Technical Article

High Expansion Foam Systems

Martin Workman
Viking Product Manager

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INTRODUCTION

High Expansion foam systems are installed in many different hazards; high piled storage, liquefied natural gas, dike or bund protection, aircraft hangars, etc.

What is a high expansion foam system? A high expansion foam system is a foam deluge system that delivers the foam solution, (foam concentrate and water mixture), to a discharge device known as a high expansion foam generator.

Figure 1: Foam Deluge Riser – Photo Courtesy of S&L Mechanical

Most commercially available foam generators are water powered fans that force or "blow" the foam solution against a screen which results in a finished foam blanket that expands into a large fluffy cloud of foam bubbles. If you ever blew bubbles as a child, you submerged the circular ring dipping wand into a soapy solution, as you blew air through the circular end of the wand where the soapy film clung to, large bubbles would result on the discharge side of the dipping wand. High expansion foam generators work in essentially the same way, with the obvious exception being that the quantity of the soapy solution is greater, more air is provided, and the screen has thousands of more holes than the dipping wand.

Figure 2: High Expansion Foam Generators – Photo Courtesy of Chemguard

High expansion foam generators are “open discharge” devices, meaning there is not a fusible link, like in an automatic sprinkler head. The piping supplying the foam generator is empty, until a deluge valve is activated. When the deluge valve is activated, water passes through the riser past a proportioning device, which is located in line with the sprinkler piping. The proportioning device is where the foam concentrate is introduced into the water stream to form a foam solution. Foam solution leaves the proportioning device and travels down the empty piping until it enters the foam generator. Think of the foam generator as a water motor alarm, the foam solution pushes the fan in a circular motion, the foam solution discharges through a nozzle or series of nozzles, (depending upon the manufacturer), and the air current provided by the fan pushes or forces the foam solution against a screen, which in turn creates the large bubbles. I made the comparison to the water motor alarm, as they operate in a similar fashion and they both need to have strainers installed on the supply piping prior to connecting to the devices. Some manufacturers include this strainer, others do not, but in all cases, consult the manufacturer for the correct strainer, as the strainer mesh will vary depending upon the integral discharge nozzle(s) orifices of the foam generator.

High Expansion Foam Systems

SYSTEM DESIGN

We normally think of sprinkler systems in two dimensional terms, we look down from the ceiling on our drawings in the plan view, our system design water flow rate is generally referred to in terms density, which is gallons per minute per square foot.

High expansion foam system design is a three dimensional thought process. NFPA utilizes a foam submergence volume as a rate of application. Most designs are based upon 3 cubic feet per square foot per minute. High expansion foam fills a space with a puffy foam blanket. Care should be taken to note where wall openings may occur. If doors are present, they must be self closing doors as the effectiveness of the high expansion foam is based on the foam blanket staying in the hazard. If wall openings are present and un-avoidable, additional high expansion foam must be provided to account for the “leakage” of the medium from the hazard area.

Figure 3: High Expansion Foam Discharge – Photo Courtesy of Chemguard

A handful of NFPA standards discuss the use of high expansion foam as a protection option. Chapter 6 of NFPA 11, The Standard for Low, Medium, and High Expansion Foam lays out the basic guidelines for the installation of a high expansion foam system. Early in the chapter it explains what hazards it can be used for and what hazards it cannot be used for. High expansion foam can be used for ordinary combustibles (Class A Fires), Flammable and Combustible Liquids (Class B Fires), and a mixture of Class A materials and Class B materials, and liquefied natural gas. Caution should be exercised when protecting combustible and flammable liquids, if the liquid is miscible, contact the high expansion foam manufacturer to determine if their high expansion foam is suitable for the miscible liquid. High expansion foam shouldn't be used where there are water reactive materials or metals, chemicals that release sufficient oxygen to sustain combustion, or liquefied flammable gas.

NFPA 11 also discusses personnel safety in the use of high expansion foam. Once the system activates, the area fills with a foam blanket, if personnel are located in the hazard at the time, they are essentially blinded by the foam blanket. Adequate pre-operation alarms must be present to prevent someone from being trapped in the hazard area. If you are to enter a space where a high expansion foam discharge has occurred, you are to use a hose stream to break down the foam or to cut your way through the foam. Generally a fire hose with a fog nozzle will do the job. One should never enter a high expansion foam blanket without some sort of life line and a breathing apparatus, the best way to enter a high expansion discharge is cutting your way through it with a hose stream.

