FOAM-WATER SPRINKLER AND FOAM-WATER SPRAY SYSTEMS

INTRODUCTION

National Fire Protection Association (NFPA) documents describe a level of fire protection agreed on by persons representing a variety of interests. The guidance in these documents does not reflect unique conditions or special considerations, such as system performance under adverse conditions. Nor does NFPA guidance reflect the increased system reliability that AXA XL Risk Consulting recommends for high valued properties.

This PRC Guideline takes a position on the provisions of NFPA 16 that AXA XL Risk Consulting believes require clarification or changes. To understand the position, this PRC Guideline must be read with a copy of NFPA 16. The provisions of the NFPA document are not repeated.

General

This standard pertains to open-head and closed-head foam-water systems using Aqueous Film Forming Foam (AFFF), polar solvent AFFF and Film Forming Fluoroprotein (FFFP) concentrate. The standard also refers to protein foam and fluoroprotein foam concentrates, although their use is limited and is diminishing quickly.

Foam-water systems differ from foam systems in that when the concentrate runs out, water discharge continues. The design density must be high enough to be effective.

When foam-water systems are used to protect flammable liquids storage, obtain and analyze details of the storage arrangement. Refer to PRC.12.2.1.2 for discussion of protection of oil and chemical plants.

Discharge devices may be either air-aspirated or non-air-aspirated. In both cases, the devices can be either sprinklers or nozzles. Air-aspirated sprinkler devices must be approved by a nationally recognized testing laboratory as foam-water sprinklers. These devices are fairly large and use a mixing chamber having openings for air. They make good quality foam, but are rarely used because they are more expensive than non-air-aspirated devices.

Non-air-aspirated devices are standard sprinkler heads tested and approved for use in foam-water systems in addition to ordinary sprinkler systems. These tests and approvals are for specific combinations of sprinkler heads with foam from specified manufacturers.

Equipment used in these systems must be listed by a nationally recognized testing laboratory. Use system components all built by the same manufacturer. This establishes a fully integrated design and accountability when service, replacement or repair is needed. If equipment from various manufacturers is used, the listing should identify the component compatibility between manufacturers.

Manual release devices for foam-water deluge and preaction systems should be accessible during an emergency and should be independent of the detection system power supply.

To maximize the impact on proper protection; involve AXA XL Risk Consulting in the project planning stage. Before scheduling final acceptance tests, the installing contractor should furnish a written report stating all work has been completed in accordance with accepted plans and specifications.

Responsibilities for AXA XL Risk Consulting, the designer, installer and the purchaser are outlined in PRC.12.1.0.1.1. Submit a minimum of three copies of pertinent data for review. The following information is required:

- Details on the hazard being protected. When foam-water systems are being used to protect flammable liquid storage, include details of the storage arrangement.
- Hydraulic flow calculations for each system, based on achieving the system design at the most hydraulically remote sprinkler head. Submit the hydraulic flow calculations for the concentrate system. Show complete input/output data and sufficient detail to aid in the prompt verification of the calculations. Data should include details on the commodity, class of flammable liquids, whether liquids are polar or hydrocarbon, and the storage arrangements.

  On closed head systems, two sets of calculations are required; one for the remote area to size system piping and one for the near area to determine how long concentrate supplies will last under the best water supply conditions.
- For flammable liquids storage concentration must be met with 4 sprinklers flowing per NFPA 30.
- An isometric sketch of the piping layout. Indicate on the sketch the size and length of pipe, type of pipe, elevation changes and the location of reference points used in the calculations.
- All the details specified in NFPA 13 and PRC.12.1.1.0 on the plans.
- A bill of materials showing sufficient information on the various devices used in the installation so that the listing can be confirmed.
- Design parameters such as the system discharge time, foam solution needed, and foam concentrate required.
- Details of the control unit and include power supply information, point-to-point electrical wiring of all detectors and associated equipment, and reserve power details with calculations to confirm battery sizing. Provide equipment interlocks and alarm devices as required by the installation.
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- Sequence of events indicating operation of system under normal and emergency conditions in a format suitable for posting in the protected area.
- Water supply details including demand and duration.
- Details on environmental features such as:
  - Construction materials
  - Combustible loading
  - Protective signaling service availability

