Participant Guide Module

6

Fire Fighting Foam Principles

Module Objective

Upon the completion of this module, participants should be able to develop firefighting strategies and foam-use tactics for controlling and fighting fires associated with flammable liquid hazards of ethanol and ethanol-blended fuels.

Enabling Objectives

1. Describe the manner in which foam applications can be used to fight fuel fires.
2. List the ways in which foam applications suppress fire.
3. Predict when to fight fuel fires and when to simply protect surrounding areas.
4. State the generally accepted "rule of thumb" for the use of foam applications on ethanol and ethanol-blended fuel fires.

Introduction

As discussed previously, we have seen a tremendous growth of the ethanol industry and it will continue to expand. As always, emergency responders should be ready for emergencies associated with flammable liquids. Ethanol and ethanol-blended fuels are similar to other flammable liquids and their hazards. The predominate danger from ethanol emergencies is not from incidents involving cars and trucks running on ethanol-blended fuel, but instead from cargo tank trucks and rail tank cars carrying large amounts of ethanol, manufacturing facilities, and storage facilities. Responders need to anticipate large-scale emergencies and where appropriate engage in operational activities using the most effective techniques and extinguishing media. This module will focus on foam basics and then foam applied specifically to ethanol-related emergencies.

In this program it is recommend to us AR-AFFF where inventories still exist and current inventories of AR-SFFF foam. Please note that fire protection foams have changed composition in recent year due to health and environmental effects of the older fluorinated foams. A new formulation know as Fluorine Free Foams is now being manufactured and has become the mandated standard in most localities.

It is recommended that you consult the safety data sheet (SDS) for your current foam supply and use caution if using older foams. For more information on per and polyfluoroaklyl substance (PFAS) or perfluoroctane acid (PFOA) please visit https://www.epa.gov/pfas.

Basic Foam Principles

Most of the following section (from Basic Foam Principles through Rain-Down) is property of the Texas Engineering Extension Service (TEEX).

What is Foam?

To understand the basic foam principles, we must first understand - **What is Foam**?
As defined in National Fire Protection Association (NFPA 11 version 2024), low-expansion foam is: "…an aggregate of air-filled bubbles formed from aqueous solutions which are lower in density than flammable liquids. It is used principally to form a cohesive floating blanket on flammable and combustible liquids and prevents or extinguishes fire by excluding air and cooling the fuel. It also prevents re-ignition by suppressing formation of flammable vapors. It has the property of adhering to surfaces, which provides a degree of exposure protection from adjacent fires."

What is Foam Concentrate?
"…a concentrated liquid foaming agent as received from the manufacturer." (NFPA 11 version 2024)

What is Alcohol Resistant Foam Concentrate?
"…a concentrate used for fighting fires on water soluble materials and other fuels destructive to regular….foams." (NFPA 11 version 2024)

What is the definition of a Synthetic Fluorine Free Foam?
As a Class B foam concentrate that contains no intentionally added fluorinated surfactants (PFAS) and relies entirely on synthetic, non-fluorinated surfactants to achieve fuel-separating and vapor-suppressing performance (NFPA 11 version 2024).

Why Use Foam?

Ethanol will continue to burn at five parts water to one-part ethanol (5:1 ratio/500% dilution). Many extinguishing agents are effective on flammable liquids. However, foam is the only agent capable of suppressing vapors and providing visible proof of security. Reasons to use foam include:

- Foam can provide protection from flammable liquids for fire and rescue personnel during emergency operations when properly applied and maintained.
- A foam blanket on an unignited spill can prevent a fire.
- The suppression of vapors prevents them from finding an ignition source.
- Foam can provide post-fire security by protecting the hazard until it can be secured or removed.

How Foam Works

Foam can control and extinguish flammable liquid fires in a number of ways. Foam can:

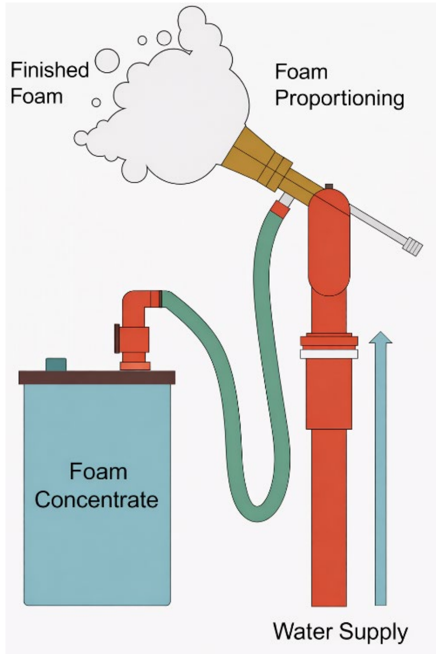
- Exclude oxygen from the fuel vapors and thus prevent a flammable mixture
- Cool the fuel surface with the water content of the foam
- Prevent the release of flammable vapors from the fuel surface
- Emulsify hydrocarbon fuels only, mixes fuel into tiny droplets to reduce flammability (some environmental foams, not effective on ethanol or ethanol-blended fuels)

Foam Tetrahedron

Foams used today are primarily of the mechanical type. This means that before being used, they must be proportioned (mixed with water) and aerated (mixed with air).

