A Publication of the
**National Wildfire
Coordinating Group**

Sponsored by
United States
Department of Agriculture

United States
Department of the Interior

National Association of
State Foresters

FOAM VS FIRE

Class A Foam for Wildland Fires

PMS 446-1
NFES 2246

October 1993
Second Edition

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NWCG has been preparing a series of publications entitled "Foam Applications for Wildland & Urban Fire Management" (starting with Volume 1, No.1 in 1988). These documents are available at no charge. They are a series of interagency, international publications that contain articles on firefighting foam, its use and application, with much information on class A foam and foam delivery systems, etc. in each issue. To start receiving a copy of these as they are issued, or to obtain back issues, send your name and complete mailing address to:

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Prepared by:
Foam Task Group
Fire Equipment Working Team
National Wildfire Coordinating Group

In cooperation with
The Canadian Committee on Forest Fire Management
and Forest Fire Equipment Working Group

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OBJECTIVES

This publication covers the basics of using class A foams and discusses their adaptability to present application equipment. Its purposes are to provide:

1. Basic understanding of how class A foams work and how they can be used.

2. Knowledge for firefighters of the concepts presently being used in foam application equipment.

3. Information needed to achieve the most efficient use of class A foam.

> *NOTE:*
> This document is one of a series of three "Foam vs Fire" publications that are available. These are:
> 1. Primer
> 2. Class A Foam for Wildland Fires
> 3. Aerial Applications
>   (to be published in 1994/95)

INTRODUCTION

History

Water has always been the mainstay for fire suppression for both wildland and structural fires. The water bucket gave way to the backpack pump, which in turn gave way to the portable pump and hose system in the early 1920's. The advent of dependable mechanized vehicles resulted in a change from horse-drawn to motorized firefighting units—except in mountainous areas where accessibility was difficult.

In the 1930's and 1940's foams were evaluated in studies aimed at improving the fire-extinguishing capabilities of water. A number of additives were identified that improved the knock-down characteristics of water. They also decreased the tendency of fires to rekindle.

Fire engines and aircraft were used in evaluating water, chemicals, equipment, and suppression techniques during Operation Firestop in 1954. The many positive results paved the way for a number of new tools in wildland fire suppression, including use of chemicals and aircraft.

By 1968 the use of foam to fight forest fires had been investigated numerous times but—due to poor performance, specialized equipment needs, and the low level of interest—no concerted investigative or developmental work was undertaken.

Recent developments in foam technology created a renewed interest in foam as a wildland firefighting tool. The first was the development and use of compressed air foam systems (CAFS). In these systems, foam is generated by injecting compressed air into a solution of water and foaming agent as it is pumped through a hose. Although CAFS increased the usefulness of limited water supplies, it did not alleviate the problem of carrying large quantities of foaming agent, since commercially available foaming agents required mix ratios of 3 to 6 percent (3 to 6 gallons of foam concentrate for every 100 gallons of water).

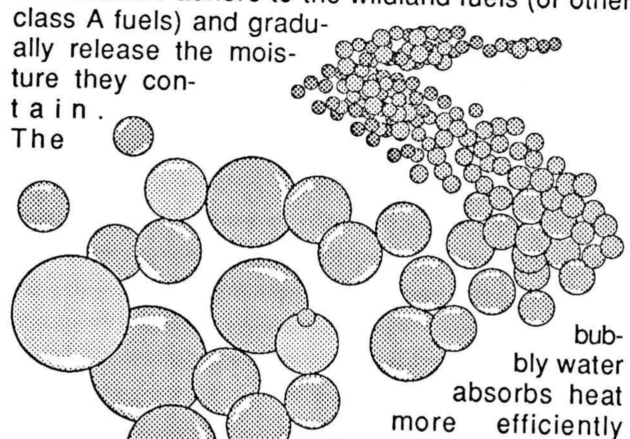
The second development was the introduction of a new family of synthetic hydrocarbon surfactant foaming agents. This foam was developed and introduced in Canada in 1985. The recommended mix for foam solutions of this concentrate is less than 1.0 percent, depending on fuel and fire characteristics and the generating/application method being used, reducing the amount of the concentrate needed.

Several foam concentrates of this type are commercially available. They are being used by most every wildland fire management agency and many municipalities responsible for wildland fire suppression in the United States and Canada. These foams are being applied from both ground equipment and aerially in a variety of suppression scenarios.

Class A Foams

Class A foam is a mechanically generated aggregation of bubbles having a lower density than water. The foam is made by introducing air into a mixture of water and foam concentrate.

The bubbles adhere to the wildland fuels (or other class A fuels) and gradually release the moisture they contain. The bubbly water absorbs heat more efficiently than unbubbled water, and the bubble mass provides



a barrier to oxygen, necessary to sustain combustion. The reduced rate of water release results in more efficient conversion of water to steam, providing enhanced cooling effects and, along with the surfactants contained in the solution, allows the water to penetrate the fuels and reach deep-seated fire sites. The bubble mass also provides a protective barrier for unburned, exposed fuels.

Although class A foam contains wetting agents that reduce the surface tension of the contained water, it should not be confused with the wetting agents which are used exclusively for improving the penetration of water into deep-seated fires in class A fuels. In fact, these wetting agents are commonly formulated to prevent foaming.

The ratio of class A foam concentrate to water is typically 0.1 to 1.0 percent. Class A foam can be produced using numerous types and configurations of equipment, which are discussed later in some detail.

Advantages of Class A Foam

- Increase the effectiveness of water
- Extend the useful life of water
- Provide short-term fire barrier
- Effective on fire in all types of class A fuels
- Reduce suppression and mop-up time
- Relatively easy to use (mixing and handling)
- Visible from ground and air.

Disadvantages of Class A Foam

- Can be irritating to the skin and eyes
- Corrosive to some metals and may speed deterioration of some types of seal material
- May have harmful environmental effect as a result of exposure to high concentrations
- Reduced life expectancy of leather goods such as footwear.

FOAM CHARACTERISTICS AND PROPERTIES

Foam Concentrate, Solution, and Foam

Foam concentrates are liquids that contain foaming and wetting agents as well as small amounts of other chemicals to inhibit corrosion, to stabilize the foam, and to maintain the homogeneity of the liquid. Although the composition of the various foam concentrates are similar, they are not identical and should be handled and stored separately. Foam concentrates are added to water (in amounts prescribed by the manufacturer) to produce foam solution which, when aerated, produces foam. Foam is a relatively stable mass of small bubbles made by forcing large quantities of air into a small quantity of water containing the foam concentrate. Class A foams are designed specifically for fighting fires in class A fuels.

Foam Properties

Expansion

Expansion is the increase in volume of a solution, resulting from the introduction of air. It is a characteristic of the specific foam concentrate being used, the mix ratio of the solution, the age of the concentrate, and the method of producing the foam. Different generators such as CAFS (compressed air foam systems) or aspirating nozzles produce foams having different expansion factors using the same foam solution.

A 10 to 1 (10:1) expansion of a 1-percent solution creates a foam that is 90 percent air, 9.9 percent water, and only 0.1 percent foam concentrate. The net result is a foam that is much lighter than water given the same volume.

Expansion ratios are divided into three classes related to how much foam is generated.

Low expansion	1:1	to	20:1
Medium expansion	21:1	to	200:1
High expansion	201:1	to	1000:1

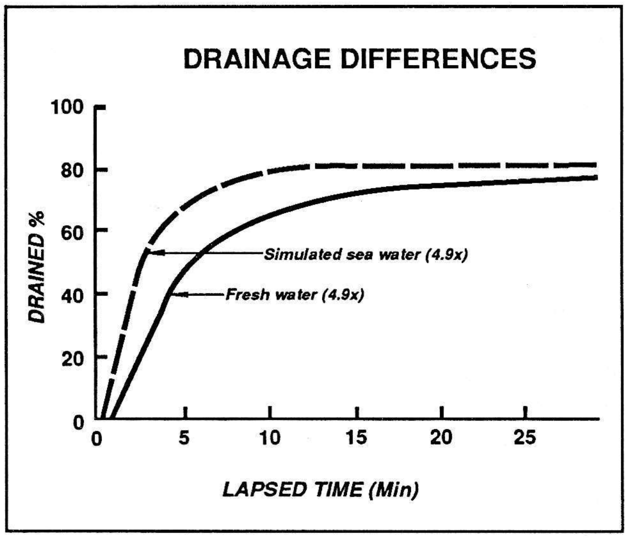
Expansion is one of several characteristics that should be considered in tailoring a foam for a specific task.

Density

The density of a foam is its weight per unit volume. It affects how well a foam projects when delivered from a nozzle and the resistance to the effects of wind. A low expansion (relatively little air, and thus heavier) foam has a higher density and more resistance to deflection by the wind than a medium or high expansion (mostly air, with a little foam solution, and thus lighter) foam.

Drainage/Drain Time

The stability of the bubble mass is measured by the rate at which the foam releases the solution from within its bubble structure. This process, known as drainage, is a measure of the foam's effective life. The use of cold water tends to decrease the rate of drainage, while the use of hard or saline water produces a much faster draining foam. Fast drainage also occurs when foam concentrates are used in combination with long-term retardants (which contain salts) to enhance the retardant's spreading and coating characteristics.



Drain time indicates how quickly the foam releases the foam solution from the bubble mass. Once the solution is released, it becomes available for wetting of fuels or it may run off the fuel. Foams with short drain times provide solution for rapid wetting. Foams with long drain times hold solution in an insulating layer for relatively long periods of time prior to releasing it.

Surface Tension

The foaming agent component of the foam concentrate facilitates the formation of bubbles and the stabilizer imparts the strength to the bubble skins to maintain this structure. The wetting agent (surfactant) reduces the surface tension of the liquid so that the fluid can spread more readily, but more importantly, penetrate deeper into organic fuels at a faster rate.

Foam Type

Foam type is a term used to describe the consistency of foam as the combination of drain time and expansion ratio (for low expansion foam). Foam type is important to understanding how the foam will perform. A foam with a fast drain time and a 5:1 expansion ratio performs differently than a foam with a slow drain time and a 15:1 ratio. The foam types you will use are as follows:

Expansion — **Drainage**

1:1 — **Rapid**

FOAM SOLUTION
- **A clear to milky fluid**
- **Lacks bubble structure**
- **Mostly water**

WET FOAM
- **Watery**
- **Large to small bubbles**
- **Lacks body**
- **Fast drain times**

FLUID FOAM
- **Similar to watery shaving cream**
- **Medium to small bubbles**
- **Flows easily**
- **Moderate drain times**

DRY FOAM
- **Similar to shaving cream**
- **Medium to small bubbles**
- **Mostly air**
- **Clings to vertical surfaces**
- **Slow drain times**

20:1 — **Slow**

A dry foam holds its shape, adheres well, and releases its solution slowly, creating a better insulating blanket than a wet foam which flows, drips, and releases its solution quickly. Fluid foam releases the solution more rapidly than a dry foam but holds its shape and adheres better than a wet foam. Fluid foam may be better at cooling and wetting than dry foam. Foam solution is a slightly frothy fluid that may be the choice when rapid penetration of liquid is necessary such as deep-seated fires and smoldering snags.

As you can see, many types of foam can be made, and each type is best suited for a specific application. Different foam types are produced by altering the amounts of air and/or foam concentrate used to produce the foam.

Mix Ratio—What Concentration Should Be Used?

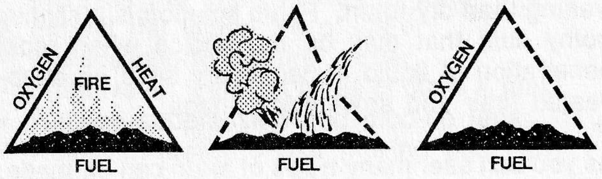
The user's specific needs and objectives must be identified before determination of a suitable mix ratio. Since each foam generating system produces a unique foam for a given mix ratio, the foam can be tailored to the specific need. If the need is to protect tree crowns, a fairly dry foam—slow-draining and adherent—should be used. For the pretreatment of the perimeter of a prescribed burn area, a slow-draining to moderately rapid-draining foam is required; otherwise, the drainage should be fast enough to provide general wetting. Each manufacturer suggests concentrations to be used for a range of needs. However, since numerous factors (such as water hardness and temperature, the generating system being used, etc.) affect the type of foam produced, these suggestions should only be considered as a starting point.