NFPA also provides guidance regarding how deep the high expansion foam has to build to. The depth requirement is as follows: 1.1 times higher than the highest hazard but in no case less than 2 ft. over the hazard. A general question of how fast does the high expansion foam have to fill the space depends upon if the hazard has a sprinkler system or not and how the building is constructed. As an example, rubber tires have a maximum submergence rate of 7 minutes in a sprinklered building of light or un-protected steel construction. The same hazard in a sprinkler building with heavy or fire resistive construction has a maximum submergence of 8 minutes. If the same hazards are not sprinklered, the foam has to fill approximately 30 percent faster.

Figure 4

NFPA 11 makes an allowance for the submergence time to be timed 30 seconds after the automatic detection has activated the system, meaning high expansion foam must be discharging from the generators within 30 seconds of system activation. If a delay longer than 30 seconds occurs, some sort of system design change must occur. The most likely cause of foam not discharging from the high expansion foam generators in 30 seconds is transit time from the deluge valve to the generator or that adequately proportioned foam solution is not provided to the generator. In the case of transit time being too great, you try to shorten your distance to the generators, which may mean changing the supply piping to the generators. In the case of the proportioning not being correct for the foam solution, there are a variety of cause and effects, such as the wrong proportioning method chosen, foam concentrate not being present at the proportioning device at the same time the water is passing through it, foam concentrate supply piping has excess fittings, not enough straight piping on the supply or discharge of the proportioning device.

SYSTEM COMMISSIONING

A high expansion foam commissioning test is an event. The only way to prove that the system is designed and installed correctly is to activate the system. In the past 7 years, high expansion foam has grown in the protection of aircraft hangars. The largest single reason is that it will generally have a lower water requirement over other protection methods. For an example, we'll use a 50,000 sq. ft. Group 1 hangar that will not house aircraft with wing projections over 3000 sq. ft., you have (3) protection options:

1. Low expansion foam deluge systems at the ceiling
2. Low expansion foam system at the floor and over head sprinklers
3. High Expansion foam system covering the floor and overhead sprinklers

Option 1 will require a .16 gpm per sq. ft. (6.51 lpm per sq. m) of low expansion foam designed over the entire ceiling, having a minimum demand of 8,000 gpm (30,283 lpm). Option 2 would require a .10 gpm per sq. ft. (4.07 lpm per sq. m) of low expansion foam over the floor area and a design of .17 gpm per sq. ft. over 15,000 sq. ft. (6.92 lpm per sq. m over 4,572 sq. m) for water sprinklers at the ceiling, requiring a minimum water flow demand of 7,550 gpm (28,580 lpm). Option 3 would require a design of 3 cubic ft per square ft over the hangar floor and a design of .17 gpm per sq. ft. over 15,000 sq. ft. (6.92 lpm per sq. m over 4,572 sq. m) for water sprinklers at the ceiling, for a minimum water flow requirement of 5,550 gpm (20,820 lpm).

When you discharge a high expansion foam system in a hangar, you will generally operate the system for (4) minutes, the first minute is to ensure that you cover the floor and the additional (3) minutes are generally needed to ensure you have submergence. Once you have the hangar full of soapy bubbles, what do you do with it? One thing you don't want to do is just open the doors, otherwise you'll have big clouds of soapy bubbles blowing across the airport and disrupting take-off and landings. Prior to activating the system, ensure that you have some hose lines with fog nozzles to spray down the foam to break it down. Once you hit high expansion foam with water spray it readily breaks down and will go down the drain.

CONCLUSION

High expansion foam systems have been in use for many years and are gaining popularity for a variety of protection schemes. The equipment is specialized and the protection schemes are different than standard sprinkler protection. Before quoting, designing, or installing a high expansion foam system, one should consult the NFPA standard that governs the design and installation for the hazard and probably speak with a manufacturer/provider of the equipment for further guidance. Each manufacturer has specific high expansion foam concentrate that is tied to their high expansion foam generator's performance, and the manufacturer will generally lead a contractor through the steps required to install their equipment correctly.

High Expansion Foam Systems

High Expansion Foam Concentrate and water are mixed in the correct proportion by various methods to form a foam solution. This solution flows to the High Expansion Foam Generator (HEFG) with a water powered motor. It is then discharged through a nozzle onto a fine mesh stainless steel screen. A rotating fan (powered by the water motor) in the generator forces large volumes of air through the stainless steel screen as the foam solution is sprayed onto it. The air mixes with the foam solution to form a large discharging mass of stable bubbles at a rate of up to 940 gallons of expanded foam for each gallon of foam solution. This clean highly expanded foam mass quickly fills large areas flowing around obstacles and flooding every void smothering the fire quickly and effectively.

The output of a Chemguard High Expansion Foam Generator (HEFG) in a fixed installation depends on which generator is selected. These generators are available in a wide output range (in cubic feet per minute) at various foam solution inlet pressures. When multiple units are used an almost limitless output can be achieved. The HEFS is suitable for use for fire extinction of solid fuel or flammable liquid fires in areas where the expanded foam can be contained.

