FOAM EXTINGUISHING SYSTEMS

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1.0 SCOPE

This data sheet contains recommendations related to low and high-expansion foam fire extinguishing systems. It provides guidelines for:

- Design, installation and acceptance testing of low-expansion foam systems
- Installation and acceptance testing of high-expansion foam system concentrate storage proportioning equipment

Unless specifically recommended in the relevant occupancy or hazard specific data sheet, foam extinguishing systems are commonly used to supplement automatic sprinkler systems. In some cases, the fire extinguishing system is used to provide sole protection for a specific piece of equipment or as an alternative to automatic sprinklers.

Currently, FM only recognizes the use of high-expansion foam systems for property loss prevention purposes in aircraft hangers when used in conjunction with sprinklers.

This data sheet does not cover the following:

- Inspection, testing, and maintenance. Refer to Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance*.

1.1 Hazards

Low-expansion foam fire extinguishing systems can provide effective fire protection for facilities whose operations involve the handling, processing, or transfer of ignitable liquid, and, in certain cases, the storage of ignitable liquid in portable containers or bulk tanks. Foam-water sprinkler systems are particularly appropriate for protecting facilities where the primary hazard is an ignitable liquid floor-spill fire (i.e., a two-dimensional spill fire), such as aircraft hangars, ignitable-liquid truck-loading and unloading stations, and single-level ignitable liquid product manufacturing, processing, and/or storage facilities.

While low-expansion foam systems can provide effective fire protection for these hazards, they need to be provided within their limitations. These protection systems lack full-scale testing (See Section 3.8, Test Data). Their abilities and shortcomings have not been fully evaluated. A few critical elements that remain uncertain are:

A. The speed of fire extinguishment in real process area or storage area fires.

B. The amount of cooling that can be provided if the ignitable liquid release is of long duration.

C. The impact on a storage array of ignitable liquids in portable containers.

Until these critical elements have been tested, the full value of foam fire extinguishing systems cannot be understood or utilized.

Low-expansion foam fire extinguishing systems are not suitable for extinguishing three-dimensional fires, such as cascading fuel or spray fires. However, with proper design and floor area containment, they can be of value in the control and extinguishment of resultant pool fires.

Data Sheet 4-0, *Special Protection Systems*, provides a list of hazard- and occupancy-specific data sheets that recommend foam fire extinguishing systems.

1.1.1 Availability

All special protection systems have inherent limitations that must be recognized and considered before a system is installed.

Foam fire extinguishing systems use a supply of foam concentrate that could be exhausted before a fire is extinguished. Like other special protection systems with a limited quantity of extinguishant, foam fire extinguishing systems are more susceptible to failure to extinguish a fire than automatic sprinkler systems.

Foam fire extinguishing systems are complex special protection systems as compared to automatic sprinkler systems and thus are susceptible to lower availability. They require qualified personnel to design, install, test, and maintain them for a satisfactory availability. Qualified personnel should be specifically trained by the special protection system Original Equipment Manufacturer (OEM). Due to the complexity of these systems, FM does not encourage client plant personnel to be involved with any inspection or testing activities for special protection systems beyond normal visual inspections. If client plant personnel will be conducting functional testing and maintenance functions on any special protection system, these personnel should be properly trained by the qualified installing contractor and provided with detailed instruction manuals for the specific equipment/installation involved.

Due to their complexity, which impacts availability, passive design options should be considered that would eliminate the need for a foam fire extinguishing system. These include emergency drainage, limiting ignitable liquid quantities, and using FM Approved containment or drainage systems.

See Understanding the Hazard (UTH): Special Protection System Reliability (FM publication P0379) for information on general deficiencies related to special protection systems.

1.2 Changes

April 2025. Interim revision. Significant changes include the following:

A. Reformatted Section 2.1, Introduction, to add general recommendations for the inclusion of medium- and high-expansion foam systems.

B. Updated Section 2.6.4.17, Alternate Test Methods, to include test liquids for Planit Safe that are allowable for SFFF and AR-SFFF.

C. Updated viscosity information in Section 2.5.4, Foam Concentrate Proportioners and Section 3.4.5, Foam Concentrate Proportioning Methods on the compatibility of SFFF and AR-SFFF concentrates for use with variable viscosity proportioners.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

2.1.1 General

2.1.1.1 Provide FM Approved systems, equipment, materials, and services whenever they are applicable and available. For a list of products and services that are FM Approved, see the *Approval Guide*, an online resource of FM Approvals.

2.1.1.2 Design and install low-expansion foam fire extinguishing systems in accordance with the following:

A. The relevant occupancy- or hazard-specific data sheet

B. The application associated with their listing in the *Approval Guide*, a publication of FM Approvals

C. The manufacturer's design, installation, operation, and maintenance (DIOM) manual as identified as part of the FM Approval by document identification number and revision level

D. Any specific jurisdictional requirements

2.1.1.3 Design and install high-expansion foam fire extinguishing systems in accordance with the following:

A. The relevant occupancy- or hazard-specific data sheet (in this case Data Sheet 7-93, *Aircraft Hangers, Aircraft Manufacturing and Assembly Facilities, and Protection of Aircraft Interiors During Assembly*).

B. The air supply for the system is fed from outside the protected volume. Ideally provide outside air for the system.

C. The listing in the *Approval Guide*, a publication of FM Approvals

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

E. The manufacturer's design, installation, operation and maintenance (DIOM) manual, identified as part of the FM Approval by document identification number and revision level.

F. Any specific jurisdictional requirements.

2.1.1.4 When a component is not part of the foam extinguishing system (e.g., alarm check valve, deluge valve, backflow preventer not identified in the manufacturer's FM Approved DIOM manual), provide FM Approved equipment that conforms to the foam fire extinguishing system's specifications (pressure rating, rate of flow, etc.)

2.1.2 Ensuring Availability and Maintainability

Ensure that the necessary initial and on-going costs for inspection, testing, and maintenance are factored into the decisional process when evaluating the installation, including but not limited to the following:

- A plan to budget for the long-term cost of the foam fire extinguishing system over the life of operation. Costs for this work regularly exceed those of other special protection system types.
- Type of foam fire extinguishing system equipment and installation
- Acceptance testing including discharge testing or proportioner testing of the system to verify proper proportioning.
- Annual operational tests to evaluate the proportioning system.
- Possible collection and disposal of foam water effluent from acceptance testing, annual discharge testing, and discharge as a result of a fire event.
- Other necessary annual inspection testing and maintenance (Reference Data Sheet 2-81).
- Stocks of replacement/spare foam concentrate where needed.

2.2 Construction and Location

2.2.1 Equipment Location

2.2.1.1 Locate storage containers (e.g., foam concentrate), water tank, compressed gas cylinders, proportioning equipment components, pumps, control/actuating valves, regulating devices, monitoring devices, and the control panel) per the following as applicable:

A. In a room separate from the protected area.

B. So temperatures are maintained between 40°F (4°C) and 130°F (54°C), within the system manufacturer's listed limits of Approval and in accordance with the applicable recommendations in Data Sheet 9-18, *Protection Against Freeze-Up* (See Section 3.2 for further information).

C. So as not to be subject to mechanical, chemical, climatic, or other conditions that can render them inoperative or susceptible to accidental damage or operation.

D. Are fully accessible for inspection, testing, maintenance, and removal or replacement.

2.2.2 Equipment Location, Remote

2.2.2.1 When foam fire extinguishing system equipment is installed in a separate, stand-alone enclosure from normal building services, provide backup power to the climate control system, or a supervisory alarm in case temperatures fall outside the range specified in 2.2.1.1.

2.2.3 Earthquake

2.2.3.1 Consider foam fire extinguishing systems equivalent to a fire protection system as identified in Data Sheet 1-2, *Earthquakes*.

2.2.3.2 If seismic restraint is needed for the foam extinguishing system equipment (e.g., concentrate storage tank, foam concentrate pump, distribution system pipe), provide the following:

A. Calculations of seismic loads in accordance with Data Sheet 1-2, *Earthquakes*

B. Bracing and anchoring of the fire protection system in accordance with Data Sheet 2-8, *Earthquake Protection for Water-Based Fire Protection Systems*

2.2.4 Emergency Drainage and Containment

To prevent the flow of liquid into adjacent areas of the facility that are not protected for an ignitable liquid hazard, provide emergency drainage and containment in accordance with the following, as applicable:

- Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*
- Data Sheet 7-32, *Ignitable Liquid Operations*
- Data Sheet 7-83, *Drainage and Containment Systems for Ignitable Liquids*

2.3 Occupancy

2.3.1 System Identification

2.3.1.1 Provide system information signage near the foam concentrate storage tanks, proportioner, or releasing control panel that gives specifications of the foam fire extinguishing system for the hazard(s) being protected (see Section 3.3.1).

2.3.1.2 Provide nameplates or other permanent markings that indicate the following:

A. For system foam concentrate containers, their contents (i.e., concentrate type, injection rate, quantity), as applicable.

B. For system compressed gas cylinders, their contents (i.e., type of gas) and volume, as applicable.

C. For system water containers, their contents (i.e., water quality) pressurization level and volume, as applicable.

2.3.1.2.1 Clearly mark foam concentrate storage tanks with the following:

- type of foam concentrate
- percentage (of foam concentrate in the foam solution)
- manufacturer
- lot number
- fill date(s)

2.3.1.3 Provide nameplates/instructions in the immediate vicinity of valves, proportioners, foam concentrate storage tanks, piping, and other critical system components to identify their function, operating positions, and contents (i.e., foam concentrate, water, or compressed air).

2.3.1.4 Provide operating instructions that indicate the location and purpose of the actuation controls.

2.3.1.5 Provide signage on the proper shutdown sequence of valves and equipment after the foam fire extinguishing system has activated.

2.4 Protection

2.4.1 Application

2.4.1.1 FM Approved low- and high-expansion foam fire extinguishing systems may be used to provide protection of equipment or a hazard in accordance with the relevant occupancy- or hazard-specific data sheet. Also provide a primary form of fire protection (typically an automatic sprinkler system) for protection of the building construction when recommended in the relevant occupancy- or hazard-specific data sheet.

2.4.2 Design

2.4.2.1 Provide low- and high-expansion foam fire extinguishing systems in accordance with their:

A. FM Approval listing limitations.

B. Manufacturer’s FM Approved design, installation, operation and maintenance (DIOM) manual.

2.4.3 Foam Concentrate

2.4.3.1 Use foam concentrates in accordance with their FM Approval listings including the ignitable liquid type, equipment, and components identified in the FM *Approval Guide* as part of the system listing.

2.4.3.2 The following foam concentrate types are acceptable to provide protection of non-polar ignitable liquids:

- Synthetic fluorine-free foam (SFFF)
- Alcohol-resistant synthetic fluorine-free foam (AR-SFFF)

Protein, fluoroprotein, and film-forming fluoroprotein, foam concentrates should not be used in new systems as there are currently no FM Approved versions of these foam concentrates.

Refer to Section 3.4.4, Foam Concentrates, for more information and references to regulations on fluorinated "C8" foam concentrates compared to fluorinated "C6" foam concentrates.

2.4.3.2.1 Use the foam concentrate with the specific ignitable liquids it has been listed within the manufacturer's FM *Approval Guide* listing.

2.4.3.2.2 For a non-polar ignitable liquid that is not listed with the concentrate, if it has a closed cup flash point that is the same or greater than heptane [25°F (- 3.9°C)], it is acceptable to use the foam concentrate with that ignitable liquid.

2.4.3.2.3 For a non-polar ignitable liquid mixture, use the liquid component with the lowest closed cup flash point and if it is the same or greater than heptane [25°F (- 3.9°C)] , it is acceptable to use the foam concentrate with that mixture.

2.4.3.2.4 If the ignitable liquid meets the criteria provided in 2.4.3.2.2 or 2.4.3.2.3 and the foam concentrate is listed for protection of heptane, design the foam-water extinguishing system based on the criteria provided for heptane in the manufacturer's FM *Approval Guide* listing and Section 2.4.9.

2.4.3.3 The following foam concentrate types are acceptable to provide protection of polar ignitable liquids:

- Alcohol-resistant synthetic fluorine-free foam (AR-SFFF)

2.4.3.3.1 Use an alcohol-resistant foam concentrate with the specific polar ignitable liquids it has been listed with in the FM *Approval Guide* listing.

2.4.3.3.2 Treat any ignitable liquid that is miscible or soluble in water as a polar liquid.

2.4.3.3.3 Treat ignitable liquid mixtures with any percentage of a water miscible or water-soluble component as a polar liquid.

2.4.3.4 Do not mix foam concentrates from different manufacturers or different types of foam concentrate.

2.4.3.4.1 If the foam concentrate manufacturer(s) provides documentation that certifies the compatibility of an AFFF-C6/AR-AFFF-C6 foam concentrate mixture to be viable, it is acceptable.

2.4.3.4.2 AFFF-C6 foam concentrates from different manufacturers that are on the Qualified Products List (QPL) for United States Military Specification (MIL-PRF-24385F) 3% AFFF can be mixed. These concentrates have been qualified to a government standard in order to be compatible.

2.4.3.5 Reevaluate the foam concentrate for providing protection (e.g., application density) and potentially replace the foam system equipment and components in a system when:

2.4.3.5.1 The ignitable liquid being protected changes from a non-polar to a polar ignitable liquid or liquid mixture.

2.4.3.5.2 The existing foam concentrate is being changed to another type of foam concentrate.

2.4.3.6 Do not use wetting agents as a substitute for foam concentrates. There is no current testing that demonstrates a wetting agent will provide protection equivalent to an FM Approved foam concentrate for ignitable liquids. See Section 3.4.4.4

2.4.4 Water Supply

2.4.4.1 Provide a water supply for the foam fire extinguishing system at the design discharge rate and pressure for at least 60 minutes, or in accordance with the applicable occupancy-specific data sheet, whichever is longer.

2.4.4.2 Connect multiple types of fixed discharge devices (e.g., foam-water sprinklers and low-level floor nozzles) to the same water supply as the foam fire extinguishing system only if the necessary water supply and foam concentrate is available for the operating time.

2.4.4.3 Compressed Air Foam

2.4.4.3.1 Provide water supplies of a capacity for both the compressed air foam system and an automatic sprinkler system:

- within the range of the minimum and maximum pressure to maintain the compressed air foam system(s), and
- automatic water sprinkler system protection discharge at the design rate for the required period of time over the entire demand area and/or protected area.

2.4.4.3.2 Provide a stable predictable water supply. Test data determining the available flow +/-10 psi (+/-0.7 bar) and inlet pressure at the point of connection for the compressed air foam system to the water supply is typically needed for design purposes.

2.4.5 Compressed Air Supply (Compressed Air Foam)

2.4.5.1 Provide at least enough compressed air for the largest single hazard protected, or a group of hazards that are to be protected simultaneously.

2.4.5.2 Provide a reserve supply of compressed air sufficient to meet system design requirements to put the system back into service after operation, or one available from an approved outside source within 24 hours.

2.4.6 Foam Concentrate Proportioning Methods

2.4.6.1 Use balanced-pressure or positive-pressure injection methods to introduce foam concentrates into the water flowing through the supply piping to the system. Based on the hazard or occupancy to be protected, use one of the following balanced- or positive-pressure injection methods:

- Bladder tank proportioning (Figure 2.4.6.1-1)
- Balanced pressure proportioning (Figure 2.4.6.1-2)
- In-line balanced proportioning (ILBP) (Figure 2.4.6.1-3 and Figure 2.4.6.1-4)
- Line proportioning, deluge applications only (Figure 2.4.6.1-5)
- Wide Range proportioning (Figure 2.4.6.1-6)
- Variable Viscosity Proportioner (Figure 2.4.6.1-7a and Figure 2.4.6.1-7b)

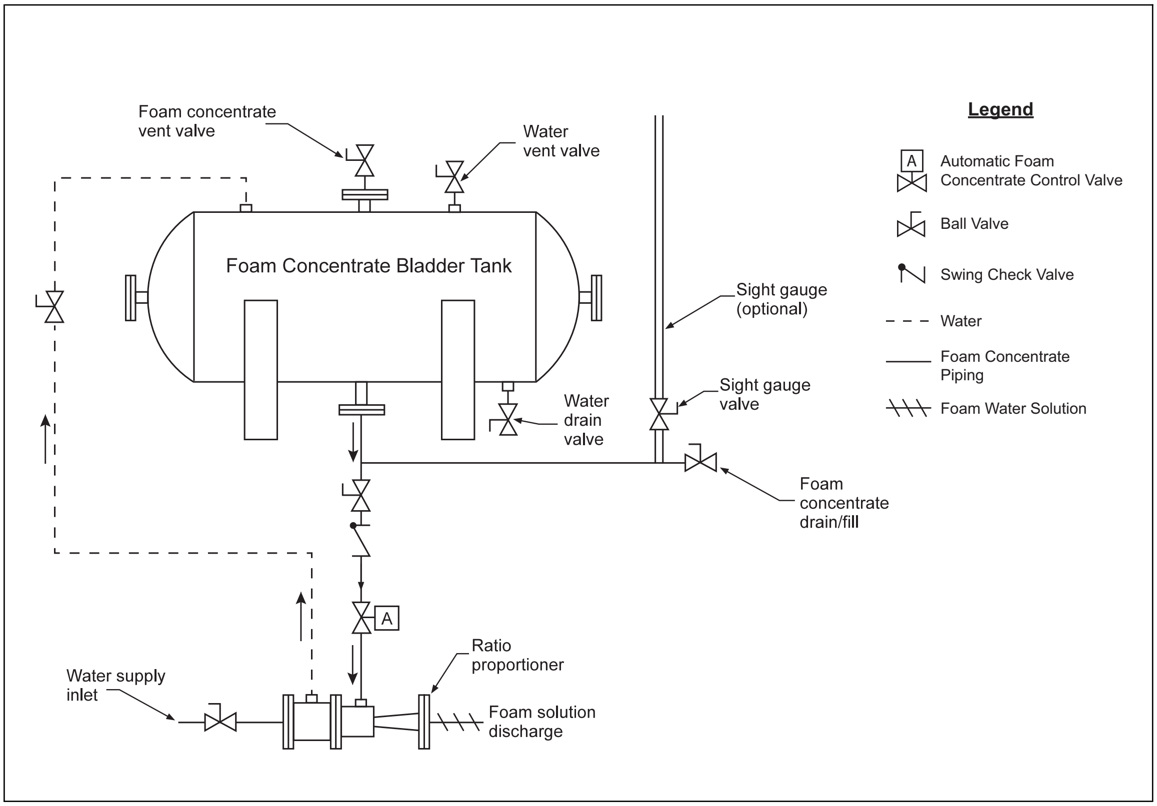


Fig. 2.4.6.1-1. Bladder tank proportioning

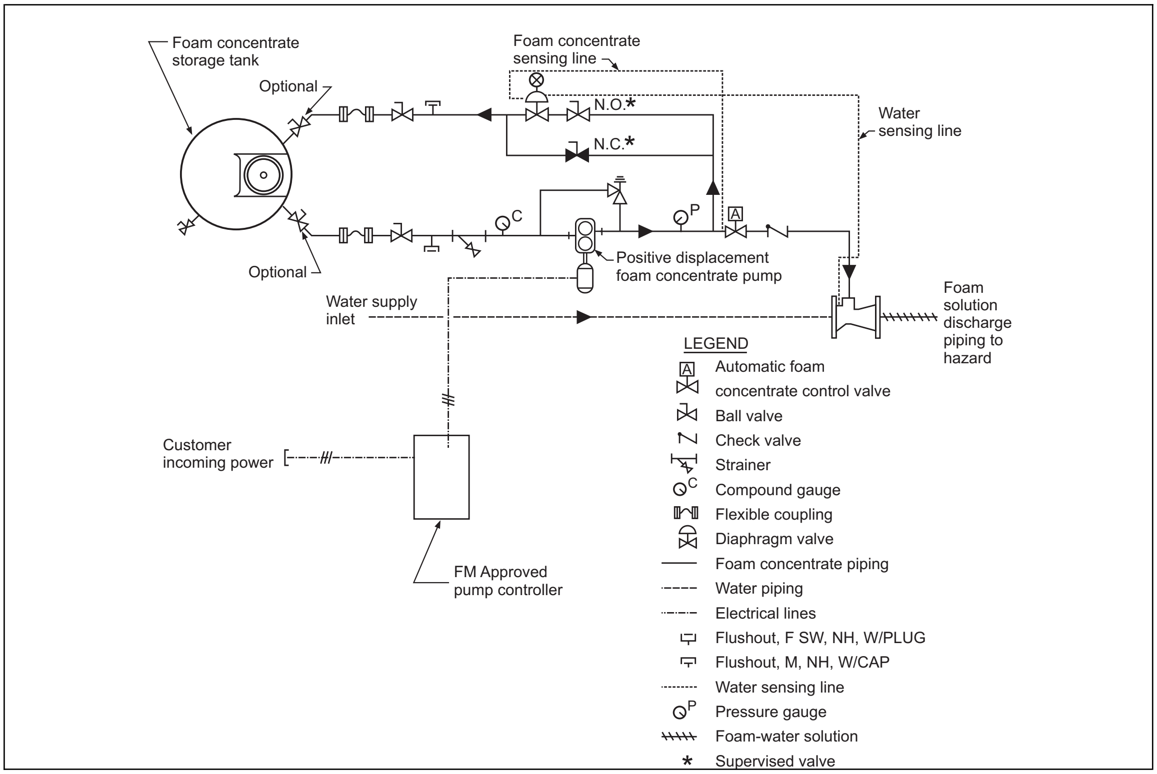


Fig. 2.4.6.1-2. Balanced pressure proportioning

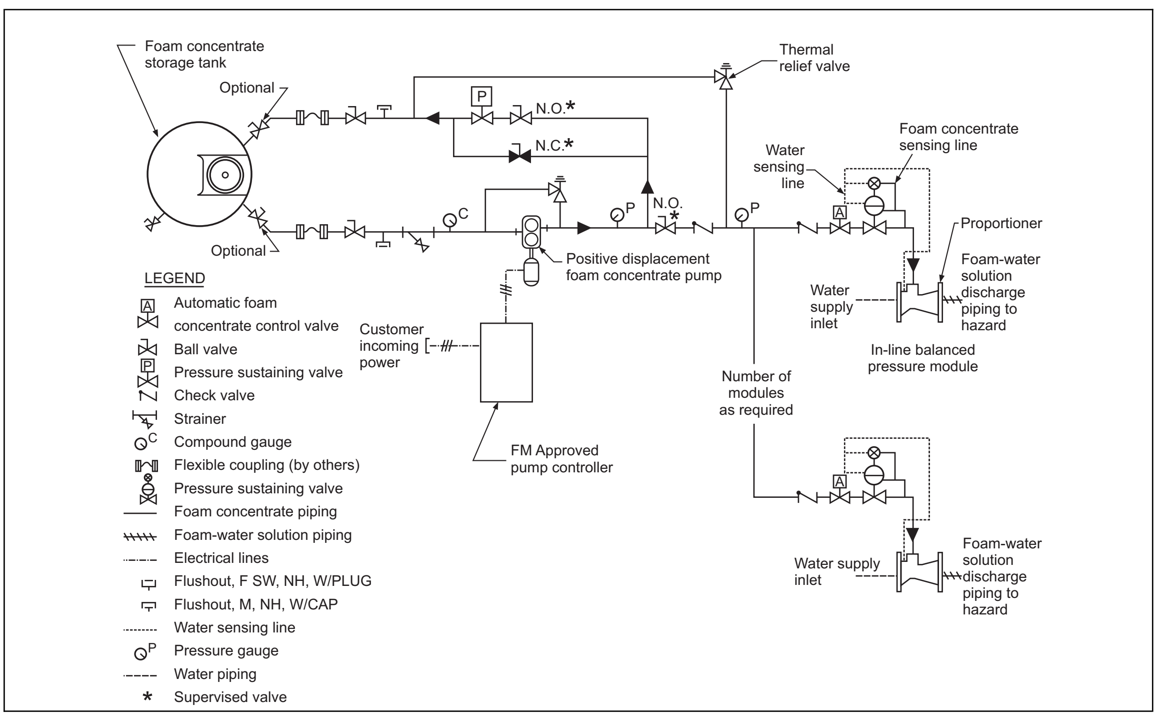


Fig. 2.4.6.1-3. In-line balanced proportioner (ILBP)

