# LOW, MEDIUM, AND HIGH-EXPANSION FOAM 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 11 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 11. The provisions of the NFPA document are not repeated.

### General

Mechanical foam systems are primarily used on flammable and combustible liquid fires. Even though localized indoor hazards are protected by a foam system, sprinkler protection is recommended for general area protection.

Flammable and combustible liquid fires are extinguished by a combination of smothering, cooling, separating the fire from its fuel source, and suppressing vapor evolution. Three-dimensional fires are not usually extinguished by foam alone unless the burning liquid has a high flash point and can be cooled by the foam.

Foam is normally used if the fuel:

- Is below its boiling point at ambient conditions;
- Is below the boiling point of water;
- Does not react with water;
- Does not break down the foam;
- Would burn only as a two-dimensional pool or surface fire.

Low-expansion foam expands less than 20 times when properly proportioned and agitated with air. The normal expansion range for low-expansion foams is usually 8 to 12 times.

High-expansion foam systems should be used in combination with sprinkler protection meeting the requirement of NFPA 13 and PRC.12.1.1.0. In addition to adding reliability, the sprinkler system also provides required protection of the roof from hot gasses prior to complete submergence of the protected volume by foam.

Flush the equipment with water after use to prevent rusting and gelling of foam concentrate.

## Adequacy Of Water Supplies

In addition to meeting the water demand of the foam system, water supplies must be adequate to feed hose streams and, where applicable, overhead sprinklers and waterspray systems for exposure protection. Due to the nature of the hazard, total water demands could be quite large.

In addition to the water system being installed in accordance with NFPA 24, any pumping supplies should be designed and installed in accordance with NFPA 20.

## Concentrate Supplies

Foam must be delivered in proper quantities to achieve control and eventual extinguishment. Confirm that adequate concentrate supplies are on hand before foam application is initiated. If concentrate supplies are inadequate, any attempt at extinguishment may be futile. The proper delivery rate is also crucial. A connected reserve concentrate supply is recommended.

## Foam Concentrate Pumps

Provide electric pump equipment suitable for the location's electrical classification. To ensure proper operation during an emergency, the source of power must be reliable. Follow the same electric power supply requirements used for electric fire pumps. (See NFPA 20 and PRC.14.2.1.)

## Method Of Actuation

Automatic systems are preferred to manual, except where semiautomatic or mobile systems have been accepted. See PRC.17.3.4.

Use fast-acting, listed, supervised, combustible gas detectors or flame detectors for automatic foam systems that protect large process equipment, storage tanks and tank farms. Smaller fires can be detected using listed rate-of-rise heat detectors. See PRC.13.0.1 regarding detection systems for controlling extinguishing system operation.

## Low-Expansion Foam Systems

### Tanks

#### Cone Roof Tanks

Fixed foam protection facilities designed to deliver the appropriate application rate of foam solution to the entire liquid surface are preferred, although semi-fixed systems may be used. A fixed system using either the surface, subsurface or semi-subsurface application method is acceptable.

Subsurface application, with foam applied near the bottom of the tank and bubbled through the fuel, can only be used with hydrocarbon fuels. Semi-subsurface application can be used with polar solvents because the foam is protected until introduced at the surface. The subsurface and semi-subsurface application methods minimize the number of penetrations through the tank wall.

Side entry alone is acceptable for cone roof tanks under 140 ft (42.7 m) in diameter. For larger tanks, subsurface application is preferred although protection can be provided by using a combination of subsurface and surface application, or by using additional foam outlets fed from the roof of the cone roof tank to protect the center portion of the tank.

Extend foam laterals in semi-fixed systems from the foam application points on the tank to suitable hose connections located outside the dike. To assure accessibility under varying wind conditions, locate foam hose connections on two sides of the tank. Use mobile foam apparatus in accordance with NFPA 1901 for this purpose, with concentrate quantities adequate for the largest fire scenario anticipated.

