DESCRIPTION

OF

FOAM

I. WATER, FOAMING AGENTS, FOAM SOLUTION, AND FOAM

Foaming agents, or surfactants, are added to water to decrease the surface tension that makes water clump together in large drops, puddles, and streams. Water with a surfactant added is wetter than untreated water, thus more effective in putting out fires. This is not because the surfactant enables water to absorb more heat than 9,300 BTU/Gallon but because it allows water to spread or go into smaller droplets thus increasing its surface area making more available to absorb heat.

Foam is defined as a relatively stable aggregation of small bubbles, which, having a lower density than water, can adhere to wildland fuels. Foam is made by entrapping air into a water solution containing a foam concentrate by means of suitably designed equipment or by cascading it through the air at high velocity. Foam does not have any more ability to absorb heat than that of the amount of water in it. When foam adheres to, and builds up on Class A fuels (wood, wood products, and vegetation -- cellulose fuels), it thereby excludes the air from the fuel and envelops the volatile combustible vapors at the fuel interface. It absorbs the heat generated by combustion and releases water from its bubble structure at a reduced measurable rate. When applied in adequate quantities, it resists disruption due to wind or heat and to flame attack, and is capable of resealing. Firefighting foams retain these properties for varying periods of time depending on the foam solution and the fire environment. Foam residues may persist and may have a positive fire control effect when re-wetted within a limited time frame. In general, foams are grouped into three ranges of expansion. They are:

Low expansion foam	expansion up to 20 times
Medium expansion foam	expansion 20 - 200 times
High expansion foam	expansion 200 - 1000 times

Let's examine some of the features of water, wet water, surfactants, and foam enough so we have a basic understanding of them. Then we will look at some specific tactics of foam use in wildland firefighting. Because applications in the wildland are relatively new, many basic questions need to be answered, such as "How much foam does it take to put out this fire?" "What is the base way to apply it?" "What can I use it for?"

Research by Dr. Haessler for the fire service in the State of Florida has shown that a straight stream of water is only 5 to 10% effective in suppressing free burning fire, for two reasons. First, water is projected in the stream with such force that a substantial amount of the water just bounces off the fuel and runs to the ground, not reaching the fire at all. Thus the water in a straight stream is only effective at the edge of a narrow zone of interface between the water and the fuel, however shaped or wrapped this plane is around the fuel particle. Second, water's surface tension (73 dynes/cm) is quite high, holding it together, so it does not spread out well or stick to the burning material. At high temperature water rolls off a vapor layer and slides down to the dirt in a cool spot. If you put a few drops of water in a 400 degree skillet, it is readily apparent that there is no coverage at all, the water tries to clump together. This reduces the size (volume) of the interface with the fuel. Our knowledge of fire behavior tells us that it is not the solid fuel that is burning, but the vapor released from the wood, vegetation, or hydrocarbon source in the chemical reactions of the pyrolysis. Something that can spread out over a larger volume and absorb substantial amounts of energy released (BTUs) from the fire would be an advantage over plain water.

Foams for wildland firefighting of Class A fires have become very popular since 1975. Low expansion foam and wetting agents have been available for decades and were demonstrated for wildland use internationally, but they were not popularized in North America until the mid 1980s.

Foam is now popular in part because of the small quantities of concentrate (0.3 to 1.0 percent) and ease of preparation required to make a stable foam for wildland fire control in ground and aircraft delivery systems. There is great interest in foam especially among firefighters faced not only with fires in vegetation, but also with structure and vehicle fires, since foam has applications in all these situations. Some jurisdictions are requiring firefighters to justify why foam was not used on a particular incident, since it has been shown to be significantly more effective than water to do the same job.

Tests have shown that one of the values of foam is its efficiency as an insulator and reflector against radiant heat. Foam may be laid on the fuels ahead of a wildfire, or on the boundary of a prescribed fire to act as a barrier to protect adjacent exposures. The application of foam to forest fuels results in an increase in fuel moisture in the forest stand. Foam covers and surrounds fuels and allows the water to penetrate the fuel (20 times faster than plain water) instead of running off.

The Standard on foam chemicals for wildland fire control is set by NFPA, the National Fire Protection Association. It is standard #298, which will be initially approved in the fall of 1988. This sets standards for manufacturers to meet in producing the concentrate, minimums for user safety, health, protection of the environment, and corrosion. Refer to this standard for more information about the generic class of foaming agents. Refer to Materials Safety Data Sheets for specific information about a specific product.

Foaming agents used to suppress Class A fires (natural fuels) are made by numerous manufacturers. The only USFS approved products are Fire Foam by Chemonix, Silvex by Ansul, WD 861 & 864 by Monsanto, and Fourxspan by Angus. These agents developed especially for wildland firefighting use and organic hydrocarbon surface active agent (anionic surfactant) to create a stable foam when air is introduced into the solution.