Type Of Systems

Closed-head systems are generally wet pipe, dry pipe or pre-action type. Wet pipe systems pre-primed with foam solution are preferred for warehouse applications or heated process areas. Do not use dry pipe systems, particularly where large volumes of flammable liquids are involved, due to their inherently slower operation. When there is the possibility of freezing temperatures, use a pre-action system. The pre-action system provides fresh foam solution upon discharge valve actuation, which does away with the need for periodic solution replacement. Pre-action systems are acceptable if they are arranged to actuate by a fast-acting detection system, such as optical flame detection. Recognize that a pre-action system is subject to delays due to detection and system valving operation. The delay may result in loss of fire control. Double interlock pre-action systems should not be used.

Proper turbulence is essential to ensure good foam generation. It is important that adequate pressure be present at the sprinkler head. Gridded foam-water systems may have very low pressure due to the hydraulics of the system.

Discharge Time

The foam-water system should initially discharge long enough to ensure control until the response team has arrived, has assessed the situation, and is in position to take the necessary action. It is recommended that both the primary system and reserve supply each be designed to discharge for a nominal 10 min. Once good quality foam is produced and the concentrate runs out, the water striking the floor causes sufficient turbulence to produce some foam from the foam that has reverted back to solution. If the fire is brought under control, the system may be shut off at the discretion of the fire officer in control.

Connected Reserve

In lieu of a connected reserve, the amount of concentrate is doubled, extending the foam discharge period to a nominal 20 min. The extended quantity of concentrate is discharged at the time of the incident rather than being held in case of a possible re-ignition. Foam concentrate injection continues until the concentrate is consumed or the system is manually shut off. In order to control the spread of fire, it is crucial that a good foam blanket be put down before water only is discharged. Waiting for the fire to rekindle before operating a second shot may result in non-extinguishment.

If the system cannot be completely restored to service through local suppliers within 8 h, provide a redundant on-premises storage supply. Pre-connection of the redundant supply to the foam system is optional.

Discharge Devices

Use only non-air-aspirating sprinkler heads listed specifically for this purpose. Experience has shown that good quality foam is produced when sufficient velocity or turbulence occurs at the orifice. UL indicates which devices are acceptable in their *Fire Protection Equipment* Directory under Foam Liquid Concentrates (GFGV). Some listed nozzles use a small diameter orifice to ensure turbulence, while others specify minimum pressures required at the nozzle. If a specific head is not listed for use with the foam water concentrate, get a written commitment to pursue listing from the foam manufacturer.

Foam Concentrates

Foam concentrates are usually named to indicate the recommended percentage of concentrate in the foam solution after proportioning. Some concentrates today have dual concentrate ratings such as 3x1, 3x3 or 3x6. The first number is generally the percent concentrate used on hydrocarbon type fuels and the second number is the recommended percent concentrate for polar-type solvents.

Store foam concentrate between 20°F (-7°C) and 120°F (49°C). Some concentrates have special freeze point depressants that are good to -30°F (-34°C). Follow the manufacturer’s recommendations for storage, usage and disposal.

Although they are similar, foam concentrates from different manufacturers should not be mixed unless the mixture has been tested, and then only with both manufacturers’ approval. Different foam concentrates from the same manufacturer should not be mixed unless the mixture has been tested, and then only with manufacturer’s approval.

Closed Head Systems

Pre-primed solutions of polar solvent (alcohol) type AFFF may deteriorate when left in the pipe for extended periods of time. Some have been known to settle out and form long polymers. The shearing action of the concentrate during discharge usually corrects this problem by breaking up the long chains.

