actual time[4]
Rift Fire > 10 ft^2	Record actual time[4]	Record actual time[4]	Record actual time[4]	Record actual time[4]
Final Observation	25:15	25:15	19:00 (or 24:00[2])	26:00

AFFF = Aqueous Film Forming Foam; FFFP = Film Forming Fluoroprotein;

P=Protein; FP=Fluoroprotein; S=Synthetic;

(alt) = reserved for new or innovative concentrate technologies

At the discretion of FM Approvals, chronology may vary slightly from target times, as long as the foam blanket remains undisturbed for a minimum of 10 minutes (15 minutes for polar solvent fuels) after the completion of all discharge (foam or water) and the rift fire is observed for a minimum of 5 minutes after removal of the stovepipe.

Notes:

1 Other application devices which may be used under fire protection sprinkler systems shall also be tested with 5 minutes of water application subsequent to the end of foam discharge at a minimum rate of 0.3 gal/min/ft^2 (12.2 mm/min). In such cases, the remaining target times will be increased to compensate for the added 5 minutes for the water application.
2 FFFP at 0.04 gal/min/ft^2 (1.63 mm/min) application rate, only.
3 Fire shall be extinguished by the end of foam application.
4 If the fire in the stovepipe rift is extinguished, the time of extinguishment shall be recorded. Conversely, if the rift fire spreads to an area greater than 10 ft^2 (0.93 m^2), the time for that event shall also be recorded.

APPENDIX G: Conductivity Test Procedure

General

This method is based on changes in electrical conductivity as foam concentrate is added to water. A handheld conductivity meter is used to measure the conductivity of foam solutions in microsiemen units. Conductivity is a very accurate method, provided there are substantial changes in conductivity as foam concentrate is added to the water in relatively low percentages (i.e., 1 percent, 3 percent, or 6 percent). Since salt or brackish water is very conductive, this method might not be suitable due to small conductivity changes as foam concentrate is added. It will be necessary to make foam and water solutions in advance to determine if adequate changes in conductivity can be detected if the water source is salty or brackish. If conductivity is not an appropriate proxy for concentration due to one of these circumstances, then direct flow rate or timed volume or weight change measurements of the water and concentrate supplies shall be used to determine concentration.

Equipment Required

A base calibration curve shall be prepared using the following apparatus:

1. Four 100-ml plastic bottles with caps
2. One 10-ml measuring pipette or 10-cc syringe
3. One 100-ml graduated cylinder
4. A laboratory stirring device and plastic-coated magnetic stirring bars
5. One portable temperature-compensated conductivity meter
6. A temperature measuring device
7. A personal computer
8. A spreadsheet program with graphing and straight line regression capability.

Procedure

Using the water and foam concentrate from the system to be tested, a minimum of three standard solutions shall be made up using the 100-ml graduate.

At minimum, these standards shall include the nominal specified percentage of injection, the nominal percentage plus 1 or 2 percentage points, and the nominal percentage minus 1 or 2 percentage points.

The water shall be placed in the 100-ml graduate (leaving adequate space for the foam concentrate) and then the foam concentrate samples shall be carefully added into the water using the syringe to measure the specified amount. Care shall be taken not to pick up air in the foam concentrate samples.

Each standard foam solution shall be poured from the 100-ml graduate into a 100-ml plastic bottle. Each bottle shall be marked to indicate the percent solution it contains. A plastic stirring bar shall be added to the bottle. The bottle shall be capped, placed on the stirring device, and stirred thoroughly to mix the foam solution.

The samples shall be brought to the same temperature as the tested solution, 70 F +/-5 F (21 C, +/-2 C).

The conductivity of each solution shall be measured. Reference shall be made to the instructions for the specific conductivity meter to determine proper procedures for taking readings. It will be necessary to switch the meter to the correct conductivity range setting to obtain a proper reading. Most synthetic-based foams used with freshwater will result in foam solution conductivity readings of less than 2000 microsiemens. Protein-based foams will generally produce conductivity readings in excess of 2000 in freshwater solutions. Due to the temperature compensation feature of the conductivity meter, it can take a short time to obtain a consistent reading.