Four elements are necessary to produce a quality foam blanket. These elements include:

- Foam concentrate (ex: AR-AFFF or AR-SFFF)
- Water
- Air
- Aeration (mechanical agitation)



All of these elements must be combined properly to produce a quality finished foam blanket. If any of these elements are missing or are not properly proportioned, the result is a poor-quality foam or no foam at all.

What is Foam Not Effective On?

Foam is not effective on all types of fires. Therefore, it is important to know the type of fire and the fuel involved in every incident. Foam is not effective on:

- Class C (electrical) fires
- Three-dimensional fires
- Pressurized gases
- Class D (combustible metal) fires

Foam is Not Effective on Class C Electrical Fires

Class C fires involve energized electrical equipment; water conducts electricity. Since foam contains 94-99% water, it is not safe for use on this type of fire. In some cases, foam concentrate is even more conductive than water. Class C fires can be extinguished using nonconductive extinguishing agents such as a dry chemical, carbon dioxide ($CO2$), or halon. The safest procedure for this type of situation is to de-energize the equipment if possible and treat it as a Class A (ordinary combustible material) or Class B (flammable/ combustible liquids) fire.

Foam is Not Effective on Three-Dimensional Fires

A three-dimensional fire is a liquid-fuel fire in which the fuel is being discharged from an elevated or pressurized source, creating a pool of fuel on a lower surface. Foam is not effective at controlling three-dimensional flowing fires. It is recommended that firefighters control a three-dimensional flowing fire by first controlling the spill fire; then they may extinguish the flowing fire using a dry chemical agent.

Foam is Not Effective on Pressurized Gases

Foam is not effective on fires involving pressurized gases. These materials are usually stored as liquids but are normally vapor at ambient temperature. The vapor pressure of these types of fuels is too high for foam to be effective. To be effective, foam must set up as a two-dimensional blanket on top of a pooled liquid. Examples of pressurized gases include:

- Acetylene
- Butane
- Liquefied Petroleum Gas (LPG)
- Propane
- Vinyl chloride

Foam is Not Effective on Combustible Metals

Class D fires involve combustible metals such as aluminum, magnesium, titanium, sodium, and potassium. Combustible metals usually react with water; therefore, foam is not an effective extinguishing agent. Fires involving combustible metals require specialized techniques and extinguishing agents that have been developed to deal with these types of fires. A Class D extinguisher or a Class D powder is the recommended choice for fires involving combustible metals.

What is Foam Effective On?

Foam is effective at suppressing vapors and extinguishing Class B fires. Class B fires are defined as fires involving flammable or combustible liquids. For the purposes of this discussion, Class B products are divided into two categories: hydrocarbons and polar solvents.

Hydrocarbons

Most hydrocarbons are byproducts of crude oil or have been extracted from vegetable fiber. Hydrocarbons for liquid fuels have a specific gravity of less than 1.0 and therefore float on water. Examples of these include:

- Gasoline
- Diesel
- Jet propellant (JP4)
- Heptane
- Kerosene
- Naphtha

Polar Solvents

Polar solvent fuels will mix with water with varying degrees of attraction for the water. For example, acetone has a stronger affinity for water than does rubbing alcohol. Polar solvent fuels are usually destructive to foams designed for use on hydrocarbons. Specially formulated foams have been developed for use on polar solvents. Some examples of polar solvent fuels include:

- Ketones
- Esters
- Alcohol including ethyl-alcohol (ethanol)

- Amine
- Methyl tertiary-butyl ether (MTBE)
- Acetone

NEVER mix foam concentrates from different manufacturers. These concentrates are proprietary blends and may counteract each other when mixed in concentrate form. Finished foam (foam concentrate properly proportioned with water and aerated to allow expansion to manufacturer's recommendations) from different manufacturers being deployed into or adjacent to the same location is acceptable.

Foam Terminology

Before discussing the types of foam and the foam making process, it is important to understand the following terms:

- *Foam concentrate* is the liquid substance purchased from a manufacturer in a container, pail, drum, or tote
- *Foam solution* is the mixture obtained when foam concentrate is proportioned (mixed) with water prior to the addition of air
- *Finished foam* is obtained by adding air to foam solution through either entrainment or mechanical agitation

Types of Foam

Several foam types have been developed over the years, each with particular qualities:

- *Protein foam*, one of the earliest foams, is produced by the hydrolysis of protein material such as animal hoof and horn. Stabilizers and inhibitors are added to prevent corrosion, resist bacterial decomposition, and control viscosity.
- *Fluoroprotein foams* are formed by the addition to protein foam of special fluorochemical surfactants that reduce the surface tension of the protein-based concentrate and allow more fluid movement.
- *Aqueous Film-Forming Foam (AFFF)* replaces protein-based foams with synthetic foaming agents added to fluorochemical surfactants. Designed for rapid knockdown, AFFFs sacrifice heat resistance and long-term stability.
- *Film-Forming Fluoroprotein Foam (FFFP)* is a protein-based foam with the more advanced fluorochemical surfactants of AFFF. FFFPs combine the burn back resistance of fluoroprotein foam with the knockdown power of AFFF.
- *Alcohol-Resistant (AR) foam* is a combination of synthetic stabilizers, foaming agents, fluorochemicals, and synthetic polymers designed for use on polar solvents. The chemical makeup of these foams prevents the polar solvents from destroying them. AR foams can be used on both polar solvents and hydrocarbons.
- *Synthetic Fluorine Free Foam (SFFF)* foam concentrate based on a mixture of hydrocarbon surface active agents that is not formulated to contain per- or polyfluoroalkyl substances (PFAS).
- *Alcohol-Resistant Synthetic Fluorine Free Foam (AR-SFFF)* is a fluorine-free foam designed for polar solvent fires that creates a foam blanket that physically separates the

fuel from oxygen. It is used as a PFAS-free alternative to AR-AFFF and can be applied to both polar solvents and hydrocarbon fuels.