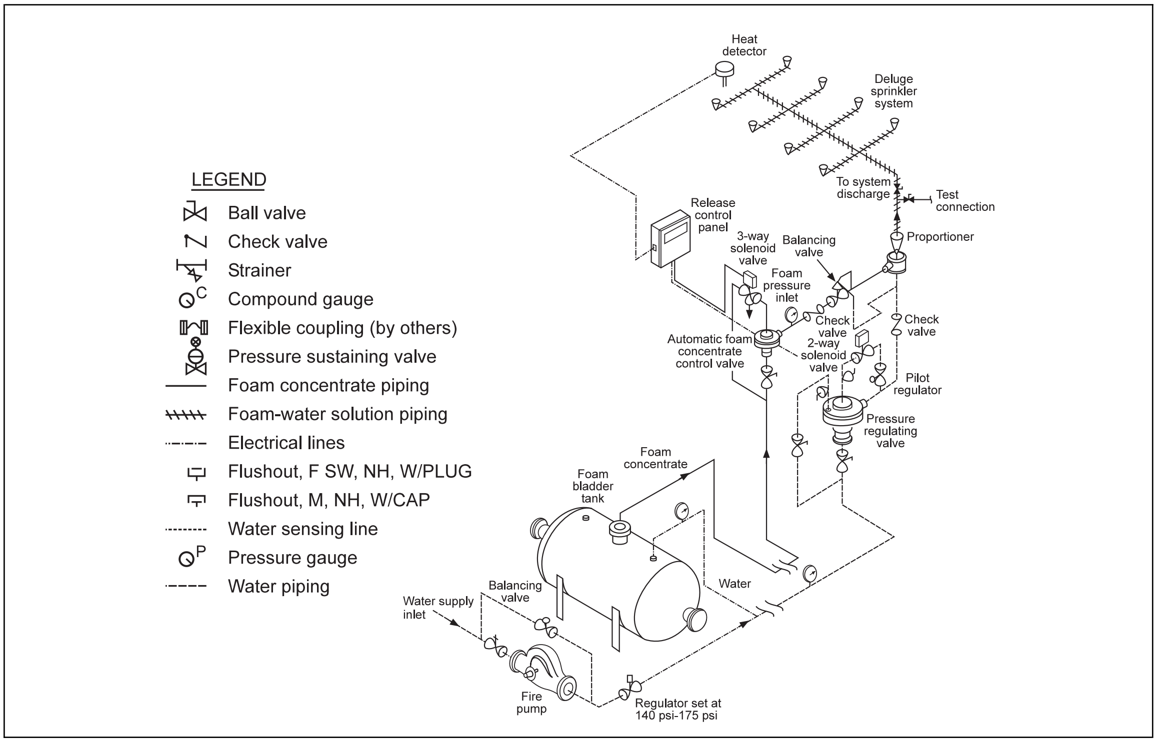


Fig. 2.4.6.1-4. In-line balanced proportioner (ILBP), deluge application

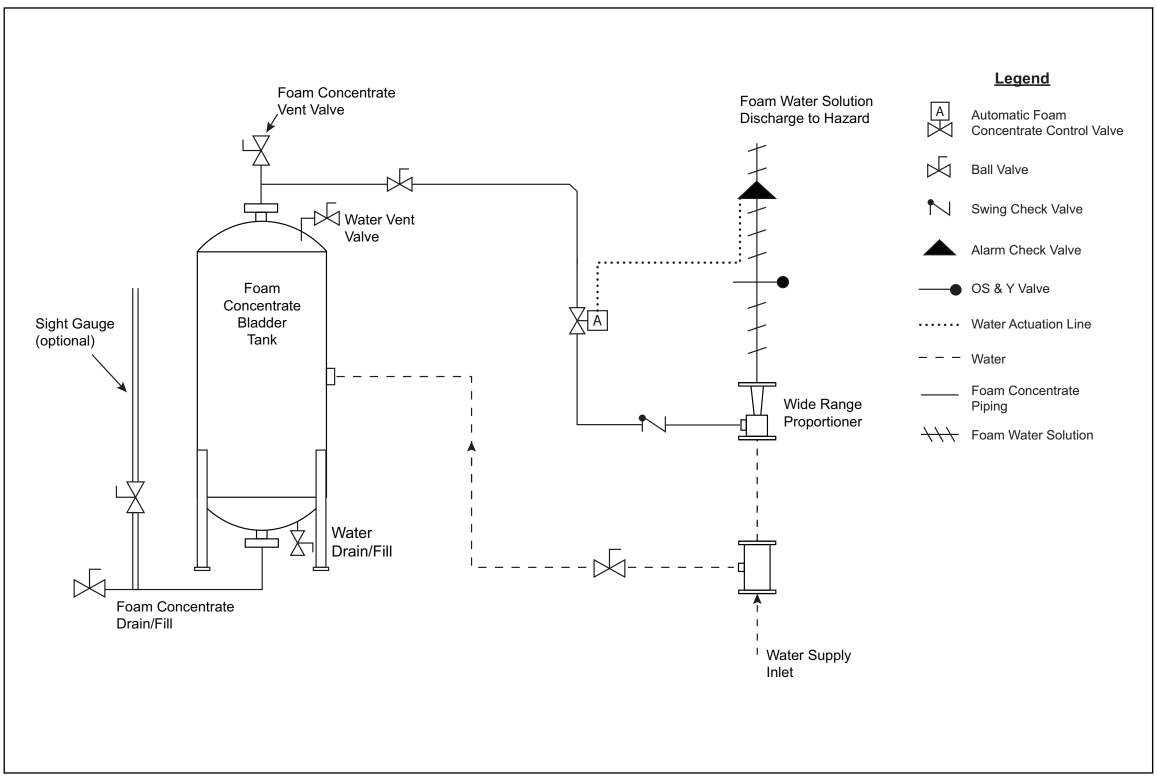


Fig. 2.4.6.1-5. Wide range proportioner

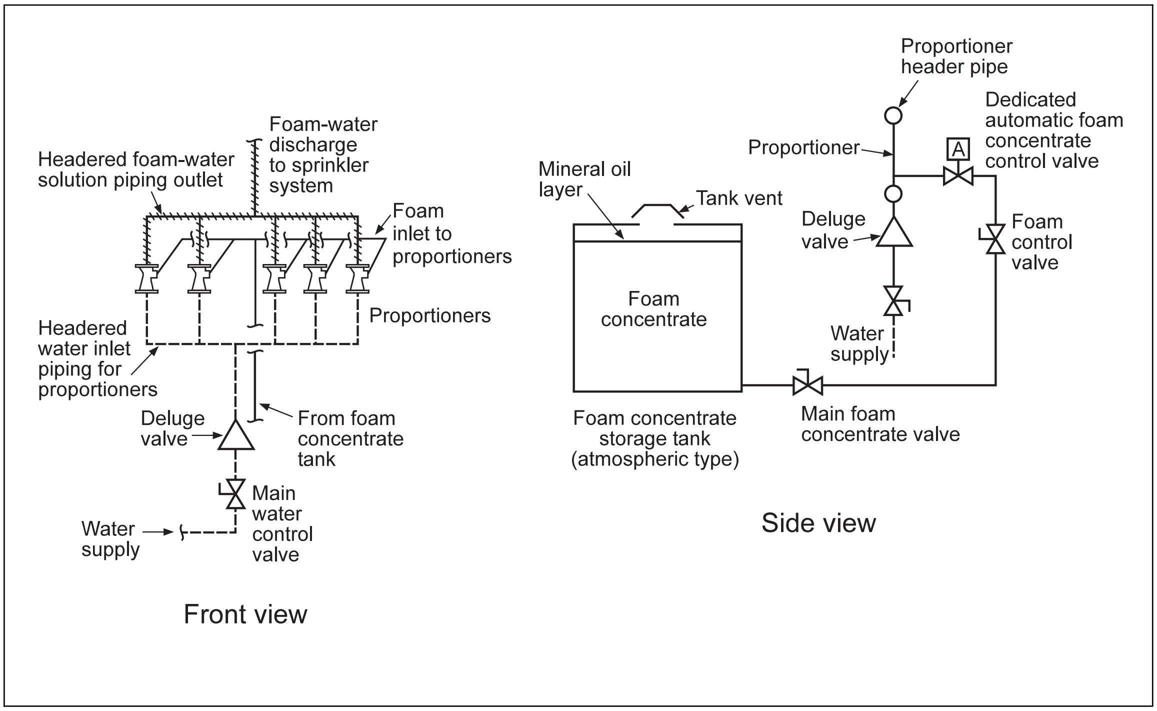


Fig. 2.4.6.1-6. Line proportioning, deluge application only

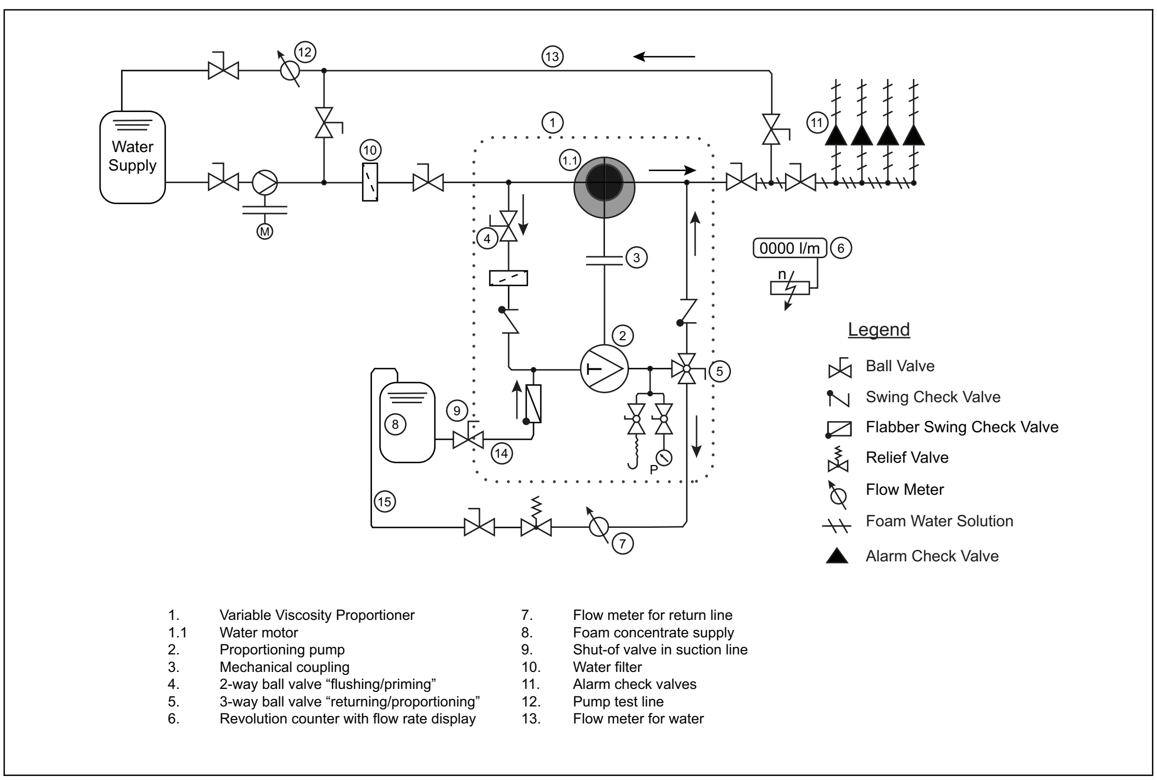


Fig. 2.4.6.1-7a. Variable viscosity proportioner: water-driven motor

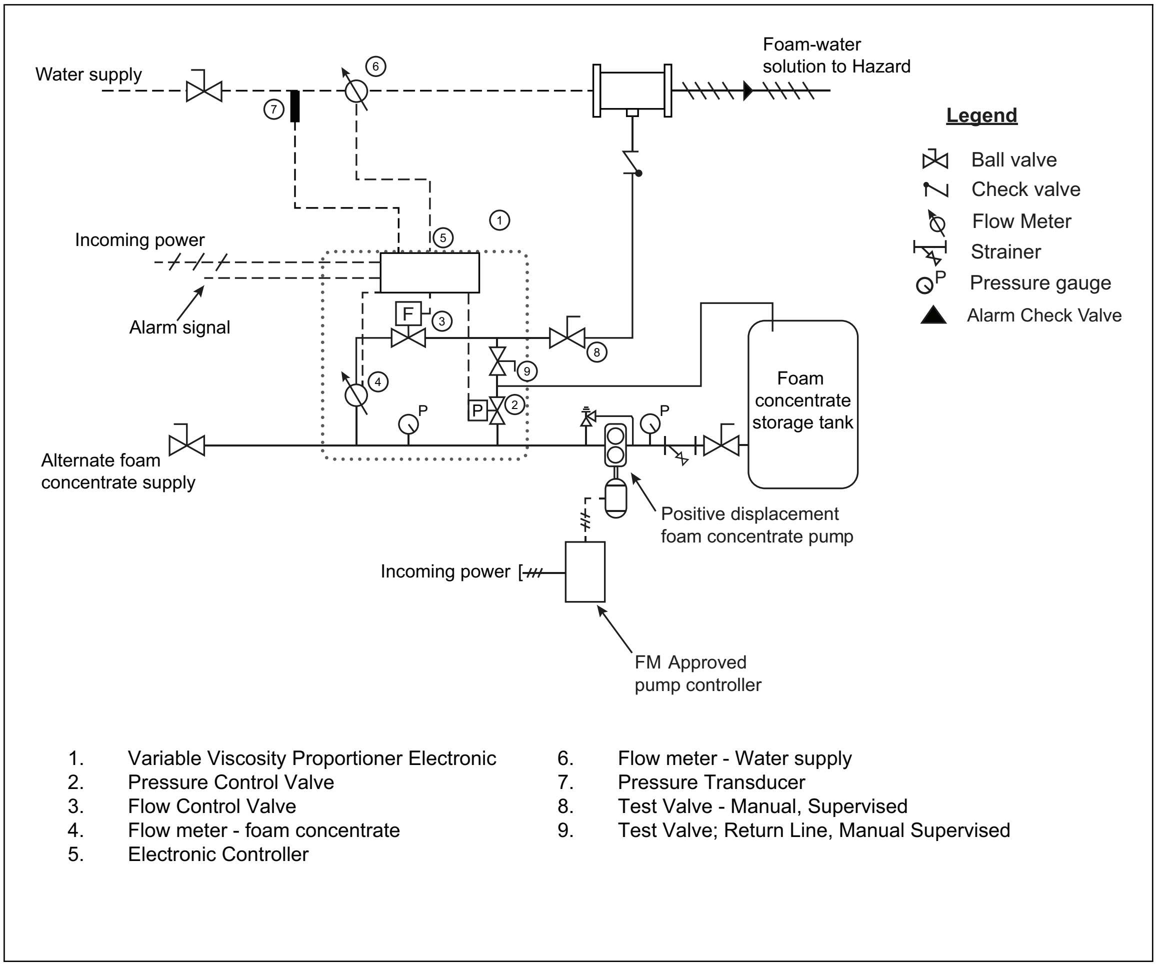


Fig. 2.4.6.1-7b. Variable viscosity proportioner: electronic controller with flowmeters

2.4.7 Ratio of Compressed Air to Foam Solution

2.4.7.1 Provide a sprinkler system in accordance with the applicable occupancy- or hazard-specific data sheet to overlay with the compressed air foam system. See Figure 2.4.7.1-8a and Figure 2.4.7.1-8b for schematics of typical compressed air foam systems.

2.4.7.2 Provide the proportioning device specific to the FM Approved manufacturer of the compressed air foam system in accordance with its FM Approved design, installation, operation, and maintenance manual.

Consult the *Approval Guide* for specific information on the proportioning parameters for the system selected.

2.4.7.3 Verify the compressed air regulator set point is in accordance with the compressed air foam fire extinguishing system manufacturer's calculation or specification.

2.4.7.4 Verify the compressed air regulator set point adjustment mechanism is sealed or secured to be tamper resistant.

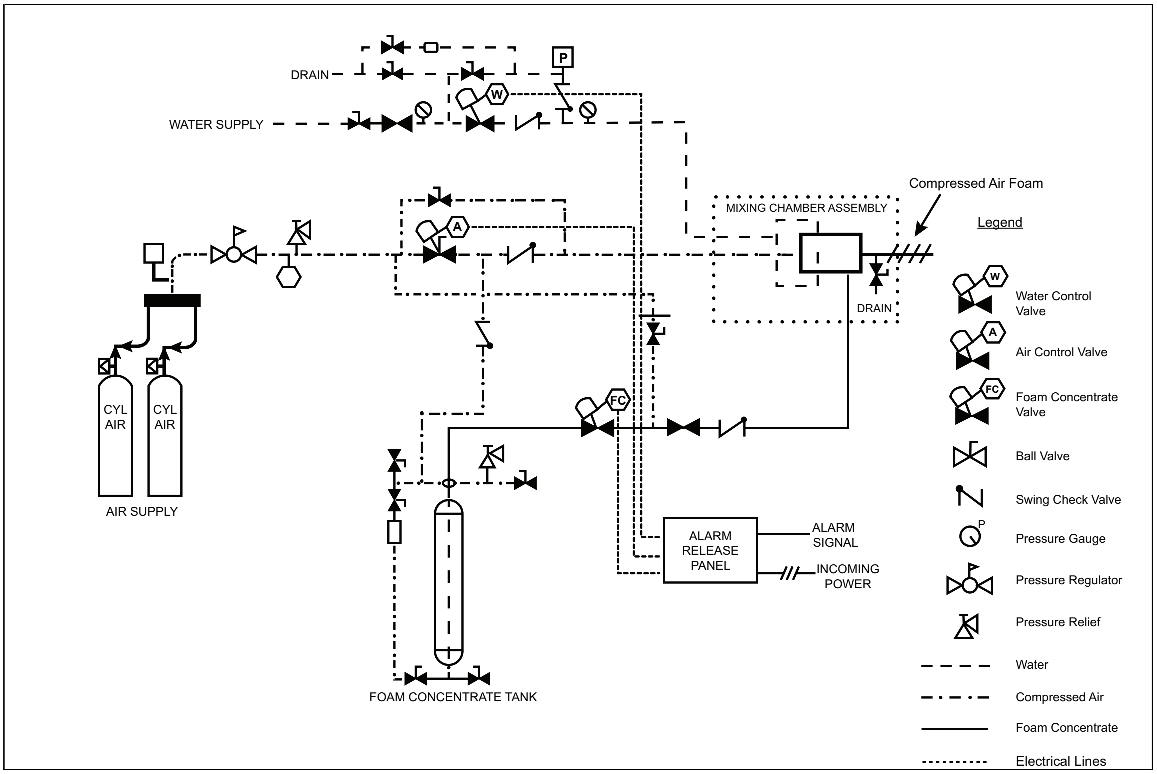


Fig. 2.4.7.1-8a. Compressed air foam: unlimited water supply (typical)

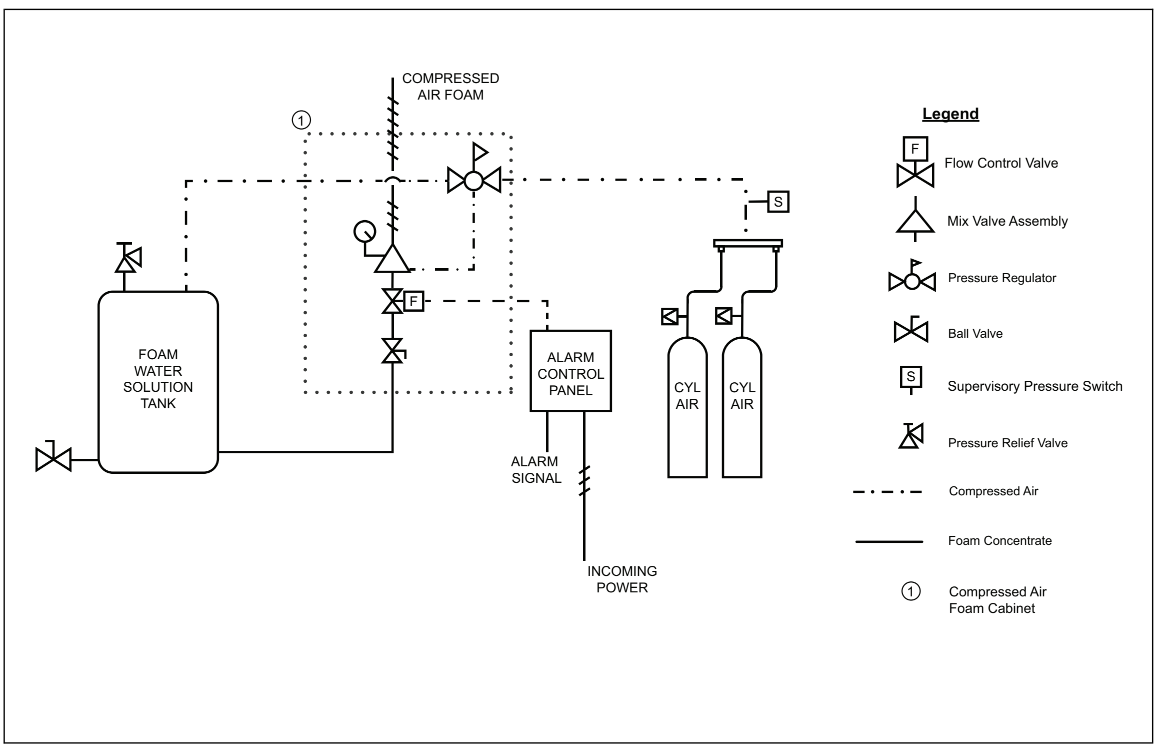


Fig. 2.4.7.1-8b. Compressed air foam: premixed foam solution (typical)

2.4.8 Distribution System

2.4.8.1 Use the appropriate foam fire extinguishing system (e.g., pre-primed, preaction, dry-pipe, deluge) distribution configuration for the discharge device (e.g., automatic or deluge foam-water sprinklers, floor nozzles, foam monitors, compressed air foam) in accordance with the applicable occupancy-specific data sheet.

2.4.8.2 Arrange the system to deliver either foam-water or compressed air foam solution from the four most remote discharge devices within 2 minutes of system operation.

2.4.8.3 When a wet-pipe, pre-primed, preaction, dry-pipe, or deluge foam-water sprinkler systems is used, arrange the configuration of the distribution system in a tree or dead-end layout.

2.4.8.4 Provide a pre-primed foam-water sprinkler system in accordance with the following:

A. If recommended for fire extinguishment in the applicable occupancy-specific data sheet.

B. In accordance with the manufacturer’s recommendations for using an alcohol-resistant foam-water solution.

C. Flushing connections and valves on the cross mains and/or branch lines of the distribution system for maintenance.

D. foam-water solution at the specified concentration in the distribution system.

2.4.8.5 Foam-water sprinkler systems are acceptable with water only (e.g., wet in the distribution system) when used as an alternative to providing emergency drainage in the applicable occupancy-specific data sheets.

2.4.8.6 Foam-Water Sprinklers

2.4.8.6.1 Use a pre-primed distribution system if necessary to meet the 2-minute delivery time.

2.4.8.6.2 For pre-primed foam-water piping systems, use automatic sprinklers with a K-factor of K11.2 (K160) or greater when pendent automatic sprinklers are used. Otherwise, use upright automatic sprinklers.

2.4.8.7 Compressed Air Systems

2.4.8.7.1 Arrange the distribution system in a balanced “H” or “Line” configuration in accordance with limitations for pipe length and fittings identified in the FM Approved manufacturer’s design, installation, operation, and maintenance manual.

2.4.8.8 Other FM Approved Discharge Devices

2.4.8.8.1 Arrange the distribution system for discharge devices (e.g., foam chamber, foam maker, foam pourer, foam monitor, floor nozzle system) in a balanced “H” or “Line” configuration in accordance with the limitations for pipe length and fittings identified in the FM Approved manufacturer’s design, installation, operation, and maintenance manual.

2.4.9 Discharge Device Design Criteria

2.4.9.1 Design FM Approved discharge devices (foam-water sprinkler, foam chamber, nozzles, low level floor nozzle, etc.) in accordance with the limitations of their Approval and the manufacturer’s design, installation, operation and maintenance manual. Limitations include the following:

A. The appropriate number based on the equipment hazard or occupancy being protected

B. Maximum height specification of the protected enclosure or hazard

C. Maximum area of coverage

D. Proper orientation (e.g., pendent or upright)

E. Spacing including distance from walls and each other

F. Distance from the ceiling

G. Location relative to obstructions (see Section 2.4.9.2)

H. In corrosive atmospheres, use of corrosion-resistant materials or coatings suitable for the application

2.4.9.2 Obstructions

2.4.9.2.1 When obstructions are present, evaluate the installation of FM Approved sprinkler, discharge device, or nozzle to verify they are in accordance with the manufacturer's specifications for position and clearance.

2.4.9.2.2 Provide additional FM Approved sprinklers, discharge devices, or nozzles to adjust placement in accordance with:

- The applicable recommendations of the hazard- or occupancy-specific data sheet.
- The manufacturer's FM Approved design, installation, operation, and maintenance manual.

2.4.9.3 Application Rate and Pressure

2.4.9.3.1 Hydraulically design the automatic foam-water sprinkler or deluge foam fire extinguishing systems, to provide:

A. The larger of the following for the ignitable liquid type:

1. The density recommended in the applicable occupancy-specific data sheet
2. The minimum required density specified in the *Approval Guide* listing

B. A minimum of 7 psi (0.5 bar) terminal end pressure for the foam-water sprinkler.

2.4.9.3.2 Hydraulically design foam chambers, foam makers, foam pourers, floor nozzles, or foam monitors to provide the following for the specific foam concentrate:

A. The larger of the following for the ignitable liquid fuel type:

1. The density recommended in the applicable occupancy-specific data sheet
2. The minimum required density specified in the *Approval Guide* listing
3. A minimum of 0.1 gpm/ft^2 (4 mm/min) for hydrocarbon ignitable liquids

B. The inlet pressure specified in the *Approval Guide* listing

C. The flow range specified in the *Approval Guide* listing

2.4.9.3.3 Hydraulically design the compressed air foam systems to provide the larger of the following for the specific foam concentrate listed with the system:

A. The minimum required density specified in the *Approval Guide* listing for the specific manufacturer's discharge device and ignitable liquid fuel type.

B. A minimum of:

- 0.04 gpm/ft^2 (1.6 mm/min) for hydrocarbon ignitable liquids
- 0.06 gpm/ft^2 (2.4 mm/min) for polar solvent and water miscible ignitable liquids

2.4.9.4 Discharge Duration

2.4.9.4.1 Design the foam-water solution for low-expansion and compressed air foam systems to discharge for the duration specified in the applicable occupancy-specific data sheet. If not specified for foam-water sprinkler systems, the discharge duration should not be less than 10 minutes over one of the following:

A. The entire system area for deluge foam-water sprinkler systems

B. The demand area for automatic foam-water sprinkler systems

2.4.9.5 Demand Area

2.4.9.5.1 For foam-water sprinkler systems, use the full demand area recommended in the applicable occupancy-specific data sheet.

2.4.9.6 Foam Quantity

2.4.9.6.1 Base the foam concentrate supply on the required foam concentrate injection percentage for the discharge device (e.g., foam-water sprinkler system, floor nozzle, foam chamber, foam-water hose stream), design requirements, and the recommendations in Section 2.4.9.1.

2.4.9.6.2 Determine the quantity of foam concentrate needed for a foam fire extinguishing system(s) design by adding the quantity of foam concentrate needed at the actual discharge devices rate of flow demand plus quantity of foam concentrate needed for foam hose lines plus quantity of foam concentrate needed to charge distribution piping in a pre-primed system. Use equation 1.

(Equation 1)

$$V_{FC} = [Q_{AA} \text{ x } t_{AA} \text{ x } (C/100) \text{ x PFF}] + [Q_{AD} \text{ x } t_{AD} \text{ x } (C/100) \text{ x PFF}] + [Q_{FHS} \text{ x } t_{FHS} \text{ x } (C/100) \text{ x PFF}] + [V_{PP}]$$

Where:

V_{FC} = Quantity of foam concentrate (gal [L]).

Q_{AA} = Actual foam-water sprinkler flow demand at the point of connection to the foam concentrate proportioning device, (gpm, [L/min]).

Q_{AD} = Actual discharge devices (e.g., floor nozzle, foam chamber, foam monitor) flow demand at the point of connection to the foam concentrate proportioning device, (gpm [L/min]).

Q_{FHS} = Foam-hose flow demand at the point of connection to the foam concentrate proportioning device, (gpm [L/min]).

$T_{AA,AD,\text{ or }FHS}$ = Foam discharge duration from applicable occupancy standard, (min).

C = Foam discharge concentration, (%).

PFF = Proportioner flow factor (see Table 2.4.9.6.2).

V_{PP} = (Volume of water in distribution system [gal or L] x foam discharge concentration [%]) + Volume of foam concentrate in feed line (gal or L) + Volume of foam concentrate below the tank suction inlet for atmospheric storage tanks (gal or L).

Note: If Q_{AA}, Q_{AD} or Q_{HFS} is not recommended in the occupancy-specific data sheet, this component of the formula will not be used.

Table 2.4.9.6.2. Proportioner Flow Factors

Proportioner Type	*Delivered Flow of Proportioner for Demand Area*	*Proportioner Flow Factor, (PFF)*[Note 1]
Wide range	Minimum flow to maximum flow	1.15
Fixed ratio	Minimum flow to midrange flow	1.10
	Midrange flow to maximum flow	1.15
In-line balanced	Minimum flow to midrange flow	1.20
proportioner (ILBP)	Midrange flow to maximum flow	1.10
Variable viscosity proportioner	Minimum flow to midrange flow	1.15
	Midrange flow to maximum flow	1.20
Compressed Air Foam[Note 2]	Minimum flow to maximum flow	1.15

Note 1. PFF is a minimum value. If a manufacturer specifies a higher value, use that value to determine the quantity of foam concentrate.
Note 2. Compressed air foam systems with a pressurized foam storage container. For other compressed air foam systems, use the PFF value associated with the type of proportioner.

2.4.9.6.3 For atmospheric foam concentrate storage tanks, include the volume below the connection of the suction pipe to determine the total quantity of foam concentrate.

2.4.9.7 Hydraulic Calculations

2.4.9.7.1 Calculate the pipe size carrying foam-water solution the same as carrying plain water. Perform hydraulic calculations in accordance with the applicable recommendations in:

- Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
- Data Sheet 3-0, *Hydraulics for Fire Protection Systems*

2.4.9.7.2 Include the pressure drop across the proportioner that is installed in the sprinkler water flow path in the system hydraulic calculations.

2.4.9.7.3 Verify the selected FM Approved proportioner has a flow range that meets the calculated minimum and maximum system demand.

2.4.9.7.4 Verify the minimum inlet pressure requirement of the proportioner is met for location of the foam concentrate supply.

2.4.9.7.5 Verify the maximum pressure differential for the water and foam concentrate supply of an in-line balanced pressure proportioner does not exceed the manufacturer's specifications.

2.4.9.7.6 Ensure that when multiple types of fixed discharge devices (e.g., foam-water sprinkler and floor nozzles or manual firefighting) are used together for possible simultaneous operation, they are accounted for in in **both** of the following:

A. The hydraulic calculations of the foam fire extinguishing system, and

B. The selection of the proportioner, due to the increased flow of foam-water solution

Alternatively, provide a separate proportioner and distribution line for each of the foam fire extinguishing systems for their respective fixed discharge devices.

2.4.9.7.7 Foam Concentrate

2.4.9.7.7.1 Calculate the friction loss in piping carrying a non-alcohol-resistant or Newtonian foam concentrate using the Darcy-Weisbach formula (also known as the Fanning formula) from the foam concentrate supply to the proportioner.

2.4.9.7.7.2 Consult the foam concentrate manufacturer for friction loss characteristics in pipe carrying an alcohol-resistant or high-viscosity (non-Newtonian fluid) foam concentrate from the foam concentrate supply to the proportioner.

2.4.9.7.7.3 Consult the variable viscosity proportioner manufacturer for calculation of the allowable suction pressure on the foam concentrate line with a water-driven pump proportioner.

2.4.9.8 Pneumatic Calculations (Compressed Air Foam)

2.4.9.8.1 Ensure the compressed air foam pneumatic flow calculations are performed using a calculation method within the limitations of the manufacturer's FM Approved design, installation, operation, and maintenance manual.

2.5 Equipment and Processes

Install only new system components. Do not use repurposed equipment for the installation of foam fire extinguishing systems.

2.5.1 Foam Concentrate Supply

2.5.1.1 General

2.5.1.1.1 Use an FM Approved foam concentrate storage tank, (e.g., atmospheric, pressurized tank or bladder type), identified in the FM Approved Design, Installation, Operation, and Maintenance (DIOM) manual as specified for the proportioner and type of system.

2.5.1.1.2 Use an atmospheric storage tank, pressurized tank, or bladder tank constructed of materials compatible with the type of foam concentrate, and ensure it is solidly mounted and permanently located.

2.5.1.1.3 Locate the foam concentrate storage tank (e.g., bladder, atmospheric, or compressed air foam) in proximity to the foam concentrate proportioner in accordance with either of the following:

A. The manufacturer's FM Approved DIOM manual

B. Hydraulic calculations for allowable pressure loss and inlet pressure (See Section 2.4.9.7)

2.5.1.1.4 Provide a gauging device or procedure to determine the quantity of foam concentrate in the tank.

2.5.1.1.5 Provide a foam concentrate storage tank that has sufficient ullage to accommodate thermal expansion of the foam concentrate based upon the manufacturer's specifications.

2.5.1.1.6 A single foam concentrate storage tank can supply multiple foam fire extinguishing systems by using a manifold concentrate supply system.

2.5.1.2 Bladder Tanks

2.5.1.2.1 Use a bladder tank stamped as meeting the requirements of the applicable local pressure vessel code(s) and acceptable to the authority having jurisdiction.

2.5.1.2.2 Provide a valve to isolate the water inlet line to the bladder tank from the system water supply.

2.5.1.3 Atmospheric Storage Tanks

2.5.1.3.1 Ensure the atmospheric storage tank is equipped with:

A. overfill protection and automatic pressure/vacuum relief devices to prevent exceeding the design pressure of the tank.

B. a pressure vacuum vent to prevent free exchange of air in accordance with the manufacturer's design, installation, operation, and maintenance manual.

2.5.1.3.2 Ensure the connection for the foam concentrate suction pipe is arranged above the tank bottom.

2.5.1.3.3 To prevent evaporation, seal alcohol-resistant foam concentrates (and other foam concentrates as required by the manufacturer) with a 1/4 to 1/2 in. (6 to 13 mm) layer of mineral oil or manufacturer's proprietary equivalent.

2.5.1.3.4 Provide an FM Approved shutoff valve to isolate the foam concentrate line to the foam concentrate pump and proportioner for servicing.

2.5.1.3.5 Locate tank discharge outlets to furnish a positive head on either the foam concentrate pump or positive displacement, water-driven foam concentrate proportioner pump suction.

2.5.1.4 Foam Concentrate Piping

2.5.1.4.1 If foam concentrate piping to the foam fire extinguishing system proportioner(s) is run underground, or if it runs aboveground for more than 50 ft (15 m), ensure the piping is kept full. Provide a means of checking the integrity of the piping.

If piping integrity is checked by pressurization from a pressure-maintenance pump or similar means, ensure the system components and piping do not become over-pressurized. Provide a pressure-relief mechanism if necessary.

2.5.1.4.2 Maintain the temperature of the foam concentrate piping within the storage temperature limits specified for the foam concentrate in the *Approval Guide*.

2.5.1.4.3 With the foam concentrate, use the following:

A. Pipe, fittings, and valves made of the following materials:

- Brass (red or naval)
- Bronze
- Stainless steel (304 or 316)
- FM Approved as compatible with the foam concentrate

B. In piping with dissimilar metals, insulate with dielectric components to reduce the possibility of galvanic corrosion.

C. Install flushing and drainage valves/connections for the foam concentrate piping that is dry in the standby condition. Provide the ability for complete drainage.

D. Do not use galvanized steel pipe or fittings.

E. Do not use black steel pipe or fittings.

2.5.1.4.4 Use Teflon tape or the foam concentrate manufacturer's compatible thread-locking compounds at pipe joints in the foam concentrate supply line.

2.5.2 Water Supply

2.5.2.1 Provide a supply of water to the foam extinguishing system with quality (e.g., hard or soft, fresh or salt, recycled or process) that is compatible with the foam concentrate being used.

2.5.2.2 Provide water at temperatures between 40°F (4°C) and 100°F (38°C) to ensure optimum foam production.

2.5.2.3 Do not use corrosion inhibitors, emulsion-breaking chemicals, or other additives unless they are listed in the *Approval Guide* as being compatible with the foam concentrate.

2.5.2.4 When cross-connections exist to potable water, other external agencies may need to review the installation.

2.5.3 Compressed Air Supply (Compressed Air Foam Systems)

2.5.3.1 Provide the compressed air supply only from those sources that are specified in the manufacturer's FM Approved design, installation, operation, and maintenance manual.

2.5.3.2 Provide supervision for high- and low-pressure of the compressed air supply (see Section 2.5.10.4).

2.5.4 Foam Concentrate Proportioners

2.5.4.1 Use the type of foam concentrate and the injection percentage specified in the proportioner's listing in the *Approval Guide*.

