A Publication of the
National Wildfire Coordinating Group

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United States
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FOAM VS FIRE
Primer

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OCTOBER 1992

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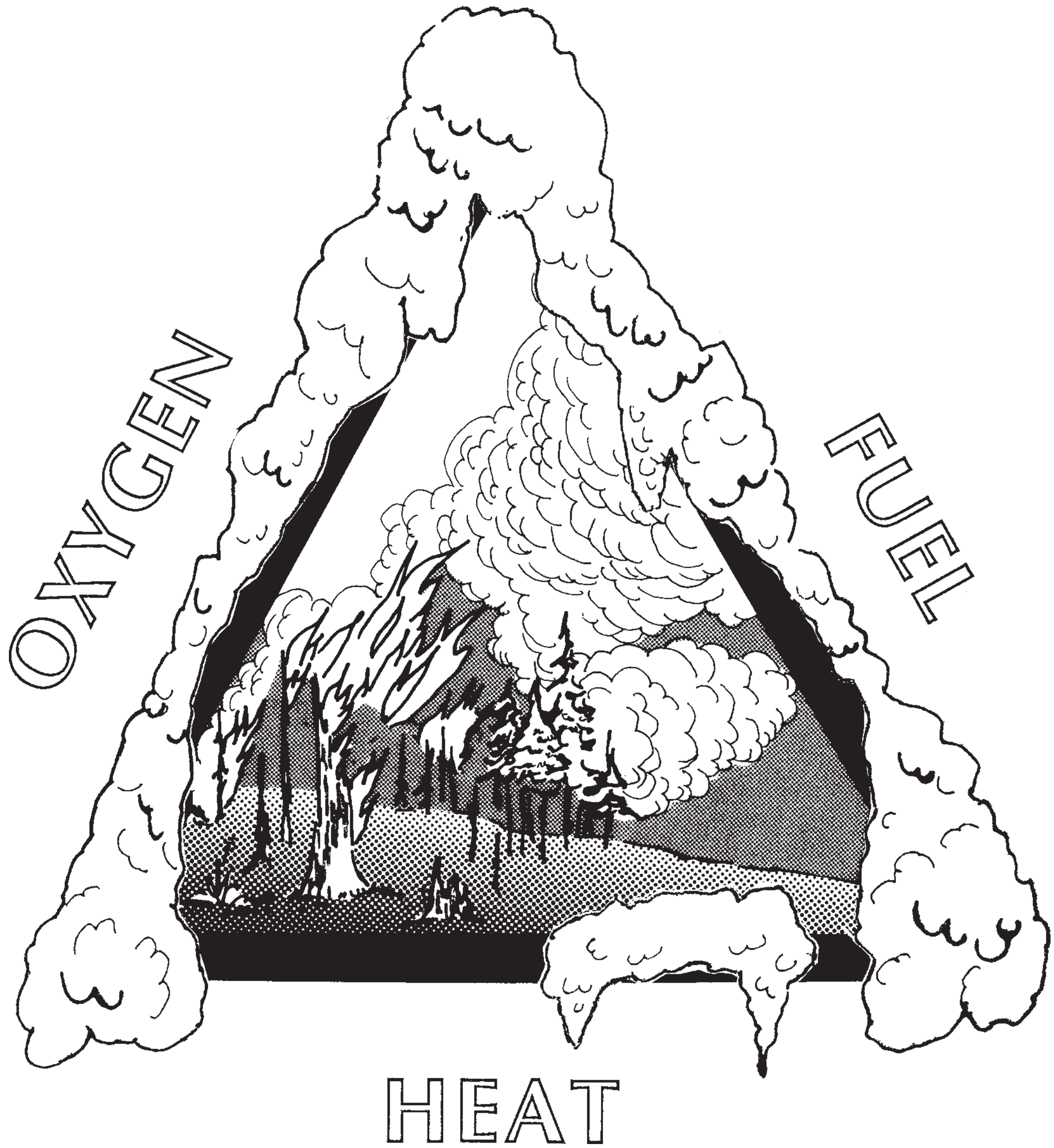