Reformulated Class B Foams

Today we are talking about reformulated Class B foams, specifically SFFF and AR-SFFF, and how they differ from legacy AFFF and AR-AFFF. These foams were developed in response to health and environmental concerns tied to PFAS found in older fluorinated foams. As a result, many agencies are transitioning to fluorine-free foam formulations.

Both SFFF and AR-SFFF are Class B firefighting foams and fall under Synthetic Fluorine-Free Foam chemistry. They do not contain fluorinated surfactants or PFAS. Most SFFF and AR-SFFF products are typically proportioned at 3 percent, but this is not universal. Always verify the correct concentrate percentage with the manufacturer. Application rates and expansion requirements can vary significantly between products.

A critical operational difference is that these foams do not form an aqueous film. Without a film, fire control depends on:

- Foam blanket integrity
- Expansion ratio
- Bubble quality and drainage

Vapor suppression is achieved by physical separation of the fuel from oxygen, but not by film or polymeric membrane spread over the surface area of the spill or fire. Because of this, application technique and maintaining the foam blanket are essential.

Despite the lack of a film or membrane, these foams offer several advantages:

- Lower long-term environmental impact
- Good vapor suppression and burnback resistance when applied correctly
- Many products are compatible with both fresh water and sea water, depending on formulation

This represents a fundamental shift from how older fluorinated foams worked and requires changes in training and expectations.

SFFF is intended for hydrocarbon fuel fires only. These include non-polar fuels such as gasoline, diesel, crude oil, and similar products. It should not be used on polar solvents.

Extinguishment is achieved through:

- A stable foam blanket
- Cooling of the fuel surface

There is no aqueous film and no polymer barrier, so foam blanket continuity is critical. Disruption of the foam can quickly lead to vapor release and potential re-ignition.

AR-SFFF is designed for polar solvent fires, such as alcohols and oxygenated fuels, as well as hydrocarbons. This makes it the appropriate choice for incidents involving ethanol and similar fuels. AR-SFFF creates a foam blanket that physically separates the fuel from the oxygen, protects against further fuel attack of the finished foam, and cools the fuel surface to prevent re-ignition. While it does not contain fluorinated surfactants, it is formulated to better withstand polar solvent interaction.

As with all fluorine-free foams:

- Manufacturer listings must be followed
- Application rates and discharge devices may differ from legacy AFFF systems
- System design and flow rates often need re-evaluation during conversion

The key takeaway for responders is that fuel type drives foam selection, and fluorine-free foams require disciplined application to be effective.

Basic Foam Principles - Disclaimer

Fire departments and industrial facilities are encouraged to select foam products that align with NFPA 11 and are independently tested and certified, such as those listed under Underwriters Laboratories (UL) 162 or Factory Mutual (FM) approvals. For products intended for use by the Department of Defense, the foam must meet F3 MIL SPEC (MIL-PRF-32725) requirements. It is absolutely critical that organizations and agencies purchase foam concentrates from reputable manufacturers.

It is important to understand the differences between foams and encapsulating agents, as they are not interchangeable and may have different use limitations and performance characteristics.

NFPA 11 includes SFFF in its definitions and guidance and treats it the same as any other foam concentrate from a system design standpoint. However, NFPA 11 does not currently include standalone performance criteria specific to SFFF in the main design chapters. Because of this, NFPA relies on third-party listings and manufacturer data to establish performance.

NFPA's expectation is clear:

- Use UL 162 listed or FM Approved SFFF products
- Follow manufacturer-specific application rates, discharge devices, and design criteria
- Do not apply legacy AFFF or AR-AFFF design rates unless the SFFF listing allows it

All foam and equipment must be used in accordance with manufacturer instructions. This training makes no guarantees or assumptions regarding the effectiveness of any specific foam or equipment.

As a reminder all foam concentrates have a shelf life and will deteriorate over time. Shelf life can exceed 20 years if the foam concentrates are properly managed and maintained in a suitable storage environment according to manufacturer's requirements.

In addition, to keep the particulates or critical ingredients of the foam in suspension and mixed, a maintenance program must be developed whereby the foam concentrate is re-agitated and rotated periodically. Foam concentrate manufacturers typically require a concentrate sample to be taken and tested on an annual basis to ensure the integrity of their product. Foam delivery systems such as foam tanks & totes cannot be shaken & remixed easily.