Although some concentrate manufacturers do not favor pre-priming of wet systems with polar AFFF, others say there is sufficient data to show that although pre-primed systems may require more frequent examining. The ability to function within acceptable limits is just slightly below that of ordinary AFFF when balanced pressure proportioning is used in conjunction with concentrate pumps.

The AFFF concentrate reacts with steel piping and minerals in the water and degrades with time. This is more prevalent in small diameter piping due to the higher ratio of internal surface area to volume. It is also more prevalent with hard water.

A commitment must be made to maintain the system's reliability by establishing proper monitoring and recordkeeping. See Section 9.1 regarding maintenance and testing.

Proportioning Equipment

If used, locate bladder tanks less than 12 ft (4 m) from the system riser being supplied.

Use materials recommended by the foam concentrate manufacturer for concentrate pipelines. Do not use exposed plastic piping. Avoid passing concentrate piping lines through protected areas.

Either bladder-type or pump-type-proportioning systems are acceptable for open head deluge systems. A bladder-type proportioning system is less complicated and depends on fewer mechanical parts than the pump-type proportioning equipment. This results in greater reliability. Bladder-type balanced proportioning systems operate lean at low flow conditions, whereas the pump-type operate rich at low flow capacities. This is not an important factor at the flow rates expected with a deluge system. The ability to obtain high levels of concentrate at low flows is accomplished by ensuring concentrate pressures greater than the maximum water pressure at all flow conditions. Enriched solution does not necessarily make more or better quality foam.

Concentrate pumps have been recommended for closed head pre-primed systems. Balanced proportioning equipment utilizing concentrate pumps usually operate on the rich side at low flows. When using a pump with balanced proportioning equipment, the concentrate pressure is always greater than the maximum water pressure. Enriched solution does not usually make more or better quality foam. However, in this application, it prevents watering down of the solution in the piping, thus maintaining a more stable foam production throughout the system's expected range of flows.

Listed variable foam proportioners are available that can be used with bladder tanks. The new proportioners work over the expected range of flows, delivering a proper solution mix throughout the discharge.

On closed-head systems, there may be occasions where two proportioners, each of a different size and range, may have to be installed in parallel in bladder type systems so that the full range of system flows can be accomplished. A smaller proportioner is used at low flows and a larger, or a combination of both, is used to deliver concentrate at higher demands.

Foam Concentrate Pumps and Power Supply

If concentrate pumps are used, they should be of the positive displacement type, and should be sized to meet the maximum anticipated demand. Consider a back-up pump where the concentrate systems are large.

Design electrical feeds to concentrate pumps to reliably maintain power throughout the operation of the foam-water system. Follow the same electric power supply requirements used for electric fire pumps. (See NFPA 20 and PRC.14.2.1.)

Where a power feeder must run into a fire area, use an electrical circuit protective system with a minimum 2 h fire resistance rating. Comply with the restrictions identified in the approval of such systems. Alternately, install pump feeders in accordance with Section 695 of NFPA 70.

Storage Tanks

Size atmospheric-type concentrate storage tanks to hold a minimum 20 min supply of concentrate. Fill the tank immediately after the system has discharged to reduce the time the inside tank surfaces are exposed to air. Restore full protection within 8 h.

When selecting the size of pressure-type storage containers, consider that these tanks cannot be replenished while the system is operating. Check the concentrate holding bag annually for wear and deterioration of the lining due to age.

Water Supply Capacity And Duration

Water supplies should meet anticipated combined demands of the foam-water system, hose streams and any exposure protection systems that may be operating at the same time. Foam-water systems are designed to deliver protection even after the foam concentrate has been used up. This is what distinguishes a foam-water system from a foam system. Design water supplies for the highest expected water demand. See PRC.14.1.1.0.