Matching foam generated with the firefighting needs increases the effectiveness of the water being applied, and decreases the effort necessary to complete the job.

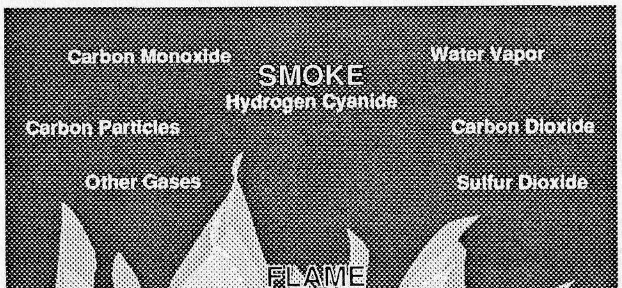
Foam's Action on the Fire Triangle

The statement "fire doesn't like water much" is as valid today as on the day it was coined. However, by converting water from a liquid state to a bubble state, new characteristics are imparted to the water to give it superior suppression qualities. This bubble mass, known as foam, is a fire suppressant because it relies on the moisture that it contains to be effective. The structure of the foam can range from a rigid to a relatively fluid aggregation of bubbles.

The combustion process is commonly depicted as a fire triangle. Each side of the triangle contains one of the components required to sustain fire: Heat, oxygen, and fuel. Suppression of a wildland fire, as with any fire, depends on breaking one or more of the sides of the fire triangle. Foam can be an effective tool for breaking each of these links.



Water, possessing the enhanced characteristics imparted by the foam concentrate, becomes much more efficient in breaking the fire triangle by attacking all three sides, although to different degrees.

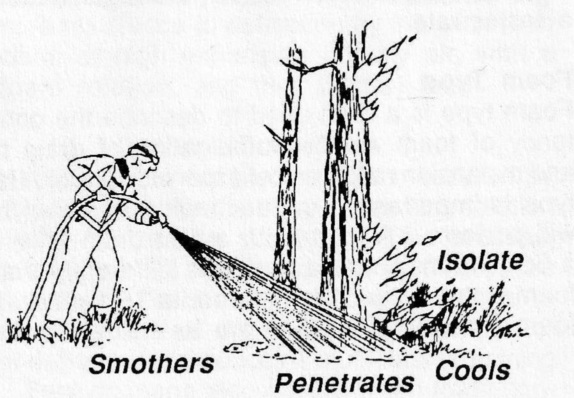


With a foam application, the fuel component is blanketed with an opaque layer whose reflective qualities intercept radiant energy and inhibit rekindling. The insulating characteristics of this layer also prevent heat from escaping and preheating other fuel particles. The foam separates the surface of the burning fuel from oxygen in the air. Vapor suppression occurs by trapping flammable vapors at the fuel interface. The foam blanket varies in depth and stability, depending on mix ratio and the foam generation process. The foam also acts as a heat sink by absorbing the heat generated by the combustion process and using this energy to evaporate the water contained in the foam rather than to propagate the fire.

The foam clings to all types of fuels on application and releases water slowly over time. The benefit of the available water is maximized when the foam holds the moisture where it is most needed until it can be absorbed. In addition, the solution that is released contains wetting agents which facilitate the water's spread over a large area, allow it to adhere to the fuel surface, and impart greater penetrating ability.

The moisture content of the treated fuel is increased due to the foam solution's enhanced wetting qualities. Consequently the heat absorption potential of foam-treated fuels is increased. Water in the foam state adheres to fuel surfaces in substantially greater quantities without running off and is available to continue wetting the fuel over a prolonged period of time. This results in a longer time span of effectiveness for a given application. The liquid that is vaporized at the hot fuel's surface cannot readily escape due to the overlying bubble mass and, therefore, remains at the surface to enhance extinguishment.

Foam descending through aerial fuels envelops the fuels it encounters, resulting in the isolation of combustible gases. The draining foam sets up

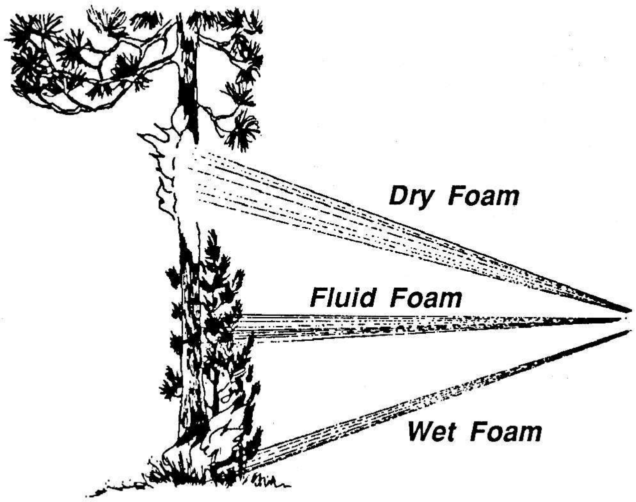


a "drizzle," which dilutes these volatile substances to a level where the temperature required for combustion is greatly elevated at the fuel/air interface. The buoyancy of the descending bubble mass causes the foam to penetrate better through aerial fuel complexes and to envelop fuels that might not otherwise be wetted.

Vertical surfaces are difficult to wet with water even if they are receptive to it; but, in the foam state, a substantially greater amount of water can be held on the fuel surface and made available for wetting of these surfaces as well as for heat absorption and dissipation. Hard to wet surfaces (such as green foliage) shed water, but foam adheres to them and wets these surfaces via the wetting agent.

If isolation rather than wetting is the prime need, a dry foam can be produced which remains rigid and does not flow when applied to vertical surfaces.

The variations in forest fuel complexes require adjusting the foam type to meet specific suppression objectives: A dry foam coats and adheres well and drains and wets at a slow rate; a fluid foam flows to some degree upon coming to rest and drains readily; and wet foam flows readily, and dissipates and penetrates rapidly.



Visibility of the foam aids in the conservation of often scarce water. The ability to see the foam avoids waste of water from over-treatment and pinpoints where the foam is breaking down so that the control line can be reinforced as needed. The foam mass is visible enough to permit tying aerial foam drops together.

PERSONAL SAFETY

Personal Safety and Protection

Foam concentrates are similar to common household detergents and shampoos. Fire suppressant foams, diluted for use in fire fighting, are more than 99 percent water. The remaining 1 percent contains surfactants (wetting agents), foaming agents, corrosion inhibitors, and dispersants.

Approved fire suppressant foam concentrates and solutions have all been tested and meet specific minimum requirements with regard to mammalian toxicity:

Acute oral toxicity
Acute dermal toxicity
Primary skin irritation
Primary eye irritation

As with any chemical substance, a small percentage of the population may be allergic to or have an unusual sensitivity to a specific product that will not be detected during testing.

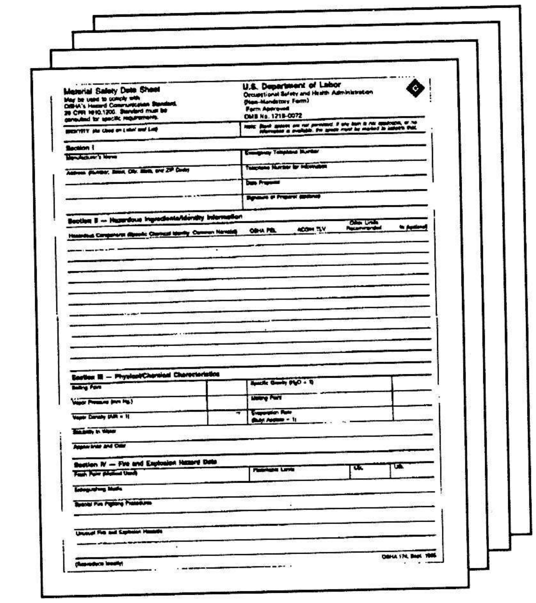
Foam concentrates are strong detergents. They can be extremely drying and exposure to the skin may cause mild to severe chapping. This can be alleviated with the application of a topical cream or lotion to the exposed areas.

All of the currently approved foam concentrates are mildly to severely irritating to the eyes. Anyone involved with or working in the vicinity of foam concentrates should use protective splash goggles. Rubbing the eyes or face may result in injury to the eyes if hands have become contaminated with the concentrate during handling.

There is no evidence to suggest that foams or their constituents have any carcinogenic, reproductive, or mutagenic effects.

All personnel involved in handling, mixing, and applying foam concentrates or solutions should be trained in proper procedures to protect both their health and safety as well as that of the environment.

All containers of foam concentrate or solutions, including backpack pumps and engine tanks, should be labeled to alert personnel that they do not contain plain water, and that the contents **MUST NOT** be used for drinking purposes. If a foam concentrate is ingested, the individual should seek medical attention as soon as possible.


Material Safety Data Sheet
May be used to comply with
OSHA's Hazard Communication Standard,
29 CFR 1910.1200. Standard must be
consulted for specific requirements.

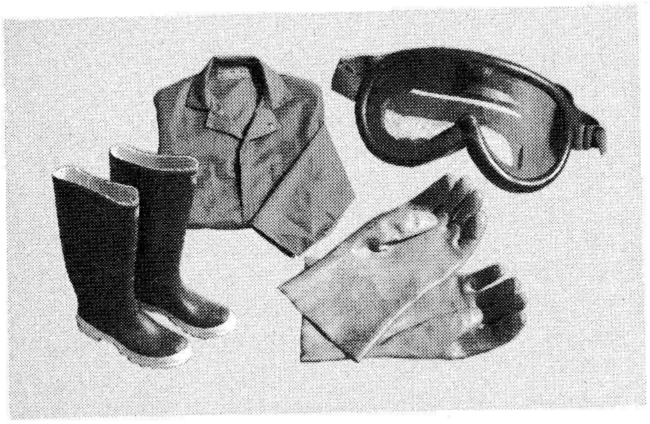
U.S. Department of Labor
Occupational Safety and Health Administration
(Non-Mandatory Form)
Form Approved
OMB No. 1218-0072

Section I
Manufacturer's Name
Emergency Telephone Number
Address (Number, Street, City, State, and ZIP Code)
Telephone Number for Information
Date Prepared
Signature of Preparer (optional)

Section II — Hazardous Ingredients/Identity Information

All personnel **MUST** follow the manufacturer's recommendations as found on the product label and product material safety data sheet (MSDS). To eliminate possible health problems from prolonged exposure to the skin and eye the following precautions should be taken:

1. When handling concentrates, goggles, waterproof gloves (rubber or plastic), and disposable coveralls should be worn. Leather boots should not be worn at the mixing site, since foam concentrate rapidly penetrates leather, resulting in wet, soapy feet.



2. Clothing soaked with foam concentrate should be removed and thoroughly rinsed with water.

3. Eyes splashed with foam concentrate or a foam solution should be flushed as soon as possible with large amounts of clean water for at least 15 minutes.

4. If skin contact occurs, wash off with water, and remove contaminated clothing.

5. A non-allergenic lotion/hand cream should be used to avoid raw chapping of skin.

6. Inhalation of foam vapors can be irritating to the upper respiratory tract, and should be avoided.

7. Ingestion of foam concentrate or, to a lesser degree, the solution can be harmful.

Working Conditions

Slipperiness is a major hazard at storage areas and unloading and mixing sites. Because foam concentrates and solutions contribute to slippery conditions, all spills **MUST** be cleaned up immediately.

Spills of foam concentrate can be covered with sand or absorbent material and then removed with a shovel. Do not apply water directly to the spill area. Foaming and possible contamination to the surrounding area may result.