Basic Foam Principles

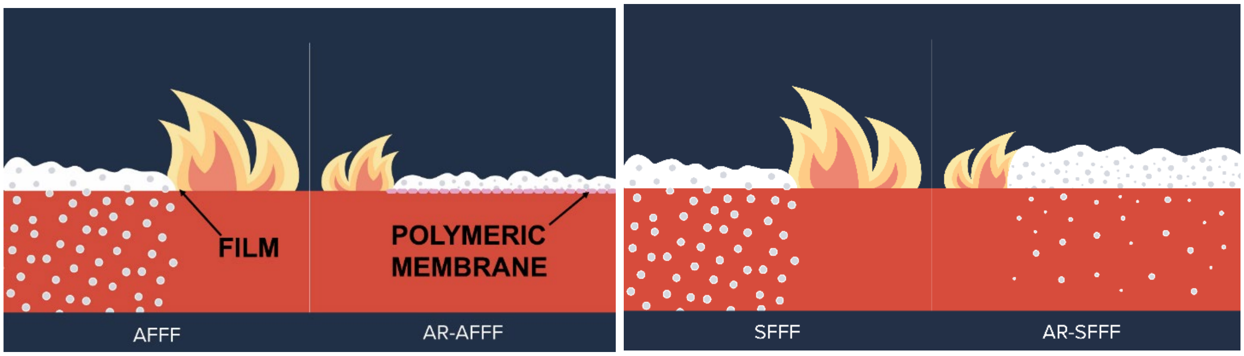
Foam will remove heat at a faster rate than it is released, separate the fuel from the oxidizing agent, dilute the vapor-phase concentration of the fuel and/ or oxidizing agent below that necessary for combustion, and terminate the chemical chain-reaction sequence.

AFFF & SFFF type of foam lowers surface tension, will rapidly spread across the surface, has a high burn back resistance and has quick knockdown.

AFFF & SFFF finished foam when applied or exposed to a water miscible fuel such as ethanol and ethanol-blended fuels is immediately attacked. The ethanol, having a greater affinity for water than the hydrocarbon it may be blended with, will aggressively mix with the water present in the AFFF & SFFF finished foam, effectively collapsing and destroying the foam's capabilities to suppress vapors and/or extinguish a fire. The left side of the both graphics in this slide is visually representing this scenario.

AR-AFFF finished foam includes a polymeric membrane which is released when applied on ethanol and ethanol-blended fuel incidents. The initial application of the AR-AFFF finished foam is attacked and sacrificed by the ethanol as mentioned before, but as additional AR-AFFF finished foam is continuously applied the polymeric membrane develops a layer on the surface of the ethanol or ethanol-blended fuel and becomes impenetrable for further ethanol attack. Continued application of the AR-AFFF finished foam will ultimately establish a satisfactory depth and complete coverage of the spilled or burning ethanol to suppress vapors, cool the fuel, break up the uncontrolled chain reaction of fire and stabilize the incident. All this is possible because the polymeric membrane prevented further destruction of the AR-AFFF finished foam as depicted on the right-hand side of the first graphic on the slide.

AR-SFFF finished foam is denser than SFFF. AR-SFFF is recommended to be applied at a 3% concentration and SFFF is applied at a 1% concentration. The foam performance depends heavily on expansion and bubble quality there is NO FILM to spread like the older AFFF & AR-AFFF foams. The initial application of the AR-SFFF finished foam is attacked and sacrificed by the ethanol as mentioned before. Continued application of the AR-SFFF finished foam will ultimately establish a satisfactory depth and complete coverage of the spill or burning ethanol to suppress vapors, cool the fuel, break up the uncontrolled chain reaction of fire and stabilize the incident. AR-SFFF finished foam is depicted on the right-hand side of the second graphic on the slide.



https://www.youtube.com/watch?v=F_HMe-aOp7A is a video emphasizing the positive attributes of AR-AFFF associated with the graphic in this slide.

Foam Proportioning and Delivery Systems

The effectiveness of foam depends on proper proportioning and the ability to deliver finished foam to the spill or fire.

Concentration Levels

Foams are applied at various concentration levels depending on the fuel involved and the concentrate being used:

- Typically for hydrocarbons, foam is proportioned between 1% - 3% AFFF and SFFF
- For polar solvents, foam is usually proportioned between 1% - 6% AR-AFFF and AR-SFFF

It is recommended that when using foam and equipment that you follow all recommendation and instruction by the manufacturers.

Foam Proportioning Systems

A number of ways exist to proportion foam. These include:

- Line eductors
- Self-educting nozzles
- Pressure systems
- Pump proportioning systems

This section will discuss the most common proportioning systems: line eductors and foam nozzle proportioners (foam nozzles with pickup tubes).

Eductors

Eductors use the Venturi Principle to pull foam into the water stream. The flow of water under pressure and velocity past an orifice or opening creates a vacuum or negative pressure that draws the concentrate through the metering valve. The metering valve controls the amount of concentrate allowed to flow into the water stream. The ball check valve prevents water from flowing back into the pickup tube and the concentrate container. Major elements of the eductor setup include foam concentrate supply, water supply, eductor arrangement, metering valve, pickup tube, and foam solution discharge. Two common types of eductors are in-line eductors and bypass eductors.

In-Line Eductors

In-line eductors are some of the least expensive and simplest pieces of proportioning equipment available (see Figures 6.1 and 6.2 in Participant Guide). For this reason, they are perhaps the most common type of foam proportioner used in the fire service. Some advantages include:

- Low cost
- Minimal maintenance
- Simple operation

Figure 6.1: In-Line Eductor

Figure 6.2: In-Line Indicator

Bypass Eductors

Bypass eductors (see Figures 6.3 and 6.4 in the Participant Guide) differ in that they have a ball valve to divert flow from foam to just water, allowing time for cooling without wasting foam and with less flow restriction.