2.5.4.2 For foam-water sprinkler systems, provide a wide-range proportioner to either wet-pipe, pre-primed, dry-pipe, or preaction distribution configurations.

Provide the wide range proportioner with the following:

- the inlet and outlet pipe diameter size does not exceed 1 nominal pipe diameter to the size of the proportioner, unless other FM Approved
- the allowable reducer fittings
- a location on the water supply upstream of the alarm check valve

A wide range proportioner can be provided for other discharge devices.

2.5.4.2.1 If a wide-range proportioner cannot be used, ensure the flow range of the ratio proportioner, in-line balanced proportioner, or variable viscosity proportioner is in the full foam-water solution range (minimum and maximum) of flow required for the hazard demand area and the delivered flow of the system.

2.5.4.3 Provide a fixed-ratio or variable viscosity proportioner for deluge systems.

2.5.4.3.1 Use a fixed-ratio proportioner or variable viscosity proportioner with a range of flow for the foam-water solution within the total water demand of the deluge system.

2.5.4.4 An FM Approved variable viscosity proportioner can be substituted for a non-variable viscosity proportioner, e.g. fixed ratio, wide range, in-line-balance, as part of a specific manufacturer's FM Approved foam extinguishing system when the following conditions are met:

A. The foam concentrate provided has a viscosity that is within the maximum viscosity limitations of the variable viscosity proportioner over the measured range of shear rates, as identified in the FM Approval listing.

B. The required foam solution flow rate is within the range of the variable viscosity proportioner, as identified in the FM Approval listing.

C. The discharge device is listed for use with the foam concentrate identified in the FM Approval listing.

2.5.4.4.1 For a variable viscosity proportioner using an electronic controller with flowmeters for controlling the flow of the foam concentrate, provide the following:

A. An FM Approved positive displacement foam concentrate pump that is compatible with the viscosity of the foam concentrate.

B. A water pressure transducer, water flow meter, check valve, and foam concentrate injection point in the locations specified in the FM Approved Design, Installation, Operation, and Maintenance manual.

2.5.4.5 Install the foam concentrate proportioner:

A. In the direction of flow identified on the proportioner body and in accordance with the manufacturer's FM Approved DIOM manual.

B. In the orientation (horizontal or vertical) specified in the manufacturer's FM Approved DIOM manual.

2.5.4.6 Provide 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.

2.5.4.7 Ensure the foam concentrate proportioner does not exceed the distance or equivalent length from the foam concentrate storage tank (e.g., bladder or atmospheric) in accordance with one of the following:

- manufacturer's FM Approved DIOM manual
- hydraulic calculations for allowable pressure loss and minimum inlet pressure (see Section 2.4.9.7)
- hydraulic calculations for allowable suction pressure with a variable viscosity proportioner

2.5.4.8 Install a spool piece of piping, grooved coupling, or union in the foam concentrate piping between the swing check valve and inlet at the proportioner to facilitate servicing either the orifice plate of the proportioner or the proportioner itself.

2.5.4.9 If a pressure-reducing valve is used with an in-line balanced pressure proportioner, ensure it is correctly set and secured.

2.5.4.10 Ensure braided steel hose is used for the sensing line to the spool valve and duplex gauge.

2.5.4.11 Ensure an FM Approved swing-check valve is provided on the foam concentrate piping from the foam concentrate supply after the automatic foam concentrate control valve, but prior to the proportioner.

2.5.5 Foam Concentrate Pump

2.5.5.1 When a foam concentrate pump is used, provide power and actuation circuitry in accordance with Data Sheet 3-7, *Fire Protection Pumps*, in conjunction with the recommendations in this section.

2.5.5.2 Use a foam concentrate pump compatible with the viscosity of the foam concentrate.

2.5.5.3 When specified for use with the proportioner (e.g., ILBP), provide an FM Approved positive displacement foam concentrate pump as specified in the manufacturer's FM Approved design, installation, operation, and maintenance manual.

2.5.5.4 Use a foam concentrate pump and drive motor that will vary the foam concentrate pump output to match water flow rates while maintaining the correct percentage of foam concentrate.

2.5.5.5 Arrange the foam concentrate piping so maximum foam concentrate demand can be supplied by any foam concentrate pump from either primary or reserve, if necessary, foam concentrate tanks.

2.5.5.6 If a pressure-reducing valve is used with the foam concentrate pump for an in-line balanced pressure proportioner, arrange it with the correct pressure setting and secure it in position.

2.5.6 Valves

2.5.6.1 Install FM Approved automatic foam concentrate control valve(s) in foam concentrate line(s) with electrical supervision for remote annunciation at the fire alarm control panel.

As an alternative, use an alarm pressure switch on the hydraulic actuation line to provide electrical supervision of the operating position for the automatic foam concentrate control valve.

2.5.6.2 Confirm the water supply pressure meets the minimum operating pressure for actuation of the automatic foam concentrate control valve.

2.5.6.3 Only if the water supply pressure exceeds the operating pressure of the actuator for the automatic foam concentrate control valve, use:

A. An FM Approved pressure release valve as a component of the foam fire extinguishing system.

B. An FM Approved pressure-relief valve set to the maximum operating pressure of the actuator body for the automatic foam concentrate control valve.

2.5.6.4 If the automatic foam concentrate control valve is actuated by water pressure upon foam extinguishing system flow, use:

A. A maximum of 36 in. (0.9 m) of braided stainless steel hose from the riser alarm valve trim to the water actuation line.

B. A maximum of 10 ft (3.0 m) of corrosion resistant schedule 40 pipe from the riser alarm valve trim to the water actuation line.

Do not use copper tubing to avoid faults that can impact the operability of the automatic foam concentrate control valve.

2.5.6.5 Do not use an automatic foam concentrate control valve with the variable viscosity proportioner.

2.5.6.6 Equip the dry portion of the foam concentrate piping from the automatic concentrate control valve to the foam concentrate proportioner with flushing devices.

2.5.6.7 Provide a separate FM Approved alarm valve on the water line to each proportioner inlet.

2.5.6.8 Provide FM Approved indicating-type valves (e.g., OS&Y, post indicator, butterfly, or ball) for water, foam solution, and isolation lines.

2.5.6.9 Install all valve types as follows:

A. In the proper orientation and direction of flow.

B. Protected from damage that would prevent their operation.

C. Accessible for operation, inspection, and maintenance.

2.5.6.10 When electrical supervision of isolation valves (e.g., test connection) is used, provide supervision to identify a “trouble/fault” in the abnormal position at the fire alarm control unit.

2.5.6.11 Provide drain valves for premixed solution or foam concentrate piping at low points, whether below or above ground.

2.5.7 Test Connection and Alternate Test Method Connections

2.5.7.1 Provide a test connection in order to functionally verify the operability of the foam fire extinguishing system proportioning components (see Figure 2.5.7.1-1 and Figure 2.5.7.1-2).

2.5.7.1.1 For variable viscosity proportioners, configure the piping and components of a test connection in accordance with the manufacturer’s FM Approved Design, Installation, Operation, and Maintenance manual.

2.5.7.2 Size the foam fire extinguishing system test connection(s) to accommodate both the minimum design flow and the maximum anticipated flow (design) through the proportioner. Multiple discharge outlet points from the test connection on the riser may be required to accommodate the range of flow.

Test headers or test valves should be installed with one 2-1/2 in. hose valve per 400 gpm (1500 L/min) of system demand. Table 2.5.7.2 is provided for guidance.

Table 2.5.7.2. Number of Hoses for Test Connection

Number of 2 1/2” hose valves	*Flow per valve (gpm)*	*Flow per valve (L/min)*
1	400	1500
2	800	3000
3	1200	4500
4	1600	6000
5	2000	7500
8	3000	11,400
10	4000	15,100

2.5.7.3 Provide the test connection at the riser in a flow direction downstream of the proportioning device.

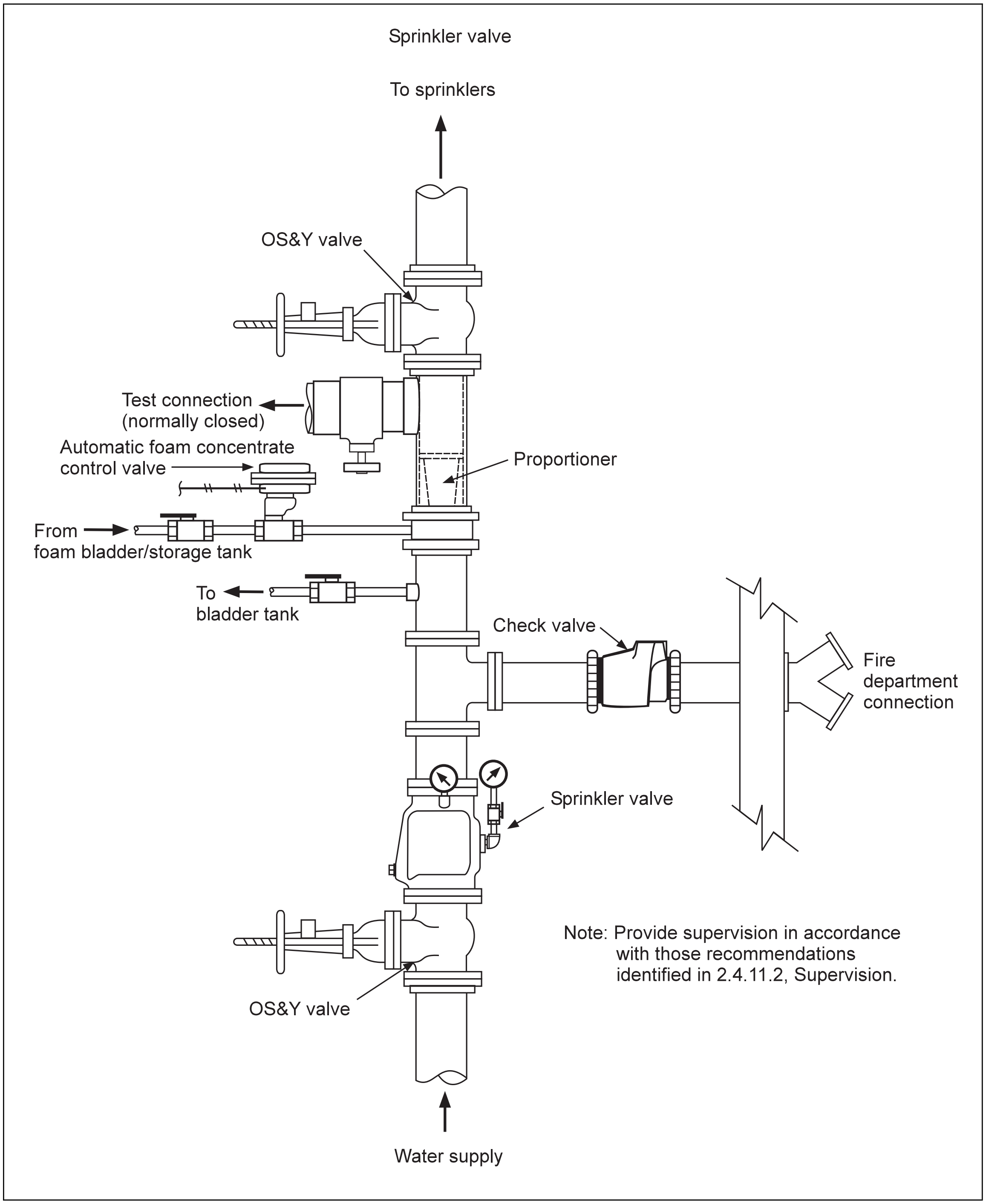


Fig. 2.5.7.1-1. Test connection; riser

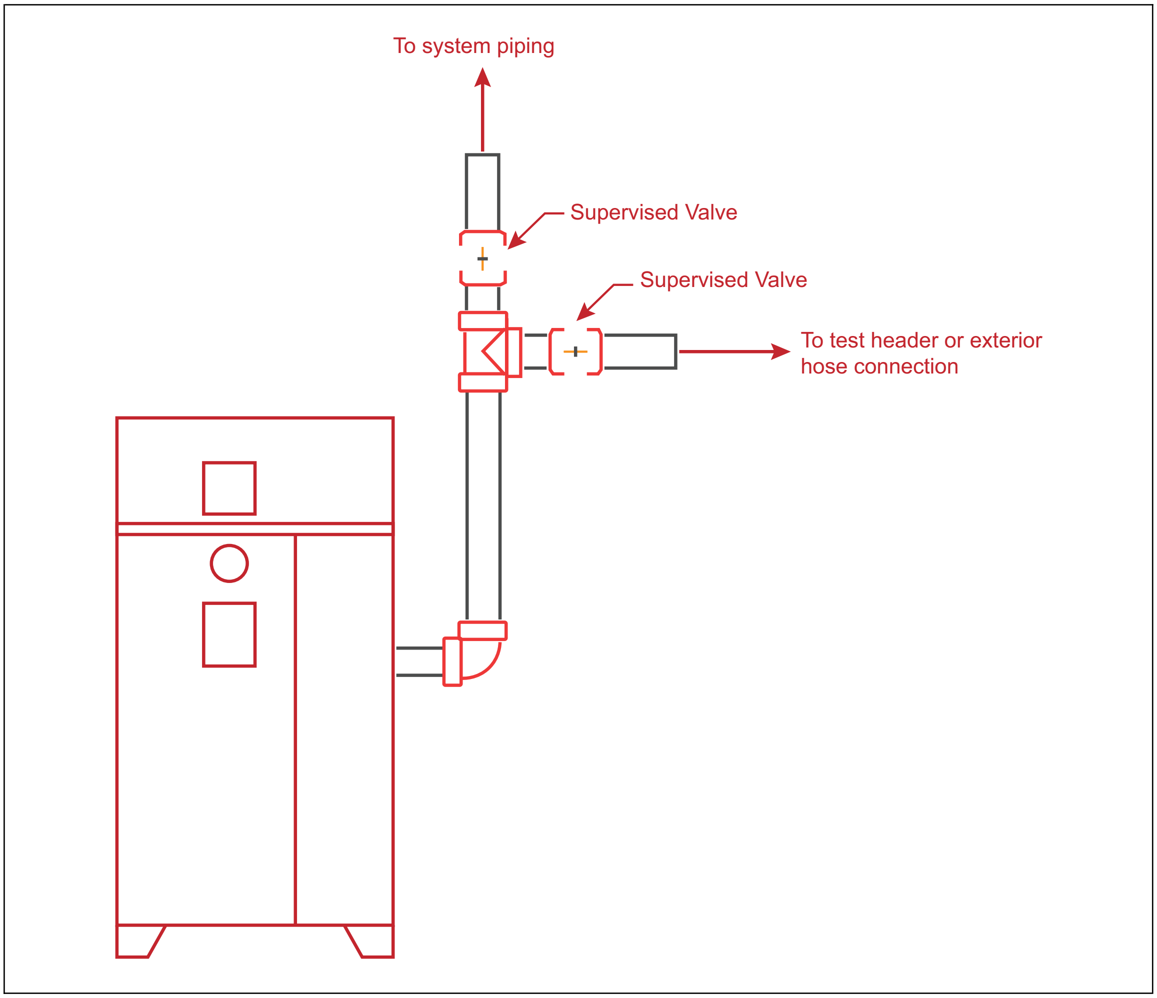


Fig. 2.5.7.1-2. Test connection: compressed air foam

2.5.7.4 Provide a secured isolation valve(s) on the test connection outlet in accordance with Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance*.

2.5.7.5 Provide a secured and supervised isolation valve of equal dimension in the distribution system riser to isolate the distribution/discharge devices.

2.5.7.6 For bladder tanks, provide a secured isolation valve on the water supply line to the bladder tank. Confirm this water supply line connection is located prior to the proportioner.

2.5.7.7 Provide a secured isolation valve in the foam concentrate pipe upstream of the automatic foam concentrate control valve from the foam concentrate storage tank.

2.5.7.8 Route the piping from the test connection to a drain area for easy collection of the foam-water solution produced during either the discharge test for acceptance or annual operability testing of the foam extinguishing system.

2.5.7.9 Keep isolation valves or three-way valve outlets for operability testing of the proportioner capped when not being used.

2.5.7.10 When utilizing a test liquid or water equivalency method from a company assessed by FM Approvals for proportioning testing, provide the connections and fittings in accordance with the configuration identified in their test method manual for the appropriate proportioning method.

- Water Equivalency - See Figure 2.5.7.10-1 and Figure 2.5.7.10-2
- Test Liquid Method - See Figure 2.5.7.10-3 and Figure 2.5.7.10-4

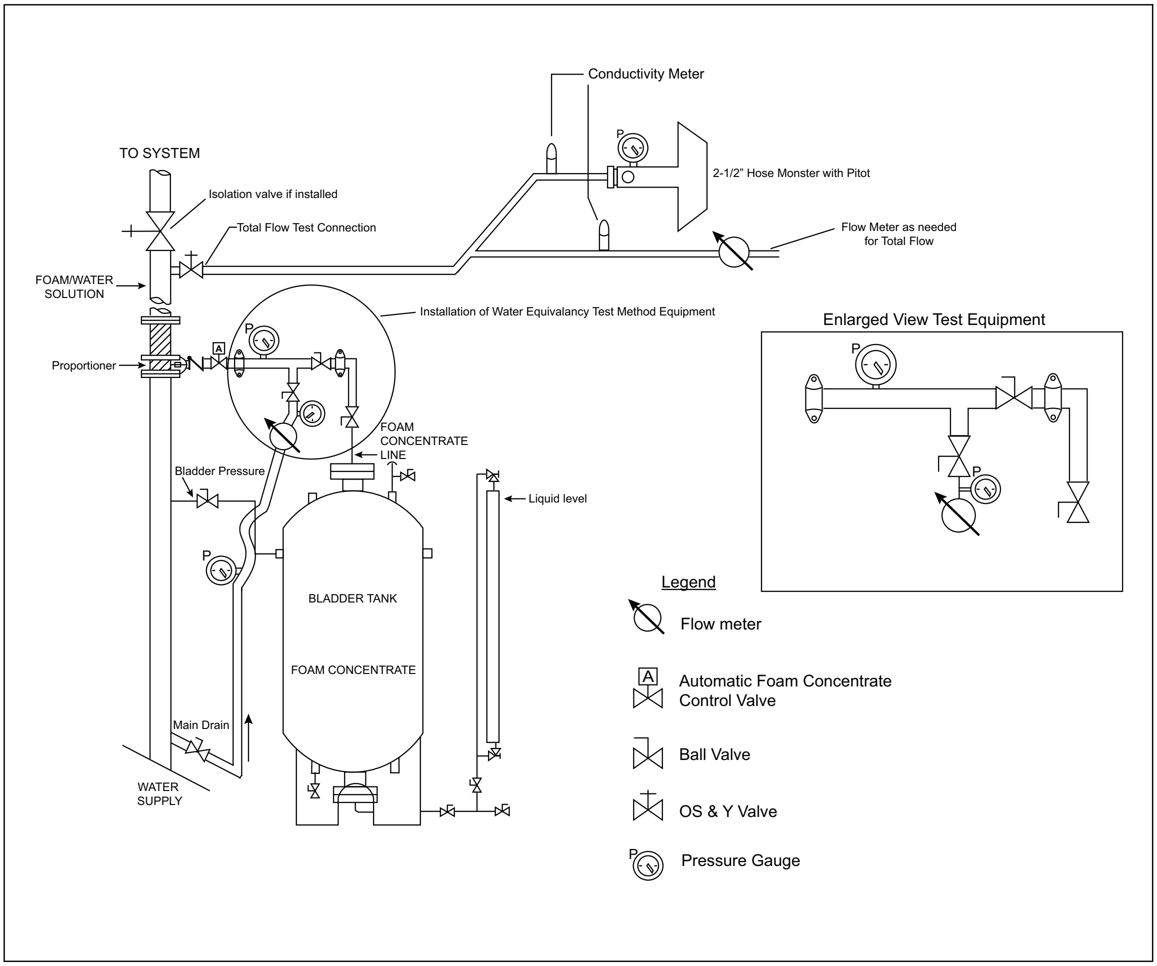


Fig. 2.5.7.10-1. Water equivalency with bladder tank system

2.5.7.10.1 Provide a tethered end cap to the isolation valve or three-way valve.

2.5.7.10.2 Confirm a tee with an isolation valve is provided on the water supply line upstream of the bladder tank to allow for either water equivalency or test liquid testing.

2.5.7.10.3 Install a water-booster pump, permanently or temporarily, for water equivalency testing to provide the necessary pressure differential with an in-line balanced pressure proportioner with foam pump.

2.5.7.10.4 At the foam concentrate tank, to allow for water equivalency testing or test liquid testing, provide:

A. A tee with isolation valve in the foam concentrate line, and isolation valve to the bladder tank outlet, or

B. Replace isolation valves with a three-way valve.

2.5.7.10.5 Install a weldolet with 1 inch (25 mm) ball valve for use with a pressure gauge or pressure transducer on the foam concentrate line prior to the proportioner for measurement of foam concentrate and subsequent water pressure.

2.5.7.10.6 If not provided on the riser alarm or deluge valve, install a weldolet with ½ inch (13 mm) ball valve for use with a pressure gauge or pressure transducer on the water supply riser prior to the proportioner for measurement of water pressure.

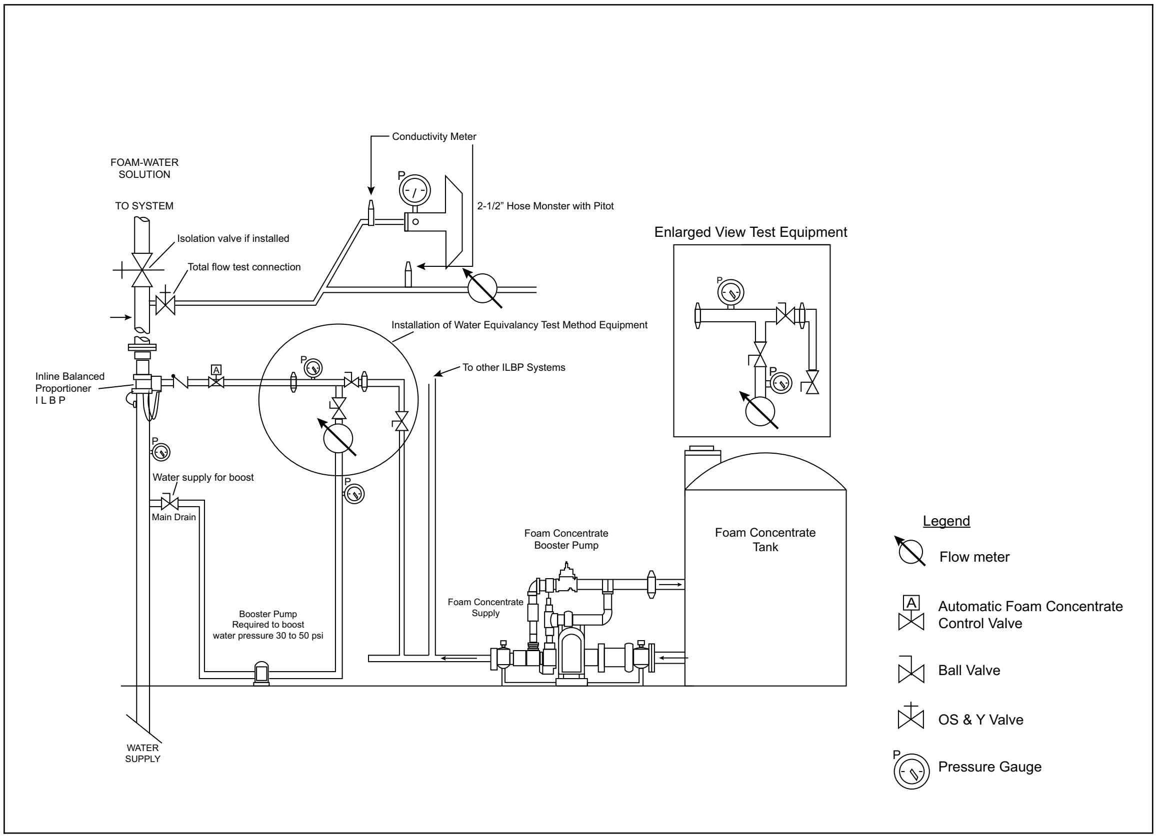


Fig. 2.5.7.10-2. Water equivalency with in-line balanced pressure proportion and atmospheric foam concentrate tank

2.5.8 Distribution System

2.5.8.1 Pipe, and Pipe Fittings

2.5.8.1.1 In addition to the following recommendations, provide pipe and fittings for foam-water solution and water in accordance with the recommendations in Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*.

2.5.8.1.2 Confirm the foam-water solution supply piping to foam discharge devices does not pass over another hazard or hazard area that can impair the protection system.

2.5.8.1.3 Use pipe, fittings, and valves of a material compatible with the foam-water solution in accordance with the manufacturer's FM Approved design, installation, operation, and maintenance manual.

2.5.8.1.4 For deluge-type and compressed air foam systems, use galvanized piping for the foam-water solution in the distribution system.

2.5.8.1.5 When grooved couplings and fittings with elastomeric seals are used, ensure compatibility with the foam concentrate, foam-water solution, or water, as applicable.

2.5.8.1.6 Do not insulate pipes against heat and cold or use antifreeze agents with wet or pre-primed foam-water sprinkler distribution systems.

2.5.8.1.7 Provide a means of draining, and a minimum pitch towards the drain of 1 in 120 for all dry, preaction, and deluge foam-water solution distribution piping.

2.5.8.1.8 If a foam-water sprinkler system is pre-primed with foam-water solution, provide drain and flushing connections in accordance with the recommendations in Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*.

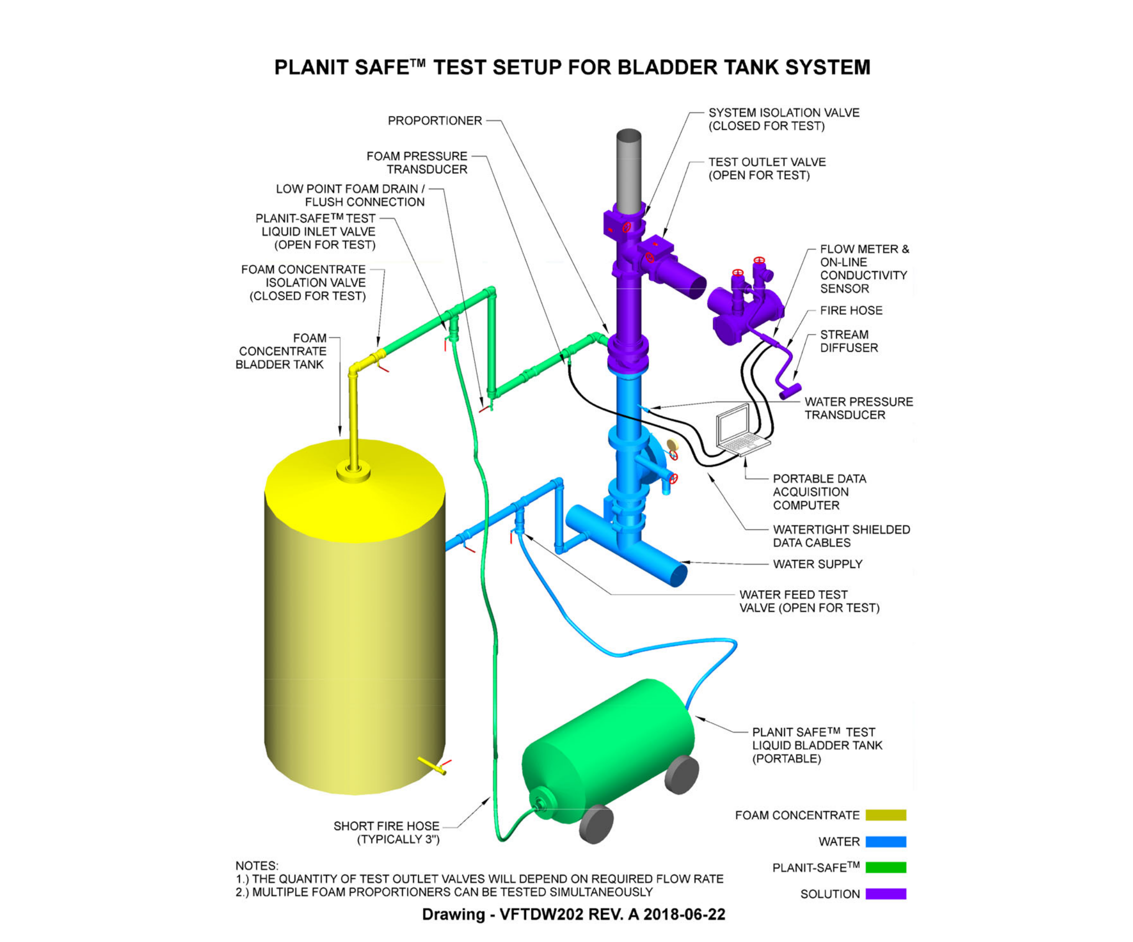


Fig. 2.5.7.10-3. Test liquid with bladder tank system (courtesy of Vector Fire Technology, Inc.)

2.5.8.1.9 Install a weldolet on the riser downstream of the proportioner riser isolation valve to provide a test port inlet for determining if sprinklers are clogged. Plug the weldolet when it is not in use for inspection and testing.

2.5.8.1.10 Provide a flange or union joint at a convenient location in each discharge device branch riser to permit hydrostatic testing of the distribution system up to this joint for foam chambers, foam pourers, foam monitors, and similar discharge devices.

2.5.8.2 Piping Support (Foam solution and foam concentrate)

2.5.8.2.1 Secure and restrain foam solution and foam concentrate piping against movement, thrust, and vibration. Mount and space FM Approved pipe supports (hangers) in accordance with Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, and as specified in the manufacturer's FM Approved design, installation, operation, and maintenance manual.

2.5.8.2.2 If galvanized clamps or supports are used with stainless steel pipes, provide galvanic isolation from the pipe by elastomeric elements, coating, or similar isolation methods.

2.5.8.3 Strainers

2.5.8.3.1 Provide FM Approved strainers in the foam concentrate and water-actuation piping if solids of a size large enough to obstruct openings or damage equipment (e.g., foam pump, foam concentrate valve actuator) are present.