Spills **MUST NOT** be flushed into drainage ditches or storm drains. Do **NOT** flush equipment near domestic or natural water supplies, creeks/rivers, or other bodies of water. If a large spill occurs or concentrate enters a water supply, contact your local authorities immediately. Be prepared to provide them with the appropriate manufacturer's information.

Care should be taken during planning that personnel applying foam from the ground are able to stand in untreated areas as they proceed. Stepping onto a foam blanket which conceals objects or holes can be dangerous.

ENVIRONMENTAL CONCERNS

Soils/Vegetation

When the foam is applied in the forest, its components will inevitably contact the soil. Surfactant absorption is dependant on many factors, including silt and clay content, organic matter, and surface area.

Generally, foams have a minimal effect on forest soils, as the approved foam products are biodegradable and have minimal adverse environmental impact.

Water Supply

Due to the sensitivity of aquatic habitats, the application of foam directly into bodies of water **MUST** be avoided.

The foam concentrates have varied toxicities with respect to fish but when used in a diluted form for application, they are generally presumed to be non-toxic.

Follow these guidelines to reduce possible impacts to the environment:

- Inform all personnel using foam of the potential problems that can be caused by foams in water bodies.
- Locate foam mixing and loading areas to minimize contact with natural bodies of water.
- Exercise care to avoid spills at mixing, loading, and application areas—especially near live streams.
- Exercise particular caution when using foams in watersheds where fish hatcheries are located.
- Avoid direct application or drops into rivers, streams, lakes, or lake shores. Use alternate methods of line building or terminate the use of foam altogether.
- Notify authorities promptly of any fish kill or spill into a water body.
- Include precautionary measures in training for fire personnel.
- Foam residues might be a problem when dipping from rivers or lakes with a helicopter because of threatened and endangered species. Helicopter managers need to be aware of local conditions and guidelines regarding dipping from streams and lakes.

When foams are used near domestic reservoirs and domestic water supplies, the same precautions MUST be exercised. Leave at least a 100- to 200-foot buffer zone from the high-water line. Under normal conditions, plants and soil can absorb a majority of the foam solution before it washes or leaches into the water body.

Foam components undergo chemical and biological degradation processes that reduce the environmental effects. Biodegradation varies from 14 to 30 days, depending on the product being used.

FOAM SYSTEMS

Storage

All of the approved class A foam concentrates have been evaluated on the basis of their ability to (a) maintain their performance characteristics and (b) produce foam, after storage for 1 year, that is similar in quality to that produced from fresh concentrate.

Each foam concentrate supplier includes proper storage information on the product label. In general, suppliers do not recommend storing below freezing or above about 100 °F. In situations where the concentrate may be required for immediate use, the minimum storage temperature should be well above freezing. The viscosity of the foam concentrate increases significantly at low temperatures. This results in slow flow of the concentrate and proportioning devices that may not function accurately, if at all.

Storage in the original shipping containers is recommended, although other polyethylene or polypropylene containers may be used. Storage in metal containers may cause product degradation. Foam solutions should not be stored any longer than necessary. Water impurities and metal tank parts in contact with the solution may drastically alter foaming characteristics.

Proportioning

The first step in creating foam is adding the required amount of foam concentrate to water to create foam solution. This process, known as proportioning, is used to proportion foam concentrate into water streams for use with standard nozzles, aspirating nozzles, or in compressed air foam systems (CAFS). There are two basic types of foam concentrate proportioning systems, manually regulated, and automatic regulating. The proportioning system chosen is independent of nozzle or foam generating device used.

Every device exposes some hardware to the cleansing, and penetrating qualities of class A foam. When foam concentrate dries, it can plug small

	Proportioners*						
ADVANTAGES	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Maintain desired mix ratio despite changes in water flow and pressure					X	X	X
Unlimited hose length	X	X		X	X	X	X
Unlimited number of hose lines	X	X		X	X	X	X
Easily adjusted mix ratios		X		X	X	X	X
No moving parts	X	X	X	X	X		
No loss in water flow or pressure	X	X					X
Requires no equipment investment	X						
DISADVANTAGES							
Tank and pump corrosion	X	X		X			
Plumbing corrosion	X	X	X	X	X	X	X
Pump priming	X	X		X			
Pump cavitation	X	X		X			
Water tank refill fluid level obscured	X	X		X			
Inconsistent dispersion of concentrate	X						
Foam solution degradation	X						
Excessive foam concentrate use	X	X		X			
Clean water supply contamination	X	X		X			
Removes lubricants	X	X	X	X	X	X	X
Cleaning required after every use	X	X	X	X	X	X	X
Specific water flow requirements			X				
Specific pressure requirements			X				
Vertically mounted attitude only			X				
Limited nozzle elevation			X				
Dependent on pump vacuum		X					
Concentrate viscosity sensitive	X	X	X	X			
Concentrate resupply interrupts concentrate input				X			
Requires auxiliary power						X	X
Accurate Water flow range							
• Any flow, single mix ratio	X						
• Single flow, single mix ratio		X	X	X			
• Any flow, any mix ratio (between 0.1 and 1.0 percent for class A foam)					X	X	X
Initial Equipment Investment							
• $ 0 - $ 500	X	X	X	X			
• $ 500 - $ 1,000							
• $ 1,000 - $ 2,000					X		
• $ 2,000 - $ 4,000						X	
• $ 4,000 - $ 6,000							X

Key to Proportioning Devices

1 Batch Mixing
2 Suction-side Regulator
3 In-line Proportioning System (Eductor)
4 Around-the-pump Proportioning System
5 Balanced Pressure Bladder Tank Proportioning System
6 Balanced Pressure Pump Proportioning System
7 Direct Injection Proportioning System

Table 1.
Advantages and Limitations of Proportioning Devices

tubing and orifices found on these proportioners. Flushing, rinsing, lubrication, and general good housekeeping are necessary for each of these devices. Advantages and disadvantages of each type are listed in table 1.

Manual Regulation

Manual regulation systems, which must be monitored and changed manually,are frequently used—although less precise regulation of concentrate addition, and the resulting foam quality, is usually achieved.

Batch Mixing

The simplest method of making a foam solution is to manually add foam concentrate to the water supply. This method, called batch mixing, is convenient for conventional water pumping systems. A measured volume of concentrate is poured into a measured volume of water to yield a foam solution of the recommended strength. Batching is potentially wasteful because the required volumes of both water and concentrate must be estimated, especially when refilling a partially full tank.

The concentrate should be added to water, because adding water to the foam concentrate causes excessive foaming in the tank as the water is added. Since the foam concentrate is heavier than water, mixing or recirculation of the concentrate/water mixture is required to obtain a homogeneous solution. The solution should be used as soon as possible for optimum performance.

Despite a number of limitations, batch mixing is a common proportioning method for engines, portable tanks, bladders, and extinguishers.

Suction-side Regulator

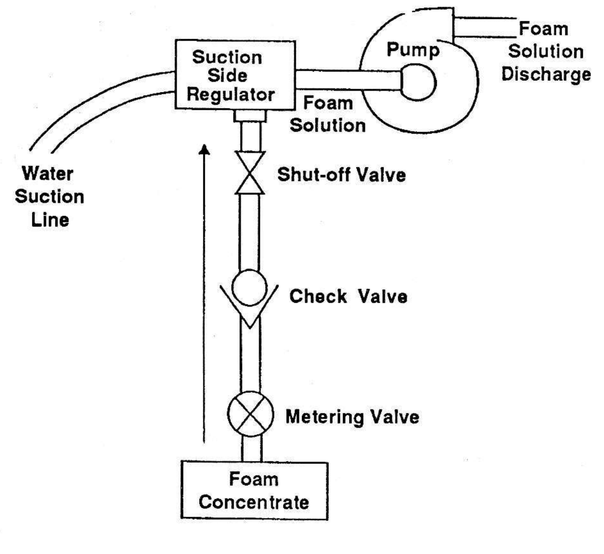
The suction-side regulator uses water pump vacuum to add foam concentrate, via an in-line tee and regulating value, to the water stream on the inlet side of the pump. At specific flow conditions the regulator is proportional. However, the in-line tee has no influence on vacuum, so the regulator can not maintain a given mix ratio as water flow changes without a manual adjustment.

Because the regulator sends concentrate through the pump and the tank, when recirculating, its limitations are similar to those of batch mixing.

Eductor

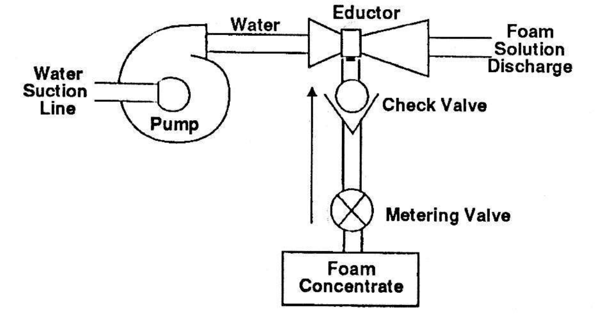
The eductor (or in-line proportioning system) drafts foam concentrate from a container to the pressure side of the water stream using venturi action. As

SUCTION SIDE REGULATOR



pressurized water flows through the venturi, an area of negative pressure is created at the venturi throat. Atmospheric pressure forces the foam concentrate into the negative pressure area of the eductor.

IN-LINE PROPORTIONER (EDUCTOR)



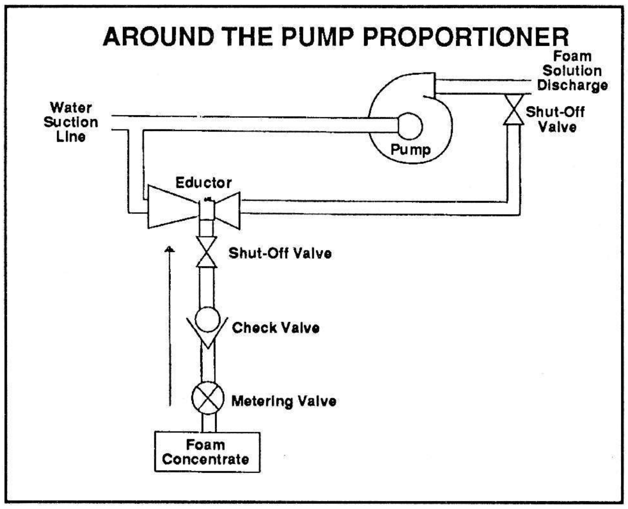
Eductors work on any pump that can generate a pressure of 200 psi. They are usually proportional at one water flow rate. Because they are designed to operate within specific concentration ranges, a different eductor may be required to operate at a concentration outside that range. In some cases diluting the concentrate may allow use of the eductor at hand.

Eductors eliminate many of the problems associated with concentrate exposure to pump and tank. They also make possible accurate proportioning while the tank is refilled or while the pump is fed from a hydrant.

Eductors are most appropriate for applications of constant water flow near the pump.

Around-the-pump Proportioner

The around-the-pump proportioner diverts a portion of the pump discharge through an in-line proportioner back to the suction side of the pump. This loop around the pump is used to draw concentrate up through the venturi and into the main water stream.



The around-the-pump system works on portable or built-in pumps of any size or output. Water tank refilling and pump nursing do not affect this system's performance. Around-the-pump devices are manually regulating because the venturi has to be adjusted when the water flow changes. The adjustment is done manually. When water flow has stopped, the shut-off valve at the venturi **MUST** be turned off to prevent more foam concentrate from being drawn into the water line.

The around-the-pump proportioner is more flexible than the eductor, but it introduces concentrate to the pump and tank in the same way as the suction-side regulator. Therefore, the same corrosion, cleansing, cavitation, and other related problems also limit the around-the-pump-proportioner.