Figure 6.3: Bypass Eductor

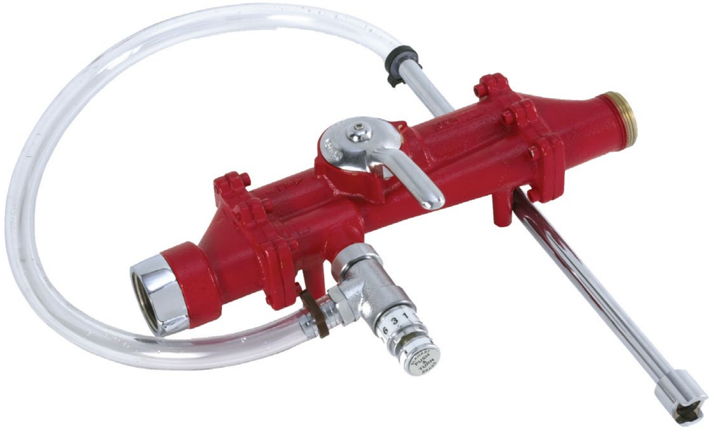
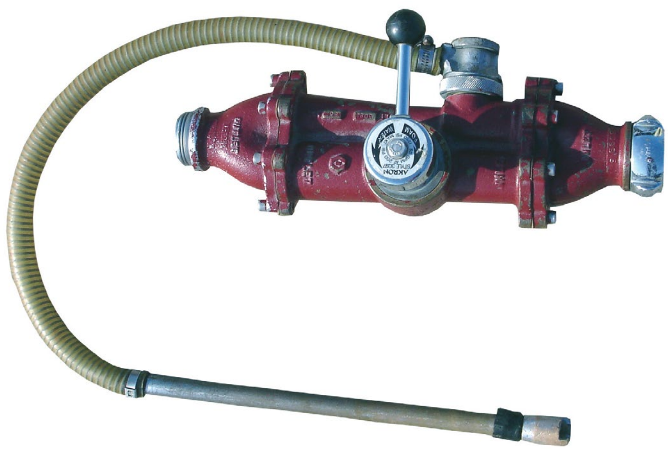


Figure 6.4: Bypass Indicator



Common Eductor Failures

The most common causes for eductor failure include:

- Mismatched eductor and nozzle
- Air leaks in the pickup tube
- Improper flushing after use
- Kinked discharge hoseline
- Improper nozzle elevation
- Too much hose between eductor and nozzle
- Incorrectly set nozzle flow

These may be eliminated by careful preparation, inspection, and use of the eductor, nozzle, and hose. Other eductor failures may be caused by:

- Incorrect inlet pressure to educator
- Partially closed nozzle shutoff
- Collapsed or obstructed pickup tube

- A pickup tube which is too long

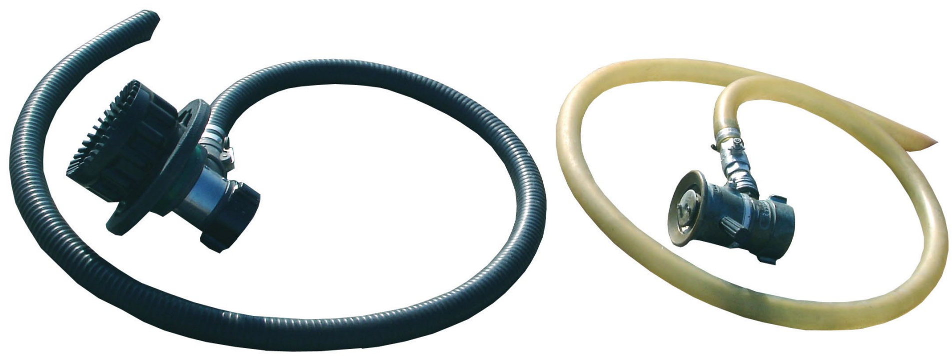
Foam Nozzles

Foam nozzles are either foam proportioning, air aspirating, or non-air aspirating.

Foam Proportioning Nozzles

Foam proportioning nozzles (see Figure 6.5 in the Participant Guide) have built-in orifice plates and utilize the Venturi Principle of operation, producing a very effective foam. These monitor nozzles have the ability to deliver significant volumes of finished foam. Due to the insignificant pressure drop across the eductor, they are able to project foam over long distances.

Figure 6.5: Foam Proportioning Nozzles with Air-Aspirator



Advantages of foam proportioning nozzles include:

- They are easy to operate
- They are easy to clean
- There are no moving parts
- There is no additional foam equipment needed

Hydrant with Foam Nozzle

Some bulk storage and ethanol production facilities have engineered, and professionally designed fire protection systems installed. As depicted by the graphic in this slide, by the flip of a switch in the "foam pump house" or when activated by a detection device this nozzle is automatically provided the appropriate amount of water at the required pressure.

It is incumbent upon emergency responders, facility owners and operators to understand the design, capabilities, and limitations of these specific systems.

In this instance, this may be a self-proportioning master stream foam nozzle that has a foam concentrate pick-up tube directly attached. Note that the coupling on the pick-up tube is specifically designed to be attached to a foam concentrate tote or similar container which has a quick coupling connection.

As part of the pre-planning process, emergency responders, facility owners and operators need to understand the resource needs to support a long-term foam operation for this foam nozzle and all others present at the bulk storage or production facility.

For example, if we assume this nozzle has a flow capacity of 1,000 gallons per minute (gpm) and the AR-SFFF foam concentrate we are using requires a 3% proportioning for ethanol and ethanol-blended fuels, then this nozzle consumes 30 gallons of foam concentrate every minute.