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FOAM VS FIRE
Primer

OCTOBER 1992

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

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. Air Applications
   (to be published in 1994)

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:

Publications, USDA Forest Service
San Dimas Technology and Development Center
444 East Bonita Avenue
San Dimas, CA 91773-3198

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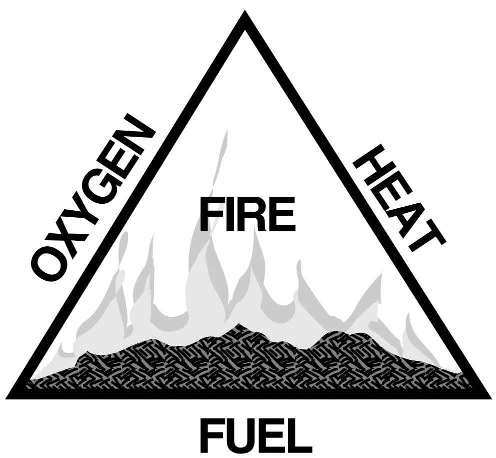
INTRODUCTION

The phrase "Fire doesn't like water much" is as true today as the day it was coined. We all know how important the proper use of water is when trying to suppress a wildfire. But, did you know that you can change water so that it will work more effectively at extinguishing fires?

That's the purpose of this booklet: To show you how to get the most firefighting punch from water that you can by converting water to class A foam.

Before we go any further, let's review just how water extinguishes a fire. You remember the fire triangle and that water can break it up by several means. The number one way that water works is to remove the heat by cooling. The fire turns the water to steam; this robs the fire of the heat that it needs to burn. The steam that is created also reduces the oxygen that is available to the fire. You can also remove the oxygen from the fuel if you submerge the fuel in water.



This all makes water sound like a pretty powerful tool, but there is a problem with water that cuts down its effectiveness. This problem is called surface tension and all water has it. Surface tension holds water together; this causes water to bead up and run off most fuels. This means that water doesn't stay on the fuel long enough to absorb all the heat that it can. We can lower the surface tension of water by adding something called a surface-active agent or surfactant. We use surfactants every day when we wash dishes or clothes. Why not use them to fight fire?

When a surfactant is added to water to lower the surface tension, several things happen:

- Water penetrates fuels faster
- Water spreads over the fuels
- Increased absorption occurs
- Fog nozzle droplets are three times smaller
- Water is more slippery, so that it increases flow in delivery lines
- Water is attracted to carbon.

SURFACTANTS

If this all sounds pretty good, it is. Surfactants can make water up to two times more effective.

There are two forms of surfactants presently being used by wildland fire agencies. These are wetting agents and class A foam concentrates.

Wetting Agents

Wetting agents have most of the properties listed for surfactants, but they are designed to prevent foaming. This is to keep bubbles from forming in water tanks. What may surprise you is that bubbles can actually make your job easier.

Class A Foam Concentrates

Class A foam concentrates also have all the properties listed for surfactants. Unlike wetting agents though, they are a detergent—these are attracted to carbon and have the ability to be turned into foam. Class A foam concentrates are similar to common household detergent products, but have been designed especially for class A fuels.

When class A foam concentrate is added to water, foam solution is produced. The recommended ratio of class A foam concentrate to water is between 1/10th of 1 percent and 1 percent, depending on the job. It doesn't take very much foam concentrate to lower the surface tension of water. Only approximately 1/10th of 1 percent, or 1 gallon of concentrate to 1,000 gallons of water, will begin to lower the surface tension.

The problem with foam solution in many fire situations is that the solution will still run off the fuels just like untreated water does. Of course, foam solution will spread over the fuel and penetrate better than plain water will, but it may not stay in place long enough to absorb all the heat that it is capable of absorbing.