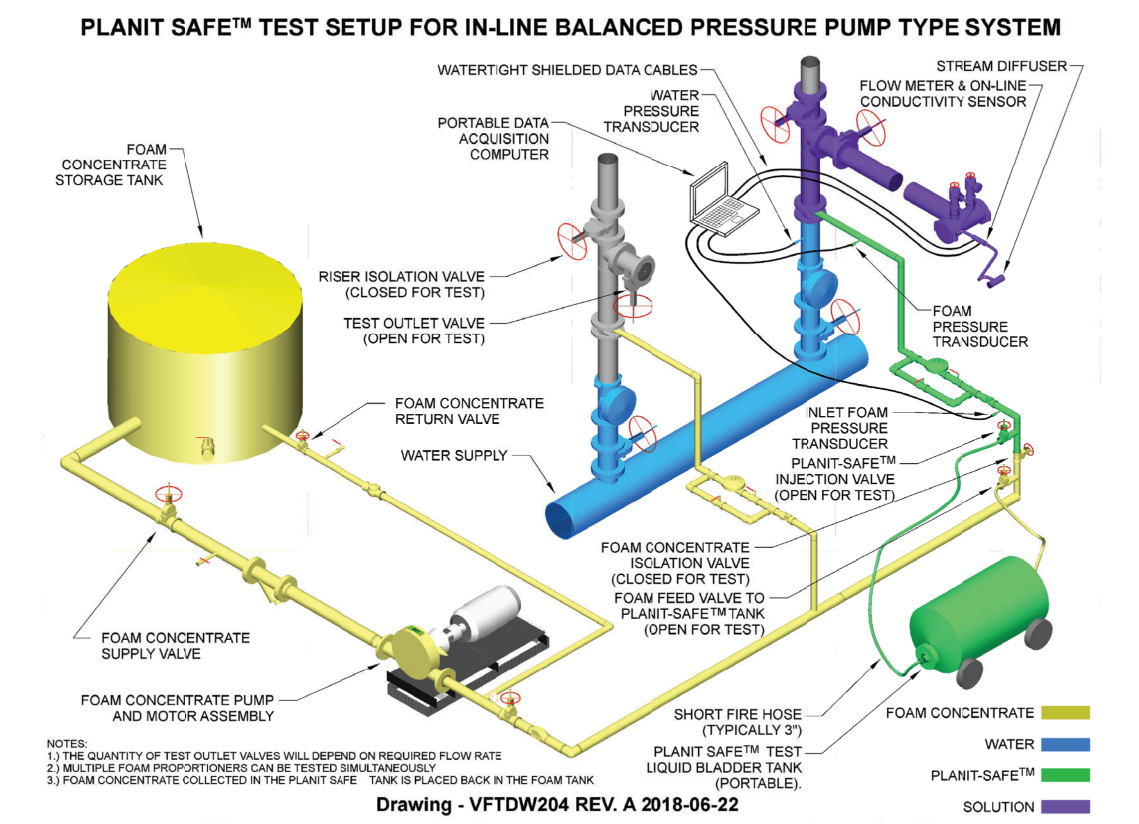


Fig. 2.5.7.10-4. Test liquid with in-line balanced pressure proportion and atmospheric foam concentrate tank (courtesy of Vector Fire Technology, Inc.)

2.5.8.3.2 Provide strainers with perforations no larger than the smallest orifice in the discharge device or foam-water sprinkler system, and no smaller than 1/8 in. (3.2 mm).

2.5.8.3.3 Install strainers for water-actuation and foam concentrate piping that are accessible for cleaning or flushing.

2.5.8.3.4 Install strainers for foam concentrate with a blow down/off valve connection or similar outlet connection for cleaning (flushing) while maintaining system discharge during an emergency.

2.5.8.3.5 Install strainer(s) in the foam concentrate piping upstream of foam concentrate pump(s), except for high-viscosity foam concentrates.

2.5.8.3.5.1 Follow the foam concentrate manufacturer's recommendations if providing a strainer(s) is allowable in the foam concentrate piping upstream of foam concentrate pump(s) for high-viscosity foam concentrates.

2.5.8.3.6 Install a compound gauge downstream of the strainer on a foam concentrate pump suction line to monitor potential blockage during operation.

2.5.8.4 Distribution System Cleaning and Flushing

2.5.8.4.1 Thoroughly flush water-supply pipe work, both underground and above ground, at the maximum practicable rate of flow, before connection is made to foam-water sprinkler system piping.

2.5.8.4.2 Confirm each pipe or tube section in the distribution system is internally cleaned after preparation and before assembly in accordance with standard piping practices or the manufacturer's instructions.

2.5.8.4.3 After installation of the distribution piping and before installation of the discharge devices:

- flush the water distribution piping using the system's normal water supply.
- prior to flushing, close the foam concentrate or foam-water solution valve connections to isolate injection to the distribution piping.
- clean by flushing for a time sufficient for the water to run clear.
- after flushing, reopen the valve connections to their normal operating positions.

2.5.8.4.4 If complete flushing of the water distribution piping cannot be accomplished, do one of the following, shown in order of preference:

A. Install plugs at the discharge device connections and flush the system at the flushing connection and remote inspector's test connection. After flushing, remove all plugs and verify there is no debris prior to the installation of the discharge devices.

B. For deluge systems, pneumatically purge the piping from a weldolet installed on the riser downstream of the proportioner riser isolation valve as a test connection.

C. Visually examine pipe interiors carefully for cleanliness during installation.

2.5.8.5 Pressure Test of Distribution Piping

2.5.8.5.1 Install test blanks for the pressure tests in lieu of the discharge devices. Ensure the test blanks are:

- brightly colored or painted to clearly indicate their presence.
- numbered so all test blanks used can be accounted for.

Use a documentation method to verify the removal of the test blanks and installation of the discharge devices after the test is complete.

2.5.8.5.2 Verify all water distribution piping and foam concentrate piping has been hydrostatically tested as follows:

A. Provide pipe conveying foam-water solution that can withstand a pressure of 1.5 x p_{nom} (minimum 220 psi [15 bar]). See acceptance testing recommendations for further guidance.

B. Maintain the hydrostatic test pressure without a drop in gauge pressure or visual leakage for 2 hours.

2.5.8.5.3 Test foam concentrate piping using foam concentrate as the test medium.

2.5.8.5.4 Do not include bladder tanks in this hydrostatic pressure test.

2.5.9 Discharge Devices

2.5.9.1 Automatic and Deluge Sprinklers

2.5.9.1.1 Foam-water sprinkler systems consist of specialized equipment connected to an automatic sprinkler system. Therefore, in addition to the specific recommendations in this document, adhere to the applicable recommendations in the following data sheets:

- Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
- Data Sheet 3-7, *Fire Protection Pumps* (for devices such as water and foam pumps, and water and foam motor controllers)

2.5.9.1.2 Use FM Approved foam-water sprinklers and associated system components in accordance with their listings in the *Approval Guide* for "Foam Extinguishing Systems". (See Section 3.4.1)

2.5.9.1.3 Do not use FM Approved sprinklers from the Automatic Sprinkler section of the FM *Approval Guide* for foam fire extinguishing systems.

FM Approved foam-water sprinklers are specifically listed for use with a foam concentrate as identified in the "Fixed Extinguishing Systems" section.

2.5.9.2 Compressed Air Foam Discharge Devices

2.5.9.2.1 Supplement the compressed air foam system with an automatic sprinkler system in accordance with the hazard or occupancy specific data sheet.

2.5.9.2.2 Provide the appropriate compressed air foam system nozzles or monitors in accordance with the manufacturer's Approval listing and DIOM manual for the system selected.

2.5.9.2.3 Verify the actual sprinkler application density from protected area does not exceed the maximum sprinkler application rate identified in the FM *Approval Guide* listing to prevent break down of the foam blanket.

2.5.9.2.4 Provide detection and actuation in accordance with Section 2.5.10.

2.5.9.3 Floor Nozzle System

2.5.9.3.1 Provide the appropriate floor nozzle(s) in accordance with the manufacturer's Approval listing and DIOM manual for:

1. The area to be protected.
2. Minimum inlet pressure for flow specification.
3. Minimum and maximum flow range of the floor nozzle.

2.5.9.3.2 Verify the actual sprinkler application density from protected area does not exceed the maximum sprinkler application rate identified in the *Approval Guide* listing to prevent break down of the foam blanket.

2.5.9.4 Foam Chambers, Foam Makers, Foam Pourers

2.5.9.4.1 Provide the appropriate branch pipe nozzle(s), foam chamber(s), foam maker(s), or foam pourer(s) in accordance with the manufacturer's Approval listing and DIOM manual for the area to be protected.

2.5.9.4.2 Provide the following:

- proper type of foam concentrate for discharge device
- minimum inlet pressure for flow specification
- flow range required for discharge device

2.5.9.5 Foam Monitors

2.5.9.5.1 Provide the appropriate foam monitor(s) for the area to be protected in accordance with the manufacturer's Approval listing and DIOM manual.

2.5.9.5.2 Evaluate documentation to determine whether the discharge pattern provides coverage to the hazard being protected, based on the inlet pressure. When multiple monitors are provided, confirm there is overlap in distribution of foam for the area of coverage so there is no unprotected area.

2.5.9.5.3 For monitors used to protect indoor applications, verify the actual sprinkler application density from the protected area does not exceed the maximum sprinkler application rate identified in the *Approval Guide* listing (to prevent break down of the foam blanket).

2.5.10 Actuation and Control

2.5.10.1 General

2.5.10.1.1 Provide automatic actuation of the foam fire extinguishing system.

2.4.10.1.2 Provide FM Approved detection, initiating device(s), and fire alarm systems that are compatible with the foam fire extinguishing system in accordance with the applicable recommendations of:

- Data Sheet 5-40, *Fire Alarm Systems*
- Data Sheet 5-48, *Automatic Fire Detection*

2.5.10.1.3 When protecting hazardous location areas, verify the electric detection equipment and any auxiliary equipment has been specifically designed and rated for such areas.

2.5.10.2 System Initiation

2.5.10.2.1 Provide **both** of the following:

A. Manual release device (mechanical or electrical) from at least one remote location

B. Emergency manual mechanical release device at a location not exposed to the effects of the hazard.

2.5.10.2.2 Use an FM Approved electrical, mechanical, or pneumatic manual release device that is a component of, or compatible with, the foam fire extinguishing system. If operation of the manual release device is electrical, provide the following:

A. A reliable primary source of power

B. Automatic transfer to a source of emergency backup power with a minimum of 24 hours standby power and 10 minutes of alarm power

2.5.10.2.3 Provide foam concentrate injection automatically by, or concurrently with, activation of the main water supply control alarm valve.

2.5.10.2.4 Provide an FM Approved manual release device and emergency mechanical release device that:

A. Is clearly marked.

B. Is secure from unauthorized operation.

C. Clearly identifies each hazard being protected.

D. Is mounted 42 in. (1.1 m) above the finished floor.

E. is in a location that is accessible at all times.

F. results in operation of all associated interlocks with the system discharge.

2.5.10.3 Control/Actuation Devices

If applicable, provide an FM Approved fire alarm control panel with a compatible FM Approved automatic release for extinguishing system module that is electrically compatible (voltage/current) as a release circuit for the following devices, as applicable:

- actuation controls and actuation device (e.g., solenoid) of the water and compressed gas control valve(s)
- other system-control equipment

For large hazard areas and/or where access may be limited, provide manual actuation devices both local to, and remote from, the actuating devices.

2.5.10.4 Supervision

2.5.10.4.1 Provide electrical supervision in accordance with Data Sheet 9-1, *Supervision of Property*.

2.5.10.4.2 Provide electrical supervision of the circuitry from the fire alarm control unit to the following devices, as applicable:

- Detection device
- Releasing circuit
- Automatic water supply and compressed gas supply control valves
- Automatic foam concentrate control valve
- Foam concentrate pump isolation valve(s)
- Foam concentrate pump regulating/diaphram by-pass valve(s)
- Manual release devices
- High and low pressure for compressed air cylinders
- Actuating devices
- Lock-out valves

2.5.10.4.3 If disconnect or manual bypass switches are provided to prevent accidental discharge of a foam fire extinguishing system during testing or servicing of the system, provide supervised, keyed lock-out devices at the control panel as follows:

A. Arrange the device(s) so they do not disable the alarm circuit.

B. Establish and follow written impairment procedures in accordance with Section 2.8.

C. Put the key(s) under the control of a responsible management or fire protection person.

2.5.10.4.4 Provide supervisory alarm signals that are different from fire alarm signals at the fire alarm control panel.

2.5.10.5 Detection

2.5.10.5.1 For deluge type and compressed air systems, provide detection and actuation circuitry in accordance with Data Sheet 5-48, *Automatic Fire Detection*, in conjunction with the recommendations in this section.

2.5.10.5.2 Select the type of FM Approved automatic detection (pneumatic, optical, heat, or smoke) and configuration (e.g., cross- or multi-zone), in accordance with the applicable occupancy or equipment hazard data sheet.

2.5.10.5.3 For compressed air foam when heat detection is used:

A. Provide a minimum 40°F (22°C) differential of the heat detector actuation temperature below the automatic sprinkler actuation temperature

B. Use a “Quick” response heat detector, spaced to provide a response time equivalent to, or preferably earlier than, the installed automatic sprinklers installed at the ceiling.

C. If the detection response time cannot be calculated, install the heat detectors at the same spacing as the automatic sprinklers installed at the ceiling.

2.5.10.5.4 If optical detection is utilized for activation of the foam fire extinguishing system and installation recommendations are not provided in the occupancy or equipment specific data sheet:

A. Provide detection logic requiring any two detectors to activate for operation.

B. Ensure at least two optical detectors cover any floor area to provide no reduction in system responsiveness.

2.5.10.5.4 When used in a corrosive atmosphere, install detection devices made of materials not subject to corrosion, or that have been treated to resist corrosion.

2.5.10.5.5 When protecting hazardous areas, ensure electric automatic detection equipment and any auxiliary equipment has been specifically designed and rated for such areas.

2.5.10.6 Alarms

2.5.10.6.1 Provide alarm and actuation circuitry in accordance with Data Sheet 5-40, *Fire Alarm Systems*, in conjunction with the recommendations in this section.

2.5.10.6.2 Provide foam fire extinguishing system alarm signals that:

A. are configured as a pre-discharge alarm with a time delay for egress of personnel, as needed. (see Section 3.3).

B. are distinct from other alarm signals (e.g., building fire alarm system, trouble/fault alarm).

C. Will continue to operate after discharge of the foam until a positive action has been taken to acknowledge the alarm and to proceed with appropriate action to the alarm operation.

2.5.10.6.3 When multiple foam fire extinguishing systems are installed, provide separate alarms to indicate operation of each system.

2.5.10.6.4 Provide audible and visual alarms that indicate locally and at a permanently manned location upon the following modes of foam fire extinguishing system operation:

A. Release and/or actuation of each foam fire extinguishing system from the detection system or alarm check valve and automatic foam concentrate control valve

B. Fault of the foam extinguishing/monitoring system of the foam fire extinguishing system

2.5.10.6.5 Arrange the detection system to alarm upon manual operation of the foam fire extinguishing system.

2.5.10.7 Power Supply and Controller

2.5.10.7.1 Provide a power supply, power feeder cables and wiring for the drivers of foam concentrate pumps in accordance with the recommendations for electric motor-driven pumps and diesel engine-driven pumps in Data Sheet 3-7, *Fire Protection Pumps*; and/or any applicable local electrical codes.

2.5.10.7.2 For electronic variable viscosity proportioners, provide:

A. A minimum of two reliable and independent power supplies (i.e., primary and secondary) designed in accordance with Data Sheet 5-40, *Fire Alarm Systems*.

B. Cables that are fire rated to the local code or protected to prevent exposure from fire.

C. Per the manufacturer's FM Approved design, installation and maintenance manual

2.5.10.7.3 Provide a power supply arranged so that disconnecting power from the protected facility during a fire will not disconnect the power supply to the foam concentrate pump or electronic variable viscosity proportioner feeder circuit.

2.5.10.7.4 Provide an FM Approved controller to govern the startup of foam concentrate pumps with electric drivers.

If the controller is provided as part of the FM Approval of the proportioner package, this meets the intent of the recommendation.

2.5.10.7.5 Provide a diesel engine fire pump controller to govern the startup of foam concentrate pumps with diesel engine drivers.

2.5.11 Fire Service Connections

2.5.11.1 When a fire service connection is recommended, provide it on the supply side of the proportioner (see Figure 9a).

2.5.11.2 Assess the following items are in accordance with the recommendations in this data sheet before installing or using the fire service connection:

A. Pressure of the system components

B. Balance of the proportioning equipment

C. Dilution of the proportioned foam solution

D. Disturbance of system accessory devices, including, but not limited to, the following:

- Pressure switches
- Hydraulic control valves
- Main control valve trim

E. Pressures and flows of the foam system design capability

2.5.11.3 At the fire service connection, post the water demand pressure based on the items evaluated above in Section 2.5.11.2.

2.5.11.4 Provide a fire service connection sized to the largest riser supplying the foam-water sprinkler system, auxiliary discharge devices, and/or hose connections.

2.5.12 Manual Firefighting

2.5.12.1 Provide a means of manual firefighting using foam in accordance with the applicable occupancy-specific data sheet.

2.5.12.2 Assess the flow rate per hose stream is in accordance with the applicable occupancy-specific data sheet. Confirm the foam nozzle is capable of this flow rate.

2.5.12.3 Evaluate the hose(s) are accounted for in **both** of the following:

A. The hydraulic calculations of the foam-water sprinkler system

B. The selection of the proportioner, due to the increased flow of foam-water solution

Alternatively, provide a separate proportioner and distribution line for the hose(s).

2.5.12.4 Evaluate the water and foam concentrate supply for the hose stream is adequate for the operating time recommended in the applicable occupancy-specific data sheet.

2.5.12.5 Provide fire hose(s) connections sufficient to reach any point within the hazard area.

2.5.12.6 Use a hose nozzle that is FM Approved for use with the foam concentrate and that can provide the appropriate application density and foam quality.

2.5.13 Plan Review

2.5.13.1 General

2.5.13.1.1 Confirm the contractor/installer is an authorized distributor or representative of the foam fire extinguishing system manufacturer and trained to design and install the system in accordance with the manufacturer's FM Approved design, installation, operation, and maintenance manual (DIOM).

2.5.13.1.2 Confirm the foam fire extinguishing system is designed in accordance with the following:

A. The applicable hazard- or occupancy-specific FM data sheet(s)

B. The specific manufacturer system's listing in the *Approval Guide*

C. The manufacturer's FM Approved design, installation, operation, and maintenance manual(s)

D. The original equipment manufacturer (OEM) equipment specification sheets

2.5.13.1.3 If alterations on the as-built area or equipment have been carried out (e.g., structural changes) from the original submitted design, revise the documentation and resubmit it to a designated representative of FM.

2.5.13.2 Design Factors

Document the following design factors:

A. Dimensions of the protected enclosure or design area

B. Location of any areas where the ambient temperature of the occupancy or hazard of expected to be less than 40°F (4°C) or more than 130°F (54°C)

C. Hazard, fuels or ignitable liquids to be protected

D. Fuel/ignitable liquid temperature

E. Fuel/ignitable liquid polarity/miscibility with water

F. Flash Point of ignitable liquid(s) protected with SFFF and AR-SFFF

G. Fuel configuration (e.g., palletized, in-rack)

H. Foam concentrate type (i.e., whether it is suitable to provide protection for the ignitable liquid hazard)

I. Discharge device orifice size or model number, as applicable

2.5.13.3 Working Drawings

2.5.13.3.1 Submit one set of drawings, foam fire extinguishing system hydraulic and pneumatic calculations, specifications, manufacturer's literature (i.e., catalog specification sheets) and any other documentation as described in Sections 2.4.13.3.2 and 2.4.13.3.4 to a designated representative of FM for review and acceptance prior to the start of any foam fire extinguishing system installation.

2.5.13.3.2 If revisions are recommended as a result of the FM review, submit revised documentation to a designated representative of FM for review and acceptance prior to the start of installation.

Provide the following information for review and acceptance:

A. The location and description of hazards protected by the foam fire extinguishing system.

B. An accurate and complete layout of the area to be protected, including drainage layout, if required.

C. System bill of materials indicating component details, including each component's name, manufacturer, model or part number, quantity, and description, as well as additional information on specific equipment, as follows:

1. Details of the foam concentrate:

- Type of foam concentrate; Suitability for either polar or non-polar ignitable liquids
- Injection percentage
- Quantity (active and reserve)
- Minimum anticipated temperature of the concentrate at the point of proportioning

2. Details of mechanical foam-water solution injection equipment, including proportioner orifice size or model and test connection size

3. Detailed data of the pumps (foam and/or water), drivers, controllers, power supply, fittings, suction and discharge connections (acquire charts from the engineer or contractor showing head delivery, efficiency, and brake horsepower curves of pumps)

4. Verification that the minimum equipment inlet pressure and pressure of discharge devices is provided from the water supply

5. Details of the proposed water supply and/or test results of the available water supply

6. Where necessary, laboratory test report to determine water supply (e.g., process water, grey water) quality and foam concentrate are compatible.

7. Discharge densities and discharge duration based upon delivered flow

8. Location, spacing and height of discharge devices

D. Scaled drawings of the distribution system, including the following:

1. Location of the foam concentrate storage tank

2. Detailed layout of the:

- piping for water supply, foam-water, and foam concentrate (include pitch of dry horizontal piping).
- riser with the specific location of the proportioner and available clear pipe diameters to the proportioner.

3. Identification of the type of piping material proposed for foam concentrate supply (brass/bronze/stainless steel)

4. Detailed layout of pipe fittings and isolation valves for test connection and test header to allow:

- discharge testing.
- water equivalency testing by Foam Solutions LLC, or
- test liquid discharge testing by Vector Fire Technology, Inc., or
- flowmeter testing with a variable viscosity proportioner.

5. Pipe hanger and bracing location and installation details. If seismic building joints, show the following:

- Where water distribution or supply piping crosses the joint
- Expected movement of the seismic joint
- Details of piping arrangement
- Flexible connectors used to accommodate seismic movement

E. Detection system information (if applicable) including control panel/annunciator panels; number, spacing, and location of detectors; control devices (dampers, doors, or auxiliary equipment); and audible/visual indicating devices (number and location) with associated wiring diagrams.

F. Foam extinguishing system information signage location and installation details in accordance with Section 2.3.1.

G. Description of the system sequence of operations, including functioning of maintenance switches, ventilation, dampers, doors, fuel interlocks, and power shutdown.

H. Tests and inspections to be conducted for commissioning and acceptance

I. Individual and integrated system tests to be conducted for system acceptance.

J. Plan for disposal of effluent

2.5.13.4 Calculations

2.5.13.4.1 Hydraulic flow calculations do not need to be provided for pre-engineered foam fire extinguishing systems. Review the isometric view of the distribution system (see 2.5.13.3.2, item D) for compliance with the pipework specifications in the manufacturer's FM Approved design, installation, operation, and maintenance manual.

2.5.13.4.2 When a computer program is used for hydraulic or pneumatic calculation, provide the name and version number of the program.

2.5.13.4.3 Provide calculations to determine the following:

A. Quantity of water

B. Quantity of foam concentrate

C. Quantity of foam-water solution

D. Quantity of compressed gas, if applicable

E. Number of discharge devices

F. Flow rates of the water and compressed gas media, if applicable

G. Rate of discharge of high-expansion foam, if applicable

H. Nozzle pressure, minimum or allowable range

I. Discharge duration time in accordance with Section 2.4.9.4

2.5.13.4.4 If seismic restraint is needed per Data Sheet 1-2, *Earthquakes*, provide calculation of seismic loads on the fire protection equipment (e.g., foam storage containers, distribution system pipe) identified in Data Sheet 2-8, *Earthquake Protection for Water-Based Fire Protection Systems*.

2.5.13.4.5 When detection is used, provide calculations to determine the size of backup batteries for the fire alarm control panel. See Data Sheet 5-40, *Fire Alarm Systems*, for further information.

2.5.14 System Restoration

2.5.14.1 After acceptance tests are completed, or following system discharge, restore the foam fire extinguishing system, alarms, and interlocks to operational condition. Identify and manage any impairments from restoring the foam fire extinguishing system to operability in accordance with Section 2.8.

2.5.14.2 Establish procedures to ensure the following:

A. Proper shutdown sequence of valves and equipment in accordance with the manufacturer's recommendations.

B. Appropriate cleanup and salvage of the protected enclosure.

C. Piping that is charged only with water is flushed, and piping that is normally empty is flushed and drained, to remove foam concentrate or foam-water solution.

D. Flushing of pre-primed foam-water sprinkler systems, and re-priming with the specified design concentration of foam-water solution.

E. Those portions of the foam fire extinguishing system that normally contain foam concentrate when in service are not flushed.

F. Foam concentrate pumps that do not normally contain foam concentrate when in service are flushed.

G. Strainers are inspected, cleaned, and placed in operational condition.

H. Different types and/or brands of foam concentrates for use in storage tanks are not mixed.

2.5.14.3 Establish procedures to ensure valves to be restored to their operational position. This includes, but is not limited to, the following:

- Test connection valve - closed
- Flushing valves, water and foam concentrate - closed
- Riser OS&Y isolation valve - open
- Water feed valve from riser to bladder tank - open
- Foam concentrate fill valve - closed
- Water drain valve for shell of bladder tank - closed
- Foam concentrate isolation valve from bladder or storage tank to automatic foam concentrate control valve - open
- Automatic foam concentrate control valve - closed/set to open
- Foam concentrate liquid level/sight glass valve - closed

2.5.14.4 Follow the manufacturer's procedure(s) to restore the installed equipment to service, including replenishment of foam concentrate, compressed gas and water, as appropriate.

2.6 Acceptance of Foam Fire Extinguishing System

2.6.1 Acceptance Test Plan

2.6.1.1 Provide a designated representative of FM with a complete step-by-step description of the proposed acceptance test procedure(s), identifying each and all devices, controls, and functions to be tested and inspected, and how any tests will be conducted prior to scheduling the acceptance test. Include any individual and interconnected system tests to be conducted for acceptance with an integrated foam fire extinguishing system(s).

2.6.1.2 Verify the installation companies have furnished written documentation and FM form(s) completed in accordance with the recommendations for system acceptance with all specified flushing of underground, lead-in, and system piping.

The documentation is to be completed in accordance with the recommendations for system acceptance in Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, together with specified hydrostatic pressure tests, system operational and discharge tests for final acceptance.

Submit the following forms (see Appendix D), as applicable:

- Contractor's Checklist for Foam Extinguishing System Installation (for FM clients)

2.6.2 Implementation of Acceptance

2.6.2.1 Provide inspection and testing by a contractor who is an authorized distributor or representative of the foam fire extinguishing system manufacturer and trained to inspect and test the system in accordance with the manufacturer's FM Approved design, installation, operation, and maintenance manual.

2.6.2.2 When multiple systems are installed, operate the maximum number of systems that are expected to operate at the same time.

2.6.2.3 When multiple equipment hazards are being protected with a single foam fire extinguishing system zoned for each hazard or single supply of foam concentrate, conduct an operational test of each protected area.

2.6.3 Visual Inspection

2.6.3.1 Verify the foam fire extinguishing system has been installed to the submitted working drawings and specifications (see Section 2.5.13, Plan Review) as well as any applicable national or international codes and standards by conducting a visual inspection in accordance with the *Contractor's Checklist for Foam Extinguishing System Installation* (Engineering Form 7615).

2.6.3.2 Verify the foam fire extinguishing system has been installed correctly to design drawing and specifications by conducting the following visual inspections:

- Confirm the foam extinguishing system components are FM Approved.
- Check the continuity of pipework to the hazard area/zone(s).
- Check that valves, controls, and gauges are accessible.
- Confirm discharge devices, proportioner(s), foam pumps, and associated hardware have been properly installed.

- Confirm the proper proportioner(s) by part number to the Working Drawing.
- For compressed air foam systems, confirm the installed orifice size or serial number of the air/water/foam concentrate manifold to the Working Drawings or software calculation sheet.

2.6.3.3 Provide a schematic of the operating valves and devices, identifying their set/normal operating position for the foam fire extinguishing system equipment.

2.6.3.4 Verify signage is provided on the proper shutdown sequence of valves and equipment for the foam fire extinguishing system(s) after activation.

2.6.3.5 Check operating valves and devices for proper identification, orientation of flow, operating position labeling, and operating instructions.

2.6.3.6 Inspect valves to verify they are set in the proper operating position (e.g., normally open or normally closed) in accordance with an operational schematic.

2.6.3.7 Inspect all normally dry horizontal piping for proper drainage pitch.

2.6.4 Operational Test of Proportioning Equipment

2.6.4.1 Verify the operation of the proportioning equipment using one of the following methods:

A. Discharge testing the foam-water solution with the foam concentrate

B. Discharge testing the foam-water solution with the foam concentrate and water for the correlating water equivalency method

C. Discharge testing the FM Approved test liquid designated for a specific foam concentrate

D. Proportioning tests of the foam concentrate and water supply using flow meters (variable viscosity proportioner)

2.6.4.2 Evaluate the hazard is fully protected by conducting a discharge test to determine the flow pressures, actual discharge capacity, consumption rate of foam concentrate, and other operating characteristics. Include the following tests:

A. Foam discharge from a single foam fire extinguishing system

B. Simultaneous foam discharge of the maximum number of foam fire extinguishing systems expected to operate on a single hazard

2.6.4.3 Use either the discharge device(s) or the test connection to evaluate the proportioning equipment in accordance with 2.6.4.1.

Consider local environmental regulations for collection of the foam-water solution effluent from the foam fire extinguishing system in choosing which discharge configuration is to be used.

2.6.4.4 Continue the discharge or flow testing for the time required to obtain stabilized discharge of foam-water solution, test liquid or foam concentrate and water.

2.6.4.5 Confirm system pressures and flows remain as described in this section and meet manufacturer's system requirements and recommendations.

2.6.4.6 Compute the rate of foam solution discharge using hydraulic calculations with recorded inlet or end-of-system operating pressures, or both.

2.6.4.7 Determine the actual foam concentration percentage injected into the foam fire extinguishing system by calculation and empirical sampling from foam-water solution or test-liquid solution discharged at the test connection using the digital conductivity method. See Appendix E.

Note: This recommendation does not apply to compressed air foam systems and flow testing of foam concentrate and water supply with flow meters.

The digital refractive index method does not produce the precision needed to differentiate between the standardized foam-water calibration solutions and the collected discharge to properly interpret the results.

2.6.4.7.1 Do not use optical refractometric index equipment for determining actual foam concentrate percentage from the foam-water solution.

2.6.4.8 Verify operational tests of the proportioning equipment for pre-primed, wet-pipe, dry-pipe, and preaction systems are conducted at the minimum expected flow (four most remote sprinklers) and the maximum expected flow for the most remote design demand area.

2.6.4.9 For pre-primed, wet-pipe, dry-pipe, and preaction foam-water sprinkler systems with a wide range flow proportioner, verify an operational test is conducted at the minimum flow equal to the flow of the most remote sprinkler, in lieu of the four most remote sprinklers.

2.6.4.10 For deluge systems and compressed air foam systems, verify an operational test is conducted using the full demand flow expected of the foam-water sprinkler system.

2.6.4.11 During the discharge flow tests, verify the test is conducted with the pressure at the proportioning device(s) as follows:

A. The design operating pressure of the foam fire extinguishing system or systems tested

B. At least equal to the highest anticipated water pressure of the foam fire extinguishing system or systems tested

C. The minimum anticipated water pressure of the foam fire extinguishing system or systems tested

2.6.4.12 For an in-line balanced proportioner, verify the proportioner is operating within the manufacturer's specified water and foam concentrate pressure differential from the duplex pressure gauge.