A long-term foam operation could easily last for 2 hours and well beyond. The AR-SFFF foam concentrate needed to support the use of this nozzle just for 2 hours is 3,600 gallons.

Air Aspirating Nozzles

Air aspirating nozzles are foam generating nozzles that mix air and atmospheric pressure with foam solution (see Figure 6.6 in the Participant Guide). These nozzles produce an expansion ratio of between 8:1 and 10:1 and produce a good-quality, low-expansion foam.

Figure 6.6: Air Aspirating Nozzles

Non-Air Aspirating Nozzles

Fog nozzles are an example of non-air aspirating nozzles (see Figure 6.7 in the Participant Guide). Non-air aspirating nozzles produce an expansion ratio of between 3:1 and 5:1. This expansion ratio is not as good as that of air aspirating nozzles, but these nozzles often add some versatility which can be beneficial in various fire attack situations. Versatility includes the ability to switch from a foam solution to water in order to protect personnel and provide area cooling. Air aspirating nozzles do not offer this advantage.

Figure 6.7: Non-Air Aspirating Nozzles

A disadvantage of aspirating and non-air aspirating nozzles is that you must have additional equipment in order to generate foam. In addition, the gallonage setting on the nozzle must match the set flow for the eductor. It is important to understand the benefits of both types of nozzles in order to select the most appropriate one for the specific encounter.

Foam Trailer

The image shown in the PowerPoint presentation (Module 6, slide 20) shows a portable foam trailers may be found at certain fire departments, local facilities for example airports and also stationed at major railroad facilities along principle routes. This specific trailer is equipped with 1,000 gpm self educting foam nozzle, an air aspirated and non –air aspirated nozzles and two totes of AR foam concentrate.

Application Techniques

Proper application is critical for foam. The key to foam application is to apply the foam as gently as possible to minimize agitation of the fuel and creation of additional vapors. The most important thing to remember is to never plunge the foam directly into the fuel.

- ***Bounce-Off* -** The bounce-off method is effective if there is an object in or behind the spill area. The foam stream can be directed at the object, which will break the force of the stream, allowing the foam to gently flow onto the fuel surface.
- ***Bank-In* -** When no obstacles exist to bounce the foam off, firefighters should attempt to roll the foam onto the fire. By hitting the ground in front of the fire, the foam will pile up increasing in depth and as the angle of nozzle in relation to the ground is decreased the velocity and direction of the foam stream will push or roll the blanket of foam into the spill area as firefighters move forward.
- ***Rain-Down* -** An alternative application technique is the rain-down method. The nozzle is elevated and falls over or rained onto the spill as gently as possible. The rain-down is found to be the least effective Type III Application technique because it sacrifices foam integrity, control, and vapor sealing before the foam ever reaches the fuel. It is a fallback option only when bounce-off or bank-in cannot be used due to access or terrain.

Remember! Never plunge a stream of foam directly into fuel!

This is the end of the section that is the property of TEEX.

The images shown in the PowerPoint presentation (Module 6, slide 22) are of actual application methods and approach as explained in the previous slide. The first image shows the Bounce-off method, the second image shows the bank-in or roll-on method and the third image depicts the rain-down method of foam application.

The most important factor to consider when using AR-AFFF and AR-SFFF finished foam on an ethanol or ethanol-blended fuel incident is to apply the foam AS GENTLY AS POSSIBLE to your spill or fire. Proper application choice and technique will minimize AR-AFFF and AR-SFFF finished foam degradation, reduce risk to operational personnel and increase potential for successful management of the incident.

Foam for Ethanol and Ethanol-Fuel Blends

Some of the foams mentioned in the previous sections have been around for over fifty years and have proven to be very effective on hydrocarbon fuels. However, these foams were not developed for application on ethanol or ethanol-blended fuels and are simply ineffective.

This is because the alcohol or ethanol content of the blended fuel literally attacks the foam solution, absorbing the water component of the foam solution into the ethanol and ethanol-blended fuel. The foam performance depends heavily on Expansion and bubble quality there is NO FILM to spread. It is crucial that these AR foams are used in combating ethanol and ethanol-blended fuel fires, including E10. This is an important point.

Additionally, to be effective, these foams must be applied gently to the surface of the alcohol or ethanol-blended fuels.

Extensive testing done at the Ansul Fire Technology Center indicated that even at low-level blends of ethanol with gasoline, such as E10, there is a major effect on foam performance. The testing also indicated that with high-level blends of ethanol with gasoline, even AR foams required careful application methodology and techniques to control fires, suppress vapors, and stabilize the incident.

Using the proper foam and application technique will also reduce the risk to emergency responders and possibly increase the time before re-application of the finished foam is required to maintain incident stabilization.

AR-type foams must be applied to ethanol fires using Type II gentle application techniques. For responding emergency services, this will mean directing the foam stream onto a vertical surface and allowing it to run down onto the fuel. Direct application to the fuel surface will likely be ineffective unless the fuel depth is very shallow (i.e., 0.25 inches or less).

Type III application (fixed and handline nozzle application) is prone to failure in ethanol and ethanol-blended fuels of any substantial depth. The only time it is effective is when it is deflected off surfaces, such as tank walls, to create a gentle style application.

It has also been determined that even with indirect foam application techniques it may require substantial increases in flow rates to accomplish extinguishments.