Minimum Discharge Densities and Design Area

The minimum design requirements are based on the specific occupancy and any applicable NFPA or AXA XL Risk Consulting requirements. This standard establishes a minimum design density of 0.16 gpm/ft^2 (6.5 L/min/m^2) which is based on a two-dimensional spill-type fire. Where greater fire exposures are anticipated, such as rack or palletized storage, much higher ceiling discharge densities are required. Install in-rack protection where appropriate. Density requirements for the foam-water systems are generally those required for water only systems. The use of foam-water helps control the floor fire, but high densities are needed to control the three dimensional fire. See NFPA 30 and PRC.8.1.0 for guidance on flammable liquid storage. Also, see PRC.12.2.1.2 for guidance on flammable liquid processes and handling.

A minimum 5000 ft^2 (465 m^2) area of application has been established based on the spill type fire scenario; however, no test data supports this. The area of application depends on the specific hazard. Typically for flammable liquids processing the design area is the entire area unless proper drainage can be verified. NFPA 30 should be consulted for all flammable liquids storage criteria. Smaller areas are acceptable with densities above 0.16 gpm/ft^2 (6.5 L/min/m^2). See NFPA 30 and PRC.8.1.0 for guidance on flammable liquid storage. Also, see PRC.12.2.1.2 for guidance on flammable liquid processes and handling.

Discharge Duration

Design the foam discharge time for a nominal 20 min to ensure control and to allow time for fire response team to arrive, assess the situation, and respond appropriately. Higher than normal achieved densities will cause the concentrate to be consumed quicker. If, by virtue of the water supply, the concentrate can be consumed faster, adjust the amount of concentrate so that there is enough for at least 14 min under the highest flow rate possible in the least hydraulically demanding area. Once good quality foam is produced, water, which discharges after the concentrate runs out, usually does not destroy the foam blanket.

Drainage

In all flammable liquids storage arrangements, consider the combined anticipated flow of the spill, the discharge from the foam-water system, and the use of hose streams.

Concentrate System Hydraulics

In piped concentrate systems, determine the pressure losses through the piping system using the Darcy Formula. This is particularly important where multiple proportioning devices of different sizes are supplied from the same concentrate supply. The proportioner manufacturer’s specified pressure differential between the foam concentrate feed and the water inlet must be adhered to.

Hydraulic Calculations In Closed Head Systems

Foam-water concentrate supplies, especially in closed head systems, raise several concerns. If a fire occurs at any area other than the remote area or if the water supply is stronger than the system requires, more water will enter the foam proportioner and use up the concentrate more quickly. Although the piping demand must be calculated on the hydraulically most remote area, the area closest to the sprinkler riser consumes the concentrate faster because of higher achieved densities. NFPA 16 requires a 10 min concentrate supply to meet the system demand in the hydraulically most remote area. However, the standard also allows for proportionally reducing the discharge time to a minimum of 7 min if the actual flow rate is greater than the design rate. For these reasons two sets of calculations are required.

Use the following procedure when evaluating the design of new closed head foam-water systems:

- Analyze the most hydraulically remote area back to the base of the riser. Base the calculation on the required density.
- Determine the quantity of concentrate needed to deliver the design flow rate for a 10 min period. This determined amount of concentrate should not be subjected to the NFPA 16 allowance for a reduction in allowable discharge time. The most remote area must be capable of a full 10 min discharge at the design conditions.
- Analyze the area nearest the sprinkler riser. Base the analysis on achievable density from the existing water supply.
- Determine the time required to consume the stored concentrate at the new flow rate. If the concentrate discharge time is less than 7 min, the concentrate storage should be increased so that the concentrate lasts at least 7 min at the higher flow rate. When determining how the water supply affects concentrate consumption, do not take into account a hose stream deduction. Hose streams are usually not applied during the first few minutes of system operation.
- The connected reserve should be sized the same as the primary system. In lieu of a connected reserve, the primary system should be designed for a nominal 20 min supply at the remote area, but only a 14 min supply is need at the highest consumption rate.