2.6.4.13 Confirm the foam-water solution meets the criteria in Table 2.6.4.13 for the percentage of concentrate injected.

Note: This recommendation does not apply to compressed air foam systems, with a pressurized foam concentrate supply tank tested for proportioning at the manufacturer's factory.

Table 2.6.4.13. Foam-Water Solution Range

Proportioner Type	*Percentage of Concentrate*	*Minimum Percentage*	*Maximum Percentage*
Balanced pressure proportioner,positive pressure (with pump, bladder tank, in-line balanced pressure), ratio, wide range flow proportioner, or variable viscosity proportioner	1%	1.0	1.3
	3%	3.0	3.9
	6%	6.0	7.0

2.6.4.14 For proportioner types not listed in Table 2.6.4.13, confirm the foam concentrate induction rate of the proportioner, expressed as a percentage of the foam solution flow (water plus foam concentrate), is between minus 0% to plus 30% of the induction rate specified in the *Approval Guide*, or 1 percentage point, whichever is less, at the recommended flow rates.

Note: This recommendation does not apply to compressed air foam systems unless a variable viscosity proportioner is provided.

2.6.4.15 For compressed air foam systems, verify the following:

- Static water pressure
- Residual water pressure at the control valve
- System air pressure
- Percentage of concentrate injected meets manufacturer's quality control documentation
- Where possible, the quality (e.g., expansion) of the foam from the discharge device(s) or test connection

If a variable viscosity proportioner is used with the foam concentrate supply, test the proportioner in accordance with Section 2.6.4.1.

Note: An additional valve or orifice plate to control the flow from the test connection may be necessary to verify the system pressure.

2.6.4.16 Collect and dispose of the discharged foam-water solution, test liquid solution, or foam in accordance with local and/or national regulations and the authority having jurisdiction.

2.6.4.17 Alternate Test Methods

Alternative test methods for discharging foam are as follow:

- Water equivalency test method
- Test liquid(s)
- Flow meters FM Approved with proportioner

(See Section 3.6.2 for differences in the attributes of these test methods.)

When using a water equivalency method or a test liquid for acceptance and subsequent annual testing, use a company evaluated by FM Approvals in accordance with their Assessment Standard 5138, *Assessment Standard for Proportioning Testing*. Type of foam concentrate, type of proportioning method, range of flow, measurement techniques, and test provider locations audited by FM Approvals are limitations of the assessment.

See Table 2.6.4.17 for a list of companies that have been assessed by FM Approvals.

Table 2.6.4.17. FM Approved Alternate Test Method Service Providers

<table>
<tr><th>Test Method</th><th>Testing Provider</th></tr>
<tr><td>Water equivalency method</td><td>Foam Solutions LLC,
Columbus, OH, USA
https://foamsolutionllc.com/#home</td></tr>
<tr><td rowspan="3">Test liquid(s)</td><td>Vector Fire Technology Inc.
Coatesville, PA, USA</td></tr>
<tr><td>Vector Fire Technology Inc
Tucson, AZ, USA
https://planitsafetest.com</td></tr>
<tr><td>NoFoam Systems
La Jolla, CA, USA
https://nofoamsystem.com/</td></tr>
<tr><td rowspan="2">Flow meters</td><td>FireDos
Wolfersheim, Germany
https://www.firedos.com/</td></tr>
<tr><td>WB FirePacks
Zwijndrecht, Netherlands
https://www.firepacks.com/en/</td></tr>
</table>

2.6.4.17.1 Water equivalency test method: Foam Solutions LLC, Columbus, Ohio, USA, is the only company acceptable to FM for water equivalency testing and follow-up inspections of foam-water sprinklers and foam fire extinguishing systems.

Foam concentrates allowed are not dependent upon type of concentrate or viscosity since this alternative test method is conducted with a discharge test using the foam concentrate for the foam fire extinguishing system.

An initial discharge test with foam concentrate must be conducted for their test method as a baseline in conjunction with a water equivalency test to correlate the equivalent water flow and pressure value(s) with the foam concentrate and foam-water solution rate of flow. Limitations of the test method are identified in Table 2.6.4.17.1.

Conduct a viscosity test of the foam concentrate being used in the system to document the baseline for subsequent annual testing.

Table 2.6.4.17.1. Water Equivalency Test Method: Foam Solutions Limitations

Type of Proportioning Assessed	*Procedure/ Document Number*	*Concentrate*	*Minimum Total System Flow Capacity*		*Maximum Total System Flow Capacity*		*Minimum Concentrate Flow Capacity*		*Maximum Concentrate Flow Capacity*	
-	-	%	gpm	(L/min)	gpm	(L/min)	gpm	(L/min)	gpm	(L/min)
Bladder tank or Atmospheric tank/ concentrate pump with fixed ratio, wide range flow, or in-line balanced proportioner	Foam Proportioner Test Manual, “Aqua Flow” Test Method, Sept. 27, 2012 Revision 2.3	1, 3, 6	60	230	600	2300	1	3.8	10	37.8
			150	570	4900	18,500	6	23	60	230
							20	76	200	760
							60	230	600	2270

2.6.4.17.2 Test liquids: Vector Fire Technology, Inc., with locations providing services from Coatesville, PA, USA, and Tucson, AZ, USA is the only company FM accepts for test liquid and follow-up inspections testing of foam-water sprinkler systems.

The Planit Safe test liquids (see Table 2.6.4.17.2) are used for this testing.

There are two methods for testing systems using a Planit Safe test liquid. The first method called the “Direct Substitution Method” involves placing the Planit Safe test liquid directly into the bladder or atmospheric foam concentrate tank as a substitute for the foam concentrate and then conducting a system flow test to determine the foam injection rate. This method is generally only practical for initial system Acceptance Tests when the foam concentrate tank is empty and clean. The second method referred to as the “Interface Device Method” uses a temporarily interconnected surrogate bladder tank or atmospheric storage tank containing the Planit Safe test liquid. If this method is used it does not validate the foam concentrate storage portion of the foam extinguishing system and additional testing needs to be conducted.

Typical test setup arrangements using these methods are shown in Section 2.5.7.10. Either method described above is suitable for initial acceptance of a bladder tank or foam concentrate pump type extinguishing system with atmospheric foam concentrate tank based upon the following:

A. Verify the Planit Safe test liquid batch being used has the same viscosity specifications as the foam concentrate in the foam fire extinguishing system.

B. Conduct a viscosity test of the foam concentrate being used in the system to document the baseline for subsequent annual testing.

C. Additional testing for the “Interface Device Test Method” to include:

1. Bladder tank

a. Analysis of water sample from bladder tank steel pressure vessel shell for foam concentrate

b. Confirm the water inlet pressure to the bladder tank is sufficient for the hydraulic pressure loss of the foam concentrate line to the proportioner.

c. Confirm a clear foam concentrate flow path from the bladder tank as the foam concentrate feed line is recharged following the Planit Safe testing.

2. Atmospheric storage tank

a. Circulation of positive displacement foam concentrate pump to maximum pressure and flow of system to verify proper pressure setting on pressure sustaining valve.

b. Confirm the foam concentrate pump pressure is sufficient for the hydraulic pressure loss of the foam concentrate line to the proportioner.

Table 2.6.4.17.2. Test Liquids: Planit Safe Limitations

Test Liquid Designation	*Type*	*Procedure /Document Number*	*Type of Proportioning Assessed*
Planit Safe “A3F1HEC”	1% AFFF3% AFFF	VFTDC306 March 24, 2025; Rev. F	Bladder tank or Atmospheric tank/ concentrate pump with fixed ratio, wide range flow, or in-line balanced proportioner
Planit Safe 1x3 – “xxxx”	*AR-AFFF	VFTDC306 March 24, 2025; Rev. F	
Planit Safe 3x3 – “xxxx”			
Planit Safe 3x6 – “xxxx”			
Planit Safe “FF3-S”	Solberg RF3	VFTDC306 March 24, 2025; Rev. F	
Planit Safe 3x3 SP100	Solberg 3x3 SP100	VFTDC306 March 24, 2025; Rev. F	
Planit Safe 3SFF-ARK	Viking 3 or 6% ARK SFFF	VFTDC306 March 24, 2025; Rev. F5	
Planit Safe 3SFF-USP	Viking 3% USP SFFF	VFTDC306 March 24, 2025; Rev. F	

Note: “xxxx” identifies product designation for viscosity.
“*” Planit Safe is product designation specific to the foam concentrate. Verify the Planit Safe product to be designated for the foam concentrate.

2.6.4.17.3 Test Liquids: NoFoam Systems, La Jolla, CA, USA provides an alternate test method that uses a test liquid in conjunction with flowmeters to determine the percent injection. Flowmeters (foam concentrate piping and foam-water solution or water) are used as an alternate to a discharge test to determine by calculation the percentage of foam concentrate proportioned.

This alternate test method correlates the foam concentrate proportioning results from the test liquid to that of a subsequent water discharge. The surrogate test liquid is used in lieu of the actual foam concentrate of the foam fire extinguishing system. The associated flow of water in the foam concentrate piping (for the system specified flow and pressure at the riser) is documented after the proportioning test with the surrogate test liquid.

This test method has only been evaluated for foam extinguishing systems using AFFF(C6) foam concentrates. The measuring devices have specific limitations to determine total flow of the water/foam solution, foam concentrate or surrogate test liquid based upon velocity of the fluid in these pipes. The testing conducted as part of the assessment had a foam solution flow of 70 to 800 gpm (265 to 3000 lpm) and 1 to 25 gpm (4 to 95 lpm) for foam concentrate. The assessment (as allowed by the manual) included mixing of the surrogate test liquid on site to match the foam concentrate in the foam extinguishing system.

A site-specific manual will be prepared by NoFoam for the test plan and installation of the by-pass connections, enabling proper evaluation of the injection rate to the proportioner.

2.6.4.17.4 Flow meters: Two flow meters are typically used to determine the injection percentage of foam concentrate with the fire protection water. The variable viscosity proportioner is configured with either isolation or by-pass valves to recirculate the foam concentrate to the storage tank. One flow meter is configured with the variable viscosity proportioner to determine the flow of the foam concentrate. A separate flow meter is provided to determine the total water flow of the fire protection water. The fire protection water may be either discharged or recirculated dependent upon its source.

When using flow testing of the foam concentrate and water supply, refer to 2.6.4.2.D. For acceptance testing and subsequent annual testing, use flowmeters that are listed as part of the FM Approval for the specific variable viscosity proportioner.

When using flow testing of the foam concentrate and water supply, determine the actual foam concentration percentage injected into the foam fire extinguishing system by calculation from foam concentrate flowmeter and system water flowmeter.

(Equation 2)

$PI = [Q_{FC} / (Q_{WF} + Q_{FC})] \times 100$

Where:

PI = Percent injection (%).

Q_{FC} = Flow of foam concentrate.

Q_{WF} = Flow of system water.

2.6.5 Operation of Components

2.6.5.1 Verify all mechanical and electrical components and systems interconnected with the foam fire extinguishing system operate in accordance with the commissioning documentation and test plan (see Section 3.6.1).

2.6.5.2 Conduct operational tests to verify the foam fire extinguishing system responds as designed from both automatic detection and manual actuation devices. At a minimum, confirm the following:

- Visual and audible local alarms
- Time delays
- Remote annunciation at the fire alarm control panel
- Releasing devices and valves
- Operation of auxiliary devices (equipment shutdown, fuel interlock, door or damper interlocks, etc.)
- Manual pull stations
- Operation in accordance with the system design specification

2.6.5.3 Confirm functionality of the system components listed in 2.6.5.2 during one of the following operational tests:

- Full discharge test (Section 2.6.4)
- Flow through the test connection

2.6.5.4 For open nozzle systems, when using the test connection, set the position of the isolation valves to discharge from the test connection in order not to discharge foam-water solution into the distribution system piping.

2.6.5.5 For low-expansion foam fire extinguishing systems with discharge devices that rotate or oscillate, confirm functionality. These devices include, at a minimum:

- Compressed air foam nozzles, as applicable
- Monitors

2.6.6 Alarm and Detection Devices

2.6.6.1 Inspect and test alarm and detection devices in accordance with Data Sheet 5-40, *Fire Alarm Systems*, and Data Sheet 5-48, *Automatic Fire Detection*.

2.6.6.2 Verify interlock devices function as intended when initiated by the fire alarm system.

2.6.7 Documentation

2.6.7.1 Maintain the following documents for reference:

A. Manufacturer's literature describing the correct operation, inspection, and maintenance of the foam fire extinguishing system and its components

B. As-built piping layout drawings, electrical schematics, and hydraulic calculations and pneumatic calculations, if appropriate.

C. Schematic of the set position of operating valves and devices

D. Procedure(s) on the proper manual shutdown sequence of valves and equipment after activation.

E. Manufacturer's design, installation, operation, and maintenance manual

F. Acceptance test report documenting the results of the following:

1. Distribution system cleaning and flushing (Section 2.5.8.4)
2. Pressure test of distribution piping (Section 2.5.8.5)
3. Visual inspection (Section 2.6.3)
4. Discharge test of proportioning system discharge test with foam concentrate or alternative test method (Section 2.6.4)

5. Operational test of components and systems (Section 2.6.5)
6. Alarm and detection devices (Section 2.6.6)

G. Provide a placard or nameplate with the foam fire extinguishing system design specifications.

H. Provide a tag or label at the proportioner to document the actual injection percentage of foam concentrate at the minimum and demand flow determined during the acceptance test and update at the annual discharge test.

2.7 Inspection, Testing and Maintenance

2.7.1 Inspect and test to identify impairments of the foam fire extinguishing system in accordance with Data Sheet 2-81, *Fire Protection System Inspection*.

2.7.2 Inspect and test to identify impairments to the fire detection of the foam fire extinguishing system in accordance with Data Sheet 5-48, *Automatic Fire Detection*.

2.7.3 Maintain the foam fire extinguishing system in accordance with the manufacturer's instructions.

2.7.4 Base maintenance intervals other than preventive maintenance on the results of visual inspections and operational tests.

2.8 Impairments

2.8.1 Manage system impairments and provide procedures for resolution of impairments in accordance with Data Sheet 10-7, *Fire Protection Impairment Management*.

2.9 Training

2.9.1 Provide training for all personnel responsible for the operation and maintenance of the system, addressing the following at a minimum:

A. Review of the manufacturer's FM Approved design, installation, operation, and maintenance manual.

B. The purpose of the foam fire extinguishing system relative to the protected equipment and enclosure.

C. Functionality of the system and major system components.

D. Associated equipment and interlocks, if applicable (enclosure venting, dampers, power and ventilation shutdown, etc.)

E. Operation of the system under normal and emergency circumstances (i.e., automatic and manual operation), including the location of manual release devices.

F. Necessary inspection, testing, and maintenance of the foam fire extinguishing system and protected enclosure or equipment.

2.10 Contingency Planning

2.10.1 Maintain a 100% reserve supply of foam concentrate, as determined from Section 2.4.9.6, Foam Quantity, in separate tanks, compartments, or drums on site, or verify it is readily available so the system can be restored within 24 hours after operating.

2.11 Electrical

Test standby power for the fire extinguishing systems in accordance with the applicable recommendations in Data Sheet 2-81, *Fire Protection System Inspection*.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General

Refer to the following FM Property Loss Prevention Data Sheets as applicable for information on occupancy-specific hazards:

- 5-23, *Design and Protection for Emergency and Standby Power Systems*
- 7-9, *Dip Tanks, Flow Coaters and Roll Coaters*
- 7-12, Mining and Mineral Processing
- 7-14, *Fire & Explosion Protection for Flammable Liquid, Flammable Gas, & Liquefied Flammable Gas Processing Equipment & Supporting Structures*
- 7-29, *Ignitable Liquid Storage in Portable Containers*
- 7-32, *Ignitable Liquid Operations*
- 7-37, *Cutting Fluids*
- 7-79, *Fire Protection for Gas Turbine and Electric Generators*
- 7-88, Outdoor Ignitable Liquid Storage Tanks
- 7-93, *Aircraft Hangars, Aircraft Manufacturing and Assembly Facilities and Protection of Aircraft Interiors During Assembly*
- 7-96, *Printing Plants*
- 7-101, *Fire Protection for Steam Turbines and Electric Generators*

3.1.1 Applications for Which Foam Fire Extinguishing Systems are Not Recommended

Low-expansion foam fire extinguishing systems are not suitable for protecting the following:

- Chemicals, such as cellulose nitrate, that release sufficient oxygen or other oxidizing agents to sustain combustion
- Liquefied or compressed gas
- Energized, unenclosed electrical equipment
- Combustible metals, such as aluminum and magnesium
- Water-reactive metals, such as lithium, sodium, potassium, and sodium-potassium alloys
- Hazardous, water-reactive materials such as triethyl-aluminum and phosphorous pentoxide.

3.2 Construction and Location

3.2.1 Installation of Foam Concentrate Tanks: When considering the installation of a vertical bladder tank, provide either (a) enough space around the tank so it can be laid on its side, or (b) adequate overhead space in which to remove and replace the bladder from the tank. An area twice as long as the tank is tall will be required to remove the bladder.

Horizontal bladder tanks require sufficient horizontal clearance to remove and replace the piping and bladder. An area at least twice as long as the tank will be required at one end. Access through double doors, etc., is an acceptable alternative.

3.2.2 Exposure Temperature: Foam concentrates that have been exposed to temperatures below their minimum storage/usable temperature and subsequently thawed need to be checked for separation (especially alcohol-resistant foam concentrates). Contact the manufacturer of the foam concentrate for corrective action.

3.2.3 Containment: Where not providing containment in accordance with Data Sheet 7-83, provide a minimum 2 in. (5 cm) curb for the retention of the low-expansion foam blanket to prevent the flow of foam into adjacent areas of the facility that are not protected.

3.3 Occupancy

3.3.1 System Identification

The system information sign provides a readily accessible summary of the protection being provided by the foam fire extinguishing system when the following information is included, as applicable:

- Location of the protected area or areas
- Description of the hazard protected
- Design type application
- System manufacturer and system designation
- Volume or area protected, depending on application
- Total number of nozzles protecting the hazard
- Design water and compressed gas flow rate and duration
- Total compressed gas agent and water requirements, as calculated
- Description of any compartment or enclosure characteristics that are essential to system performance
- Name of installing contractor and contact information

- Date of installation
- Date of modification
- Plan identification number or project number of the submitted as-built plans

3.4 Protection

3.4.1 Where to Find Foam Fire Extinguishing “System” Components in the Approval Guide

The following components are listed in the Low-Expansion Foam Systems section of the *Approval Guide*:

A. Bladder tanks

B. Pressure switches

C. Wide Range flow proportioners

D. Ratio proportioners

E. Variable viscosity proportioner*

F. Foam concentrate pumps

G. In-line balanced proportioners (ILBPs)

H. Foam concentrate control valves

I. Sprinklers**

J. Discharge devices; low level nozzles, foam chambers, foam monitors

* The use of an FM Approved variable viscosity proportioner, by itself, will not create a complete FM Approved foam fire extinguishing system. The design of the system also requires the use of an FM Approved foam concentrate, within the viscosity range of the FM Approved variable viscosity proportioner, and an FM Approved discharge device that is compatible with the FM Approved foam concentrate as identified in the manufacturer’s FM *Approval Guide* listing. If these compatible components are part of the manufacturer’s FM Approval listing the FM Approved variable viscosity proportioner could be a substitute for the manufacturer’s proportioner identified, provided it meets the specification for viscosity and range of flow.

** Deluge sprinklers are not listed as such in the *Approval Guide*; they are simply FM Approved automatic sprinklers that can be ordered in the open orifice (deluge) configuration from the manufacturer.

The following components are listed in the Automatic Sprinklers section of the *Approval Guide*:

A. Deluge sprinkler systems

B. Water motor gongs

C. Pipe hangers

D. Water flow detectors

E. OS&Y valves

F. Pressure gauges

G. Strainers

H. Automatic releases for preaction and deluge sprinkler systems

I. Automatic water control valves

The following components are listed in the Fire Pump Installation section of the *Approval Guide*:

A. Pump controllers (water & foam)

B. Diaphragm valves

3.4.2 Distribution and Discharge Devices

The following foam-water sprinkler systems are considered to be automatic:

- Wet-pipe
- Pre-primed pipe
- Foam-water dry-pipe
- Foam-water preaction

Prompt foam water delivery to discharge devices is important to fire control and extinguishment. Minimizing delays can be accomplished through a variety of design concepts such as the proximal location of the foam supply and proportioner to the hazard area, use of pumped systems, and ensuring dry type systems are properly arranged for fast water delivery times

Deluge foam-water sprinkler systems are used in applications where an immediate application of foam over a large area involving ignitable liquids is desired, such as chemical process areas, truck loading racks, and aircraft hangars.

3.4.3 Pre-Primed Foam-Water Distribution Systems

Protein-based foam concentrate products are fairly rapid in biodegradability in their foam-water solution state and are not recommended for pre-primed distribution systems.

Fire testing conducted by FM to date to evaluate automatic sprinkler protection with AFFF foam-solution has involved freshly primed (i.e., foam solution in the piping from the riser to the sprinklers) sprinkler systems. This arrangement resulted in foam being discharged immediately upon operation of the automatic sprinklers with very rapid control and extinguishment of the ignitable liquid test fires. Consequently, pre-primed systems are normally preferred for systems recommended for extinguishment of ignitable liquid fires. Recognition of additional maintenance on such a system (e.g., periodic flushing and replacement of the foam solution) and the associated need to dispose of the foam solution must be considered in its operational cost. Hence preprimed distribution systems are typically only recommended when the 2 minute delivery time of the foam-solution is exceeded.

Testing of foam-water solutions in a preprimed distribution system on an annual basis is recommended at least initially (during the first few years) to determine foam-water solution quality. This is due to environmental conditions, such as ceiling temperature and fluctuations of that temperature. Eventually, possible protocols can be established for replenishing with fresh foam-water solution at longer intervals.

3.4.4 Foam Concentrates

3.4.4.1 Some foam concentrates contain fluorochemicals, and their persistent degradation products have been found in living organisms. This has drawn the concern of environmental authorities worldwide and led to both regulatory and non-regulatory actions being enacted to reduce emissions for fluorochemicals that contain Per- and Polyfluorinated Alkyl Substance (PFAS). The focus of these actions has been on fluorochemicals that contain eight carbons (C8) or more, such as perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). In addition, foam concentrates manufactured with short chain fluorochemicals that are known as a “C6” foam concentrate contain PFAS are being included in these actions, but do not contain or breakdown into PFOS or PFOA.

The U.S. EPA has only placed restrictions on foam concentrates that are known to contain or break down into perfluorooctane sulfonate (PFOS) and/or perfluorooctanoic acid (PFOA). Both have been thought to have various adverse health effects on humans. The fluorinated “C8” foam concentrates are no longer produced. There are no fluorinated C8 foam concentrates listed in the FM *Approval Guide*. In the United States, foam fire extinguishing systems may still have fluorinated C8 foam concentrates in their systems because there has not been a mandate to eliminate existing systems by the U.S. EPA. However, individual states are enacting legislation. Also, in Australia, Canada, and EU countries, there are policies for replacing existing fluorinated C8 foam concentrates that have “persistent organic pollutants.” Additional details are identified in each section for the various countries.

Once the foam manufacturers recognized the environmental challenges associated with the fluorinated C8 foam concentrates, they began developing new ones. The replacement for fluorinated C8 foam is known as a fluorinated “C6” foam concentrate. These foam concentrates are manufactured with short chain fluorochemicals. As a result of these regulations, foam concentrates have been reformulated, with short chain fluorochemicals (C6) and have been received certification for FM Approval.

3.4.4.1.1 Environmental regulations that involve fluorine-based foam concentrates are described below with some detail for informational purposes, but are not complete. Regulations for PFAS fluorochemicals continue to be enacted, so local, state, and federal/national rules should be consulted:

A. United States

United States Environmental Protection Agency (EPA) regulations do not restrict the use of existing stocks of PFOS-based foam concentrates. The only AFFF foam concentrates restricted were those manufactured by 3M, due to the electrochemical fluorination process and its effect on the environment.Rather than regulate emissions of PFOA, the United States EPA developed a global stewardship program where fluorochemical manufacturers have voluntarily agreed to reduce emissions of PFOA, PFOA precursors, and higher homologue chemicals 95% by the end of 2010, and eliminate them altogether by the end of 2015. As a result, telomer-based fluorochemicals used in foam concentrates after 2015 contain only six carbons (C6) or fewer in order to comply with the EPA program.

The US EPA does not currently regulate fluorinated C6 foams; however, some US states and other countries seem to be regulating the general category of PFAS foam concentrates. All foam concentrates with fluorochemicals are PFAS foams. These include both C8 and C6 foam concentrates. We are not aware of any bans on the use of fluorinated C6 foam.

US states are enacting regulatory restrictions on the general category of PFAS used in foam concentrates. Some of these regulations restrict only the use of AFFF for testing and training, while others include restrictions on the sale of AFFF. The Firefighting Foam Coalition has developed a Newsletter (May 2022) that summarizes some of the actions being enacted in each state, but not necessarily all of the regulations.

B. Canada

Regulations in Canada prohibit AFFF containing certain PFASs under the Prohibition of Certain Toxic Substances Regulations, 2012 with a few exemptions. PFOS has been regulated since 2008. It was originally regulated under the Perfluorooctane Sulfonate and Its Salts and Certain Other Compounds Regulations (the PFOS Regulations). PFOA and LC-PFCAs were added to the regulations in 2016. Those regulations prohibit the manufacture, use, sale, offer for sale and import of PFOS, PFOA and long-chain (LC) perfluorocarboxylic acids (PFCAs) with a limited number of exemptions. The limited exemptions in the regulations allow:

1. The use of AFFF that contains residual levels of PFOS at a maximum concentration of 10 ppm.

2. The use and import of AFFF contaminated with PFOS in a military vessel or military fire-fighting vehicle returning from a foreign military operation.

C. Europe

European Union (EU) member countries following regulations from the European Chemicals Agency (ECHA) are expected to be subject to a January 2022 proposal for a separate REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals Regulation)restriction on PFAS in firefighting foams. The ECHA REACH restriction on PFAS in firefighting foam will be the regulation moving forward covering fluorinated Class B foams. The Firefighting Foam Coalition has developed a Newsletter (May 2023) that summarizes these actions being enacted, but not necessarily all of the regulations.

European Union (EU) member countries had to provide an inventory of PFOS-based foams to EC by December 2008. This is in accordance with Directive 2006/122/ECOF.

EU regulations require existing stocks of PFOS-based foams to be removed from service by June 27, 2011. This is in accordance with Directive 2006/122/ECOF and Annex.

EU regulations allow PFOA-based foams to be used until July 4, 2025 subject to the following conditions:

1. fire-fighting foam that contains or may contain PFOA, its salts and/or PFOA-related compounds shall not be used for training;

2. fire-fighting foam that contains or may contain PFOA, its salts and/or PFOA-related compounds shall not be used for testing unless all releases are contained;

3. as from 1 January 2023, uses of fire-fighting foam that contains or may contain PFOA, its salts and/or PFOA-related compounds shall only be allowed in sites where all releases can be contained;

4. fire-fighting foam stockpiles that contain or may contain PFOA, its salts and/or PFOA-related compounds shall be managed in accordance with Article 5.

This is in accordance with Directive 2020/784/EU published on 8 April 2020.

D. Australia

1. All Australian state/territory governments agreed that further release of PFAS into the environment from ongoing use should be prevented where practicable, and that actions to reduce or phase out the use of PFAS should be nationally consistent. A summary of that proposed National Environmental Management Plan is as follows:

- Ongoing sale or use of products (i.e., chemical based formulations) and articles (i.e., objects that contain chemicals) that contain long-chain PFAS, for any industrial or commercial application, should be phased out, in line with the Stockholm Convention.

- Where a product or article is suspected of containing PFAS, information should be gathered to ascertain if it contains long-chain PFAS and it should then be managed accordingly.

- Transitioning away from the use of chemicals that cause irreversible or long-term contamination of Australia's environment should be the goal for all users of PFAS in Australia.

- Where short-chain PFAS are used in aqueous film forming foam (AFFF), they should only be used in emergency situations and in accordance with all relevant regulations. Any releases should be fully contained, and wastes managed in accordance with the PFAS National Environmental Management Plan (NEMP).

- Until effective and economically feasible non-PFAS alternatives are developed, the ongoing sale and use of products and articles containing short-chain PFAS may be necessary for uses for which no suitable and less hazardous alternatives are available.

- Replacement chemicals should be degradable in the natural environment and not be bioaccumulative.

- Importers, sellers, and users of chemicals should inform themselves about the presence of PFAS in products and articles, due to their potential negative environmental, health and socioeconomic impacts.

- Entities that currently sell or use long- or short-chain PFAS are encouraged to develop a strategy that outlines their current uses, and how and when they will transition away from these chemicals.

The National Standard for Environmental Risk Management of Industrial Chemicals (the National Standard) will set a nationally consistent environmental management approach for the use and disposal of industrial chemicals, including PFAS. The National Standard will be established by Commonwealth framework legislation and implemented in regulatory frameworks in jurisdictions. Work on framework legislation to establish the National Standard is currently underway. The National Standard will also form part of a national legislative framework that would support the Australian government in deciding whether to ratify the listing of PFOS and PFOA (and any future listings) under the Stockholm Convention.

2. Queensland; Department of Environment and Science Environmental Management of Firefighting Foam, implemented in July 2016. The policy requires the following:

- Immediate removal of PFOS legacy foam concentrates from service.

- Containment and control measures for all PFAS foams so none enters the environment.

- Phase out of fluorinated firefighting foam where primarily the perfluorinated part of the carbon chain is longer than or equal to 7 carbon atoms (C8 foams) within 3 years.

- Preference for Synthetic Fluorine free foam use wherever possible, but acceptance where this can be demonstrated not possible that C6 foams with a purity of >99.5% could be used providing there is complete collection and containment of all foam solution, firewater runoff and wastes in impervious dikes, with proper and safe disposal. This includes accidental spills and the testing/maintenance of fixed and mobile equipment.

- High temperature (>1,100°C) disposal of all fluorinated organic wastes (including firewater runoff)

- Containment of non-persistent synthetic fluorine free foam wastes, wherever possible, using all reasonable and practical measures to minimise environmental harm.

- A 10 parts per million (ppm or mg/L) limit of PFOS/PFHxS residual contamination in replacement firefighting foam stock

• A 50 ppm limit of PFOA, precursors and higher homologues (≥C7) contamination in replacement foam stock.

• Full compliance required of all foam users implementing F3 foams by July 2019 (extension by negotiation and documented progress, if necessary, for major industries).