Therefore, in situations where AR foam cannot be applied indirectly by deflection of the foam off tank walls or other surfaces or there is no built-in application device to provide gentle application, the best option may be to protect surrounding exposures.

Foam Application Rates

Foam application with portable application devices will require higher rates. Application device types whether they are portable or stationary will have operational set points which are fixed operating parameters a foam system or device needs to work as designed.

As with all types of foam, mixing percentage, application rate and flow rate are dependent upon the type and design of the foam concentrate. It is important to refer to the foam manufacturers recommendations.

Ethanol and ethanol-blended fuels require higher flow rate of foam to extinguish fires, suppress vapors and increase emergency responder safety. SFFF-type foams require approximately 1 gallon per minute (gpm) foam solution flow for every 10 square feet of burning surface on a hydrocarbon-type fuel. Ethanol and ethanol-blended fuels require approximately double that flow (2 gpm/ 10 square feet) of an AR-type foam solution.

NFPA 11 has recommended application rates for ethanol and ethanol-blended fuels. However, each foam manufacturer provides guidance on application rates based on testing and their UL162 certifications.

Application Formula

To determine the amount of foam concentrate required, you must find out the type of fuel and the area of involvement. The square footage multiplied by the application rate will give the recommended gallons per minute (gpm). The whole formula will give the concentrate total, this includes the time duration for the attack and percentage rate for the concentrate to be used. As a note, double the amount of foam concentrate on hand prior to initiating fire attack (covers fire attack and maintaining foam blanket following knockdown). Time duration depends on the nature of the incident. Typical times are 60 minutes for tanks and 20 minutes for ground spills for hydrocarbon only based incidents. Ethanol and ethanol-blended fuel type incident duration type stamps could easily be 2 hours or more for bulk storage tanks and 40 minutes or more for ground spills and fires.

*Foam calculations courtesy of Williams Fire and Hazard Control.

Application Rates

Application rates recommended for ethanol spill fires of shallow depth follow NFPA 11. Increasing the foam application rate over the minimum recommendation will generally reduce the time required for extinguishment.

For ethanol and ethanol-blended fuel incidents of any kind, flow times are based on specific manufacturer recommendations as well as the application rate which will be at least doubled.

Application Rates

This chart shows the GPM requirements.

Area (Square Feet)	X	Minimum Application Rate	=	GPM Solution
	X	0.10 Hydrocarbon Liquid Spill/ Fire	=	
	X	0.16 Tank Dia.<150'	=	
	X	0.18 Tank Dia.<200'	=	
	X	0.20 Tank Dia.<250'	=	
	X	**0.20 Polar Solvent Spill/ Fire**	=	

This specific form provides resource need guidance as part of a detailed pre-plan for any flammable/ combustible liquid bulk storage facility, ethanol or hydrocarbon production facility bulk storage and large scale above ground storage tanks at a retail facility.

NOTE that the recommended application rates or densities indicated are for hydrocarbon fuels. The RED highlighted information is a starting point for ethanol and ethanol-blended fuels. Current methodology indicates that greater application rates or densities are required as tank diameter increases.

Emergency response organizations with statutory responsibilities or functional capabilities should work closely with owners and operators of these facilities during pre-plan development. It is highly encouraged to take advantage of fire protection engineers and other nationally recognized private contractors who engage in ethanol and ethanol-blended fuel incidents of scope and magnitude when calculating resource needs to include AR-AFFF and AR-SFFF foam concentrate needs, water supply and specialized foam firefighting equipment.

This chart shows the concentrate requirements.

GPM Solution	X	% of Foam Concentrate	=	Foam Concentrate GPM	X (Time)	Total Concentrate (Gal)
	X		=		30 Min. (Spill/fire) 40 Min. (Bulk Storage Ancillary spill/fire)	
	X		=		120 Min. (Tank Fire)	

Remember that due to the characteristics of ethanol and ethanol-blended fuels, additional foam concentrate needs and increased finished foam flow times may be required or doubled to achieve incident objectives and scene safety.

Total Concentrate (Gallons)	X 2	Incident Foam Needs Prior to Initiating Fire Attack
	X2 (Spill/fire or bulk storage ancillary spill/fire)	
	X2 (Bulk storage tank)	

Incident foam needs rule of thumb is to double the amount of foam concentrate on hand prior to initiating fire attack (covers fire attack and maintaining foam blanket following knockdown).

Spill Calculation

To determine the Spill Calculation:

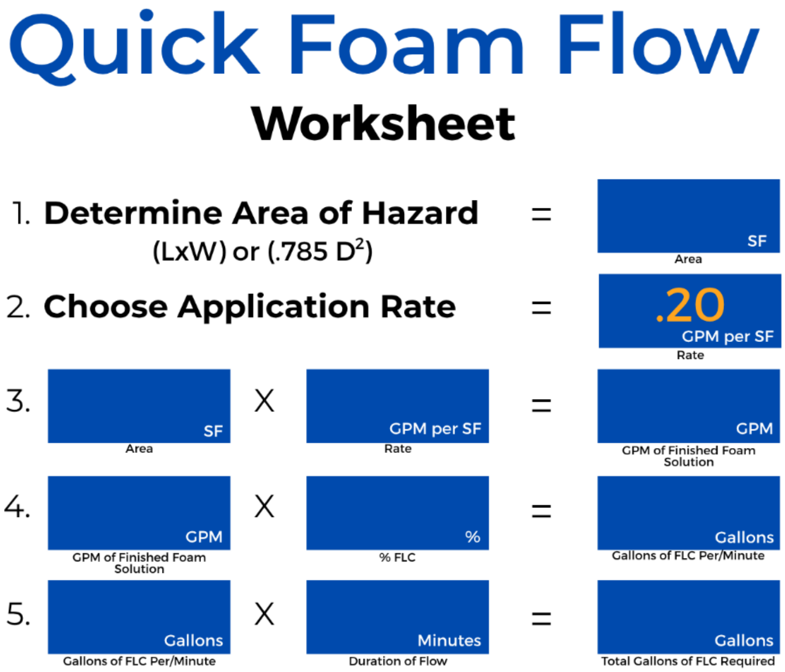
- Determine area of hazard
- Choose appropriate application rate
- Rate x Area = Gallons per minute (GPM) finished foam solution
- GPM of finished foam solution x % foam liquid concentrate (FLC) = Gallons of FLC per minute
- Gallons of FLC per minute x Duration of flow = Total foam liquid concentrate required