If we increase the amount of concentrate we add to water (between 3/10ths and 5/10ths of 1 percent) and add air, we can change foam solution to a foam. It takes energy to add the air to foam solution to produce class A foam—this is discussed later in the booklet. By changing foam solution to foam, water is held in place on the fuel longer so that it can absorb more heat. Foam wraps around fuel so that the water is spread uniformly over all the surfaces of the fuel.

Let's stop for a second and review:

WATER + FOAM CONCENTRATE = FOAM SOLUTION

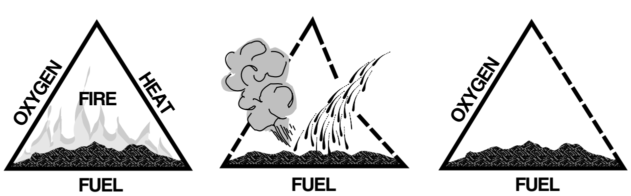
FOAM SOLUTION + AIR = FOAM

Besides holding the water in place on the fuel longer, class A foam removes heat better than water or wet water because of the way water is held in a bubble. As a bubble, water is in a film that surrounds a pocket of air. This allows water to be converted to steam faster than if the water is in droplets. Foam also attacks the heat leg of the triangle in three other ways:

- The opaque, white surface of foam reflects heat away from the fuel.
- This same foam layer insulates the fuel from heat.
- Water is stored in the foam blanket where it can be absorbed by the fuel. By creating wet fuel, the chance of reignition is reduced.
- The action of the detergent allows the water to be absorbed by the fuel.

Not only does foam help water absorb heat more efficiently, foam also works on the other two sides of the fire triangle. Foam removes the fuel from fire in much the same way that it protects against heat. A foam blanket on burning fuel holds in flammable vapors which can prevent the vapors from igniting.

This same foam blanket can help to remove oxygen from the fire by separating the fuel and flammable vapors from the air. But remember, to cut off the air supply to the fuel, the foam must spread completely over the fuel surface and then stay in place for awhile.



We've just covered a lot of new material, so let's review what we have learned:

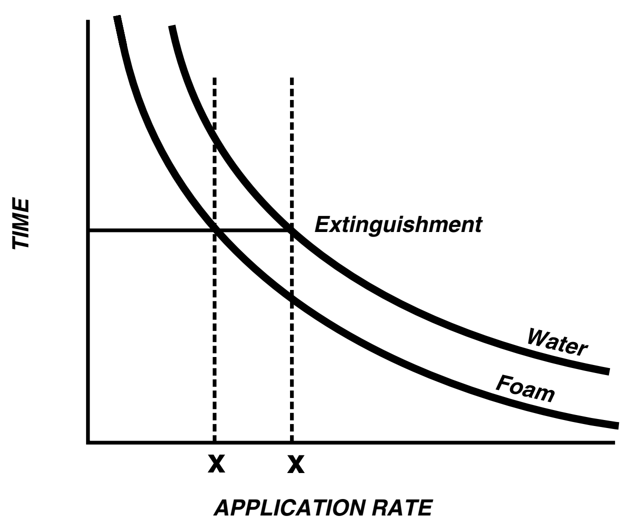
Plain water is **NOT** as efficient as foam at removing heat. By adding foam concentrate to water to make foam solution, efficiency can be increased by as much as two times that of water. When foam solution is turned into a foam, all three legs of the fire triangle can be attacked. Foam holds water in place so that heat is absorbed and reflected, oxygen is separated from the fuel, fuel is insulated, and vapors are suppressed.

CLASS A FOAM

A few words to the wise on using class A foam follow.

First, don't confuse class A foam with the foam that is used on class B fires. These class B foams are designed specifically for burning flammable liquid fires and class A foam will not work the same way. It's just not safe to fight a class B fire with class A foam.

Secondly, class A foam is not magic. It's still the water in the foam that is doing the work on the fire. Every fire has a critical application rate; that is, every fire has a minimum amount of water that must be applied to extinguish the fire. This is true for foam also. But, since the water in foam is being used more efficiently, the critical application rate for a given fire is somewhat lower with foam than with water. Remember, there is still a critical application rate that must be applied for a fire to be suppressed.