3. South Australia; EPA 1114/19: A ban on fluorinated firefighting foams in South Australia came into effect on 30 January 2018 following an amendment of the Environment Protection (Water Quality) Policy 2015 (WQ Policy) under the Environment Protection Act 1993 (EP Act). Legislative requirements are set out in Section 13A of the Policy. A summary of the policy includes the following:

• A ban on the use of all fluorinated firefighting foams for all applications with a timeframe of two years for compliance for all non-handheld applications ending in January 2020.

• That EPA South Australia may consider an exemption application after January 2020 by demonstrating assessment of actions already taken and proposed to be taken plus a justification why fluorine free foams cannot currently be used at the site.

• Provisions to address PFAS contamination in existing equipment.

• Certification of fluorine concentrations in foam to be provided by suppliers.

• Disposal of fluorinated foams to the environment is already strictly prohibited. All fluorinated foams need to be taken to a licensed facility that is authorized to receive this waste.

E. New Zealand

New Zealand has proposed updated guidance in October 2020 under the “Fire Fighting Chemicals Group Standard 2020 – HSR002573, to be effective April 2021 which is pursuant to section 96B of the Hazardous Substances and New Organisms Act 1996 (the Act) for which the Environmental Protection Authority issues this Group.

A summary of the key elements of the updated guidance are as follow:

• All PFAS foams to be prohibited from use in training and testing, unless fully contained, consistent with Stockholm Convention.

• Fluorinated C8 foam concentrates are restricted after 2 years for “Unconfined” use and 5 years for “confined” (fixed systems) use where foam can be contained.

• Fluorinated C6 foams restricted after 5 years for “Unconfined” use, and 5 years for “confined” (fixed systems) use with possible extension on case by case basis where adequately justified, subject to conditions.

• Fluorinated C6 foams in use to meet EU REACH regulation 2017/1000 for trace PFOA levels.

• Thorough clean-out equipment as far as reasonably practicable. This guidance takes a risk based approach. In systems with difficult to clean out components (e.g. pipework), an allowance would be made for the estimated residual PFAS in these components to be apportioned across the total replacement volume of foam concentrate, and there would not be an expectation that these components be replaced (requests for more guidance!).

• Residual PFAS levels generally in line with QLD policy:

- Transition from fluorinated C8 foam concentrates to Synthetic Fluorine Free Foam concentrates has requirements for maximum residual levels.

- Transition from fluorinated C8 foam concentrates to fluorinated C6 foam concentrates has requirements for maximum residual levels

Since 2011, no import, manufacture or use of PFOS compounds is permitted in New Zealand, other than for specified, identified uses, such as laboratory analysis.

F. Global

Stockholm Convention on Persistent Organic Pollutants (POPs) treaty partners agreed in at its ninth meeting May 2019 to eliminate (Annex A) production or restrict (Annex B) the use of firefighting foams containing

PFOA or PFOS in training exercises and to prohibit the production, import, or export of foams with either or both chemicals. A list of the signatory countries are identified on the Stockholm Convention webpage. Amendments are detailed in Part X of SC-9/12:

1.The production and use of perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds shall be eliminated except for Parties that have notified the Secretariat of their intention to produce and/or use them in accordance with Article 4 of the Convention.

2.Each Party that has registered for a specific exemption pursuant to Article 4 for the use of PFOA, its salts and PFOA-related compounds for fire-fighting foam shall:

(a) Notwithstanding paragraph 2 of Article 3, ensure that fire-fighting foam that contains or may contain PFOA, its salts and PFOA-related compounds shall not be exported or imported exceptfor the purpose of environmentally sound disposal as set forth in paragraph 1 (d) of Article 6;

(b) Not use fire-fighting foam that contains or may contain PFOA, its salts and PFOA-related compounds for training;

(c) Not use fire-fighting foam that contains or may contain PFOA, its salts and PFOA-related compounds for testing unless all releases are contained;

(d) By the end of 2022, if it has the capacity to do so, but no later than 2025, restrict uses of fire-fighting foam that contains or may contain PFOA, its salts and PFOA-related compounds to sites where all releases can be contained;

(e) Make determined efforts designed to lead to the environmentally sound management of fire-fighting foam stockpiles and wastes that contain or may contain PFOA, its salts and PFOA-related compounds, in accordance with paragraph 1 of Article 6, as soon as possible.

3.4.4.2 In addition to the development of fluorinated C6 foam concentrates, a new type of foam concentrate has been introduced. It is called a ″synthetic fluorine-free″ foam (SFFF or SF3). The original fluorine-free foams were protein foams made from animal by-products. The term “synthetic” was added to clarify that the new foam is not a protein foam. However, the new synthetic fluorine-free foams (SFFF or SF3) share an important trait with the original protein foams: they do not produce a film that can isolate the liquid fuel from air. Both foams require good bubble development to increase the expansion rate for fire extinguishment, which can only be achieved with aerating nozzles (i.e., nozzles specifically designed to mix the foam-water solution with air). Sprinklers (non-aspirating type) do not do a good job producing expanded foam.

There is limited fire test data on the performance of Synthetic Fluorine Free Foams (SFFF or SF3) to extinguish different types of ignitable liquid fuels. The National Fire Protection Association Fire Protection Research Foundation conducted a research project in 2019 that indicated different application densities are needed to extinguish various non-polar/hydrocarbon ignitable liquid fuels. Previously with Aqueous Film Forming Foams (AFFF) heptane could be used a representative surrogate for all types of non-polar/hydrocarbon ignitable liquid fuels. In addition, it indicated increased application densities are required to produce comparable performance of AFFF.

3.4.4.3 A protein, fluoroprotein, film-forming fluoroprotein or aqueous-film forming foam can only be used to extinguish fires on hydrocarbon or non-water miscible ignitable liquid fires. An alcohol-resistant foam concentrate can be used to extinguish fires on both hydrocarbon or non-water miscible ignitable liquid fires.

Synthetic fluorine-free foams and Alcohol-resistant synthetic fluorine free foams will not form films at the interface of most hydrocarbon fuels.

3.4.4.4 There are no FM Approved wetting agents. The purpose of a wetting agent is to reduce water’s surface tension. This results in an increased ability to penetrate or spread across a fuel’s surface, thereby improving the water’s ability to control or extinguish a fire. National Fire Protection Association (NFPA) 18, *Standard on Wetting Agents*, 2021 edition, identifies the specific requirements for a wetting agent.

3.4.4.5 The difference from injection rate of 1%, 3%, or 6% only impacts the size of the foam concentrate storage tank for the quantity of foam concentrate and the space needed for the equipment to be located in the fire protection equipment room. The cost of a 1% foam concentrate is typical more expensive due to the increase of active ingredients in the formulation to allow for a smaller footprint of the foam concentrate storage tank. It typical does not impact the application density to be used with the discharge device.

3.4.4.6 There are no FM Approved wetting agents. The reported purpose of a wetting agent is to reduce water's surface tension, resulting in an increased ability to penetrate or spread across a fuels surface. This is supposed to improve water's ability to extinguish a fire mainly for combustible materials. National Fire Protection Association (NFPA) 18, Standard on Wetting Agents, 2021 edition, uses small-scale tests that do not represent real-life scenarios. Neither re-ignition resistance nor burn-back resistance are considered for ignitable liquid fire extinguishment. These agents are not evaluated for use in any delivery systems. Therefore, the use of wetting agents in a foam-water sprinkler system or foam fire extinguishing is unacceptable and will not likely result in improved fire protection.

3.4.5 Foam Concentrate Proportioning Methods

Balanced-pressure proportioning systems (i.e., those arranged to balance water and concentrate pressures at the proportioner inlet) are considered suited for sprinkler applications, particularly automatic sprinkler systems, due to their ability to function properly over a wide range of flows and pressures.

Use balanced-pressure injection methods from one of the following:

A. A balance-pressure proportioning system using a foam concentrate pump discharging through a metering orifice into a proportioning controller with the foam concentrate and water pressures automatically maintained as equal by the use of a pressure-balancing valve.

B. A balanced-pressure proportioning system using a pressure proportioning tank with a diaphragm or bladder to separate the water and foam concentrate discharging through a metering orifice into a proportioning controller. In many cases, bladder tank systems may be preferred as being simpler to operate and less costly (no pumps with their associated driver/controller needs, no power supply reliability issues, etc.), particularly for smaller systems.

C. An in-line balanced-pressure proportioning system using a foam concentrate pump or bladder tank. A pressure-regulating device placed in the pump return line should maintain constant pressure in the foam concentrate supply line at all design flow rates. This constant pressure should be greater than the maximum water pressure under all operating conditions. For multiple use-point systems (i.e., serving multiple risers/hazard locations), in-line balanced pressure proportioners (ILBPs) typically use foam concentrate pumps, but may use bladder tanks from a single source of foam concentrate.

D. Foam concentrate pump discharging through a metering orifice into the protection system riser with the foam pressure at the upstream side of the orifice exceeding the water pressure in the system riser by a specific design value.

E. A variable viscosity proportioner is also considered appropriate for sprinkler applications, particularly automatic sprinkler systems, due to their ability to function properly over a wide range of flows and pressures as the number of operating sprinklers increase.

A variable viscosity proportioner will vary the positive displacement foam concentrate pump output to match water flow rates while maintaining the correct percentage of foam concentrate for positive-pressure injection methods. Two methods are used to accomplish the positive-pressure injection. This can be achieved by either a water motor driven pump or electronic controller with flowmeters. For either method the positive displacement foam concentrate pump draws the foam concentrate from an atmospheric storage tank and feeds it into the water flow. The mixing point of the foam concentrate for the water motor driven pump is at the outlet to the drive unit. The mixing point of the foam concentrate for the electronic controller is downstream of the electric metering valve at the interconnection with the water supply. As a result, the proportioning ratio is little affected by flow rate or foam concentrate viscosity. A variable viscosity proportioner can be used for either single or multiple use-point systems.

Flowmeters are an optional accessory equipment for the water motor driven pump type and must ordered separately. The flowmeters to be provided are those identified as part of the FM Approval listing. For the electronic controller with flowmeters type, the positive displacement foam concentrate pump, is a separate component of the proportioner configuration and are to be from an FM Approved manufacturer.

3.4.5.1 Compressed Air Foam (CAF)

The application densities applied by the compressed air foam (CAF) system are insufficient to provide structural protection of a building or enclosure. Those application densities are only sufficient to address the ignitable liquid hazard. A sprinkler system is required to supplement the compressed air foam system should the ignitable liquid fire not be extinguished.

CAF systems are designed at a lower density than a standard foam-water sprinkler system therefore they can be used in self-contained configuration using a water tank where water supply is not available or avoid the need to install a fire pump were water supply is not sufficient to supply a standard foam-water sprinkler 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.

The proportioning device may be a separate FM Approved proportioner or be integral to the mixing chamber for the foam concentrate, water and compressed air.

The activation temperature of the detection to activate the compressed air foam system should be sufficient to allow operation of the automatic sprinkler system.

CAF systems have unique hydraulic considerations that 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.

3.4.6 Design Criteria

FM Approved non-aspirating sprinklers can be used with foam-water sprinkler systems in conjunction with aqueous film forming foam (AFFF) or alcohol resistant-aqueous film forming foam (AR-AFFF) concentrates. Non-aspirating sprinklers typically provide an expansion ratio of 4:1 to 7:1, which minimizes the fire extinguishing performance of the foam. But since it is being used with a film forming foam the ability to prohibit re-ignition is enhanced and assists in sealing of the ignitable liquid vapors even with a lower expansion ratio.

3.4.6.1 Application Rate

Foam-water sprinkler systems may have the capability to extinguish fires in various ignitable liquid occupancies at lower densities and open fewer sprinklers than with water sprinkler protection only. However, unless specifically proven to be adequate for a particular occupancy as determined through fire testing, and specifically recommended in the appropriate occupancy-specific data sheet, densities and areas of demand should be the same as those recommended for water sprinkler protection. This approach particularly applies where a foam-water sprinkler system is being accepted in lieu of adequate drainage.

The minimum density of 0.2 gpm/ft^2 (4 mm/min), is normally only acceptable for a pool (two-dimensional) fire involving a hydrocarbon ignitable liquid protected by a foam-water sprinkler system.

Ignitable liquids that are polar or water miscible, as well as some hydrocarbon or non-polar ignitable liquids, may require higher foam solution densities than specified in this data sheet. The specific requirements in the *Approval Guide* under Fixed Extinguishing Systems or the hazard specific occupancy data sheet should be used for any installation.

3.4.6.1.1 For ignitable liquids to be protected by SFFF or AR-SFFF, determine if fire test data is available from FM Approvals on the fire extinguishment application density. Even though an FM Approved AR-SFFF concentrate exists, the application density for fire extinguishment of ignitable liquid(s) other than those typically tested (see Table 3.4.6.1.1) is not known.

In order to address this deficiency, fire testing would need to be conducted to determine the AR-SFFF application density for extinguishment of the polar ignitable liquid or component of the mixture.

Table 3.4.6.1.1. Designation and Closed Cup Flash Point of Representative Ignitable Liquids

Ignitable Liquid	*Designation*	*Closed Cup Flash Point, °F (°C)*	*Category*
Heptane	Non-polar	19.4 (-7)	Alkane hydrocarbon
Acetone	Polar	-0.4 (-18)	Ketone
Isopropyl Alcohol	Polar	53 (11.7)	Alcohol

3.4.6.2 Discharge Duration

Where the delivered flow greatly exceeds the demand flow, the excess discharge can result in the available duration of the foam extinguishing system being below the recommended discharge duration time. A verification calculation should be made to ensure that the needed duration is available.

3.4.6.3 Foam Quantity

The PFF multiplier is applied in the formula based on the proportioner being allowed to proportion the foam-water solution rich by up to a 30% tolerance of the injection rate. The multiplier is an average value based on a review of FM Approvals data for the various proportioner types, manufacturers, and foam concentrates. This multiplier will reduce the probability of an insufficient quantity of foam concentrate for the discharge duration and the injection characteristics of the type of proportioner.

3.5 Equipment and Processes

3.5.1 Foam Concentrate Proportioners

3.5.1.1 An in-line balanced pressure proportioner typically uses a spool valve or diaphragm balancing valve that is reliant upon being installed in the proper orientation as specified by the manufacturer for proper operation.

3.5.2 Valves

Typically, when a concentrate storage tank is provided, the foam concentrate supply is isolated from the water/solution in the riser by an automatic foam concentrate control valve. The need for this valve has been questioned, but it is necessary to ensure the foam concentrate supply is neither contaminated/diluted by water from the vertical riser backflowing nor depleting the foam concentrate supply over time in a bladder tank from transient surges in the water supply. The operation of this valve is essential to providing foam concentrate, and consequently, foam solution to the sprinkler system. This is also the basis for the recommendation that the automatic foam concentrate valve be supervised. If actuated by water pressure upon sprinkler system flow, the water actuation line should be piped from the sprinkler valve trim (i.e., not tubing, which could be subject to bending or crimping). An advantage to this arrangement is that the automatic foam concentrate control valve can be functionally tested when an alarm test is conducted.

3.5.3 Foam Concentrate Storage Tanks

Filling foam concentrate from the bottom of the storage tank prevents the formation of aerated foam concentrate.

3.5.3.1 Atmospheric Storage Tanks

Atmospheric storage tanks need to be constructed from a material that is compatible with the foam concentrate, such as:

- Stainless steel 304L or 316 grades
- High-density cross-linked polyethylene
- Fiberglass with isophthalic-based polyester and an internal layer (50100 mils minimum) of vinyl ester resin in contact with foam concentrate

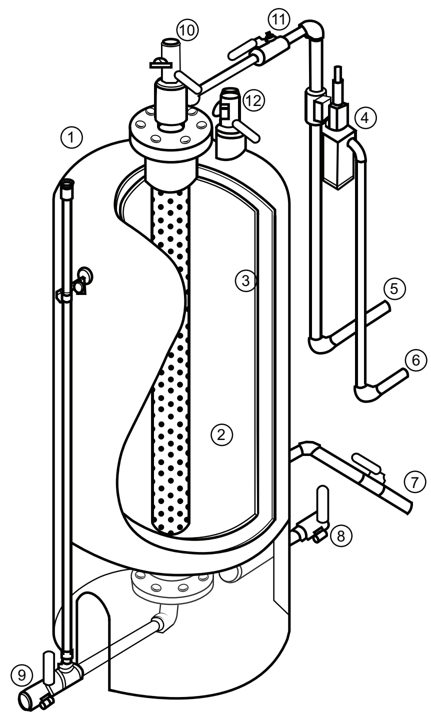
Verify the acceptability of the material based upon the FM Approval or with the foam concentrate manufacturer (e.g., some fluoroprotein foam concentrates are not compatible with stainless steel).

A layer of mineral oil or a manufacturer's proprietary sealer oil is sometimes added to minimize the effect of evaporation.

3.5.3.2 Bladder Tanks

Failure to properly fill the bladder tank with foam concentrate in accordance with manufacturer's instructions can result in breaks or rupture of the elastomeric material. This will lead to insufficient water pressure on the elastomer bladder to allow the foam concentrate to flow to the proportioner.

Typical tank connections and a cut away view of a bladder tank are illustrated in Figure 3.5.3.2.



1. Steel shell of bladder tank
2. Foam concentrate
3. Elastomer bladder
4. Automatic foam concentrate control valve
5. Foam concentrate to proportioner
6. Activation water to automatic foam concentrate valve
7. Water to pressurize steel shell of bladder tank
8. Drain for water of steel shell
9. Foam Concentrate drain/fill
10. Pressure vent from elastomer bladder (foam concentrate)
11. Foam concentrate isolation valve
12. Pressure vent from steel shell (water)

Fig. 3.5.3.2. Bladder tank connections and construction

3.5.4 Distribution System

3.5.4.1 Piping

Ensure no galvanic corrosion occurs between piping, fittings, and different materials of construction.

Check with the manufacturer of the foam concentrate to ensure the acceptability of the material (e.g., some fluoroprotein foam concentrates are not compatible with stainless steel).

When selecting pipe wall thickness, anticipate internal pressure, internal and external pipe wall corrosion, and mechanical bending requirements.

Use corrosion-resistant materials or finishes where the pipe may be subjected to corrosive atmospheres.

Use Teflon tape or the foam concentrate manufacturer's thread locker compounds at pipe joints. Foam concentrates are harsh detergents and may wash or dissolve other pipe joint compounds (pipe dope) out of the joint.

Foam-water solution will form sediment and can deteriorate when stored in system piping. Not all foam concentrates are suitable for storage as a foam-water solution and the manufacturer's advice should be sought and followed. High storage temperatures may accelerate deterioration due to aging of the foam-water solution. Therefore, the effectiveness may be reduced until the degraded, preprimed, foam-water solution is flushed out and fresh foam-water solution reaches the open sprinklers.

Drain and flushing connections enable the foam-water solution in the mains to be removed and replenished with fresh foam-water solution to minimize this effect. The foam-water solution drained from the system should be disposed of using environmentally responsible means.

3.5.4.2 Strainers

Concentrate strainers should be capable of removing all solids of a size that would obstruct system components.

3.5.4.3 Flushing

For all foam-water sprinklers systems (especially in-line proportioner designs), it is very important that a means is provided to flush all of the concentrate supply piping from just downstream of the foam tank outlet through the discharge of the proportioner following any testing or activation of the system. Failure to accomplish this flushing will likely result in foam concentrate being left in the piping/proportioner orifice, where it will deteriorate and possibly cause partial or total impairment of the system.

To prevent the risk of water damage in the case of a break, use a small-capacity pump to maintain pressure during the test period.

Longevity of the foam solution in the distribution piping is related to water quality. Generally speaking, foam-water solution quality is expected to last two to three years. Flushing or a flushing investigation is necessary on a regular periodic frequency and is particularly critical of pendent sprinklers are used. Testing on an annual basis is recommended at least initially (during the first few years) to determine foam solution quality. Eventually, possible protocols can be established for replenishing with fresh solution at longer intervals.

3.5.4.4 Pressure Test of Distribution Piping

To prevent the risk of water damage in the case of a break, use a small-capacity pump to maintain pressure.

Use standardized test procedures to conduct the hydrostatic pressure test such as Section 137, Pressure Tests, of the ASME B31.1. Power Piping Code that include requirements on:

- Temperature of the Test Medium
- Personnel Protection
- Preparation for testing
- Water Quality

3.5.5 Operation and Control of Systems

3.5.5.1 Actuation

For large hazard areas and/or where access may be limited, manual release devices both local to and remote from the operating devices are recommended.

3.5.5.2 Supervision

Many valves in the foam proportioning system, if left in an incorrect position, can compromise or even disable the foam proportioning system. Examples of valves critical to proper operation of the foam proportioning system that are intended to be supervised include, but are not limited to, valves in the supply from the foam concentrate storage tank, valves in the return to the foam concentrate storage tank, storage tank drain valves, liquid-level valve for the foam concentrate storage tank, strainer blow-off valves, foam concentrate pump supply and discharge valves, bypass valves around diaphragm valves or pressure-regulating valves, and valves at the inlet to the proportioner.

3.5.6 Fire Service Connection

Provide the fire service connection to the foam-water sprinkler system connection separate from the normal building sprinkler system whenever practical. Identify this condition in the signage for the fire service connection of the foam-water sprinkler system.Install a sign that states the following or similar information at the fire service connection:

FIRE SERVICE CONNECTION
THIS CONNECTION FEEDS A FOAM-WATER SPRINKLER SYSTEM

.

DO NOT PUMP AT PRESSURES
EXCEEDING [insert design pressure] UNTIL FOAM
LIQUID SUPPLY IS EXHAUSTED.
IF INCIDENT IS CONTROLLED BY FOAM BLANKET,
DO NOT DESTROY FOAM BLANKET BY EXCESSIVE APPLICATION OF WATER

3.6 Acceptance Testing

Key issues related to foam fire extinguishing system testing (See Section 3.4.4, Foam Concentrates for additional information):

1. Discharge testing for acceptance and annual operability has not been banned for any foam concentrate type, but will have requirements on the disposal of effluent.

2. Fluorinated C8 foam concentrates cannot be released into the environment during testing.

3. Fluorinated C6 foam concentrate discharge into the environment has been banned in some areas/ countries and has been limited in many areas for some time.

4. Fluorinated C8 foam concentrates may need to be incinerated for disposal.

5. Fluorinated C6 foam concentrates may also need to be incinerated for disposal. There may also be less expensive methods available. FM will be acquiring information on these disposal methods and costs.

6. The disposal requirements for fluorine-free foams have not been defined.

7. If a foam fire extinguishing system with fluorinated C8 foam concentrate is tested, there won’t necessarily be replacement foam concentrate available. The client will need to work with the foam manufacturer to see if they have a C6 that would work with the remaining C8 foam concentrate and foam system equipment.

8. Foam-water sprinkler systems need testing to ensure the system will provide the expected level of protection.

9. FM has continued to work in finding better options to conducting discharge tests to verify operability of proportioning equipment for several years. FM Approvals has assessed some surrogate test agents, a water-based equivalency test method, and a couple of foam extinguishing systems that can be tested with little to no foam discharge (compressed air foam [CAF], variable viscosity proportioners with flow meters).

10. All foam fire extinguishing systems should be installed with test connections (reference Section 2.5.7) that permit discharge to a containment system.

3.6.1 In order to guarantee the system is designed and installed properly for the application for which it was intended, it is imperative that verification is made that the foam-water solution being discharged meets the intent of the system and the listed performance of the product. Most foam fire extinguishing system proportioning equipment is installed at the job site. In order to make sure all correct equipment and proper foam concentrate for the protection has been installed properly and in the correct arrangement, an acceptance test must be performed that indicates performance and operability as specified under the listings of the products.

Also, this makes sure all components are installed in their proper orientation and pressure settings. It is advisable to note the performance of the system at its commissioning and then compare the results of annual testing to flag any potential problems.

Use these tests to confirm that the foam fire extinguishing system has been properly installed, and functions as intended.

3.6.2 Many jurisdictions require the collection of foam water solution discharges, which can have a significant impact on the cost and extent of acceptance testing and subsequent maintenance procedures for foam-water sprinkler system installations.

Prevent discharge from entering ground water, surface water, or storm drains.

Confirm the proper containment and disposal of the foam water solution discharge has been arranged to meet the requirements of the client and the authority having jurisdiction, including any disposal requirements by national/federal, state, and local regulations.

Consider the usage of antifoam agents in the foam-water solution discharge from the acceptance testing. Use those antifoam agents recommended by the foam concentrate manufacturer for the specific foam concentrate.

Consider the usage of Alternative Test Methods to reduce the impact on the environment. Water Equivalency after the initial discharge test with foam concentrate only uses fire protection water. Test Liquids are formulated to be biodegradable. Flow meters in the proper configuration will recirculate the foam concentrate to the storage tank and either discharge or recirculate the fire protection water. In all cases, ensure the proper containment and disposal of the discharged effluent, if any, has been arranged to meet the requirements of the client and the authority having jurisdiction, including any disposal requirements by national/federal, state, and local regulations.

3.6.3 Record the following data, as applicable, to document the performance specifications of the foam-water sprinkler system:

- Static water pressure
- Residual water pressure at the control valve and at a remote reference point in the system
- Actual discharge rate
- Consumption rate of foam-producing material
- Concentration of the foam solution
- Pressure differential on duplex gauge for in-line balanced proportioners of water and foam concentrate in manufacturers specified range (foam pressure to be higher)

Thirty to 60 seconds after the foam appears from the test connection valve, take a sample of the foam-water solution discharge.

3.6.4 See Appendix E for steps in in determining the foam-water solution concentration. The method used for measuring the foam-water solution should consider the type of foam concentrate, water supply quality, and precision of the instrumentation.

3.7 Loss History

During a recent 15-year period, FM clients reported 132 ignitable liquid fire losses at locations with typical ignitable liquids storage and use operations and other occupancies, including aircraft hangars, oil cookers, heating treating, printing, and power generation operations. The magnitude of these fire losses was greatly affected by the type of automatic protection provided, with the financial impact of ignitable liquid fires protected by automatic foam systems being 70% – 75% less than those in which there was no protection or only water-based protection (see Table 3.7).

Table 3.7. Ignitable Liquid Fire Losses, 2005–2019

Automatic Protection Type	*Number of Losses*	*Gross Loss Amount*[1]	*Average Loss Amount*[Note 1]
None	60	US$693.0 million	US$11.6 million
Water-Based Only	64	US$634.2 million	US$9.9 million
Foam System	8	US$23.4 million	US$2.9 million

Note 1. Indexed to 2020 values.

There were also eight losses (average US$0.5 million of damage) reported by FM clients in which foam extinguishing systems operated accidentally or in areas peripheral to the fire area. This highlights the importance of using FM Approved equipment, proper selection of actuation methods, and rigorous inspection, testing, and maintenance procedures.

3.7.1 Illustrative Losses

3.7.1.1 Automatic Foam Extinguishing System Controls Ignitable Liquid in Mixing Operation

A fire occurred during the manual addition of ingredients to a batch tank at a coatings manufacturing facility. While an employee was adding a mineral spirit-impregnated component to a 5,000 gal (1320 L) batch tank, vapors ignited with the ensuing fireball also involving in an adjacent 5,000 gal. (1320 L) batch tank. The foam-water ceiling sprinkler system, which is designed to provide a sprinkler density of 0.40 gpm/ft^2 (16 mm/min) with a 3% AR-AFFF foam concentrate, operated properly and the fire was extinguished by fourteen K8.0 (K115) operating sprinklers. The fire melted and charred electrical wiring, controls, hoses, etc., which were replaced within approximately 1 week. There was minimal damage to the reinforced concrete building.

3.7.1.2 Non-FM Approved Foam-Water Deluge Systems Failed to Operate

This facility manufactures various coatings utilizing low flashpoint ignitable liquids. During transportation of finished product, two paint drums fell from a rack in the detached finished products warehouse. One of the drums was damaged and the spilled paint was ignited by a non-rated forklift. Although both the detection system and the manual actuation system were triggered, the not FM Approved foam-water deluge systems failed to operate. It was later determined that the solenoids on the deluge valves could not release due to low electrical voltage to the solenoids. Fire spread throughout the warehouse area of origin and an adjacent warehouse area. Manual firefighting efforts by the public fire department kept the fire from spreading to a 3rd warehouse area.

3.7.1.3 Accidental Trip of Automatic Foam-Water Monitor Nozzle System in Aircraft Hangar

An aircraft hangar used for finishing operations of aircraft was protected by two ceiling-level sprinkler systems and six AFFF foam/water monitor nozzles. Actuation of the monitor nozzles is by activation of a flow alarm on the wet ceiling sprinkler systems. The fire protection water is provided by four booster pumps taking suction from the public supply. Prior to this incident there was no history of false starts of the fire booster pumps. One of the fire booster pumps operated for unknown reasons, apparently activating the waterflow alarms in the aircraft hangar. Activation of the flow alarms then actuated the foam/water monitor nozzle systems. Foam-water entered the interior of two of the aircraft that were open. In addition, several auxiliary power units and three sets of interiors (cabinetry, upholstered seat, and liner panels) that were staged for assembly into aircraft were also wet down by the direct spray of the monitor nozzles. Operations were interrupted for 1 day while cleanup was conducted.

3.8 Test Data: Research Fire Testing of Foam Fire Extinguishing Systems

Because of the cost of foam-water fire testing, there have been a limited number of full-scale fire tests. This creates significant challenges in developing foam system designs. AFFF foam has been showed to be very effective against unobstructed ignitable liquid pool fires. The formation of a film over the pool fire can quickly extinguish the fire, however, fuel releases above the pool will not be extinguished. Sprinkler discharge is needed in these cases to provide cooling to equipment and building elements until the fuel release can be shut down. Adding extra AFFF concentrate by using higher sprinkler discharge densities to provide the needed cooling will impact the amount of concentrate that needs to be provided but should not increase the time to extinguishment. If the foam concentrate does not form a film over the fuel and instead relies on the development of a bubble layers, sprinkler discharge will act to break down the foam bubble layer. Without fire testing that replicates the expected fuel release scenario and sprinkler discharge density there is no way to know how the combination of higher sprinkler discharge rates plus the higher rate of foam discharge will impact the pool fire extinguishing capabilities of the foam.

Ignitable liquid storage arrays create a wide range of fire scenarios and most do not produce a fixed unobstructed pool fire. Storage arrays can produce spilling liquid discharges or spray discharges and will have combustibles such as cardboard and plastic in a three-dimensional array. Without full-scale fire tests there is no way to know what impact the foam extinguishing system will have on the storage array. It is reasonable to assume a potential pool fire will be limited to the area of liquid release, but fire spread above the floor level will also likely continue. Past testing of small (i.e., 6.5 gal [25 L] or smaller) plastic containers filled with ignitable liquids have failed to control the fire. Unfortunately, a number of those tests failed to ensure the foam system operated as intended so no real conclusions can be drawn on the use of AFFF foam-water sprinkler systems for a storage array.

The bottom line is that without properly designed full-scale fire tests there is no way to understand how changing foam concentrate durations, changing a particular sprinkler, or the impact of real fire scenarios will have on the foam extinguishing systems ability to extinguish a fire.