Once the solution samples have been measured and recorded, the bottles shall be set aside for control sample references. The standard concentrations and conductivity readings shall then be entered into a spreadsheet program and plotted with the foam solution percentage on the horizontal axis and conductivity readings on the vertical axis.

Using the spreadsheet utility, the best line shall then be fitted to the data and the equation of that line, as well as its R^2 correlation coefficient shall be obtained. If the correlation coefficient is 0.95, or higher, then the equation for that line shall be used to calculate the concentrations from conductivity readings, for that concentrate and water supply. If the correlation coefficient is less than 0.95, the test shall be repeated until data is obtained which will generate a curve fit of acceptable accuracy. This plot will serve as the known base (calibration) curve to be used for the test series.

Obtaining and Evaluating Test Samples

Foam solution samples shall be collected from the proportioning system, using care to ensure the sample is taken at an adequate distance downstream from the proportioner being tested and that the flow has been well established to flush any stagnant water from the system. Using foam solution samples that are allowed to drain from expanded foam can produce misleading conductivity readings and, therefore, is not allowed.

Once one or more samples have been collected and stabilized at 70 F, +/-5 F (21 C, +/-2 C), their conductivity shall be read and the corresponding percentage found using the line equation of the base curve prepared from the control sample solutions.

At the conclusion of all readings a water sample shall be obtained and a new calibration sample produced at the specified concentration to revalidate the base curve. If the measured and specified values do not match within 5 percent of the specified value, then additional calibration samples shall be made, and the software used to produce a new baseline equation. The test sample conductivities shall then be used to obtain new calculated concentrations and these averaged with those obtained from the pretest baseline to produce the final figures to be used for evaluation of the proportioning device.

APPENDIX H: United States Coast Guard Requirements

The USCG generally requires testing of foam extinguishing systems performed by FM Approvals per this standard, but has some further restrictions on configurations and acceptable performance. These include:

Only complete systems shall be FM Approved. Component Approval shall not be allowed.

Fire extinguishment tests shall be conducted per NFPA 11, *Standard for Low-, Medium-, and High Expansion Foam*, (2005 Edition), Annex G, Test Method for Marine Fire-Fighting Foam Concentrates Protecting Hydrocarbon Hazards.

A safety factor of 8/3 of the successfully tested fire tested application rate shall be used for the design application rate.

Metallic components shall be resistant to corrosion in foam concentrate.

Hard rubber hoses shall be FM Approved for use with the foam solution. Tests shall include hydrostatic integrity, flexure at low temperature, and resistance to concentrate at maximum temperature.

Discharge devices shall be constructed of corrosion-resistant materials but cannot be aluminum, brass having more than 15 percent zinc, or non-metallic materials.

Monitors shall be tested for range. Design range of monitors shall be limited to 75 percent of the successfully tested range.

ASME pressure tanks shall meet the criteria of Subchapter F of the CFR (Code of Federal Regulations).

Piping for AFFF concentrates shall be stainless steel.

Proportioners cannot be field-adjustable. They shall be factory-preset for a specific proportioning ratio.

Foam vests (foam concentrate containers designed to be worn by personnel) shall not be FM Approved. Eductors shall be configured to allow proportioning from 5 gal (18.9 L) concentrate containers.

APPENDIX I: Alternate Foam Quality Test Procedure

General

This method is an alternative to that described in Section 4.2 and is most useful for relatively slow draining foams, such as those with 5 minute or longer 25 percent drainage times.

Equipment Required

1. The foam slider, as described in Section 4.2.
2. A transparent or translucent collection container of 0.25 to 0.50 gal (1 to 2 L) size having a conical bottom. An inexpensive container can be made from an inverted 2 liter soft drink bottle with its bottom cut off.
3. A cock or valve to allow slow draining of liquid from the conical bottom of the container. A 1/4 in. nominal size plastic or brass valve can be fastened to the container by a length of transparent or translucent plastic tubing, a hose barb x threaded fitting, and hose clamps. A short length of tubing on the discharge side of the valve is useful to improve control of the drained fluid.
4. A receiving container for the drained fluid.
5. A stand to support the conical-bottomed collection container above the receiving container and scale.
6. A scale with accuracy of +/- 0.1 g.
7. A squeegee or other straight edge for removing excess foam from the collection container.
8. A timer for measuring the drainage time.