Critical Application Rate

Before we discuss how to make foam, there are a few foam properties that need to be understood. These properties are drain time, expansion ratio, and foam type.

Drain Time

Drain time is the time it takes for a certain amount of foam solution to drain from the foam mass. Drain time is important because it tells you how durable the foam is and how quickly the foam solution will be released. Foams with a shorter drain time are best suited for flame knockdown, immediate wetting, and mopup—any time quick cooling is needed. Foams with longer drain times are better at insulating fuels, such as in exposure protection.

Expansion Ratio

Expansion ratio is the measure of foam that is produced compared to the amount of foam solution used to make the foam. To get the expansion ratio, divide the volume of foam by the volume of foam solution. For example,if 100 gallons of foam is made from 10 gallons of foam solution, then the expansion ratio of the foam is 10 to 1. There are three categories of expansion ratios you will hear about when working with foam:

Expansion Ratios

LOW	1:1 to 20:1
MEDIUM	20:1 to 200:1
HIGH	200:1 to 1,000:1

Low-expansion foam has the widest range of application and is the most common because of its greater discharge distances. Medium expansion foam is usually used for putting down barriers, exposure protection, and mopup. High-expansion foam is most effective in creating barriers in heavy fuels and tall brush. Remember that a change in expansion ratio also results in a change in drain time and the volume of water per gallon of foam. This leads us to the third property which is foam type.

Foam Type

Foam type is a way of describing the combination of drain time and expansion ratio of low-expansion class A foam. A foam with a fast drain time and a low expansion ratio of 5 to 1 behaves much differently than a foam with a slow drain time and a 15 to 1 expansion ratio. The foam types you will use are as follows:

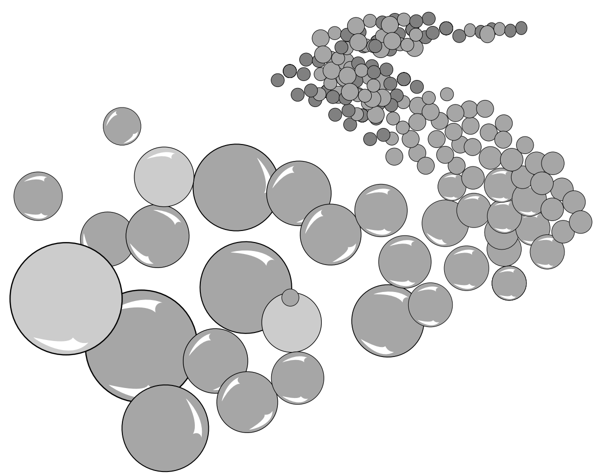
FOAM SOLUTION
- A clear to milky fluid
- Lacks bubble structure
- Mostly water

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

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. Now that we have covered the properties of foam, let's discuss how to add foam concentrate to water.



PROPORTIONING

Batch Mixing

The process of adding the right amount of foam concentrate to water is called proportioning. The simplest form of proportioning is batch mixing. Batch mixing is the pouring of a measured amount of foam concentrate into a tank of a known volume of water. It is an easy way to create foam solution with no investment in equipment. As simple as this method is, there are some drawbacks:

- Corrosion of the tank, pump, and plumbing increases when foam solution is used.
- Pump priming and cavitation problems can occur from foam solution passing through the pump.

- It is difficult to change the mix ratio of the solution.
- Water drawn from a hydrant or water tender can not be used directly for foam production because the foam concentrate must be added to a tank.
- Foam solution in a water tank makes sight gauges hard to read and can overflow when agitated by driving or water recircula tion.

Despite these limitations, batch mixing is a common proportioning method for engines, portable tanks, and bladders. In addition to batch mixing, there are manual and automatic proportioning devices. These are discussed next.