Automatic Regulation

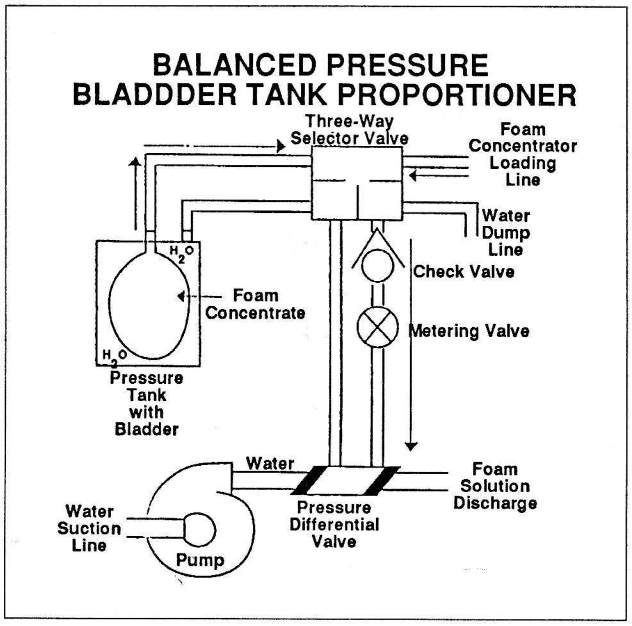
Automatic regulation devices are designed to minimize the limitations of the previously discussed methods. Specifically, they proportion accurately over wide ranges of water flow or pressure, adjusting automatically to changes in water flow and pressure to maintain the desired mix ratio. Foam concentrate is added on the discharge side of the pump to avoid tank and pump problems. The mix ratio can be quickly changed during operation. These devices place no restrictions on hose length or number of hoselays.

Balanced-Pressure Bladder Tank Proportioner

The balanced-pressure bladder tank system uses a small diversion of water to pressurize a bladder containing foam concentrate. The concentrate passes through a metering valve before it enters the water stream on the low pressure side of a pressure differential valve or venturi.

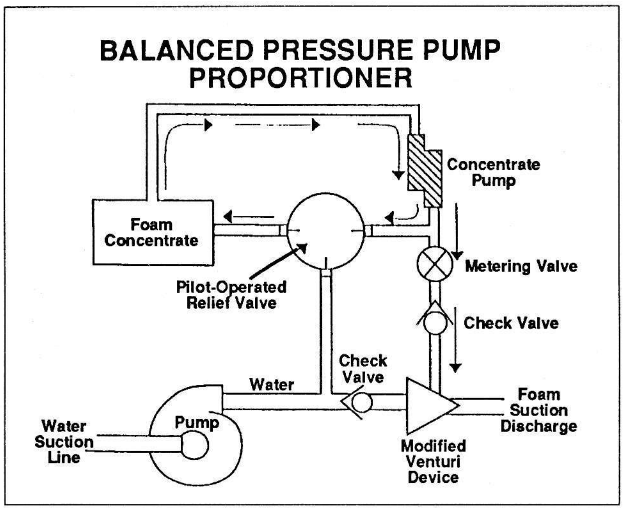
Concentrate is added according to the difference in pressure at the differential valve. As water flow increases and the difference in pressure increases, foam concentrate flow is able to increase proportionally.

The bladder tank proportioner has no moving parts. It can be portable or plumbed integrally. Foam concentrate must be transferred to the bladder for storage and dispensing. When the bladder is being filled, concentrate flow is interrupted.



Balanced-Pressure Pump Proportioner

The balanced-pressure pump system senses water pressure with a pilot-operated relief valve. A pump delivers concentrate to a venturi in the water line according to the pressure at the relief valve. A metering valve allows for selection or change of the desired mix ratio.

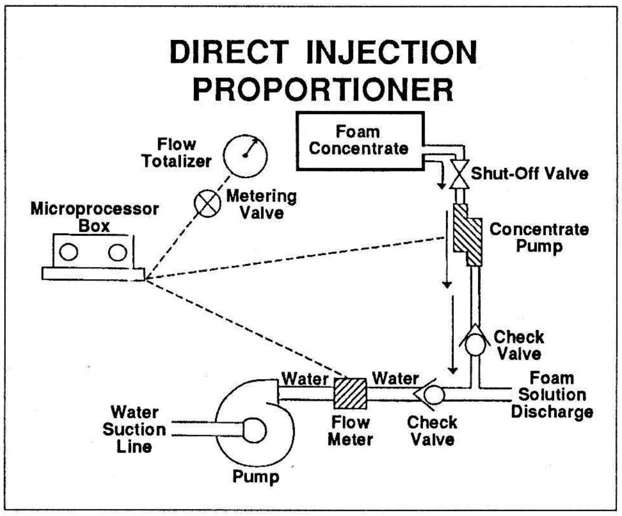


If the relief valve senses 150 psi of water pressure, then it will ensure that 150 psi of foam concentrate pressure flows from the foam pump to the venturi. Concentrate enters the water stream in proportion to the pressure differential across the venturi. Excess foam concentrate is relieved to the concentrate tank.

Refilling the concentrate tank does not interrupt concentrate flow. Concentrate flow is dependent on an auxiliary powered pump.

Direct Injection Proportioner

The direct injection proportioner adds concentrate based on measured water flow. An in-line flow sensor determines water flow past the pump. A micro-processor receives electronic signals of mix ratio from the control panel and water flow from the flow sensor. The processor then commands a pump to deliver concentrate at a proportional rate.



This proportioner is capable of providing more than one foam concentrate when more than one storage container is linked to the pump. The pump runs only on demand.

Aerial Suppression Proportioning System

The proportioning system used to produce foam solution in airtankers and helitankers injects the foam concentrate into water in the tank or bucket using a pump and timer system triggered by the pilot. Circulating systems have been devised for some helibuckets but in all other instances dispersion of the foam concentate depends on injection pressure and the often minimal agitation occurring during flight.

The consistent foam injection rate combined with careful calibration provides an accurate method of proportioning that is straightforward and reliable.

Call-when-needed (CWN) contracts permit helicopter contractors to furnish equipment for dispensing foam and retardant concentrates into buckets. Since the equipment is relatively new, detailed design or performance specifications are not yet available. Thus, until specifications are developed, the evaluation criteria presented here can be used —along with good judgement.

General Requirements
for Aerial Proportioner

Compatibility of Materials: The materials used in construction of any foam dispensing unit must be compatible with all foams, and resistant to corrosion, erosion, etching, or softening. To evaluate the materials, submerge a sample in foam concentrate for 96 hours, then in a 1-1/2 percent solution for 96 hours. Any change indicates that the material must not be used.

Installation: Installation of the unit must not require any major or permanent modifications to the helicopter.

Restraint: The foam pumping unit containment vessel and concentrate must be affixed to the helicopter in a way to prevent injury to personnel or damage to the helicopter. The design must meet the ultimate inertia forces specified in FAR 23.56 1(b)(2). All parts of the foam pumping unit must be designed so that at all points of contact with the helicopter, no abrasion or damage occurs to the helicopter.

Location of Unit: The preferred mounting location of the foam pumping unit and containment vessel is external to the helicopter, perhaps attached to or within the water supply.

Routing of Hose: The hose used to carry the concentrate must be routed out the side of the helicopter away from the pilot. Hoses must be routed in a manner that will not interfere with flight controls.

Breakaway Fittings: Any hose must have a disconnect that will pull away from the hose when the bucket is released. The disconnect must be close to the helicopter to keep the hose from beating against the helicopter. The helicopter side of the disconnect must be able to hold the fluid pressure in the line, and be able to be pulled apart at one-third the buckets empty weight. The lower part of the hose must be securely attached at the bucket such that, if the bucket is released, a sufficient load is applied to the disconnect to release it.

Containment: Any unit mounted inside the helicopter (other than those that have STC's or 337's), must have a containment vessel around the pumping unit and concentrate storage supply. The containment vessel must be able to hold 125 percent of the concentrate supply. Even in moderate turbulence, the containment vessel must be able to contain the foam concentrate. The discharge hose and fittings must have a containment sleeve of clear hose so that leaks will be visible.

Size: The unit must be small enough to easily fit into or onto the helicopter.

Weight: The foam dispensing system empty weight shall not exceed 50 pounds.

Maintenance: The foam dispensing system is expected to require no major maintenance during each fire season.

Foam Quantity: The unit shall carry a minimum of 5 gallons of concentrate for each 100 gallons of bucket capacity.

Power to Operate: Power source for the dispenser must be obtained from the helicopter by installing a MS 3116F-12-3P, three-pin connector on the cord to the unit. Pin A shall be +28 vdc and pin B for ground. (This is the same plug used for the infrared imaging system.)

Vibration: The unit must be designed and constructed so as to be damaged or fail due to vibration or shock loading when installed in the helicopter. The unit must not cause undue vibration in the helicopter during operation or in flight. The unit must be designed and installed so as not to cause any concentrated stress on the helicopter.

Operational Requirements
for Aerial Proportioner

Operation: The pilot of the aircraft must be able to operate the unit with a minimal level of attention so as not to interfere with normal flying of the aircraft. An automatic system would be preferred. Under no circumstances can any phase or aspect of the foam dispensing system impair the flight safety of the aircraft. Once the control is set for flow rate, there should be no adjustment necessary to the unit.

Flow Rate: The system must be capable of dispensing a variable amount of concentrate, in flight, to achieve a mixture ratio ranging from 0.1 to 1.0 percent by volume, in 0.05 percent increments. (Example: for a water bucket load of 250 gallons, a mixture ratio of 0.5 percent would require 1.25 gallons of injected concentrate; the next selected increment of 0.6 percent would require 1.375 gallons of injected concentrate.)

Concentrate Loading: Loading of 5-gallon containers is preferred. If bulk loading is to be used, a system must be employed such that any spillage of the concentrate will not come into contact with the helicopter. Servicing must be accomplished during normal refueling time for the helicopter and take no longer than the refueling operation. (Reference publication 9257 1201—SDTDC, August 1992, *Field Survey of Helicopter Foam Injection Systems.*)

Foam Generation

Foam is made by mechanically adding air to the foam solution. Class A foams can be made with aspirating nozzles, compressed air foam systems, and by dropping foam solution through the air. Conventional water nozzles deliver an effective foam solution (wet water). All of the foam generating equipment devices have a role in fire suppression. A summary of the advantages and disadvantages of each is given in table 2.

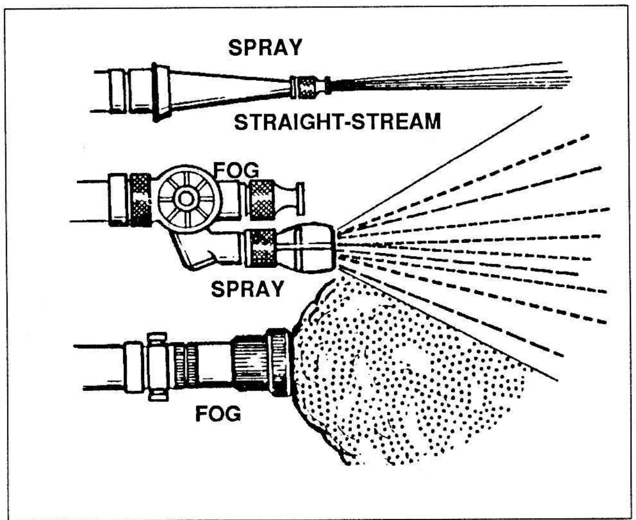
	ADVANTAGES	DISADVANTAGES
Conventional Nozzles	Can use existing equipment More efficient use of common equipment	Normal water flow Limited to foam solution applications only Generally creates only froth
Low Expansion Aspirating Nozzle	Makes foam Requires minimal equipment Simple to operate Simplest and initially the cheapest generating device	Needs a high ratio of concentrate to water Needs a high working pressure to develop foam Needs high water flows Incomplete conversion of water to foam Limited foam variability Limited discharge distance Same hydraulics as water Less viable foam
Medium Expansion Aspirating Nozzle	Creates excellent ground fire break Easy to operate	High water flow Requires more concentrate Poor discharge distance Obscures ground footing
CAFS	Requires less water Greater discharge distance Complete conversion of water to foam Requires less concentrate Rope effect Can produce all foam types Light hose weight Reduced head pressure Stored energy in hose Most stable foam	More mechanical components Slug flow High initial cost More complex operation Deceiving energy stored in hose is a safety hazard
Aerial Delivery	Uses conventional drop systems	Limited control of final product

Table 2.
Summary of the Advantages and Disadvantages of Foam Generating Systems.