#### Open Top Floating Roof Tanks

These tanks are usually designed with steel pontoon decks, which are compartmented and fairly difficult to sink. For open-top floating roof tanks, provide fixed or semi-fixed foam protection for the seal area between the tank wall and the foam dam. Extend foam laterals in semi-fixed systems from the foam application points on the tank to suitable foam connections located outside the dike. To assure accessibility under varying conditions, locate foam connections on two sides of the tank. Design the distribution of foam application points around the perimeter of the tank. Protection is usually not a problem for tanks over 140 ft (42.7 m) diameter. Use either a distribution spider mounted on the surface of the floating roof or surface mounted foam outlets.

Prevent overfilling of open-top floating roof tanks. Set the maximum fill level of these tanks so that effective foam distribution is available by maintaining the top of the foam dike below the tank rim.

Some systems utilize Halon 1211 fixed systems to protect the seal area on open- top floating roof tanks; however, Halon 1211 does not appear to be effective when used outdoors. One disadvantage associated with halon for seal area protection is the likelihood of the wind diluting the concentration and reignition occurring from hot metal or a smoldering fabric seal. Due to the unavailability of Halon 1211, replace all such systems with fixed or semi-fixed foam protection.

#### Covered Internal Floating Roof Tanks

Tanks with internal floaters that may sink must be protected for full tank top involvement. Where an internal floating roof could sink, do not use subsurface foam injection. Only a system employing foam chambers just below the fixed roof is acceptable.

When a steel double deck or pontoon deck is used, protect the tank for a seal-type fire with protection provided above the seal. Many of the new unsinkable floaters are constructed of closed-cell honeycomb expanded metal in full contact with the liquid surface. This type of floater could eliminate many potential fires and is thus highly recommended. Protect the tank for a seal-type fire with protection provided above the seal.

## Medium- and High-Expansion Systems

### General

By definition medium-expansion foam is one that expands 20 to 200 times when agitated with air. High-expansion foam is one that expands 200 to 1000 times when agitated with air. In practice, the solution for high-expansion foam systems normally expands between 750 to 1000 times.

$$Expansion\ ratio = \frac{Foam\ Generated}{Foam\ Solution\ Used}$$

High-expansion foam is usually formed by blowing air through a solution-wetted netting or wire mesh. Air-aspirated foam generators are also used; however, the resulting expansion ratio is usually within the range of medium-expansion foam.

When protecting hazards within buildings, foam systems should be used in combination with sprinkler protection meeting the requirement of NFPA 13 and PRC.12.1.1.0. In addition to adding reliability, the sprinkler system also provides required protection of the roof from hot gasses prior to complete submergence of the protected volume by foam.

Flammable and combustible liquid fires are extinguished by a combination of cooling, smothering, oxygen dilution, and by retarding the release of flammable vapors. As the heat of the fire destroys the foam front it is converted to steam. The presence of steam dilutes the oxygen content.

Foam will not extinguish flowing or falling liquid. Heated air or vapors can support the foam. Medium- and high-expansion foam concentrate is not recommended for use on polar solvents.

When applied to Class A materials, the extinguishing mechanisms are smothering, oxygen dilution by the generation of steam, cooling quenching, and the insulating quality of the foam. The foam cools only the surfaces, which it comes in contact with, and it inhibits ignition of nearby combustible materials by insulating the void space and limiting the propagation of radiant heat.

Foam is not effective on fuels with their own oxygen supply

The following items should also be considered:

- Because of the light weight of high expansion foam, outdoor use is impractical in most cases.
- High expansion foam must be used in a volume confined by walls.
- Foam should not be used on water reactive materials or energized electrical equipment.
- Foam generation rate decreases logarithmically as inlet temperature increases; therefore, cool clean air should be drawn from a source outside the fire area.
- High expansion foam has been found to be effective on rolled paper and flammable liquid storage and mixing rooms.
- High expansion foam should not be used where contamination, collapse by wetting, or repackaging may be a problem.

#### Types Of Systems

These foam systems can be the total flooding, local application or spot protection, or portable type.