Manually Regulated Proportioners

Manually regulated proportioners are controlled by the operator and do not adjust the mix ratio of concentrate to water when the water flow or pressure changes. Manually regulated proportioning devices include:

- Suction-side proportioner
- In-line proportioner (eductor)
- Around-the-pump proportioner
- Direct-injection proportioner

Automatically Regulated Proportioners

Automatically regulated proportioners add the desired amount of foam concentrate into the water stream and adjust the flow of concentrate to any changes in the water flow or pressure. In other words, you automatically maintain the desired mix ratio of foam concentrate to water. These proportioners were designed to overcome the limitations found in the manual devices. They add the concentrate on the discharge side of the pump to avoid pump and tank problems. Also, they can be set for any mix ratio between 1/10th of 1 and 1 percent. Most automatic proportioners do not limit or restrict the water volume or pressure, and have no effect on the number of hoselays, nozzles, or length of hose which can be used.

Automatic systems include:

- Balanced-pressure tank
- Balanced-pressure pump
- Direct injection

One thing to watch with all proportioning devices is that when foam concentrate dries, it can plug up the small tubing, openings, and valves found on all of these systems. After every use, these should be flushed and cleaned. General, good housekeeping is necessary for each device.

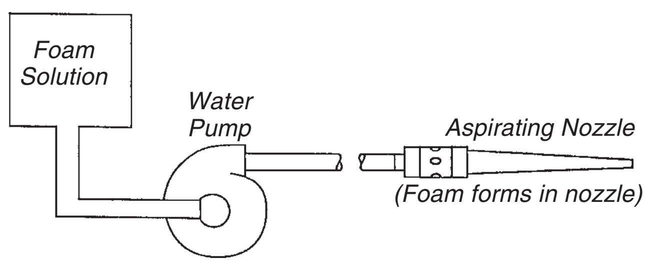
Remember that the purpose of proportioners is to create foam solution to make water work better. All of these devices and methods will improve the performance of water. They each have a place on the fire scene. Now that you know how to add foam concentrate to your water supply, let's discuss how to turn foam solution into foam.

ASPIRATING NOZZLES AND COMPRESSED AIR FOAM SYSTEMS

Firefighting foams are mechanically generated by either low-energy or high-energy systems. Aspirating nozzles are low-energy systems, while compressed air foam systems (CAFS) are high-energy systems. Each type is used in wildland fire suppression.

Aspirating Nozzles

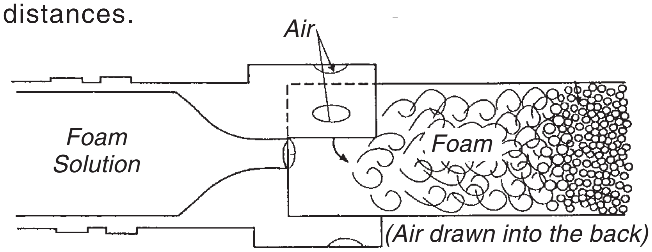
Aspirating nozzles use energy from the water pump to create foam. Energy, in the form of water pressure, is delivered by the pump to the aspirating nozzle. The nozzle restricts the flow of foam solution which causes air to be drawn into the foam solution stream. The air and foam solution mix in a chamber and are discharged as foam.



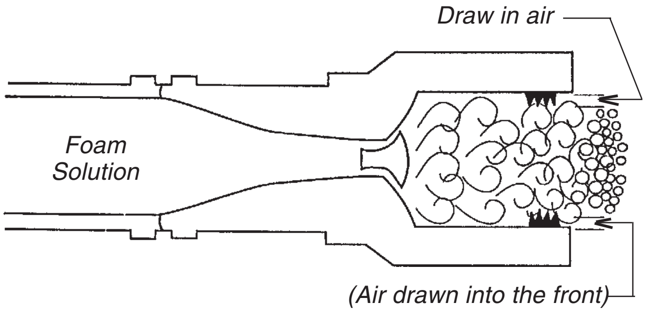
Nozzle Aspirating Foam systems

Low-Expansion Nozzles

Low-expansion nozzles have small openings for air. They can produce a volume of foam up to 20 times the amount of foam solution used to make the foam, or a 20:1 expansion ratio. These nozzles focus pump energy into a narrow chamber that creates a limited air flow. Smaller volumes of foam are produced, but they are projected great distances.