Nozzles

Conventional Nozzles

Conventional nozzles are a simple way to deliver foam solution with existing equipment when the objective is rapid wetting of the fuel and foam is not needed. The unstable foam applied in this manner is essentially wet water that enhances wetting of fuel, penetration, and spread of the water but does not give sufficient foam structure to provide insulation or heat reflection.

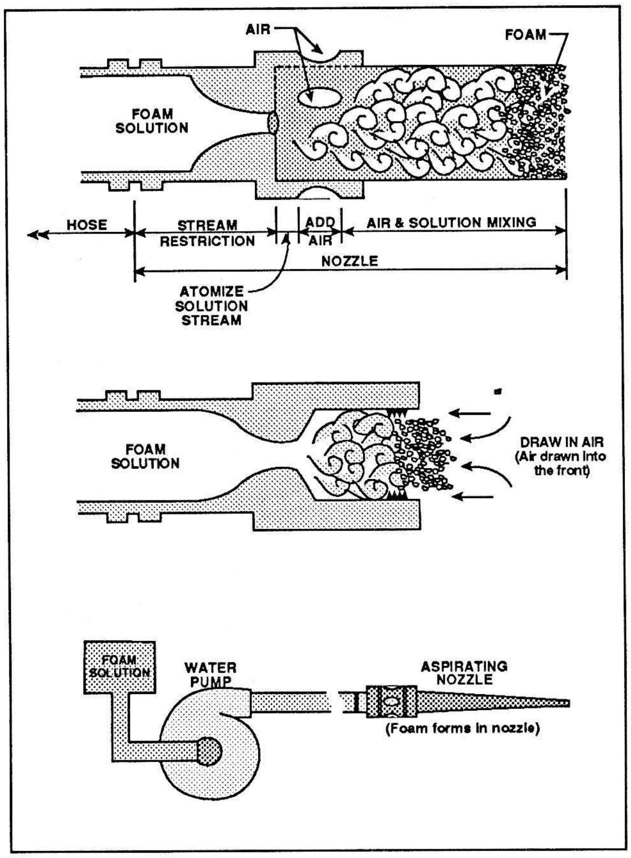


Aspirating Nozzles

Aspirating nozzles are low-energy systems consisting of standard water pumping apparatus to move foam solution through the hose to a nozzle, which passes the foam solution through a venturi like device to add air, creating foam.

At the nozzle, foam solution is constricted and broken into fine streams, creating a pressure drop on the back side of the venturi. Air is drawn into the nozzle either through openings placed radially in front of the expansion chamber or through teeth placed at the end of the chamber. In the expansion chamber, bubbles are formed, expanded, and combined to make foam. This process of pulling in air and spreading out in a larger diameter chamber costs energy. Discharge distance is dependent on the size of the chamber and the direction and volume of air flow.

Bubble size is variable and the conversion effectiveness of water to foam can be as high as 65 percent. Nozzles with larger expansion chambers create a drier foam with larger bubbles but their discharge distance is short, whereas a wetter foam made in a nozzle with a smaller expansion chamber can be propelled a greater distance through the air. With the same nozzle and water flow, foam type can be changed by adjusting the mix ratio.

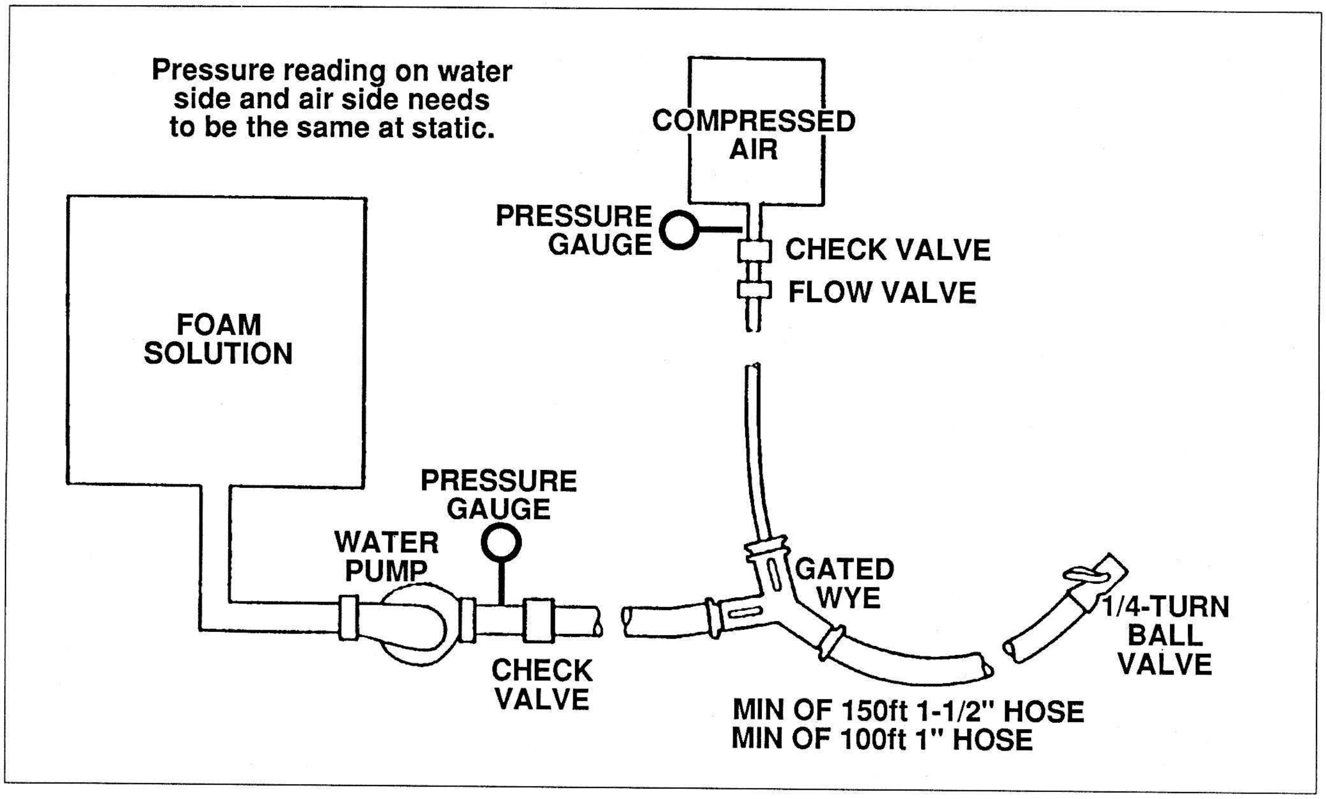


Aspirating nozzles require up to 1.0 percent mix ratio; usually 0.5 for low expansion nozzles and 0.7 for medium expansion nozzles. Low expansion nozzles are made for solution flow from 5 to 100 gpm with up to 20:1 expansion. There are relatively low-cost nozzles available for single flow rates and more expensive adjustable nozzles that cover wide ranges of flow rates. Medium expansion nozzles are designed for flows up to 100 gpm with expansion ratios from 20:1 up to 200:1.

Compressed Air Foam Systems (CAFS)

Compressed air foam is a high energy foam; that is, it adds the energy of an air compressor to that of the water pump to create and discharge foam. Foam generation does not cost energy, it increases the energy of the system.

A CAFS produces foam by injecting compressed air into a foam solution. Foam is generated when



foam solution and air are mixed together due to hose friction or a mixing device. Because compressed air systems use brute force to produce foam, they can be used with almost any foaming agent to make foam.

As a general rule, the mix ratio for CAFS should start at 0.3 percent. This is less than other systems because the blending of air and foam solution is more efficient. The primary components of this system are the water pump and the air compressor. Many combinations of pump and compressor styles are possible. Centrifugal pumps and rotary screw compressors best meet the demands of the system. The use of the compressor should add to the performance of the water pump. It should never reduce the full performance of the pump alone. The inputs of air and water should be matched at the ratio of 1 gallon per minute of water for every cubic foot per minute of air.

Other essential components are flow valves and check valves for air and water. The flow valves control inputs to the mixing chamber where air and foam solution meet. The check valves prevent water from flowing into the air compressor and air from flowing into the water pump.

Pressure gauges and adjustable valves for air and water are necessary to produce the desired foam type. Static pressures of air and water should be nearly equal. Flow pressures drop off until the back pressure in the hoselay is too great to overcome. A pressure gauge at the point of mixing helps determine when this maximum hose length has occurred.

A water flow meter is recommended because it indicates to the operator how wet or dry the foam is at the nozzle and provides a reference for any changes to be made in the foam. The water flow meter should be located before the check valves. Flow meters require specific lengths of straight bore flow for proper measurement.

Beyond the flow valves, the foam solution and air are mixed to produce bubbles. Most CAFS rely on the length of hose to provide the agitation and mixing necessary to produce foam. As the bubbles travel through the hose they cling to the hose linings and to other bubbles. This friction further agitates the foam. If the hose is long enough, the foam is agitated to a point where all the bubbles are tiny and uniform in size and water content. These bubbles create a foam plug against which oncoming foam is compressed as it in turn forms into tiny, uniform bubbles. This process is called scrubbing. As the foam approaches the end of the hose, it increases in velocity as the compressed air begins to expand to atmospheric pressure.

Bubbles are created by either the scrubbing action of the hose line or by a mixing chamber. The length of hose required for scrubbing depends upon the type and diameter of hose and the mix ratio. For example, scrubbing of 0.3 percent solution foam in 1-inch cotton jacket rubber-lined hose occurs within 50 feet at approximately 65 °F; 0.3 percent foam in 1.5-inch woven rubber hose requires 100 feet or more.

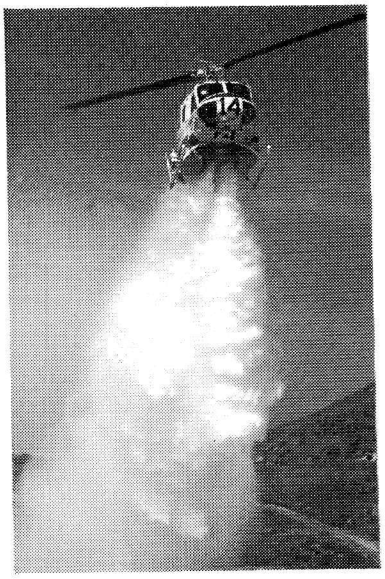
There are mixing devices that eliminate the need for long lengths of hose. These use motionless mixers which bring water, concentrate, and air together in a short space. Various designs exist which produce foam with little or no loss in pressure. These motionless mixers are especially useful for engine-mounted foam monitors and applicators which have no need for long lengths of hose.

Conventional and variable pattern nozzles, wands, and other attachments are compatible with a CAFS. The bigger the waterway the greater the flow. A one-quarter turn ball valve that has a waterway equal to the hose inside diameter provides the greatest foam flow. Any restriction of foam flow mechanically breaks down the bubble structure creating a more fluid foam. A combination barrel nozzle tip can be used to break up the bubble structure of the foam and create a high-pressure foam solution for rapid penetration. At pressures above 125 psi, horizontal pumping distance of foam and water are similar, while vertical pumping loft is much higher with foam.

Continuous, unimpeded foam flow requires the use of hose that is resistant to kinking. Woven rubber hose is very kink resistant; extruded rubber hose and cotton jacket rubber-lined hose are fairly resistant to kinking. Synthetic hose kinks easily when filled with foam.