Examples:

- Ship holds
- Aircraft hangars
- Hazardous material/waste storage areas
- Flammable liquid packaging areas
- Flammable liquid drum storage
- Warehouse areas such as: Rolled paper, tire storage, in rack storage of combustible materials and boat storage

High Expansion Foam Systems have been installed as added protection for Liquid Natural Gas (LNG) facilities where it is used as a fire suppressant and for controlling vapors released from an accidental LNG spill. Blanketing spills with High Expansion Foam is an effective method for reducing and controlling fire intensity and decreasing LNG vapor generation.

METHOD OF EXTINGUISHMENT

When the High Expansion Foam is discharged into a fire compartment, three extinguishing mechanisms simultaneously occur:

1. The large mass of the discharging foam fills all voids and seals the area involved in the fire and prevents fresh air from reaching the base of the flames. The foam mass maintains an oxygen deficient area until the fire is extinguished.

2. The steam generated is a result of the radiant heat from the fire evaporating the water in the foam blanket. This conversion to steam absorbs large quantities of heat and the resulting steam-air mixture is well below the oxygen level that is required to support continued combustion.

3. The cooling effect of the Hi-Ex foam occurs as the bubbles break and release water onto any hot surfaces. The surface tension of the draining water is lowered and the cooling and wetting effect of the draining water penetrates any Class “A” type materials more rapidly than water. This cools the burning material to below its ignition temperature.

INSTALLATION

The High Expansion Foam System (HEFS) must be designed and installed in strict accordance with NFPA 11 (2002 or later) Standard for Low-, Medium-, and High Expansion Foam and any guidelines established by the "Authority Having Jurisdiction" or Insurance Provider.

Chemguard recommends a contractor having previous experience in installing fixed fire protection foam systems install the HEFS. Upon installation, the HEFS components should be located and arranged so that any recharging, inspection, testing or general maintenance will cause a minimum disruption to the fire protection system. The HEFG may be installed in either a vertical or a horizontal position.

When mounting a generator in a fixed location, care should be taken so as not to distort the cylinder section of the generator housing as this could interfere with the rotation of the fan/motor assembly. The generator should be supported from the bottom not the top and both the front and the rear. It is imperative that the generator be firmly braced to ensure there is no flex or movement when the system is in operation.

PIPING MATERIALS

Stainless steel 304, 316, brass, galvanized and black steel pipe are suitable for use with foam solutions. The black steel pipe is only recommended for use with foam concentrates when the pipe is kept flooded at all times. Stainless steel pipe is suitable for use with foam concentrates at all times. Galvanized pipe cannot be used with foam concentrate.

It is recommended that where threaded pipe joints are in contact with the foam concentrate or the foam solution, a quality Teflon™ based pipe joining compound and a quality Teflon™ tape in accordance with MIL- T-27730 are both used to ensure leak tight screw fittings.

DESIGN INFORMATION

For Aircraft Hangars please see the red tab “AIRCRAFT HANGARS” in this manual.

TOTAL FLOODING SYSTEM is a fixed foam fire protection system consisting of the High Expansion Foam Generators, proportioning system, foam concentrate, water supply and necessary interconnecting piping. This type system is designed to discharge the expanded foam into an enclosed space or around the hazard. The total flood system is suitable for use where there is a permanent enclosure around the hazard that is capable of holding the required amount of foam for the designed duration.

For adequate protection, there should be sufficient foam concentrate to allow the system a discharge rate sufficient to cover the hazard to an effective depth before any unacceptable damage occurs.

The minimum total depth of foam is to be not less than 1.1 times the height of the highest hazard being protected but in no case can it be less than 2 ft. above that hazard. Submergence time varies with the type of building construction and if the building has a sprinkler system.

Figure 25: provides maximum submergence times in minutes for high expansion foam measured from the start of foam discharge. The chart does not include submergence times when used on water miscible/polar solvent type fuels or flammable liquids having a boiling point less than 100ºF (38ºC). These products may require higher application rates. Please check with the engineering department at Chemguard for application guidelines. When used in tire storage areas, the submergence time shown reflects the area also having sprinkler protection. When certain combustible products are stored 15 feet or higher, fire spread may still be rapid and the discharge times in the submergence chart may not be suitable. A faster submergence time may be more appropriate.

The foam discharge rate is to be sufficient to satisfy the foam depth requirements and submergence times allowing compensation for normal foam shrinkage, foam leakage and breakdown effects of any sprinkler discharge.

The factor for compensation for normal foam shrinkage is 1.15.