Low-Expansion Aspirating Nozzle

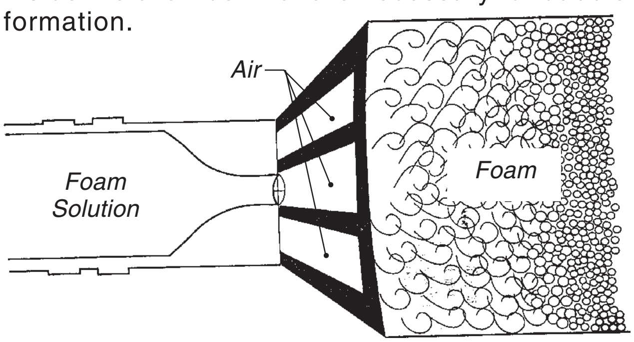


Low-Expansion Aspirating Nozzle

There are two variations in nozzle design based on where the air is drawn into the nozzle. Air can be drawn into the back of the nozzle or into the front.

Medium-Expansion Nozzles

Medium-expansion nozzles have much larger air openings than low-expansion nozzles. They can produce expansions from 20:1 up to 200:1, depending on the design of the nozzle. A medium-expansion nozzle has a wide chamber that draws in large amounts of air, which in turn slows down the stream velocity. There are screens located inside the chamber that are necessary for bubble formation.



Medium-Expansion Aspirating Nozzle

High-Expansion Nozzles

High-expansion nozzles work along the same lines as the medium-expansion ones, but put out a larger volume of foam.

Aspirating Nozzle Designs

Aspirating nozzles are designed for specific water flows, water pressures, and mix ratios of foam solution. Nozzles may be single or variable flow by design. Water pressure is normally between 100 and 150 psi. Mix ratio is usually 1/2 of 1 percent. Changes in any of these will affect foam production.

Single-pattern, low-expansion nozzles are designed for only one discharge pattern. There are also low-expansion nozzles that provide several discharge patterns. These nozzles offer a variety of patterns which may include long-range straight stream, fog, or spray, and foam patterns.

Medium-expansion nozzles are generally designed for lower pressures than low-expansion nozzles. Low pressures are required to build and maintain the larger bubbles of medium-expansion foam.

Low-expansion nozzles are commonly used for direct attack because of their extended discharge distances. They can also be used for pretreatment of aerial fuels and mopup. Medium-expansion nozzles are best on surface applications at short distances. They can be used to create fire barriers during indirect attack or prescription burning, and are very useful for rapid mopup.

Advantages of aspirated nozzles are:

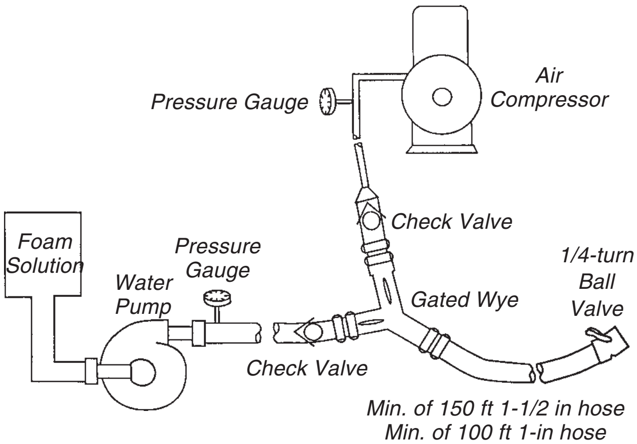
- Relatively inexpensive and simple
- They do not require extensive training
- Easy to maintain
- Many are attachments to common water nozzles.