Aerial Delivery

Air shear is the only mechanism for incorporating air to generate the bubble structure when solutions are delivered by airtankers, helitankers, and helibuckets. How efficiently the solution is converted from a liquid to a foam depends on the volume of solution making up the parcel of liquid, the air speed, the drop height, and the mix ratio. Exiting liquid is sheared only on the periphery of the solution package; consequently the smaller the volume the more rapid is foam generation. The rate at which the outer boundaries of the fluid mass are aerated depends on the air velocity. Gravitational force alone is not adequate to generate



a stable foam structure; consequently helicopters must fly at 30 mph or greater to obtain adequate aeration. A drop height of 100 feet is adequate when the solution exit rate is slow but as the volume in the exiting mass increases, drop height must be increased up to as much as 500 feet above canopy to achieve foam formation. An increase in the mix ratio works the same as increased aircraft speed or increased drop height.

Equipment Maintenance and Housekeeping

Guidelines for maintenance and housekeeping follow.

- All foam concentrates have a detergent base. Therefore, cleansing of all plumbing, pumps, tanks, and other exposed surfaces can be expected. This may promote the corrosive actions of water.

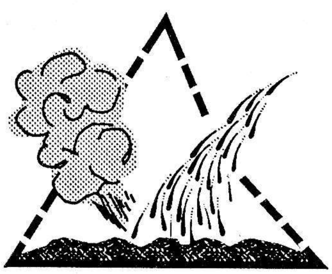
• Flush pumps exposed to foam solution for 20 minutes at the end of each shift.
• Existing rust, scale, or dirt will be cleaned from inside your tank, and may plug the nozzle, pressure gauge parts, etc.
• Proportioning devices which place foam concentrate on the discharge side of the pump are recommended to minimize corrosion problems associated with foam.
• Galvanized or fiberglass tanks for water and plastic or fiberglass tanks for foam concentrate are preferred.
• Recommended general housekeeping practices include:
  —Washing concentrate storage tank and engine body.
  —Flushing injection systems and pumps.
  —Using pour spouts when transferring concentrate.

APPLICATION

Basic Considerations

This section provides an overview of foam characteristics that aid in fire suppression efforts and overcome problems that may be encountered. Remember that class A foam makes water work more effectively in all fire applications. Water alone works on one side of the fire triangle; straight streams are 5 to 10 percent effective at extinguishment. Water that is applied as a foam works on all three sides of the fire triangle.

As a foam, water is most efficiently turned to steam, absorbing heat. Foam itself has no chemical or long-term retardant effect. Foam's performance is determined by its drain rate, expansion ratio, and surface tension. The inability to generate useful foam may be due to use of the wrong type of foaming agent, foam generator problems, improper application, or inappropriate expectations of the foam's performance.



FUEL

One important feature of foam is that the applicator can see where it has been applied; and foam tends to stay where it is applied. In general, as long as foam is visible, the treated fuel remains wet. However, a foam's effectiveness as a barrier should not be judged by visibility alone. Fire may burn under or through a thick blanket of foam that drains too slowly to wet adjacent fuels, while a rapidly draining foam that disappears quickly may leave behind very wet fuels as the draining fluid penetrates the fuels. The amount of water absorbed depends on the amount of water (as foam) applied, the amount of water evaporated, the foam stability, and the fuel type.

The techniques employed with a CAFS and aspirated nozzles are basically the same as when using a water stream. However, with foam, less time will be necessary in any given location or situation than with water.

Water flow must fit the task. Recognize that some foam generating devices may flow more water than conventional systems. Operators must learn to let foam work for them, allowing the operator to complete the task more efficiently.

Foam should quickly penetrate live and dead fuels, charred fuels, and litter and duff material and immediately knock down and extinguish flames and eliminate smoke when applied at the base of the flames. Foam can also be made to form a short-term foam layer that is greater than 1/2 inch on trees, snags, roofs, walls, eaves, and vehicles.

Width and depth of application depend primarily upon wind, temperature, fuel moisture, and fuel loading and change as any of these factors change. Foam should be applied to provide enough water and the appropriate rate of drainage necessary to accomplish the task. The depth of the foam blanket and the amount of water available for wetting must increase as the fire intensity increases.

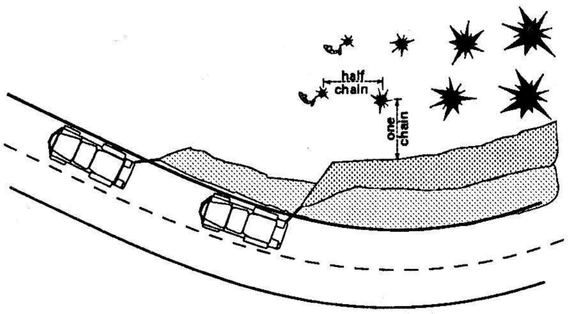
Foam durability depends on the weather. Foam will be visible in exposed areas for about 1 hour in hot weather, for up to 4 hours in cool weather, and in shaded areas will be visible even longer. CAFS foam will generally last longer than aspirated nozzle foam because of its stronger, more uniform bubble structure.

FOAM TYPE	CHARACTERISTIC
Solution	A clear to milky fluid, lacks bubble structure, mostly water
Wet	Watery, large to small bubbles, lacks body, fast drain times
Fluid	Similar to watery shaving cream, medium to small bubbles, flows easily, moderate drain times
Dry	Similar to shaving cream, medium to small bubbles, mostly air, clings to vertical surfaces, slow drain times

Prescribed Fire

The foam characteristics most important to fuel protection are wetting ability and durability. The foam must break down sufficiently to wet the fuels, but must remain stable to maintain a protective barrier.

The amount of foam required for fuel protection depends on air temperature, wind, relative humidity, fuel loading, and the fuel's moisture content. Foam is a very short-term treatment on a hot, dry, windy day. It is most effective when applied prior to ignition, allowing only enough time for the treated fuels to be wetted by moisture escaping from the foam blanket.



In general, the more adverse the burning conditions, the shorter the time between foam application and ignition should be. The need to repeat the treatment should also be considered when ignition time must be delayed. Start with a 0.3 percent foam solution for CAFS or 0.5 percent for aspirating nozzle systems and adjust the mix ratio to obtain the required foam type. Apply foam directly to the fuel from a short distance at high pressure for maximum penetration of foam mass into ground and surface fuels. Then apply the foam from a distance and with a trajectory to allow the flakes of bubbles to settle gently upon the fuel. This technique, known as lofting, provides greater coverage of fuel surfaces and reduces bubble breakdown on impact. An insulating, reflecting water barrier is formed.

On fireline applications most work can be accomplished from the fireline; but fuels should be treated from two angles to ensure coverage. Foam line width depends on the fuel and expected fire behavior conditions. To ensure thorough coating, apply foam to all exposed sides of the fuel and, when possible, to ladder and crown fuels above the foamline. A high-pressure stream directed into the fuels at the interface of fireline and foamline ensures wetting through the entire depth of fuel and minimizes the likelihood of underburning.

To provide adequate water for wetting below the insulative foam blanket, foam solution can also be used. Apply foam solution to wet the area entirely. Because foam agents wet living, dead, charred, and uncharred fuels, they are recommended for this treatment over standard wetting agents which wet charred fuels only.

Foam applied to protect seed trees, wildlife trees,snags, log decks, telephone poles, and other resources and properties should be a fluid or dry foam that will cling to vertical, upside-down, slippery surfaces in sufficient quantities to form a protective blanket. More time may be required than for fireline application to adequately protect these types of fuels. Surrounding fuels should be treated from 25 to 50 feet out from the base of standing objects. Time of application before ignition is the same as with other foamline applications.

The abilities of foam to penetrate dead and live fuels quickly, to form an insulating blanket, to cling to vertical surfaces, and to reach great distances from the nozzle have provided a powerful new tool for fuel protection. Foam can prevent fire spread. It can protect stands of timber, structures, wildlife habitat, fuelwood concentrations, endangered plants, and other resource values. Foam accomplishes extinguishment with less application time, with fewer personnel, and less water than conventional water applicaton.

OPERATING GUIDELINES

Foam Delivery Systems

Any of the foam proportioning/mixing methods can be used with any foam generating device. Automatic regulating devices are preferred for compressed air foam systems to prevent slug flow.

Conventional Nozzles

1. 0.1 to 0.3 percent mix ratio
2. Match gpm flow to task.

Aspirating Nozzles

1. 0.2 to 1.0 percent mix ratio, dependent on nozzle and type of application, with adjustments to best meet the needs and objectives as dictated by fuels and fire behavior.
2. Match gpm flow to task.

CAFS

CAFS can operate at any water flow the pump and hose can handle. Water flow can be adjusted at the engine or the nozzle. At 150 psi and maximum air:

Hose (in)	Maximum Water Flow	Maximum Discharge
1.0-inch hose	20 gpm	80 ft
1.5-inch hose	40 gpm	100 ft
2.5-inch hose	80 gpm	180 ft

Compressed air foam can be adjusted by changing any of the three inputs—air, water, concentrate.

1. Keep static air and water pressures equal.
2. Start with a 0.3 percent mix ratio.
3. Maximum production/output.

   • 30 gpm/30 cfm for one 1-inch hose
   • 60 gpm/60 cfm for one 1.5-inch hose or two 1-inch hoses.
   • 100 gpm/100 cfm for one 2.5-inch hose; two 1.5-inch hoses; five 1-inch hoses.

4. Operate with 1 cfm of air for every gpm of water.
5. 100 feet of hose or a motionless mixer
6. Match gpm flow to task.

Aerial Generating Systems

Mix ratios of 0.5 to 0.6 percent are commonly used.

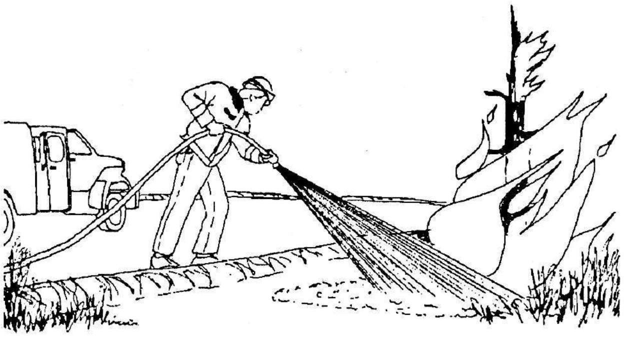
SUPPRESSION

Initial Attack

Direct

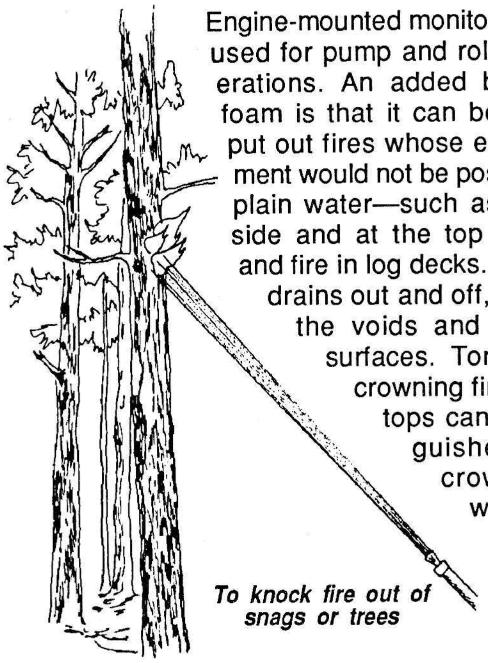
The ability of foam to continue wetting and cooling fuels long after the application is completed is a key to foam use strategies. Greatest efficiency is achieved with continuous, rapid application; knocking out the flaming fire front, blanketing smoldering stumps, and allowing the foam to work where it is applied.

A good starting point is a 0.3 percent mix ratio for CAFS, and 0.5 percent for aspirating nozzle systems. Make adjustments to the mix ratio to produce foam solution, wet foam, or fluid foam to meet the needs of the particular situation. Hard or saline water may require a higher mix ratio than with other water to produce comparable foam.