Spills involving ethanol or ethanol-blended fuels require a minimum flow time of 30 minutes, with the exact incident flow time determined by the foam manufacturer's recommendations and the type of foam used.

Flow rates will dictate what nozzles or combination of nozzles will be required.

Application rates are provided by manufacturer, application time stamps or flow times are representative of NFPA 11 recommendations. The rule of thumb is that whatever time stamp is recommended for hydrocarbon-based incidents, ethanol and ethanol-blended fuel incidents have a time stamp that is DOUBLED as a minimum for determining resource needs, incident success and long-term incident stabilization.

Application Rates



For ethanol-blended fuel incidents the application time is based on the recommendations from the manufacturer of the foam and the type of foam that will be used. Look at an example of application rates for an ethanol-blended fuel spill.

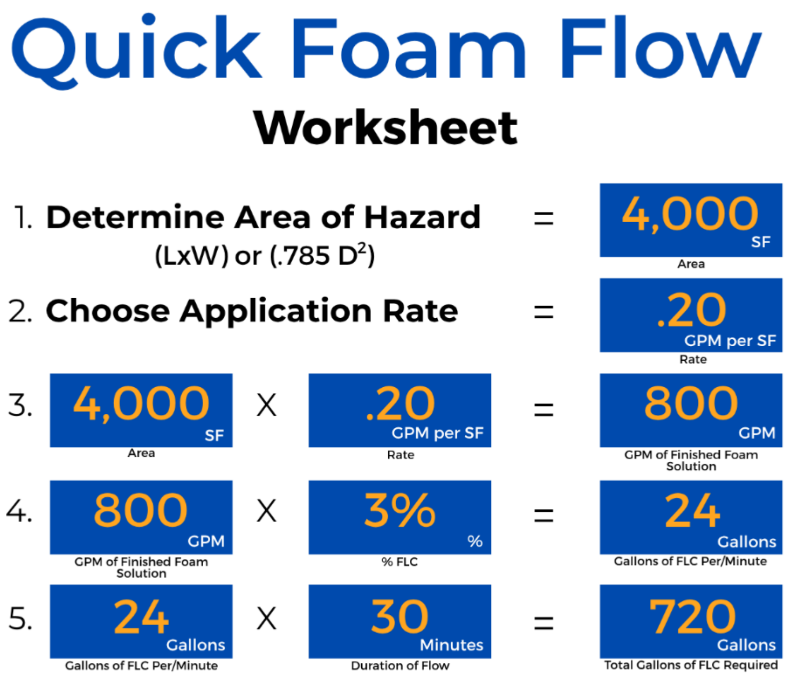
Application rate calculations tell you more than just "How much foam do I need?"; they also tell you what hardware, tools, appliances and even possibly what application technique may prove most effective based on the incident specifics such as weather and terrain.

EXAMPLE: Ethanol-Blended Fuel Spill Calculation

An area of 4,000 square feet of ethanol-blended fuel is burning. You have AR-AFFF foam that is 3%/6% foam available for securing the flame. For this example, we will use 3%.

1. Enter the area of 4,000 square feet.
2. Enter the application rate. Because this is an ethanol-blended fuel spill the application rate is .20 gallons per minute/square foot.
3. Taking the area of 4,000 square feet and multiplying it by the application rate of .20 tells us 800 gallons per minute of finished foam solution that is required.
4. From here, the 800 gallons per minute of required finished foam solution is multiplied by the 3% (.03) foam liquid concentrate. This tells us 24 gallons of foam liquid concentrate/minute is required.

5. Multiply the 24 gallons of foam liquid concentrate per minute by a 30-minute flow time. This final figure tells us 720 gallons of foam liquid concentrate is needed to fight the ethanol-blended fuel fire.



Summary

Eventually current inventories of AR-AFFF will be used on actual incidents or replaced with AR-SFFF in the ongoing efforts to meet regulatory standards. WHERE AVAILABLE, AR-AFFF continues to be recommended for ethanol and ethanol-blended fuel emergency incidents.

AR foam is accepted as the best fire suppression/ firefighting agent for use in incidents involving hydrocarbons, ethanol, and ethanol-blended fuels. If it is unclear the chemical nature of the burning fuel, AR foam is the preferred choice from a response standpoint.

NFPA 11 directs users to UL 162 as guidance when selecting foam concentrates. Follow manufacturer-specified flow rates and use appropriate application tactics and techniques.