Disadvantages include:

- Ability to change the foam type is limited
- Foam will not cling to vertical surfaces as well as compressed air foam
- Water pressure from the water stream is "robbed" to produce foam
- More foam concentrate is used than com pressed air foam systems.

Compressed Air Foam Systems (CAFS)

Compressed air foam systems (CAFS) produce high-energy foam because compressed air is injected into the foam solution. This system includes a water pump, air compressor, foam solution, pressure gauges, and assorted valves; it does not require an aspirated nozzle. Foam is produced differently with CAFS than aspirating systems. Air from the compressor is injected into the foam solution. This air represents stored energy for use in the discharge of foam. Once the air and foam solution are combined; they mix, agitate, and expand to produce foam. The mixing and agitation occurs in a hose line or a specialized mixing chamber. When hose is used to produce the foam, approximately 100 to 150 feet of hose is required. Mixing chambers are usually used when foam discharge must occur close to the pump, as with monitors.



Compressed Air Foam System

Air and water flows—along with pressures—from the compressor and pump should be roughly matched. Because of the energy provided by the air compressor, gallon for gallon, compressed air foam is propelled farther than discharges from aspirating or standard water nozzles.

Almost any shutoff or nozzle, full flow or fog pattern, will work with CAFS. The nozzle type affects the type of foam which will be discharged. For example, a full-flow shutoff will provide the best foam, while a variable-pattern nozzle will break up the bubbles and create an air-charged foam solution. Each application has its place in fire suppression; this is discussed later.

The advantages of compressed air foam are many:

- The foam type can be easily changed by changing the ratio of water to air.
- Hose lines are considerably lighter than conventional water lines.
- Less foam concentrate is used.
- CAFS can be pumped higher and farther than plain water at the same pressure.
- The air compressor can be used separately to run pneumatic tools.
- Bubbles are more uniform, creating a more durable foam.

The disadvantages of CAFS are also worth listing:

- The system is more complex than aspirat ing nozzles, and requires education and training.
- Maintenance requires more expertise and time.
- The large amount of energy stored in the hose can be difficult to control; thus, if an operator is not properly trained or prepared it can be unsafe.
- Purchase price.
- Weight of the module.

APPLICATIONS

Water that is applied as a foam works on all three sides of the fire triangle. Remember, foam itself has no chemical retardant effect. Foam's performance is determined by its drain time, expansion ratio, and surface tension. In general, foam application techniques are the same as those used with water. It is still water that is extinguishing the fire; we are just using it in a different form. Water flow as foam and the foam's drain time must fit the suppression task. Remember that each fire has a critical application rate, even when you are using foam. Also remember that if the foam is too dry, the fire may burn underneath surface fuels.

DIRECT ATTACK

The ability of foam to continue wetting and cooling fuels long after the firefighter has left the area is a key to effective foam use. Foam solution or wet foam should be used for direct attack. Apply foam to the base of a linear flame front. While attacking the edge, direct a portion of the foam stream onto adjacent unburned fuels. On wide hotspots, secure the edge and move toward the center. Apply foam long enough to ensure extinguishment, but realize this may not take very long. Work quickly; as soon as steam is visible, move on. Vapor suppression, cooling, and wetting have occurred. Leave a foam blanket over the hot fuels to smother and continue wetting. It is important to return to the treated area after the foam dissipates to check for any missed spots.

Foam can be used to put out fires whose extinguishment would not be considered with plain water. Fire inside and at the top of snags, and fire within log decks, can be extinguished with foam. Torching fires in tree tops can be attacked. In deep fuel beds, a foam solution may be required for rapid penetration. Remember to choose the right foam type for the job that you have to do.

INDIRECT ATTACK

All foam types may be effectively used in indirect attack. Foam can be used as a firebreak for burning out or back-firing. The foam line should be at least two and one half times as wide as the expected flame length.