Electricity, water, or air can power the foam generator’s blower systems. To ensure proper operation during an emergency, the source of power must be reliable and must remain in service during a hostile fire. Electric power requirements should follow the same precepts as fire pump power supplies. (See NFPA 20 and PRC.14.2.1.) In addition, use Mineral Insulated Metal Sheathed cable for wiring to generators located in the fire area.

Compressed air operated equipment may also indirectly depend on electricity and is subject to the same requirements as the electrically operated generators.

Water operated units are inherently more reliable, but they deplete the water pressure which could be important in systems with marginal water supplies.

#### Personnel Safety

Deaths have occurred when using and testing high expansion foam. A certain degree of risk is present when entering an area immersed in foam. This hazard is compounded by the presence of fire.

Never enter an area filled with foam, unless adequate precautions are taken, such as wearing a self-contained breathing unit and using a lifeline.

### Acceptance Testing

Foam systems are rather complex. It is important that operating and maintenance instructions, piping and electrical schematics be readily available at the control equipment. Since 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. See PRC.13.0.4, PRC.13.0.5 and PRC.13.0.5.A regarding acceptance of extinguishing systems.

## DISCUSSION

### Types of Foam

Protein foam is produced from complex nitrogen compounds derived from natural vegetable or animal sources. Fluoroprotein foam is similar to protein foam except that it contains fluorinated surface-active agents (surfactants). These surfactants give this foam its “oleophobicity” or fuel shedding ability. Fluoroprotein foam is excellent for subsurface injection and is compatible with the simultaneous application of dry chemical extinguishing agents.

AFFF (Aqueous Film Forming Foam) contains the same fluorocarbons found in fluoroprotein foam. It forms an aqueous film that quickly flows across the surface of the liquid. AFFF is excellent for crash rescue and petroleum spills. The concentrate has a shelf life in excess of 20 yr. AFFF may be used simultaneously with dry chemical. Disadvantages are that AFFF drains quickly and does not have good burnback resistance.

FFFP (Fluorinated Film Forming Protein Foam) is fairly new to the market. It is presently being used in extinguishing applications as a substitute for AFFF.

Polar solvents are water-miscible and contain nitrogen, oxygen or sulfur compounds. Some common polar solvents include alcohol, lacquer thinner, MEK and acetone. These solvents deteriorate ordinary foam by absorbing water from the foam bubble. Polar-solvent compatible AFFFs, which form a polymeric layer under the aqueous film that protects the film and foam from degradation, are becoming the leading polar solvent concentrates.

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Foam concentrates are usually designated by the recommended percentage of concentrate in the foam solution after proportioning. Some concentrates today have dual concentrate ratings, such as $3 \times 3$ or $3 \times 6$. The first rating is the percent concentrate recommended for hydrocarbon fuels and the second rating is the percent concentrate recommended for polar solvents.

Compressed Air Foam is a combination of two technologies. The proportioning system injects a small percentage of Class A foam concentrate into a water stream and uses compressed air to produce an expanded volume of extinguishing agent. Proportioning rates vary from .1% with an air to foam solution ratio of 8:1 to 1% with an air foam solution ratio of 44:1.

## Environmental Concern

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 (USEPA) National Response Center.

Though reporting is no longer necessary, many large foam users continue to limit their use of foams for environmentally related reasons. New “environmentally responsible” foam concentrates are currently being marketed. These new concentrates give users an alternative.

Another concern has always been the disposal of the foam solution and concentrates. Users must ensure that large amounts of these materials do not enter ground water and surface water. Avoid discharging the materials directly to storm sewers, because most sewers discharge to rivers, streams or ponds. Holding ponds can be effective in collecting runoff and storing it until the runoff can be properly processed.

A problem arises when concentrate or solution arrives at wastewater treatment facilities. When the waste water is aerated, if there is a sufficient concentration of foam solution, foam will form on the surface and may deprive microbes of necessary oxygen. This is not usually a problem in large systems with ample dilution. In small systems, the manufacturer’s guidelines for dilution must be strictly followed. Where there is concern, an anti-foaming agent can be added to the disposed foam solution before it enters the waste treatment system.