Application of foam to the base of a linear flame front is crucial to minimize losses due to heat and updraft. Hotspots should be secured first around the edge, and then the interior should be blanketed. While attacking the edge, a portion of the foam stream should be directed onto the adjacent unburned fuels. The stream initially may be directed at very hot or distant flames to allow safer approach to the fire front.

When penetration into burning material is necessary, increase the application or impact from a short distance; apply enough to ensure extinguishment. Since foam is highly visible, over-application can be minimized. Work quickly—as soon as steam is visible move on. Leave a foam blanket over the hot fuel to smother it, and continue to wet and cool the fuel. Proceed to coat additional untreated fuels.

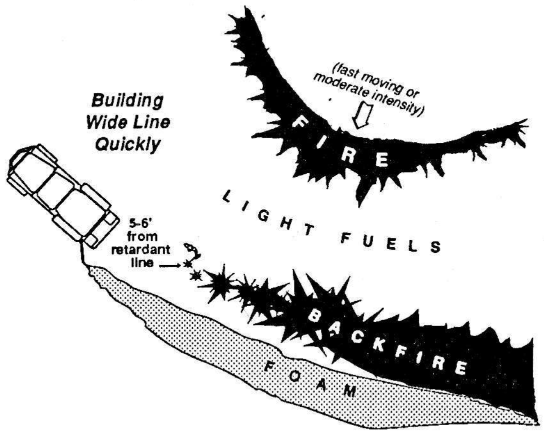


Engine-mounted monitors may be used for pump and roll-type operations. An added benefit of foam is that it can be used to put out fires whose extinguishment would not be possible with plain water—such as fires inside and at the top of snags and fire in log decks. As water drains out and off, foam fills the voids and clings to surfaces. Torching and crowning fires in tree tops can be extinguished if the crowns are within reach of the foam stream.

To knock fire out of snags or trees

Indirect

Mix ratios of 0.3 percent for CAFS and 0.3 to 0.5 percent for aspirating nozzle systems are appropriate starting points. Apply foam as a wet line at least two and a half times as wide as the expected flame lengths adjacent to a back fire. Apply foam directly at close range and attempt to coat all sides of fuel to the ground. Foam can also be lofted onto brush, tree trunks, and canopies to add an insulating barrier. Allow time for wetting of fuels where possible.



Water in the foam is doing the work against the fire. The effectiveness of a foam line in indirect attack is limited by the time it takes the water to evaporate.

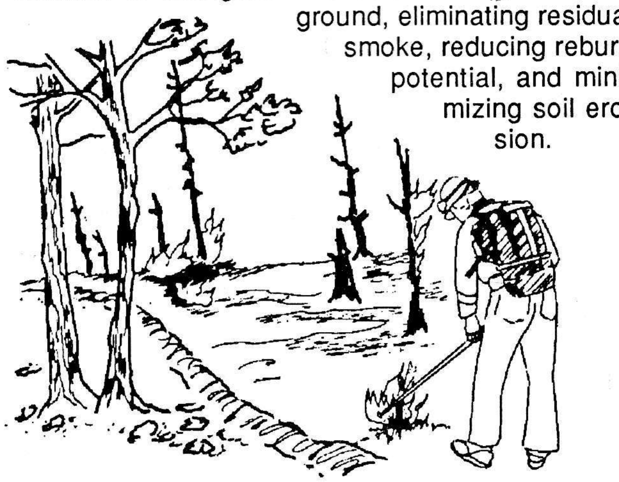
Structure Protection

The ability of foam to adhere to vertical, sloped, undersides, and slippery surfaces is the key to structure protection. Start with a 0.3 percent mix ratio for CAFS or a 0.5 percent for aspirating nozzles and adjust the mix ratio as necessary to obtain the desired foam consistency. Apply a dry foam to outside walls, eaves, roofs, columns, or other threatened surfaces, lofting it rather than directing it at the surfaces to avoid foam breakdown and runoff due to impact of additional foam. Durability is dependent on weather and fire behavior conditions. In general, CAFS foam should last for 1 hour in hot weather, nozzle aspirated foam for about 30 minutes. The effectiveness and life of the foam blanket is dependent on foam dryness and the depth of application. At least 1/2 inch of foam should remain on all surfaces, even if excess amounts slough off.

Depending on the fire intensity, foam can be used successfully to prevent wildland and structure fires from igniting adjacent structures. However, if a structure becomes involved, foam-treated walls alone may not save it because the water requirement for preventing combustion may be greater than the water applied as foam.

Mop-up

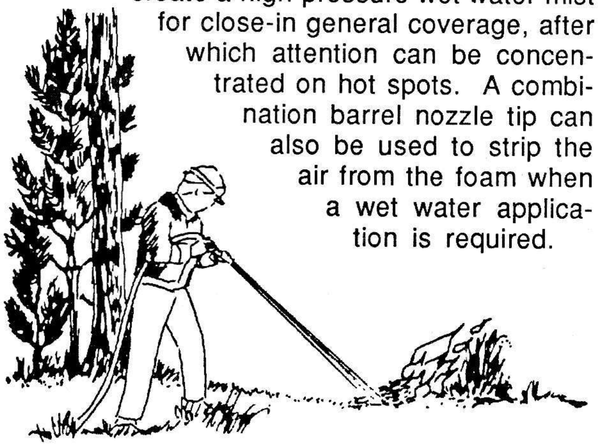
Foam's extinguishing, penetrating, and discharge distance capabilities allow mop-up operations to begin earlier and take less time to complete. The smothering action of the foam and the penetration of the solution can be used soon after flames subside to extinguish fire before it burns underground, eliminating residual smoke, reducing reburn potential, and minimizing soil erosion.



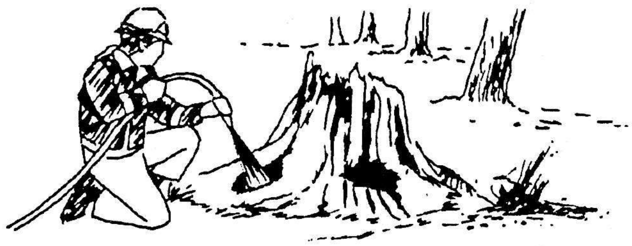
Hand tools, mop-up wands, and forester nozzles can be used with compressed air foam or foam solution for mop-up operations. Application techniques are the same as those for plain water, but the water, aided by the wetting agents contained in the foam, does the work more efficiently.

Start with a 0.2 percent solution for CAFS or 0.3 for nozzle aspirating systems. Application of the foam should begin on the burn edge and work should progress inward with particular attention to hot spots. Any remaining flames should be attacked directly.

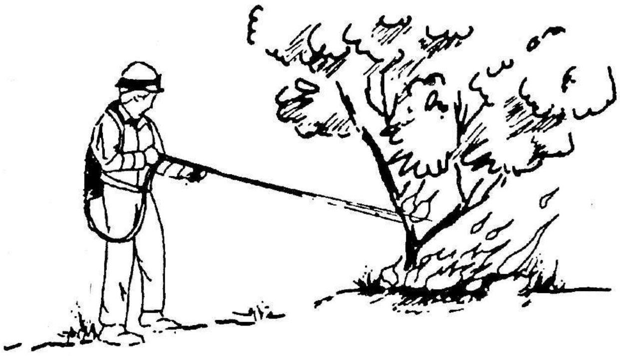
By partially closing the valve, when a CAFS is used, to strip air from the foam it is possible to create a high-pressure wet water mist for close-in general coverage, after which attention can be concentrated on hot spots. A combination barrel nozzle tip can also be used to strip the air from the foam when a wet water application is required.



For surface fires, a wet foam can penetrate the fuel quickly to cool and smother the fire and create an oxygen barrier around any remaining smoldering fuel. This strategy works extremely well on pitchy and punky material, duff and litter material.



Avoid applying dry foam during mop-up. This slow-draining foam forms a lid over deep-seated fires, trapping heat. Pockets of low-level combustion may show up as steam plumes or as patches with no foam remaining. These places should be treated again.



Backpack Pumps

Backpack pumps with conventional fog and straight-stream tips can be used to deliver foam solution. A mix ratio of 0.05 to 0.1 percent is common for this type of application. To avoid excessive foaming, the foam concentrate should always be added to water once the container is filled. Because the detergent properties of the foam solution strips the lubricant from the pump wand periodic lubrication of the pump is required.

Application techniques are the same for foam solution as for water, except that the quantity needed for a given task is less. Aspirating nozzles are available for use with a backpack pump, but aeration is incomplete. The wet foam or foam solution produced is suitable for hand suppression and mop-up activities.

SUMMARY

Foams:

1. Enable water to most efficiently absorb heat by forming water into a thin film.
2. Protect fuels from ignition by:
   a. Suppressing vapors.
   b. Wetting fuels
   c. Insulating fuels from flame, heat, and oxygen.
   d. Reflecting heat from fuels.
3. Are more effective because:
   a. They can hold water in place over time.
   b. They spread water to a thin film enabling increased penetration and spreading.
4. Reduce smoke and related emissions.
5. Raise humidity of treated air space.
6. Fills vertical cavities; not affected by gravity.

CLASSIFICATION SYSTEM FOR APPLICATION OF WILDLAND FIREFIGHTING FOAMS

Several types of foams can be created with the foam generating equipment discussed. Each of them has a role in the wildland fire suppression. Listed below are the foam types and associated characteristics.

Foam "Solution"

CHARACTERISTICS
Foam "SOLUTION" has no real bubble structure but some bubble formation may occur due to agitation and impact.

DESCRIPTION
- A clear to milky fluid
- No bubble structure
- Mostly water
- Immediately runs off vertical surfaces

TYPICAL USES
- Areas requiring immediate penetration
- Thick fuel beds like sawdust piles, peat, tundra, and muskeg
- Tall grass
- Deep-seated fires
- Mop-up

EQUIPMENT REQUIRED TO PRODUCE
- Proportioner
- Conventional nozzles
- CAFS (using conventional nozzles or partially opened shut-off valve)

"Wet" Foam

CHARACTERISTICS
The bubbles of "WET" foams are spherical masses of air which are enclosed in solution. The bubble walls are separated by a large amount of solution, relative to other types of foams. Wet foams have very fast drainage rates.

DESCRIPTION
- Watery
- Very runny on vertical surfaces
- Bubble size varies from large to small
- More water than air
- No 'body'
- Fast draining

TYPICAL USES
- Direct attack on fine fuels or desert type fuels
- Mop-up
- Deep duff and anywhere fuel penetration is essential
- Tall grass and deep fine fuels
- Muskeg, tundra, sawdust pits and piles, peat, and other such deep-seated fires
- Aerial application, canopy penetration

EQUIPMENT REQUIRED TO PRODUCE
- Proportioner
- Low-expansion aspirated nozzles
- CAFS units
- Aircraft

"Fluid" Foam

CHARACTERISTICS
The bubbles of "FLUID" foams are mostly spherical. There is less separation of bubbles by the solution than with wet foam. Some of the bubble walls may be touching. Fluid foams have medium to fast drainage rates.

DESCRIPTION
- Watery shaving cream
- Does not hold peaks
- Flows readily from vertical surfaces
- Medium to small bubbles
- Flows easily
- Moderate drain rates

TYPICAL USES
- Direct attack on most fuels
- Protection of vertical surfaces
- Protection of standing timber
- Protection of structures
- Prescribed burn fuel protection
- Mop-up
- Aerial penetration of forest fuels
- Fuel or resource protection for short periods (less than 30 minutes)
- Grass and fine fuels

EQUIPMENT REQUIRED TO PRODUCE
- Proportioner
- Low-expansion aspirating nozzles
- CAFS units
- Aircraft

"Dry" Foam

CHARACTERISTICS
The bubbles of "DRY" foams are polyhedral in shape. The bubble walls are very thin with only small amounts of solution between the bubbles. These types of foams have very slow drainage rates.