You will want to wet the entire fuel layer so that the fire will not burn under the foam line. The foam should be applied at close range so that penetration of surface fuels can occur. Apply foam immediately ahead of the burning crew, but allow time for foam solution to drain out of the foam and wet the fuels. Another technique for wetting the fuel bed is to apply foam solution first through a conventional nozzle (such as a forester nozzle). After wetting the fuels, apply a blanket of foam to continue wetting and to insulate the fuels. In adverse conditions (such as low humidities and high temperatures) reapplication may be necessary. Foam can be lofted onto brush, tree trunks, and crowns to add a protective insulating barrier.

MOPUP

Foam's vapor suppressing, penetrating, smothering, and cooling qualities allow firefighters to move from the suppression phase to mopup more quickly than with plain water. Foam solution and wet foam are best suited for this type of work. You will still have to use handtools on deep-seated fires, but foam will reduce the amount of time that mopup will require.

When most surface fuels are smoldering or openly burning, medium-expansion nozzles can be used to cover an area in foam when the mopup work begins. Leave the foam alone for approximately a 1/2 hour, and watch for steam rising from the foam or an area where foam has dissipated rapidly. This will show you where there is a pocket of heat which needs more attention.

Depending on the fuel type, two applications may be warranted to reduce the time spent on mopup. In addition to increased efficiency, this application also reduces the amount of smoke and vapors to which firefighters are commonly exposed. For mopup of deep-seated fires, use foam solution or wet foam to penetrate down to smoldering fuels. Mopup wands and hand tools are recommended.

STRUCTURE PROTECTION

The ability of foam to adhere to sloped, vertical, upside-down, and slippery surfaces is the key to structure protection with foam. Use a dry or fluid foam type, depending on the fire situation and structural requirements. Foam durability is dependent on weather and fire behavior conditions. Apply foam to outside walls, eaves, roofs, columns, or other threatened surfaces, lofting it to avoid breaking the bubbles. Try to leave 1/2 inch of foam on all surfaces, even if the excess sloughs off. The difference in protecting structures with foam as compared to water, is that foam allows firefighters to pretreat a structure before the fire arrives and evaluate the scene if necessary.

Medium-expansion nozzles can be used to put down foam barriers around threatened exposures. This technique allows the fire to burn into the foam barrier. This can also be used in combination with a low-expansion foam treatment of the structure.

SAFETY

For any new equipment, there are new procedures and techniques to follow. This is also true when dealing with new chemicals like foam concentrates. Learn what Material Safety Data Sheets are and how they can help you. The U.S. Department of Agriculture (USDA)-approved foam concentrates have met the standards for skin and eye toxicity, lethal dose for fish, and metal corrosion.

Foam concentrates have health effects similar to those of household detergents.Everyone involved in handling, mixing, and applying foam should be properly trained. All containers of concentrate or solution should be labeled. Concentrates can produce eye irritation and can dry the skin. The following precautions should be taken:

- When mixing concentrates, goggles, waterproof gloves, and rubber boots should be worn.
- Clothing soaked in concentrates should be rinsed out.
- Eyes splashed with concentrate or solution should be flushed with clean water for 15 minutes.
- Hand lotion should be used to avoid chapping.
- Concentrate which is spilled should be cleaned up with an absorbent material to prevent accidents.
- Care should be taken when walking in a foam blanket since foam wil l conceal ob jects and holes.
- Avoid contaminating water sources with con centrate or solution.
- When using CAFS, avoid opening valves quickly ; since this can result in a firefighter losing control of the hose or being knocked down.

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 measurementby Fiscal Year 1992, in procurements, grants, and other business related activities.

THE METRIC SYSTEM AND EQUIVALENTS

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=	32.8 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 ounces
1 hectogram=	10 dekagrams=	3.52 ounces
1 kilogram=	10 hectograms=	2.2 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	liters	3.785
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

Temperature (Exact)

°F=Fahrenheit °C=Celsius

°F=(°Cx9/5)+32 °C=5/9x(°F-32)