The compensation factor for loss of foam due to leakage around doors, windows and through unclosable openings is determined by the design engineer after proper evaluation of the structure. This factor cannot be less than 1.0. Depending on foam expansion ratio, sprinkler operation and foam depth, this factor may be as high as 1.2 for a building with all openings normally closed.

The factor (Rs) for compensation of breakdown by sprinkler discharge is determined by the following formula or by test:

R_S= S X Q where

S = Foam breakdown in cfm per gpm of sprinkler discharge. S is to be 10 cfm/gpm (0.748 cu. M/minutes/L/minutes)

Q= Estimated total discharge from maximum number of sprinklers expected to operate gpm (L/minutes)

The following is the formula for calculating the minimum rate of foam discharge or total generator capacity allowing for compensation of normal foam shrinkage, foam leakage and breakdown effects of sprinkler discharge:

Formula for Calculating

R	$(V/T + R_S) \times C_N \times C_L$ where:
R	Rate of discharge in m^3/min (ft^3 / min)
V	Submergence volume in m^3 (ft^3)
T	Submergence time in minutes
R_S	Rate of foam breakdown by sprinklers in m^3/ min (ft^3/min)
C_N	Compensation for normal foam shrinkage
C_L	Compensation for leakage

All openings such as doorways, windows, etc. below the design filling depth shall close automatically before or during foam discharge when the system is activated.

DISCHARGE DURATION: There shall be sufficient high expansion foam concentrate and water to allow continuous operation of the system at the design density for 25 minutes or to generate 4 times the submergence volume, whichever is less, but in no case less than enough for a 15 minute discharge.

Following is a typical High Expansion Foam System for a building without a sprinkler system:

Building: Light Steel, No Sprinklers

Size: 100 ft. x 30 ft. x 10 ft.

Products Stored: Low density combustibles 7 ft. in height

Cubic area to be protected: 100 x 30 x 9, 2 ft. above height of combustibles=27,000 cu. ft.

Fill Time: Per NFPA 11, 3 minutes

Formula for system without sprinklers

R = (V/T) x Cn x Cl

V = 27,000 cubic feet

T = 3 minutes

Cn = 1.15

Cl = 1.1 (slight leakage)

R = (9,000) x 1.15 x 1.1 = 11,385 cfm

11,385 cfm is required for the above building.

EQUIPMENT LIST

1 x High Expansion Foam Generator 12,000 CFM / 59 psi /170 gpm

1 x 3" Between flange style, Ratio controller, Flow range 70 – 750 gpm

1 x 50 Gallon Vertical Bladder Tank
(170 gpm x 0.02 - 3.4 gpm of 2% High-X Foam x 15 minutes = 51 gallons of foam concentrate)

55 x Gallons High-X Foam Concentrate
(51 gallons system fill, 4 gallons system test)

Plus miscellaneous swing checks and ball valves

LOCAL APPLICATION SYSTEM

This type of system consists of a fixed foam-generating device complete with the necessary piping and foam concentrate proportioning equipment. The system is designed to protect a specific piece of equipment or discharge directly onto a potential hazard area. Local application systems can be used to protect hazards located indoors, outdoors or in partly sheltered areas. When used outdoors or in partly sheltered areas, provisions should be made to compensate for the effects of wind or other climatic conditions.

FIG. 25

MAXIMUM SUBMERGENCE TIME (MINUTES) FOR HIGH EXPANSION FOAM MEASURED FROM START OF ACTUAL FOAM DISCHARGE

Hazard	Light or Unprotected Steel Construction		Heavy or Protected or Fire-Resistive Construction	
	Sprinklered	Not Sprinklered	Sprinklered	Not Sprinklered
Flammable liquids [flash points below 38ºC(100ºF)] having a vapor pressure not exceeding 276 kPa (40 psia)	3	2	5	3
Combustible liquids [flash points of 38ºC (100ºF) and above][a]	4	3	5	3
Low-density combustibles (i.e., foam rubber, foam plastics, rolled tissue, or crepe paper)	4	3[b]	6	4[b]
High-density combustibles (i.e., rolled paper kraft or coated banded)	7	5[b]	8	6[b]
High-density combustibles (i.e., rolled paper kraft or coated unbanded	5	4[b]	6	5[b]
Rubber tires	7	5[b]	8	6[b]
Combustibles in cartons, bags, fiber drums	7	5[b]	8	6[b]

[a]Polar solvents are not included in this table. Flammable liquids having boiling points less than 38ºC (100ºF) might require higher application rates. See NFPA 30.

[b]These submergence times might not be directly applicable to storage piled above 4.6m (15ft) or where fire spread through combustible contents is very rapid.