Acceptance Tests

Both open head and closed head systems should be acceptance tested. The five tests performed during system acceptance testing include checking:

- The strength of the concentrate in the solution using a refractometer. (See Section 5.3.4.) Recent research has shown that checking the solution with a conductivity meter may be a more exact, easier procedure than using a refractometer. The conductivity meter is not as definitive in salt water systems and should not be used.
- The expansion ratio. The test method is detailed in NFPA 11.
- The 25% drainage time. Tests method and equipment setup is detailed in NFPA 11.
- The proportioning rates.
- Proof that a vapor suppressing film is formed on AFFF. Tests are detailed in NFPA 11.

Proportioning System Testing

Before performing tests of the proportioning equipment at both the high and low ranges, ensure that foam runoff can be disposed of in an acceptable manner. Using an in-line conductivity meter can greatly reduce water discharge.

For testing purposes, design deluge and pre-action systems with a normally open supervised gate valve above the system valve to divert the solution discharge to a safe location. The quality of foam produced can be checked by diverting the foam solution through a foam-making device. Confirm the quantity discharged is within the range expected during a fire.

On closed head systems, in addition to the required test connections, provide piping provisions for system draining and flushing. Install a 2 in. (50 mm) connection off of a crossmain near the end of the system for purging the system during filling, testing and flushing. Periodically flushing from end of the system replaces stale solution in pre-primed systems.

Open deluge systems, as well as the closed systems, should be tested for all design points.

Inspection, Testing And Maintenance

Foam systems are complex. Operating and maintenance instructions, piping and electrical schematics should be readily available at the control equipment. Because these complex systems provide protection for large complex hazards, provide a maintenance service and testing contract by a qualified vendor or by plant personnel trained by the manufacturer of the equipment.

Test the foam-water system in accordance with PRC.13.0.4, PRC.13.0.5 and PRC.13.0.5.A. Test the foam solution and foam generation in accordance with NFPA 25 and NFPA 11.

Send samples of concentrate to the manufacturer annually for periodic testing. Replace as recommended.

Foam solution deterioration depends on many factors; the greatest of these is the quality of water. In order to determine the correct frequency for replacement for the particular system, it is suggested that samples of the solution be sent to the manufacturer at six month intervals for evaluation until a replacement schedule is established.

Test and inspect alarm and detection devices in accordance with NFPA 72 and PRC.11.1.1.0.

DISCUSSION

The use of foam has advantages and disadvantages. It is beneficial in reducing water usage and flammable liquid runoff. The main environmental concern has been the use of ethylene glycol and/or Diethylene Glycol Monobutyl Ether (commonly known as Butyl Carbitol) in the foam concentrate formulations. Until recently, the release of more than 10 gal (38 L) of foam concentrate required reporting to the U.S. Environmental Protection Agency (EPA) National Response Center.

Environmentally responsible foams are currently being marketed. Many large users of foam, however, will continue to limit their use of nonenvironmentally responsible foams because it the correct thing to do. These new foams will give them an option.

Another concern is the disposal of the foam solution. Users must use diligence to insure the discharged foam solution does not enter ground water and surface water. Storm sewers should also be avoided since in most cases they discharge directly to water (rivers, streams, ponds, etc.). The problem arises when solution arrives at the wastewater treatment facility. The manufacturer’s guidelines for dilution must be followed. When aerated, if there is a sufficient concentration of foam in the wastewater, foam will form on the surface and may deprive microbes of necessary oxygen. This is not usually a problem in large systems where the dilution is extreme. Where there is concern, an anti-foaming agent can be added to the disposed foam solution before it enters the waste treatment system.

There are generally two chemical processes used to manufacture alcohol-resistant AFFF, PFOS and PFOA. The USEPA is citing materials made from these chemical processes for elimination. PFOS is persistent, bioaccumulative and toxic to humans. Only one U.S. manufacturer uses the PFOS chemistry and they have announced that they will voluntarily cease manufacturing in 2002. More work is needed to prove the case for PFOA removal. For updates, see http://www.fffc.org/