DESCRIPTION
- Shaving or whipped cream
- Medium to small bubbles
- Mostly air
- Very "dry" and fluffy
- Clings to vertical surfaces
- Holds peaks for a long time
- Slow drain times

TYPICAL USES
- Insulating ground and ladder fuels
- Visible barriers for long time periods (greater than 30 minutes)
- Protection of structures and other vertical surfaces
- Protection of standing timber

EQUIPMENT REQUIRED TO PRODUCE
- Proportioner
- CAFS units
- Low-expansion aspirating nozzles

Absorption
The act of absorbing or being absorbed.

Adherence
See viscosity.

Agent Concentrate
The fire chemical product as received from the supplier that, when diluted with water, becomes foam solution.

Agent Solution
The dilute working-form of foam concentrate to which air is added to produce foam.

Aspirate
To draw in air; nozzle aspirating systems draw air into the nozzle to mix with the agent solution.

Automatic
Readily adjusts to changes in water flow and or pressure to maintain a desired mix ratio.

Balanced
See Automatic.

Barrier
Any obstruction to the spread of fire; typically, an area or strip devoid of flammable fuel.

Batch Mix
Manual addition of foam concentrate to a water storage container or tank to make foam solution.

Biodegradation
Decomposition by microbial action, as with some detergents.

Blanket
A body of foam - used for fuel protection and/or suppression.

Bubble
The building block of foam; bubble characteristics of water's content and durability influence foam performance.

Carcinogenic
Cancer-causing.

Class A Fire
Fire in "ordinary" combustible solids. (However, if a plastic readily melts in a fire, it might be Class B rather than Class A.)

Class B Fire
Fire in flammable liquids, gasses, and greases.

Class A Foam
Foam intended for use on Class A or woody fuels; made from hydrocarbon-based surfactant, therefore lacking the strong filming properties of Class B foam, but possessing excellent wetting properties.

Class B Foam
Foam designed for use on Class B or flammable liquid fires; made from fluorocarbon-based surfactants, therefore capable of strong filming action, but incapable of efficient wetting of Class A foam.

Combination Nozzle
Also called an "adjustable fog nozzle." This nozzle is designed to provide either a solid stream or a fixed spray pattern suitable for water or wet water application.

Compressed Air Foam Systems (CAFS)
A generic term used to describe foam systems consisting of an air compressor (or air source), a water pump, and foam solution.

Concentrate
A substance that has been concentrated; specifically, a liquid that has been made denser, as by the removal of some of its water.

Consistency
Uniformity and size of bubbles.

Corrosion
Result of chemical reaction between a metal and its environment (i.e., air, water, and impurities in same).

Degradation
The act of degrading or being degraded in rank, status, or condition.

Density
The amount of foam solution in the foam (note difference from "expansion").

Drain Time
The time (minutes) it takes for foam solution to drop out from the foam mass for a specified percent of the total solution contained in the foam to revert to liquid and drain out of the bubble structure.

Durability
The effective life span of foam bubbles.

Eductor
A mixing system that uses water pressure to draw the fire chemical into the water stream for mixing; enables a pump to draw foam concentrate, as well as water, into the hose line.

Ejector
Occasionally an injector is used to proportion mixes; this type of equipment is frequently referred to as an "ejector," though sometimes as an "injector."

Environment
Something that surrounds; surroundings, such as air, water, or natural resources.

Expansion
The ratio of the volume of the foam in its aerated state to the original volume of the non-aerated foam solution.

Fire Retardant
Any substance that by chemical or physical action reduces the flammability of combustibles.

Foam
The aerated solution created by forcing air into, or entraining air in, a water solution containing a foam concentrate by means of suitably designed equipment or by cascading it through the air at a high velocity.

Foam Concentrate
The concentrated foaming agent as received from the manufacturer; use only those approved for use in wildland fire situations by the authority having jurisdiction.

Foam Generation
The foam production process of solution agitation in a hose, mix chamber, or nozzle.

Foam Line
A body of foam placed along areas to be protected from fire; also used as an anchor for indirect attack in place of hand-made fire trail.

Foam Solution
A homogeneous mixture of water and foam concentrate in a proportion that meets the needs of the user.

Foam Systems
The apparatus and techniques used to mix concentrate with water to make solution, pump and mix air and solution to make foam, and transport and eject foam. (Systems defined here include compressed air foam and nozzle aspirated.)

Foam Type
A combined measure of drain time and expansion to describe durability, consistency, viscosity, and density.

Inductor
A control mechanism that allows a regulated quantity of foam concentrate to be introduced into the main hose line.

Ingestion
To take things into the body (food, drugs, etc.) by swallowing or absorption.

Ingredient
Each chemical component used in the formulation of a product.

Manual
Worked or done by hand and not by machine.

Manual Regulation
A proportioning method or device that requires a manual adjustment to maintain a desired mix ratio over a changing range of water flows and pressures.

Mix Ratio
The ratio of liquid foam concentrate to water, usually expressed as a percent.

Mixed Solution
The combination of water and foam concentrate used to produce the foam used for fire suppression.

Mixing Chamber
A tube drilled, with deflectors or baffles, that produces tiny, uniform bubbles in a short distance (1 to 2 ft).

Monitor
A turret-type nozzle usually mounted on an engine.

Mutagenic
Any agent or substance capable of noticeably increasing the frequency of mutation.

Nozzle Aspirated Foam System
A foam generating device that mixes air at atmospheric pressure with foam solution in a nozzle chamber.

Proportioner
Pumps foam concentrate, as demanded into the hose line.

Reproductive
The process, sexual or asexual, by which animals and plants produce new individuals.

Scrubbing
The process of agitating foam solution and air within a confined space (usually a hose) that produces tiny, uniform bubbles - the length and type of hose determine the amount of scrubbing and, therefore, foam quality.

Short-Term Retardant
A viscous, water-based substance wherein water is the fire suppressing agent.
Slug Flow: In CAFS only, when foam solution is not rich enough to mix with air, inadequate mixing occurs; this sends pockets (or plugs) of water and air to the nozzle.

Stability
See Viscosity.

Suppressant
An agent used to extinguish the flaming and flowing phases of combustion by direct application to the burning fuel.

Surface Tension
The elastic-like force in the surface of a liquid, tending to minimize the surface area and causing drops to form. (Expressed as Newtons per meter or dynes per centimeter; there are 1,000,000 dynes per Newton.)

Surfactant
A surface active agent; any wetting agent.

Use Level
The appropriate ratio of liquid foam concentrate to water recommended by the chemical manufacturer for each class of fire.

Variable
See Automatic.

Viscosity
An indication in the ability of the foam to spread and cling, as well as to cling to itself, upon delivery.

Wet Water
Water with added chemicals, called wetting agents, that increase water's spreading and penetrating properties due to a reduction in surface tension.

Wetting Agent
A chemical that, when added to water, reduces the surface tension of the solution and causes it to spread and penetrate exposed objects more effectively.

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NWCG Fire Equipment Working Team, Foam Task Group. *Foam vs Fire—Class A Foam for Wildland Fires.* Copies available from the National Interagency Fire Center, 3905 Vista Ave., Boise, Idaho 83705. NFES 2246

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USDI-BLM. *A Performance Test of Low Expansion Nozzle Aspirated Systems and Class A Foam, 2nd Edition.* National Interagency Fire Center, 3905 Vista Ave., Boise, Idaho 83705

The National Wildfire Coordinating Group (NWCG) has sponsored the publication of the following videos produced by the NWCG Fire Equipment Working team. Copies of each of these items may be ordered from the National Interagency Fire Center (NIFC). Attn: Supply, 3905 Vista Avenue, Boise, Idaho 83705

Introduction to Class A Foam, 1989
NFES #2073

The Properties of Foam, 1992,
NFES #2219.

Class A Foam Proportioners, 1992,
NFES #2245

Aspirating Nozzles, 1992,
NFES #2272

Compressed Air Foam Systems, 1993,
NFES #2161

THE METRIC SYSTEM AND EQUIVALENTS

The purpose for including the following metric system equivalents and approximate conversion factors is to meet the requirements of Public Law 100-418. This law requires each Federal agency to use the metric system of measurement by Fiscal Year 1992, in procurements, grants, and other business related activities.

Linear Measure

1 centimeter=	10 millimeters=	0.39 inch
1 decimeters=	10 centimeters=	3.94 inches
1 meter=	10 decimeters=	39.37 inches
1 dekameter=	meters=	32.80 feet
1 hectometer=	10 dekameters=	328.08 feet
1 kilometer=	10 hectometers=	3,280.8 feet

Liquid Measure

1 centiliter=	10 milliliters=	0.34 fl ounce
1 deciliter=	10 centiliters=	3.38 fl ounces
1 liter=	10 deciliters=	38.82 fl ounces
1 dekaliter=	10 liters=	2.64 gallons
1 hectoliter=	10 dekaliters=	26.42 gallons
1 kiloliter=	10 hectoliters=	264.18 gallons

Weights

1 centigram=	10 milligrams=	0.15 grain
1 decigram=	10 centigrams=	1.54 grains
1 gram=	10 decigrams=	0.035 ounce
1 dekagram=	10 grams=	0.35 ounce
1 hectogram=	10 dekagrams=	3.52 ounces
1 kilogram=	10 hectograms=	2.20 pounds
1 quintal=	100 kilograms=	220.46 pounds
1 metric ton=	10 quintals=	1.1 short tons

Square Measure

1 sq centimeter=	100 sq millimeters=	0.155 sq in
1 sq decimeter=	100 sq centimeters=	15.5 sq in
1 sq meter (centare)=	100 sq decimeters=	10.76 sq ft
1 sq dekameter (are)=	100 sq meters=	1,076.4 sq ft
1 sq hectometer (hectare)=	100 sq dekameters=	2.47 acres
1 sq kilometer=	100 sq hectometers=	0.386 sq mi

Cubic Measure

1 cu centimeter=	1000 cu millimeters=	0.06 cu inch
1 cu meter=	1000 cu decimeters=	35.31 cu feet
1 cu decimeter=	1000 cu centimeters=	61.02 cu inches

APPROXIMATE CONVERSION FACTORS

To Change	To	Multiply By
inches	centimeters	2.54
feet	meters	0.305
yards	meters	0.914
miles	kilometers	1.609
square inches	square centimeters	6.451
square feet	square meters	0.093
square yards	square meters	0.836
square miles	square kilometers	2.590
acres	square hectometers	0.405
cubic feet	cubic meters	0.028
cubic yards	cubic meters	0.765
fluid ounces	milliliters	29,573
pints	liters	0.473
quarts	liters	0.946
gallons (US)	liters	3.785
liters	gallons (US)	0.264
gallons (Imp)	liters	4.546
liters	gallons (Imp)	2.220
gallon (US)	gallon (Imp)	0.333
gallon (Imp)	gallon (US)	1.201
ounces	grams	28.349
pounds	kilograms	0.454
short tons	metric tons	0.907
pound-feet	newton-meters	1.365
pound-inches	newton-meters	0.11375

To Change	To	Multiply By
ounce-inches	newton-meters	0.007062
centimeters	inches	0.394
meters	feet	3.280
meters	yards	1.094
kilometers	miles	0.621
square centimeters	square inches	0.155
square meters	square feet	10.764
square meters	square yards	1.196
square kilometers	square miles	0.386
square hectometer	acres	2.471
cubic meters	cubic feet	35.315
cubic meters	cubic yards	1.308
milliliters	fluid ounces	0.034
liters	pints	0.2113
liters	quarts	1.057
liters	gallons	0.264
grams	ounces	0.035
kilograms	pounds	2.205
metric tons	short tons	1.102
PSI	kilopascals	6.895
kilopascals	PSI	0.145
acres	hectares	0.405
hectares	acres	2.470

Temperature (Exact)

°F=Fahrenheit °C=Celsius

°F=(°Cx9/5)+32 °C=5/9x(°F-32)

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