Procedure

1. Zero the scale with the assembled empty collection container and its stand.
2. Fill the collection container with the foam solution and record the net weight. Discard the solution.
3. Collect the foam sample as described in Section 4.2, starting the timer when the container is full.
4. Clean any excess foam off the outside of the container and stand and doctor the foam surface flush with the top of the container using the straight edge.
5. Weigh the foam-filled container to obtain the net foam weight and remove from scale, recording that weight.
6. Place the receiving container on the scale and rezero the scale.
7. Divide the net foam weight by 4 to obtain the 25 percent drainage weight.
8. Place the collection container straddling, but not touching, the scale and receiving container.
9. Observe the tubing connecting the bottom of the collection container to the drain valve for presence of liquid.
10. Slightly open the valve to drain off any accumulated liquid until foam begins to emerge.
11. Repeat steps 9 & 10 until the 25 percent weight is reached and record the elapsed time as the 25 percent drainage time.
12. Divide the net weight of the solution by that of the foam and record the result as the expansion ratio.

APPENDIX J: Viscosity Test Procedure

Viscosity determinations shall be made at 65 F ± 5 F (18 C ± 2.7 C).

The viscosity of the concentrate or test liquid shall be measured at the temperatures of 35 F, 70 F, 77 F, 120 F and minimum concentrate use temperature (2 C, 21 C, 25 C and 49 C) according to the following:

A Brookfield viscometer, model LVT or LVF, or the equivalent, set at 30 r/min or 60 r/min with the appropriate spindle (Number 2 for viscosities from 1 to 500 centipoise and Number 4 for viscosities greater than 500 centipoise), shall be used to measure the viscosity.

A straight-sided container that contains approximately 27 oz (800 ml) of the test sample shall be positioned under the viscometer.

The spindle shall be immersed in the liquid to the indicated depth.

The viscometer then shall be turned on, and the spindle shall be allowed to rotate for 1 minute prior to taking the measurement.

Triplicate measurements shall be made, stirring gently between each measurement, and the viscosity of the sample shall be reported in centipoise.

APPENDIX K: Listing Information

List in appropriate subcategory, Low Expansion, High Expansion, Foam Water Sprinklers, or Compressed Air Foam.

Manufacturer's name and address

Concentrate name, type, applicable fuels, design concentration percentage, acceptable proportioning devices and methods, acceptable discharge devices.

Bladder Tank capacity, orientation (horizontal or vertical) and acceptable concentrates.

Concentrate Control Valve type, name, nominal pipe size, connection, pressure rating and required operating pressure or voltage.

Proportioner type, name, nominal pipe size, connection type, orientation (horizontal or vertical), inlet pressure range, solution flow range, finish, and acceptable concentrates.

Foam Discharge Device type, name, nominal size, connection type, inlet pressure range, flow rate or flow range, finish, and acceptable concentrates.

Air Aspirating Foam Water Sprinklers or Automatic Sprinkler type, acceptable concentrates, connection type, orientation, acceptable fuels, minimum design application rate, maximum sustainable water application rate, deflector minimum height above floor and maximum height above floor.

High Expansion Foam Generator type, name, orientation, flow rate (foam solution), volumetric flow rate (expanded foam), volumetric flow rate when under water impingement, inlet pressure range, and acceptable concentrates.

Low Level Foam Discharge Device type, name, orientation, flow rate (foam solution), minimum design application rate, maximum sustainable water application rate, inlet pressure range, area of coverage, horizontal angle of coverage and acceptable concentrates.

For Compressed Air Foam (CAF) Systems:

Fuel	*Concentrate*	*Discharge Device Description*	*Nozzle Height*		*Maximum nozzles per system (If applicable per above system description)*	*Spacing or maximum area of coverage per nozzle*	*System Capacity*		*Minimum Design Application Rate*	*Maximum Sprinkler Density**
			Min ft (m)	*Max ft (m)*		*ft^2 (m^2)*	*Gallons (liters)*	*Minutes*	*Gal/min/ft^2 (mm/min)*	*Gal/min/ft^2 (mm/min)*