4.0 REFERENCES

4.1 FM

Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 2-8, *Earthquake Protection for Water-Based Fire Protection Systems*
Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance*
Data Sheet 3-7, *Fire Protection Pumps*
Data Sheet 3-10, *Installation and Maintenance of Private Fire Service Mains and Their Appurtenances*
Data Sheet 4-0, *Special Protection Systems*
Data Sheet 5-40, *Fire Alarm Systems*
Data Sheet 5-48, *Automatic Fire Detection*
Data Sheet 7-29, *Flammable Liquid Storage in Portable Containers*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-93, *Aircraft Hangars, Aircraft Manufacturing and Assembly Facilities, and Protection of Aircraft Interiors During Assembly*

4.1.1 FM Approvals

Class 5130, *Approval Standard for Foam Extinguishing Systems*
Class 5138, *Assessment Standard for Proportioning Testing*

4.2 Other

British Standards Institute (BSI). *Fire Extinguishing Installations and Equipment on Premises*. Part 6: Foam Systems, Section 6.1 Specification for Low-Expansion Foam Systems. BS 5306-6.1:1988.

European Committee for Standardization (CEN). *Fixed Firefighting Systems*. Part 2: Design, Construction and Maintenance (Draft). prEN 13565-2.

National Fire Protection Association (NFPA). *Standard for Low-, Medium-, and High-Expansion Foam*. NFPA 11, 2016.

National Fire Protection Association (NFPA). *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*. NFPA 25, 2018.

National Fire Protection Association (NFPA) Fire Protection Research Foundation. *Evaluation of the Fire Protection Effectiveness of Fluorine Free Firefighting Foam*. Gerard G. Back & John P. Farley. January 2020.

Naval Research Laboratory. *Fuel for Firefighting Foam Evaluations: Gasoline vs. Heptane*. Arthur W. Snow & Spencer Giles. NRL/MR/6123—19-9895. June 15, 2019.

VdS Schadenverh)tung GmbH. *Guidelines for Foam Extinguishing Systems: Planning and Installation*. VdS 2108en: 2005-09.

APPENDIX A GLOSSARY OF TERMS

Note: See Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*, for sprinkler-related terms.

Alcohol-Resistant (AR) Foam Concentrate: A concentrate used for fighting fires on water-soluble material and other fuels destructive to regular, AFFF, or FFFP foams, as well as for fires involving hydrocarbons. Alcohol-resistant foam concentrates are generally used at 1%, 3%, or 6% concentration on both water miscible fuels and hydrocarbon fuels.

Approval Guide: An online resource of FM Approvals, the *Approval Guide* provides access to a fully searchable, Web-based database of the most up-to-date information on approximately 50,000 FM Approved fire protection products, building materials, electrical equipment, and services that conform to the highest property protection standards.

Aqueous Film-Forming Foam Concentrate (AFFF): A concentrate based on fluorinated surfactants plus foam stabilizers to produce a fluid aqueous film for suppressing hydrocarbon fuel vapors. AFFF foam concentrates are generally used at 1%, 3%, or 6% concentration.

Automatic Foam Concentrate Control Valve: A valve controlling the flow of foam concentrate to the proportioner. The valve is automatically actuated by hydraulic, pneumatic, or electric means. Supervision is provided to the position of the valve.

Availability: The probability that a system performs its defined function when a demand is placed for use.

Bladder Tank: A foam concentrate tank fitted with an internal bladder that uses water flow/pressure to control the foam concentrate injection rate by displacing the foam concentrate within the bladder with water outside the bladder.

Compressed air foam (CAF): 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.

Delivered Flow: The flow derived from the point at which the demand curve meets the water supply curve.

Discharge Device: A device designed to create foam from foam-water solution in a predetermined, fixed, or adjustable pattern. This may be a standard (non-aspirated) sprinkler, deluge-type sprinkler, foam-water (aspirated) sprinkler, CAF nozzle, foam chamber, foam pourer or floor nozzle.

Expansion Ratio: The ratio of volume of foam formed to the volume of foam-water solution used to generate the foam. For example, a 7:1 expansion ratio equates to 700 gals of finished foam from 100 gals of foam-water solution.

Flash Point: The minimum temperature at which sufficient vapor is liberated to form a vapor-air mixture that will ignite and propagate a flame away from the ignition source (flash fire, not continuous combustion). Evaporation will take place below the flash point, but the quantity of vapor released is not sufficient to produce an ignitable vapor-air mixture. A flash point can be determined by using either a closed- or open-cup test apparatus. The closed-cup test will produce a lower flash point than the open-cup test, because it provides greater vapor containment (i.e., increases vapor accumulation). The closed-cup flash point is used to classify a liquid, because it is conservative (i.e., produces the lowest flash point for the liquid) and represents the condition in which most liquids are handled (i.e., most liquids are kept in closed containers or equipment). (Data Sheet 7-32.)

Film-Forming Fluoroprotein Foam Concentrate (FFFP): A protein foam concentrate that uses fluorinated surfactants to produce a fluid aqueous film for suppressing hydrocarbon fuel vapors. The foam is more fluid than both protein and standard fluoroprotein foams. FFFP foam concentrates are film-forming on some liquid hydrocarbon fuel surfaces and are generally used at 3% or 6% concentration.

Floor Nozzle System: An FM Approved system that provides low-expansion foam discharge nozzles installed flush with the structural floor, supplied with foam-water solution through piping installed in trenches in the floor.

Fluoroprotein Foam Concentrate: A protein foam concentrate with added fluorinated surface active agents. The foam is generally more fluid than protein foam, gives faster control and extinction of fire, and has a greater ability to reseal if the foam blanket is disturbed. Fluoroprotein foam is generally used at 3% or 6% concentration for hydrocarbon fuels.

Foam: A stable aggregation of bubbles that are of lower density than ignitable liquids or water. Exhibits a tenacity for covering horizontal surfaces to form a continuous barrier between the ignitable vapors and air/oxygen.

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-Water Density: The unit rate of foam-water solution application to an area, expressed in gpm/ft^2 (L/min|b4m^2).

Foam Solution: See foam-water solution.

Foam-Water Solution: A homogeneous mixture of water and foam concentrate in the correct proportions.

Foam-Water Sprinkler System: A sprinkler system that is pipe-connected to a source of foam concentrate and water supply to proportion each at the correct ratio. The system is equipped with the appropriate sprinkler for discharge of foam-water solution that creates foam for distribution over the area to be protected. These sprinkler systems can be arranged in a variety of ways, such as dry pipe, preaction, and pre-primed.

FM Approved: The term “FM Approved” is used to describe a product or service that has satisfied the criteria for Approval by FM Approvals. Refer to the *Approval Guide* for a complete list of products and services that are FM Approved.

Ignitable Liquid: Any liquid or liquid mixture that has a measurable flash point. The hazard of a liquid depends on its ability to sustain combustion or create a flammable vapor-air mixture above its surface. Flash point is one way of understanding if a liquid can create that flammable vapor-air mixture. For a liquid to burn in a pool, it must have a fire point as well as a flash point. Ignitable liquids include flammable liquids, combustible liquids, inflammable liquids, and any other term for a liquid that will burn. (Data Sheet 7-29/7-32)

Non-polar: An ignitable liquid with a molecular structure in which the electron density distribution is more or less evenly distributed. As such, it does not contain any partial positive or partial negative charge. Nonpolar ignitable liquids are neither water-miscible nor dissolvable in polar ignitable liquids as they do not carry any charge. Hydrocarbons, aromatics, alkyl halides, nitros, peroxides and ethers are non-polar ignitable liquids.

Per- and poly-fluorinated substances (PFAS): A group/family of fluorinated organic compounds.

Perfluorooctane sulfonate (PFOS): The parent acid (Chemical Abstract Number [CAS] number 1763-23-1) and any salts thereof, including the potassium (CAS number 2795-39-3), lithium (CAS number 29457-72-5), ammonium (CAS number 29081-56-9) and diethanolamine (CAS number 70225-14-8) salts

Perfluorooctanoic acid (PFOA): A fully fluorinated eight-carbon chain carboxylic acid (Chemical Abstract Number [CAS] number 335-67-1)

Polar: An ignitable liquid having a molecular structure in which the electron density distribution is uneven. This produces a strong dielectric constant from a partial positive and partial negative charge. Common functional groups for polar ignitable liquids include alcohols, ketones, esters, carboxylic acids and amides.

Pre-primed System: A wet-pipe system containing foam-water solution.

Proportioning: The continuous introduction of foam concentrate at the recommended ratio into the water stream to form a foam-water solution.

- **Balanced Pressure Pump Proportioning:** A foam proportioning system that uses a foam pump and valve(s) to balance foam and water pressures at a modified venturi-type proportioner located in the foam solution delivery piping; a foam concentrate metering orifice is fitted in the foam inlet section of the proportioner.

- **In-Line Balanced-Pressure Proportioning:** A foam proportioning system using either a foam concentrate pump or a bladder tank in conjunction with a pressure-reducing valve. At all design flow rates, the constant foam concentrate pressure is greater than the maximum water pressure at the inlet to the in-line balanced-pressure proportioner. A pressure-balancing valve is integral to the in-line balanced proportioner to regulate foam concentrate pressure to be balanced with incoming water pressure.

- **Direct Injection Variable Pump Output Proportioning:** A direct injection proportioning system that uses flowmeters for foam concentrate and water in conjunction with a variable output foam pump control system.

- **Pump Proportioner (Around-the-Pump Proportioner):** A system that uses an eductor installed in a bypass line between the discharge and suction side of a water pump and suitable variable or fixed orifices to induct foam concentrate from a tank or container into the pump suction line.

Proportioner Flow Factor (PFF): A safety factor for the injection tolerance of the proportioner, based on the type, flow range and data from FM Approvals testing.

Protein Foam Concentrate: 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 under emergency conditions. Protein foam concentrates are generally used at 3% and 6% concentration.

Synthetic Fluorine-Free Foam (SFFF) Concentrate: Concentrate that is based on a mixture of hydrocarbon surface active agents that is not formulated to contain per- or polyfluoroalkyl substances (PFAS)

Synthetic Foam Concentrate: Concentrate based on foaming agents other than proteins and including aqueous film-forming foam (AFFF) concentrates, medium- and high-expansion foam concentrates, and other synthetic foam concentrates.

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

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 foam concentrate. This method minimizes the difficulties in disposing of the discharge required in testing a foam system.

Variable Viscosity Proportioner: A proportioner with the capability to accurately proportion foam concentrates at the specified ratio into the water stream to form foam-water solution at a range of concentrate viscosities and system flow rates without adjustment or modification (such as changing an orifice plate). These are commonly of the water motor driven or electronically controlled types. (Formally identified as a Positive Displacement, Water Motor Driven Foam Proportioning Pump)

Water Equivalency Proportioning Testing: A method of evaluating the proportioning accuracy of an installed foam fire extinguishing system using water in lieu of the foam concentrate. This method minimizes the difficulties in disposing of the discharge required in testing a foam system.

Water-miscible: A water-miscible liquid mixes in all proportions with water. When water-miscible ignitable liquids are mixed with water, a homogeneous solution is formed. The flash point, fire point, heat of combustion and heat release rate of the solution will be different from the pure ignitable liquid. The flash point and fire point of the solution will increase as the water concentration increases. At a certain water concentration (which varies for different ignitable liquids), the fire point will no longer exist; and the solution will no longer present a fire hazard (e.g., 15% ethyl alcohol in water, 15% acetone in water). (Data Sheet 7-29)

Wide Range Proportioner: A proportioner with the capability to accurately proportion a foam concentrate at the specified ratio into the water stream to form foam solution at a range of system flow rates.

Wetting Agent: A concentrate that when added to water reduces the surface tension and increases its ability to penetrate and spread.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

April 2025. Interim revision. Significant changes include the following:

A. Reformatted Section 2.1, Introduction, to add general recommendations for the inclusion of medium- and high-expansion foam systems.

B. Updated Section 2.6.4.17, Alternate Test Methods, to include test liquids for Planit Safe that are allowable for SFFF and AR-SFFF.

C. Updated viscosity information in Section 2.5.4, Foam Concentrate Proportioners and Section 3.4.5, Foam Concentrate Proportioning Methods on the compatibility of SFFF and AR-SFFF concentrates for use with variable viscosity proportioners.

July 2023. Interim revision. Made editorial change to Section 3.4.4.1.1 to include reference of the European Chemicals Agency (ECHA) published proposal for a separate REACH (Registration, Evaluation, Authorization and Restriction of Chemicals Regulation) restriction on PFAS in firefighting foams.

January 2023. Interim Revision. The following changes were made:

A. Modified recommendations in Section 2.4.3, Foam Concentrate to address the application of Synthetic Fluorine Free Foam (SFFF) and Alcohol-Resistant Synthetic Fluorine Free Foam (AR-SFFF) when protecting non-polar (hydrocarbons) and polar (water-miscible) ignitable liquids.

B. Provided viscosity information in Section 2.5.4, Foam Concentrate Proportioners and Section 3.4.5, Foam Concentrate Proportioning Methods on the compatibility of SFFF and AR-SFFF concentrates for use with variable viscosity proportioners.

C. Revised Table 4 of Section 2.6.4.17, Alternate Test Methods to include NoFoam, La Jolla, California, USA and the Vector Fire Technologies, Tucson, Arizona, USA location assessed by FM Approvals to the Class 5138 Standard.

April 2021. This document has been completely revised. The following significant changes were made:

A. Changed the title to "*Foam Extinguishing Systems*" (was "*Foam-Water Sprinkler Systems*").

B. Transferred content from Data Sheet 4-7N, *Low-Expansion Foam Systems*, and made that data sheet obsolete.

C. Added recommendations for compressed air foam (CAF).

D. Added recommendations on the transition to synthetic fluorine-free foam (SFFF) and aqueous film-forming foam-C6.

E. Added recommendations for alternative discharge devices (e.g., floor nozzle, foam chambers).

July 2020. Interim revision. The following changes were made:

A. Added guidance on an alternative proportioning test method assessed by FM Approvals.

B. Made minor editorial revisions.

April 2020. Interim Revision. Minor editorial changes were made.

January 2020. Interim revision. Minor editorial changes were made.

October 2017. Interim revision. Reference to NFPA 409, *Standard on Aircraft Hangars*, was deleted in Section 2.7, *Maintenance,* since this guidance is covered in Data Sheet 7-93, *Aircraft Hangars, Aircraft Manufacturing and Assembly Facilities, and Protection of Aircraft Interiors During Assembly.*

January 2017. Interim revision. Minor editorial changes were made.

January 2013 (Interim revision). Minor editorial changes were made for this revision.

October 2011. Inclusion of Proportioning Testing Assessment by FM Approvals, clarification on general recommendation, minor editorial revisions.

July 2011. Minor editorial changes were made for this revision. Figure 2, 3, and 6 were revised.

September 2010. Minor editorial changes were made for this revision.

January 2010. This is the first publication of this document.

APPENDIX C COMPARISON WITH OTHER FOAM INSTALLATION STANDARDS

There is relative agreement between this data sheet and the following standards:

- National Fire Protection Association (NFPA) 11, Standard for Low-, Medium-, and High-Expansion Foam
- BS 5306-6.1, Fire Extinguishing Installations and Equipment on Premises. Part 6: Foam Systems
- European Standard pr13565-2, Fixed Firefighting Systems-Foam Systems. Part 2: Design, Construction and Maintenance
- VdS 2108en: Foam Extinguishing Systems-Planning and Installation

One significant area of disagreement is with the foam concentrate supply. The standards listed above do not account for the allowable injection tolerance of the proportioner in the discharge duration of the foam concentrate. The foam concentrate supply in this data sheet is adjusted with a "proportioner flow factor" for the injection tolerance based on the type and flow range of proportioner and data from FM Approvals testing.

Also, the standards listed above do not recommend the supervision of the automatic foam concentrate control valve and test connection isolation valve as identified in this data sheet.

APPENDIX D FORMS

D.1 Commissioning Forms

The following forms may be used to assist in the commissioning of the foam fire extinguishing system:

- Contractor's Material & Test Certificate for Underground Piping (85B, 85BS, 85BR)
- Pump Acceptance Test Data (105, 105B)
- Contractor's Checklist for Foam Extinguishing System Installation (Form FM 7615)

D.1 Contractor's Checklist for Foam Extinguishing System Installation

CONTRACTOR'S CHECKLIST FOR FOAM EXTINGUISHING SYSTEM INSTALLATION

FM Global

JOB OR CONTRACT NUMBER	DATE	FM GLOBAL OPERATIONS CENTER
INDEX NUMBER	ACCOUNT NUMBER:	☐ New System ☐ Upgrade of Existing System
LOCATION:		
HAZARD:		

INSTRUCTIONS:

1. The contractor will fill out "Plans and Specifications" and send, along with 1 print of all drawings (including a wiring diagram when applicable), to the FM Global Operations Center serving the facility in which the system is to be installed. A separate application should be submitted for each system to be installed.

2. The FM Global office will retain information and 1 print of each drawing and return a copy with "acknowledgement" of "Plans and Specifications" indicated.

PLANS AND SPECIFICATIONS:

NAME OF CUSTOMER	STREET ADDRESS
CITY/STATE/PROVINCE/POSTAL CODE & COUNTRY	DRAWINGS SUBMITTED (NOS.)
NAME & ADDRESS OF EQUIPMENT CONTRACTOR	
NAME AND ADDRESS OF EQUIPMENT MANUFACTURER	

Type of System:

☐ Automatic ☐ Deluge ☐ Supplementary Protection	☐ Low Expansion ☐ High Expansion	If High Expansion, outside air provided: ☐ Yes ☐ No

Hazard:

Location Building Name or Number	Story	Sprinkler or Discharge Device Elevation Ft. (m)	Temperature Variation at Hazard Min °F(C) Max ° F(C)
Description:			
Ignitable Liquids? ☐ Yes ☐ No	In Open Tank? ☐ Yes ☐ No		

Component	Manufacturer	Model	FM Approved System Component	Miscellaneous
Foam Concentrate			☐ Yes ☐ No	☐ 1% ☐ 3% ☐ 6% ☐ C6 AFFF ☐ C6 AFFF-AR ☐ Synthetic Fluorine Free Foam ☐ Synthetic Fluorine Free Foam - AR
Proportioner			☐ Yes ☐ No	☐ Wide Range Proportioner ☐ Ratio ☐ ILBP ☐ Variable Viscosity Proportioner ☐ Compressed Air Foam
Sprinkler or Discharge Device			☐ Yes ☐ No	Unobstructed Discharge? ☐ Yes ☐ No
Automatic Foam Concentrate Control Valve			☐ Yes ☐ No	Supervised? ☐ Yes ☐ No NEMA Type I or IP-10 housing if Electrical? ☐ Yes ☐ No
Foam Storage Tank			☐ Yes ☐ No	☐ Bladder ☐ Atmospheric

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Fig. D.1. Contractor's checklist for commissioning of foam-water sprinkler system installation

CONTRACTOR'S CHECKLIST FOR FOAM EXTINGUISHING SYSTEM INSTALLATION

Check Valve (s)			☐ Yes ☐ No	
Strainer(s)			☐ Yes ☐ No	
Foam Concentrate Pump			☐ Yes ☐ No	
Diaphragm Valve			☐ Yes ☐ No	
Pressure Reducing Valve/Regulator-Foam Concentrate			☐ Yes ☐ No	
Pump Controller (Water & Foam)			☐ Yes ☐ No	
Control Panel			☐ Yes ☐ No	Alarms: ☐ 1st Detector ☐ 2nd Detector
Detectors			☐ Yes ☐ No	Cross-Zoned? ☐ Yes ☐ No Supervised? ☐ Yes ☐ No
Manual Actuation (Deluge/Preaction)			☐ Yes ☐ No	
			☐ Yes ☐ No	

Abort Switch? ☐ Yes ☐ No System Isolated? ☐ Yes ☐ No	Alarm? ☐ Yes No System Operational? ☐ Yes ☐ No	☐ Yes ☐ No
Time Delay Setting: Sec.	Emergency Mechanical Manual Release? ☐ Yes ☐ No	Control Panel? ☐ Yes ☐ No
Reserve Supply of Foam Concentrate? ☐ Yes ☐ No	Connected? ☐ Yes ☐ No	Changeover: ☐ Auto ☐ Manual ☐ DNA
Interlocks: ☐ Yes ☐ No (See Below)		Electrical Shutdown? ☐ Yes ☐ No
Alarm to Manned Location? ☐ Yes ☐ No		
Panel Location *(Describe)*:		
Foam Concentrate Storage Tank & Equipment Location *(Describe)*:		
Plans Submitted? ☐ Yes ☐ No	Foam Concentrate Calculations Submitted? ☐ Yes ☐ No	Plans/Calculations reviewed By:

Discharge Pipe Material Conforms to Data Sheet 4-12: Material ☐ Yes ☐ No	Discharge Fittings Conform to Data Sheet 4-12: Material ☐ Yes ☐ No
Foam Concentrate Pipe Conforms to Data Sheet 4-12: Material ☐ Yes ☐ No	Foam Concentrate Fittings Conforms to Data Sheet 4-12: Material ☐ Yes ☐ No
Test Connection Provided? ☐ Yes ☐ No	Dedicated Electrical Power Supply Provided for: Foam Concentrate Pump Controller ☐ Yes ☐ No ☐ DNA Variable Viscosity Proportioner- Electronic ☐ Yes ☐ No ☐ DNA Detection and Alarm Panel ☐ Yes ☐ No ☐ DNA

Interlocked Associated Equipment:

Process Pumps ☐ Yes ☐ No	Fans ☐ Yes ☐ No	Drive Motors ☐ Yes ☐ No	Dampers ☐ Yes ☐ No	Door - Closer ☐ Yes ☐ No	Other ☐ Yes ☐ No
If "Yes", Enumerate and Describe:					
Are they interlocked with the system? ☐ Yes ☐ No	If not interlocked, explain:				

Variations from Drawings or Information submitted to FM Global Property Loss Prevention Data Sheet:

Other Remarks:

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Fig. D.1. Continued

D.2 ″Acceptance Testing″ from OS 4-12 Foam Evaluation Job Aid

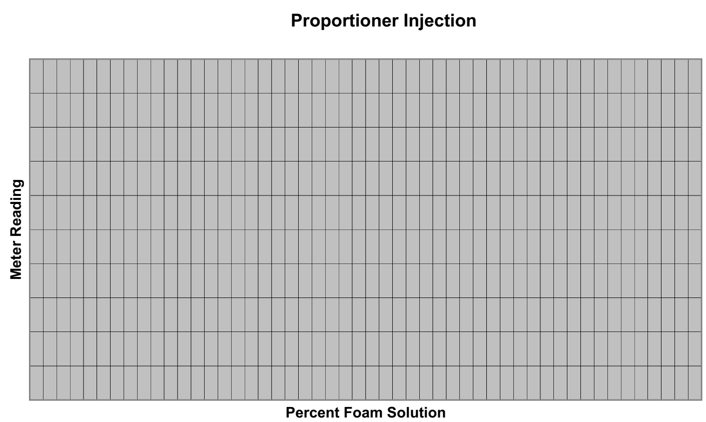
"ACCEPTANCE TEST" FOR PERCENT INJECTION OF FOAM CONCENTRATE

JOB or CONTRACT NUMBER	DATE	FM GLOBAL OPERATIONS CENTER
INDEX NUMBER	ACCOUNT NUMBER	
LOCATION :		
HAZARD:		

NAME OF CUSTOMER	STREET ADDRESS	
CITY/STATE/PROVIDENCE/POSTAL CODE & COUNTRY		DRAWINGS SUBMITTED
NAME & ADDRESS OF EQUIPMENT CONTRACTOR:		
NAME OF EQUIPMENT MANUFACTURER:		

FOAM CONCENTRATE TYPE	LOT NUMBER		PERCENT INJECTION
METER TYPE:	CONDUCTIVITY	REFRACTOMETER	
MANUFACTURER	MODEL		

CALIBRATION STANDARDS[1,2]			METER READING[4]
FOAM CONCENTRATE			
WATER	0	%	
PRE-MIX #1		%	
PRE-MIX #2		%	
PRE-MIX #3		%	



SYSTEM DISCHARGE SAMPLE

FLOW	PRESSURE	METER READING[6]	PERCENT FOAM SOLUTION[7]	RESULT[8]

**** Values included only for example***

NOTES:

1. Identify foam concentrate being used 1%, 3% or 6%.
2. Use Pre-mix solutions recommended in Appendix E for the appropriate foam concentrate injection
3. Identify those pre-mix solutions in the "yellow" cell for the Calibration Standard
4. Identify the meter reading, either conductivity or refractive index, in the "tan" cell for respective cell.
5. Graph
6. Identify "Meter Reading" into "blue" cells for System Discharge Samples.
7. Identify "Percent Foam Solution" from "blue" cells for System Discharge Samples.
8. Determine if Results either "Pass" or "Fail"

1%	1.0 to 1.3%
3%	3.0 to 3.9%
6%	6.0 to 7.0%

Fig. D.2 Acceptance Test for Percent Injection of Foam Concentrate

APPENDIX E DETERMINATION OF FOAM-WATER SOLUTION CONCENTRATION FROM PROPORTIONER INJECTION

The following is guidance for conducting acceptance testing of foam-water sprinkler systems. These are key elements to be considered in the recommended step-by-step Test Plan procedure to be submitted by the installing contractor and in agreement with the foam equipment manufacturer's manuals.

The following equipment, or similar, is needed for testing:

A. Test Connection Valve Header

1. Fifty ft (15 m) lengths, 2 ½ in. (65 mm) lined hose

2. Smooth-bore nozzles (Underwriters' play pipes) or FM Approved fire pump flowmeter system (e.g., Hose Monster) as needed to flow required volume of water (if a calibrated and reliable in-line test flow meter is provided, these may not be needed)

B. Test instruments of high quality that are accurate and in good repair.

1. Test pressure gauges

2. Pitot tube with gauge (for use with hose and nozzle)

C. Test instrumentation that has been calibrated within the previous 12 months.

To limit the amount of foam-water solution discharge, adjust the water flow first from the test connection discharge valves for the recommended foam-water sprinkler system test flows prior to the actual testing of the proportioner for proper injection of the foam concentrate. Conduct this operation for each of the recommended test flows.

Communication is critical between personnel involved in the acceptance testing. Several people may be required to coordinate operations between the water control valve, automatic concentrate control valve, test connection discharge valve, and sample point to minimize the amount of foam concentrate used. Communication devices such two-way radios may be needed due to the distance between these operational points.

When a containment tank/tanker is used, the pretreatment of the hoses subsequent to the sample point and tank/tanker with antifoaming agent is recommended. This will prevent nuisance foaming during the acceptance test. The amount of antifoam agent depends on the volume of foam-water solution being discharged.

Antifoam agents may be obtained from one of the following suppliers, but only after the manufacturer has confirmed they are compatible with the foam concentrate:

- Dow Chemical
- General Electric
- Henkel
- Union Carbide
- Wacker Silicones

Verify the proper containment and disposal of the foam-water solution discharge has been arranged to meet the requirements of the client and the authority having jurisdiction, including any disposal requirements by national/federal, state, and local regulations.

There are two acceptable methods for measuring foam concentrate percentage in water. Both methods are based on comparing foam solution test samples with pre-measured solutions, which are plotted on a baseline graph of percent concentration versus instrument reading.

E.1 Conductivity Method

This method is based on changes in electrical conductivity as foam concentrate is added to water. A conductivity meter is used to measure the conductivity of foam solutions in microsiemens 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, relative to the conductivity of the water.

It will be necessary to make foam-water solutions in advance to determine if adequate changes in conductivity can be detected if the water source is salty or brackish.

Equipment Required

Prepare a base (calibration) curve using the following apparatus:

- Four 1000 ml plastic bottles with caps*
- One 60 ml measuring pipette or 60 cc syringe
- One 1000 ml graduated cylinder or beaker
- Three plastic-coated magnetic stirring bars
- One temperature-compensated conductivity meter:
  - Range (minimum): 0 to 2000 microS
  - Accuracy: +/-40 microS
  - Resolution: 2 microS
- Standard graph paper or electronic graphing
- Ruler or other straightedge

* Minimum size bottles and graduated cylinder. Larger sample volumes (2000 or 3000 ml) may reduce the possible error in mixing of samples. This should be considered for 1% foam concentrate and if the band of error for instrumentation is being considered.

Procedure

Using the water from the water supply and foam concentrate from the system to be tested, make up a minimum of three standard foam-water solutions using the 1000 ml graduated cylinder or beaker. These samples should include the nominal intended percentage of injection, the nominal percentage plus 1 or 2 percentage points, and the nominal percentage minus 1 or 2 percentage points and water from the supply water.

Typical premix solutions are as follows:

Foam Concentrate	*Sample #1*	*Sample #2*	*Sample #3*
1%	0.5	1.0	1.5
3%	2.0	3.0	5.0
6%	4.0	6.0	8.0

It may also be advisable to prepare samples that identify the band of error for the instrumentation being used.

Foam Concentrate	*Sample #4*	*Sample #5*
1%	0.9	1.4
3%	2.9	4.0
6%	5.9	7.0

Place the water in the 1000 ml graduated cylinder or beaker. Carefully remove the amount of water for the sample standard mixture being prepared using the syringe. Then carefully measure the foam concentrate samples into the water using the syringe. Use care not to pick up air in the foam concentrate samples. Pour each measured foam solution from the 1000 ml graduated cylinder or beaker into a 1000 ml plastic bottle. Each bottle should be marked to indicate the percent solution it contains. Add a plastic stirring bar to the bottle, cap it, and shake thoroughly to mix the foam solution.

After making the three foam solutions in this manner, measure the conductivity of each solution and the water from the water supply. Refer to the instructions that come with the 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, set the capped bottles aside for control sample references.

Over long tests (i.e., multiple tests lasting all day), it may be necessary to mix new samples as the base water conductivity can change enough over this period (or due to evaporation if the bottles are not capped) to affect the conductivity reading of the standard solutions.

The conductivity readings should then be plotted on the graph paper or equivalent electronic method. It is most convenient to plot the foamsolution percentage on the horizontal (X) axis and conductivity readings on the (Y) vertical axis (See Fig E.1).

It might not be possible to hit all three points with a straight line, but they should be very close. If they are not, repeat the conductivity measurements and, if necessary, make new control sample solutions until all three points plot in a nearly straight line. This plot will serve as the known base (calibration) curve to be used for the test series.

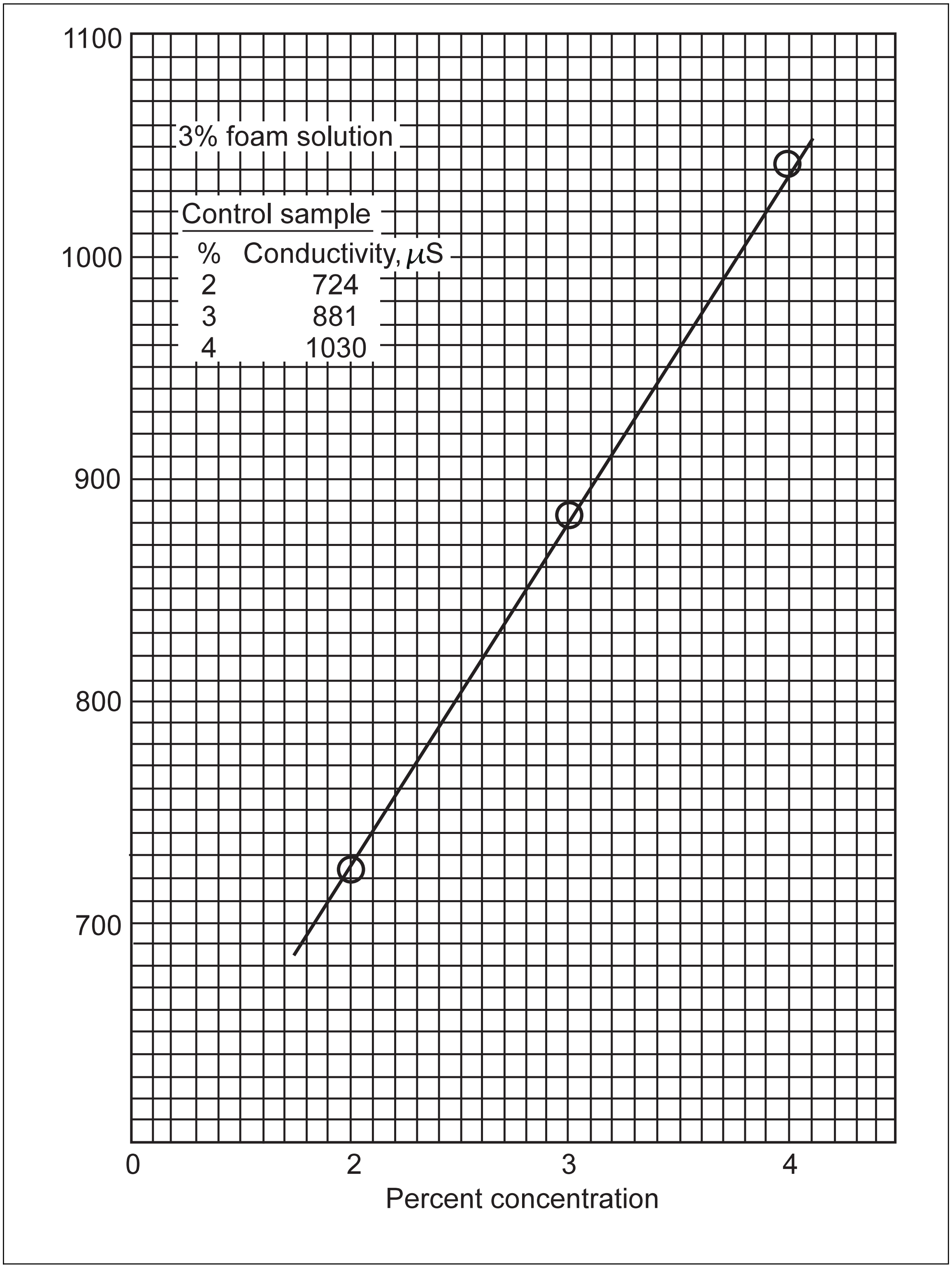


Fig. E.1. Determining foam concentrate percentage using the conductivity method

E.2 Refractive Index Method

A digital refractometer is used to measure the refractive index of the solution samples. This method is not particularly accurate for 1% AFFF or alcohol-resistant foams since they typically exhibit very low refractive index readings. For this reason, the conductivity method might be preferred when these products are used.

Equipment Required

A base (calibration) curve is prepared using the following apparatus:

- Four 1000 ml plastic bottles with caps*
- One 60 ml measuring pipette or 60 cc syringe
- One 1000 ml graduated cylinder* or beaker
- Three plastic-coated magnetic stirring bars
- One digital refractometer:
  - Refractive Index Scale (Minimum): 1.3330 - 1.3700
  - Scale Division: 0.0001
  - Accuracy: ±0.0001
- Standard graph paper or electronic graphing
- Ruler or other straightedge

* Minimum size bottles and graduated cylinder. Larger sample volumes (2000 or 3000 ml) may reduce the possible error in mixing of samples. This method should not be considered for 1% and AR-AFFF foam concentrate.

Procedure

Using the water from the water supply and foam concentrate from the system to be tested, make up a minimum of three standard solutions using the 1000 ml graduated cylinder or beaker. These samples should include the nominal intended percentage of injection, the nominal percentage plus 1 or 2 percentage points, and the nominal percentage minus 1 or 2 percentage points and water from the water supply.

Typical premix solutions are as follows:

Foam Concentrate	*Sample #1*	*Sample #2*	*Sample #3*
1%	0.5	1.0	1.5
3%	2.0	3.0	5.0
6%	4.0	6.0	8.0

It may also be advisable to prepare samples that identify the band of error for the instrumentation being used.

Foam Concentrate	*Sample #4*	*Sample #5*
1%	0.9	1.4
3%	2.9	4.0
6%	5.9	7.0

Place the water in the 1000 ml graduated cylinder or beaker. Carefully remove the amount of water for the sample standard mixture being prepared using the syringe. Then carefully measure the foam concentrate samples into the water using the syringe. Use care not to pick up air in the foam concentrate samples. Pour each measured foam solution from the 1000 ml graduated cylinder or beaker into a 1000 ml plastic bottle. Each bottle should be marked to indicate the percent solution it contains. Add a plastic stirring bar to the bottle, cap it, and shake thoroughly to mix the foam solution.

After thoroughly mixing the foam solution samples, take a digital refractive index reading of each percentage foam solution sample and the water supply. This is done by placing a few drops of the solution on the refractometer prism, closing the cover plate, and observing the scale reading at the dark yield intersection. Since the refractometer is temperature compensated, it can take 10 to 20 seconds for the sample to be read properly. It is important to take all refractometer readings at ambient temperatures of 50°F (10°C) or above.

Once the solution samples have been measured and recorded, set the capped bottles aside for control sample references.

Over long tests (i.e., multiple tests lasting all day), it may be necessary to mix new samples as the base water refractivity can change enough over this period (or due to evaporation if the bottles are not capped) to affect the refractive reading of the standard solutions.

Using standard graph paper or equivalent electronic graphing method, (See Appendix D - Forms, ″Acceptance Test″ for Percent Injection of Foam) plot the refractive index readings on the vertical (Y) axis and the percent concentration on the horizontal (X) axis. The resulting plotted curve will serve as the known baseline for the test series. Set the solution samples aside in the event the measurements need to be checked. (See Fig. E.2).

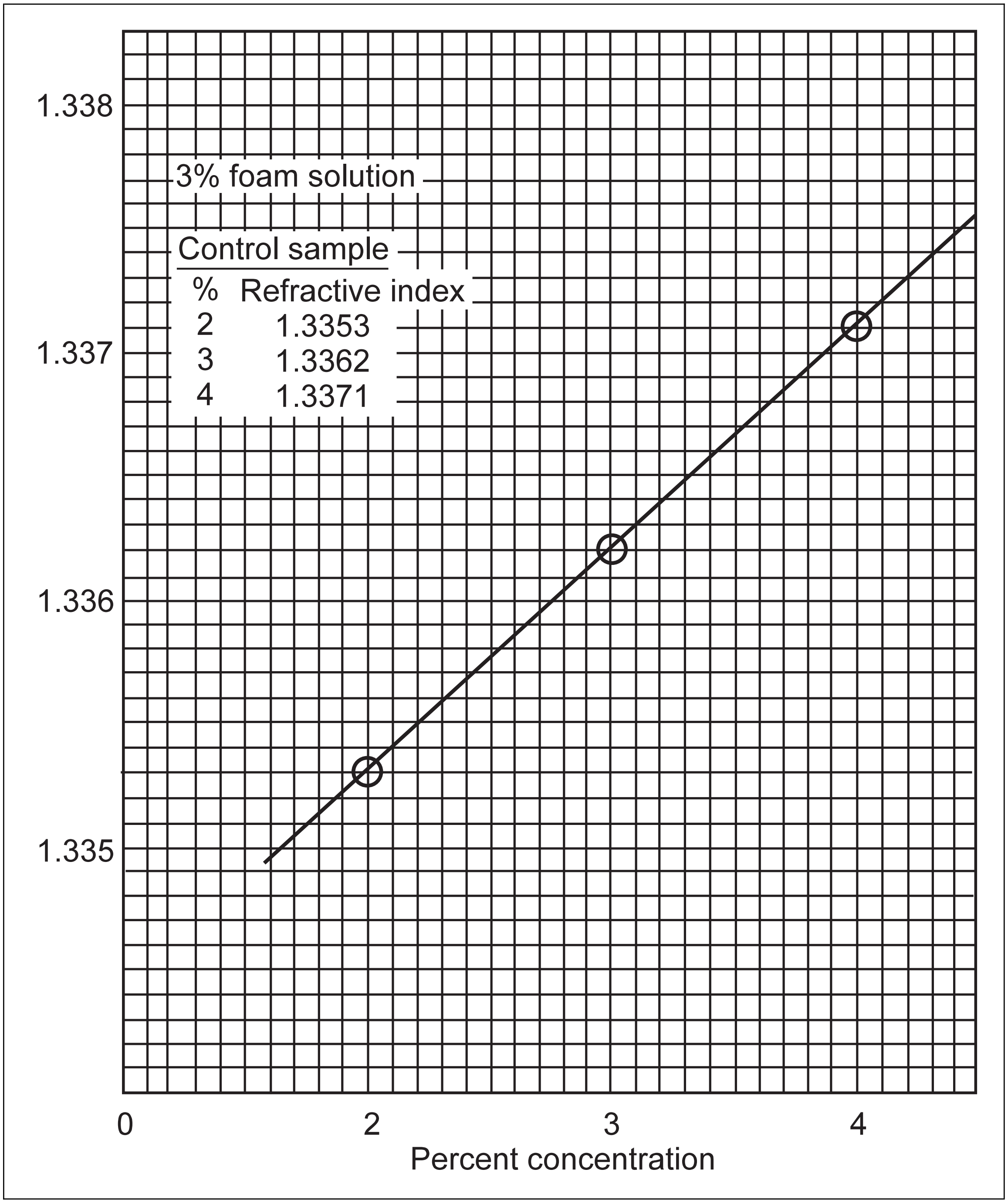


Fig. E.2. Determining foam concentrate percentage using the refractive index method

E.3 Sampling and Analysis

Collect foam-water solution samples from the proportioning system, using care to verify the sample is taken at an adequate distance downstream from the proportioner being tested. Using foam-water solution samples that are allowed to drain from expanded foam can produce misleading conductivity readings.

Thirty to 60 seconds after the foam appears from the test valve, take a sample of the foam-water solution discharge.

Once one or more samples have been collected, read their conductivity or refractive index and find the corresponding percentage from the plotted base curve prepared from the control sample solutions.

E.4 Interpretation of Foam Solution Concentration

Analyze the percent of foam concentrate in the water being used to generate foam-water solution is within the allowable range. See Section 2.6.4 Operational Test of Proportioning Equipment. If the level of foam concentrate injection varies widely from allowable design, it could abnormally influence the expansion and drainage foam quality values, which could influence the foam's performance during a fire. If the solution is too lean, it could negatively impact performance in a fire event. If the solution is too rich, it could result in a reduced discharge duration.

APPENDIX F HYDRAULIC FRICTION LOSS CALCULATIONS FOR FOAM CONCETRATES

The friction loss in piping for foam concentrates is calculated using the Darcy-Weisbach formula (also known as the Fanning formula)

For U.S. customary units:

Darcy-Weisbach formula: $\Delta P = 0.000216\left(\frac{fL\ \rho\ Q^2}{d^5}\right)$

Reynolds number: $Re = \frac{50.6\ Q\rho}{d\mu}$

Where:

ΔP = friction loss (psi)
f = friction factor
L = length of pipe (ft)
ρ = weight density of foam concentrate (lb/ ft^3)
Q = flow (gpm)
d = pipe diameter (in.)
R = Reynolds number
μ = absolute (dynamic) viscosity of foam concentrate (cP)

For SI units:

Darcy-Weisbach formula: $\Delta P_m = 2.252\left(\frac{fL\ \rho\ Q^2}{d^5}\right)$

Reynolds number: $R_e = 21.22\left(\frac{Q\rho}{d\mu}\right)$

Where:

ΔP_m = friction loss (bar, kPa)
f = friction factor
L = length of pipe (m)
ρ = density of foam concentrate (kg/ m^3)
Q = flow (L/ min)
d = pipe diameter (mm)
R_e = Reynolds number
μ = absolute (dynamic) viscosity of foam concentrate (cP)

Select friction factors for use with the Darcy-Weisbach formula from the graphs shown in Figures F.1 through F.4.

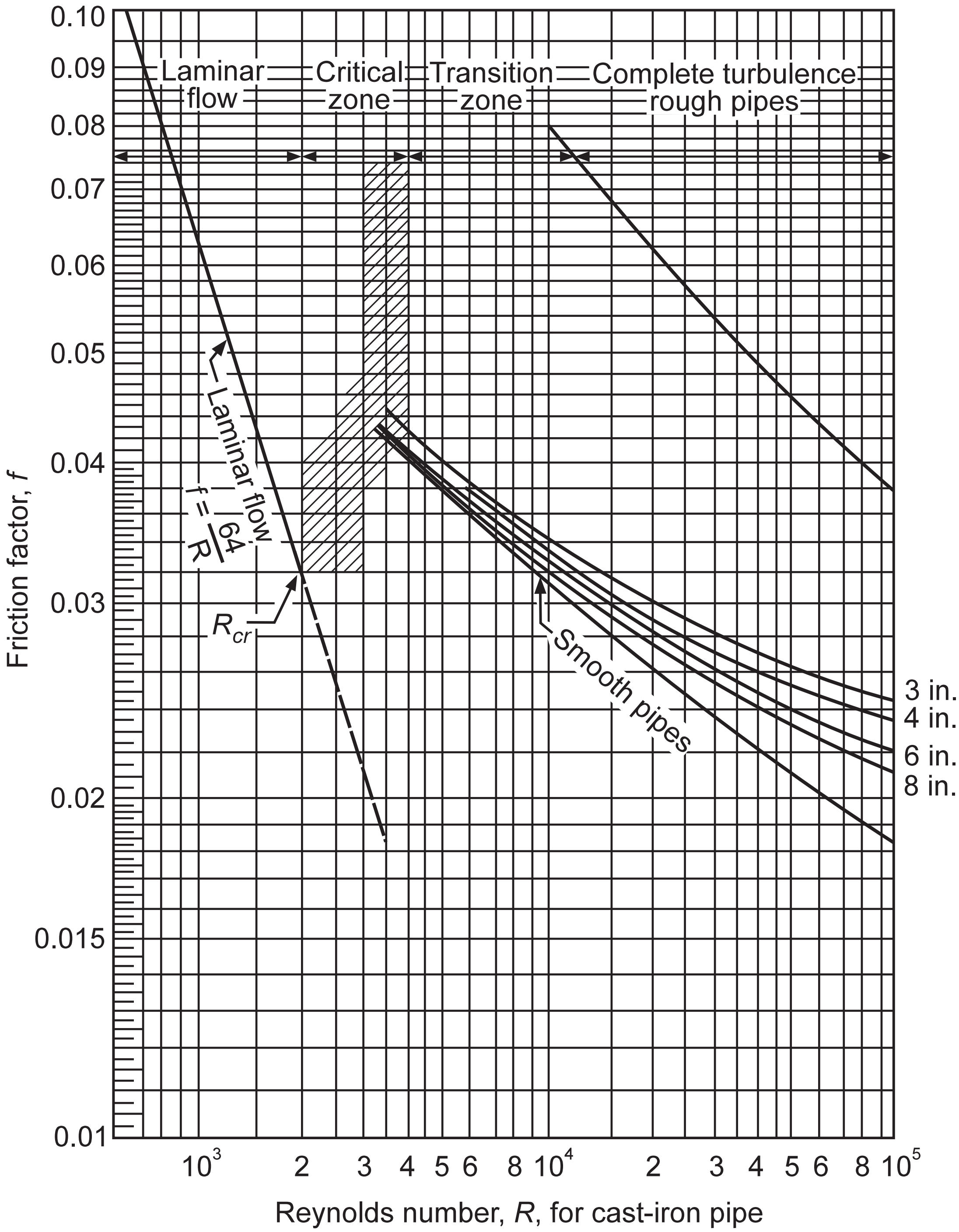


Fig. F.1. Moody diagram for cast-iron pipe, $R \leq 10^5$

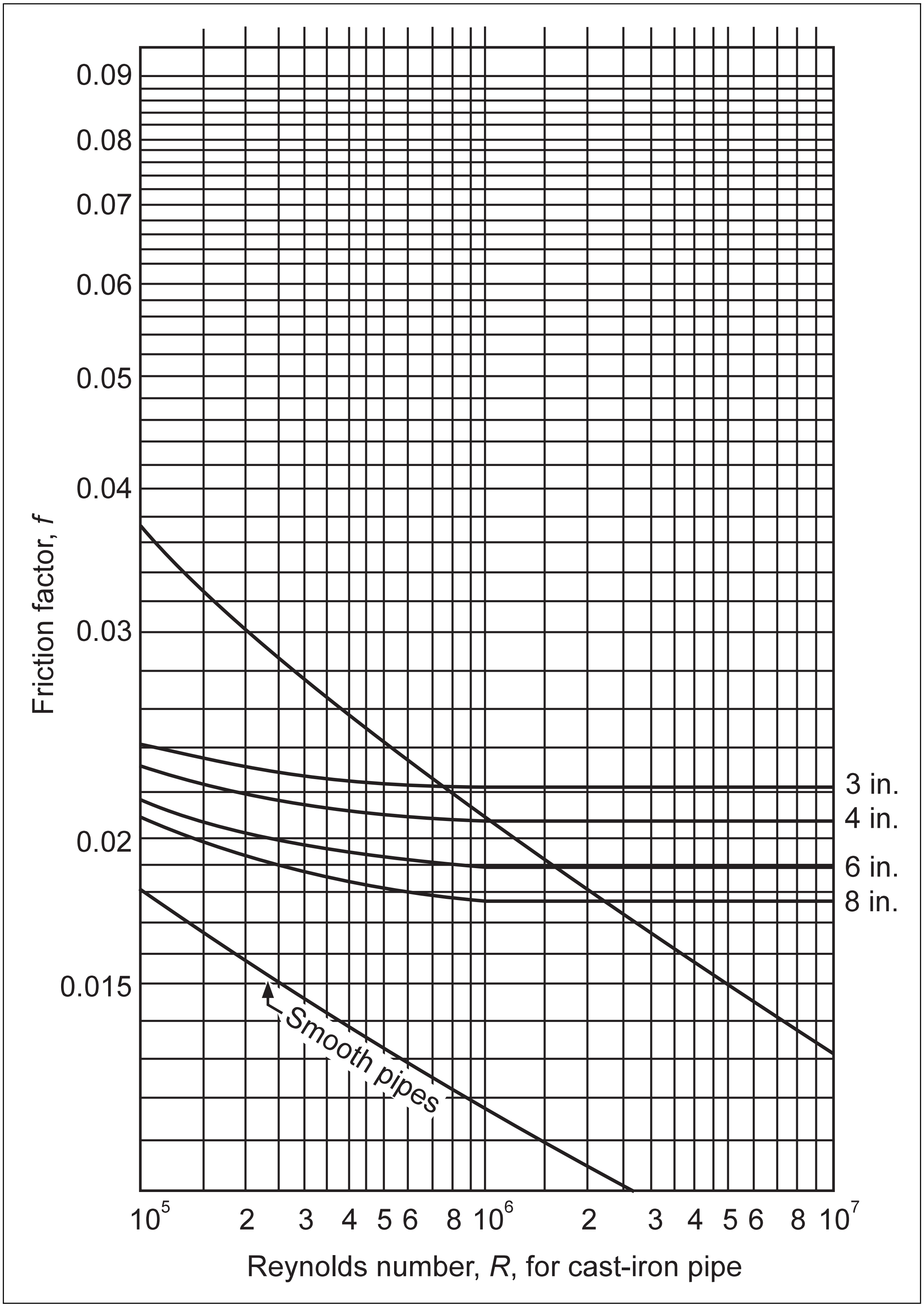


Fig. F.2. Moody diagram for cast-iron pipe, R ≥10⁵

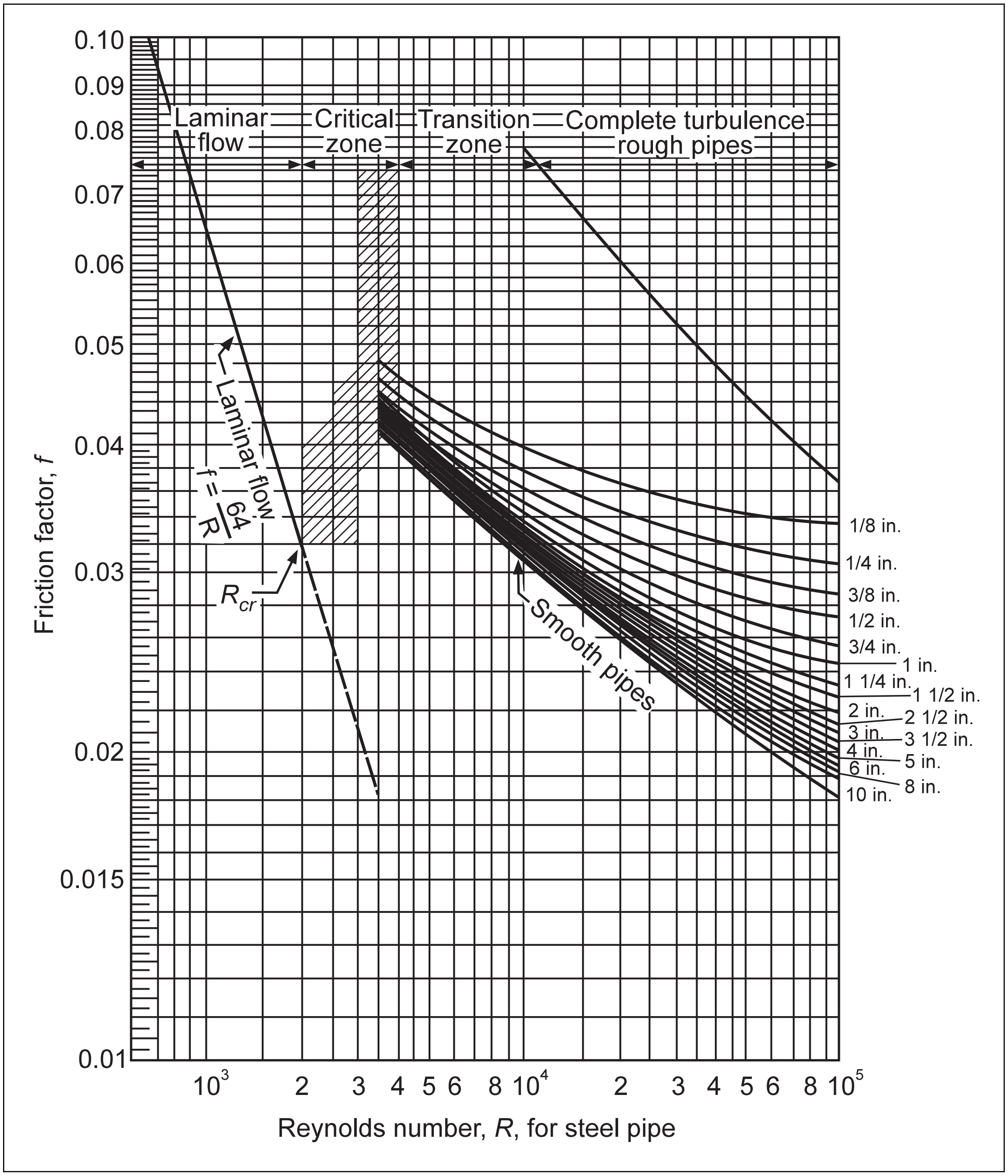


Fig. F.3. Moody diagram for steel pipe, $R \leq 10^5$

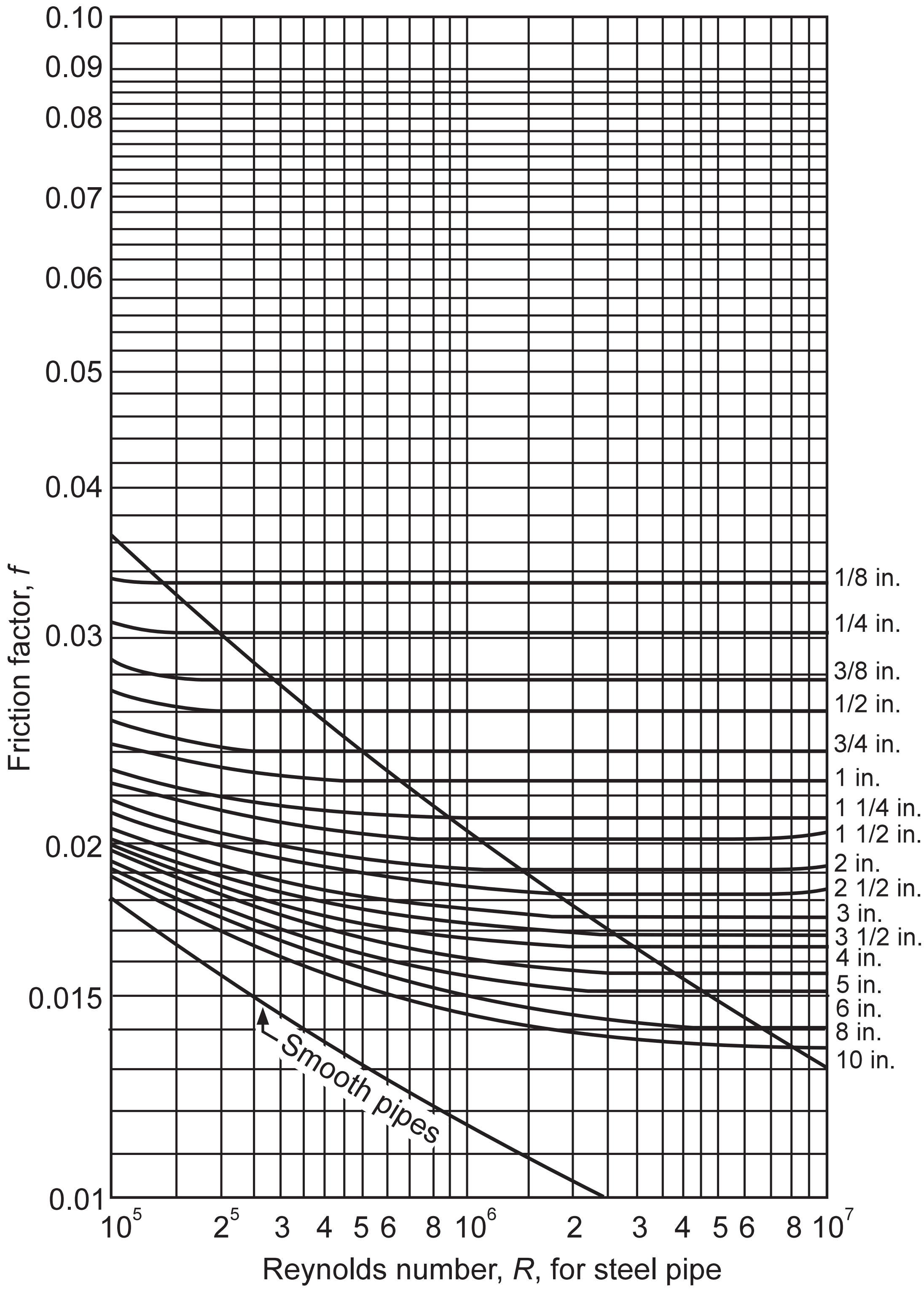


Fig. F.4. Moody diagram for steel pipe, R ≥10^5

Calculate the Reynolds number for selecting friction factors from the graphs using the actual density (or specific gravity) of the foam concentrate.

Use the dynamic viscosity of the foam concentrate at its lowest anticipated storage temperature.

Table F.1. Characteristics of Foam Concentrates

Manufacturer	*Foam Concentrate[1]*	*Temperature Range°F (°C)*	*Density[2] lb/ft^3 (kg/m^3)*	*Specific Gravity*	*Dynamic Viscosity[2] (cp)*
Ansul	3% protein	20 to 120 (-6.7 to 49)	71.3 (1142)	-	3
	3% (AFC-3A) AFFF	35 to 120 (2 to 49)	64.0 (1025)	-	3
	Premium 3% (AFC-5A) AFFF	35 to 120 (2 to 49)	63.9 (1024)	-	3
	Premium 6% (AFC-5) AFFF	35 to 120 (2 to 49)	63.4 (1016)	-	3
	3x3 low-viscosity AR-AFFF	35 to 120 (2 to 49)	63.7 (1020)	-	1500 ± 500
	ARC 3% or 6% AR-AFFF	35 to 120 (2 to 49)	62.4 (1000)	-	2525 ± 700
Buckeye	Platinum 1% AFFF	35 to 120 (2 to 49)	-	1.020 - 1.040	6.5–10.5 @ 68°F (20°C)
	Platinum 3% AFFF	35 to 120 (2 to 49)	-	1.007 - 1.009	3
	Platinum 3×3 AR-AFFF	35 to 120 (2 to 49)	-	1.015 - 1.055	3
Chemguard	3% AFFF C302				
	Ultraguard 3% AR-AFFF	35 to 120 (2 to 49)	-	1.020	3000–3200
National Foam	Universal Gold 3% AFFF	35 to 120 (2 to 49)	-	1.025	2500
	Aer-O-Lite 3% AFFF	20 to 120 (-7 to 49)	-	1.03	
	Aer-O-Water 3EM 3% AFFF	35 to 120 (2 to 49)	-	1.04	
	Aer-O-Water 1% AFFF	20 to 120 (-6.7 to 49)	-	1.08	

Note 1. These foam concentrates may be FM Approved for use with other manufacturer's foam-water sprinkler systems as specified in their *Approval Guide* listings.
Note 2. At a temperature of 77°F (25°C), unless specified otherwise.
Note 3. These manufacturers have friction loss data for various pipe diameters in the form of charts/graphs for their foam concentrates. Contact the manufacturer for this friction loss data.

Non-Newtonian (e.g., alcohol-resistant) foam concentrates have viscosities that increase as their flow rate (shear rate) decreases, and viscosities that increase as temperatures decrease. In view of these properties, special care and attention should be taken when designing distribution piping for them. In particular, minimize the lengths of piping that are filled with non-Newtonian foam concentrates under no-flow conditions.

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