Another property of a surfactant is that it reduces the surface tension of water. When this happens the free energy in water that holds it together as drops and makes it not penetrate is released allowing water to spread and wet becoming more effective. The foam solution use level (the mixture of water and concentrate) should be used in accordance to the manufacturers recommendation. It will also vary depending on what foam generation system is used.

Try an experiment for yourself to see how foaming agents work at reducing water's surface tension. Fill a small bowl, saucer, or cup with water. Lay a needle or pin on the water, using a tweezers if necessary. The steel floats, dense as it is compared to wood, paper, or oil. Now put in a drop of dishwashing concentrate like Dawn or Joy with an eye dropper. The pin is pushed across the surface of the water by the oncoming layer of soap, trying to stay on top of the water with high surface tension. At the edge of the dish, it has nowhere to go, is overtaken by the soap and sinks as the surface tension drops to 25 to 30 dynes/cm. Or, take two bowls and put water in one and soap solution in the other (making sure you don't have any foam on top) and drop a ball of moss, at the same time, in each bowl. The one in the soap solution immediately starts to sink. Why? The lowering surface tension allows water to spread and penetrate.

Foaming agents have been known since around 1877 when the first chemical foams were made and recognized as more effective than water at putting out fires or flammable liquids. These foams were produced by a chemical reaction between substances like sodium bicarbonate and licorice root. The ability of foams to suppress vapor production, reducing fuel gas volume was noted at that time. The next foam developed was a protein foam produced from animal and vegetable by-products, giving a stable foam that holds its shape well.

Foams used in wildland firefighting today are mechanical foams, so-called because they are produced by agitation of a surfactant mixed with water and air. Wildland foams have been divided into five types (Rochna, Boise Interagency Fire Center). Type 1 is very dry, adheres well to walls and ceilings and on the undersides of eaves. Type 5 is very wet, more able to penetrate into fuels during mop-up or overhaul. Type 3 foam is good for initial suppression action or forming a barrier in wildland fuels since it adheres and penetrates into the fuels and can be used to create a line by itself. Compressed air foam systems can make foams drier or wetter by adjusting the mix ratios of water, air, or concentrate. Nozzle aspirating systems are less flexible and can be adjusting only by changing the concentrate ratio. These systems are discussed more in Part II.

Before discussing how foam is made and distinguishing between low and high energy foam, let's look at the differences and similarities between wet water and water on the one hand, and foam on the other. Both wet water and foam contain water, which absorbs BTUs from combustion. Both break down surface tension and enable water to spread out more. A very important difference is that foam holds the water in place longer to let it work. As a result, the water stays next to the fuel longer and so is able to penetrate, increasing the volume of interface with the fuel. Foam-treated substances actually undergo an increase in fuel moisture. This is very significant in charred fuels, where wet water will run off, but the water in foam actually penetrates into the fuel where the fire is. (Note: mop-up requires a wet foam or froth). A second difference is that foam, being white and opaque, reflects radiant heat away from otherwise pre-heated fuels, reducing the spread rate of an oncoming fire. Water on the other hand, is transparent to radiant heat energy, like glass is to sunlight. Thirdly, foams coats and seals the fuel from air, choking the fire, like cleaning out a carburetor. A fourth difference, foam will adhere to vertical and overhead surfaces like paint.

In summary, foam extinguishes, retards and reduces combustion by reducing the concentration of oxygen at the fire, by cooling and absorbing heat, and by increasing the fuel moisture. It attacks all three legs of the fire triangle, whereas wet water still only attacks the heat leg. Furthermore, foam alters heat transfer by impeding convection and radiation, reducing the ability of a fire to feed upon itself.

II. MAKING FOAM

Handling the foam concentrate requires rubber gloves and goggles. Most nozzle operators are not sensitive to skin contact at the common use levels, but some persons have shown sensitivity. No significant hazards appear to exist, although widespread experience is limited. The mixture of concentrate to water and its expansion depends on the application.

Aerial application	0.3-0.7 gal./100 gal. water
Nozzle aspirating ground application	0.5 gal./100 gal. water
Compressed air form system (ground)	0.3 gal./100 gal. water

In air tankers and helitankers, the foam is metered and injected into the tank or bucket. Some helicopters may be equipped with circulating pumping systems that mix the solution in the bucket. In air tanker drops, foam is formed as the water mixes with the air while falling to the ground. The optimum foam drops reported in forest fuels from air tankers are fifty to ninety feet above the canopy at 90 mph air speed. The exact amount of foam produced and its coverage will vary; a 6,000 gallon drop of water as foam from a Martin-Mars air tanker covered 4.5 acres with foam 4 inches deep.

Although foam itself has little mass and therefore little momentum associated with it to cause a drop impact like a retardant drop, a great caution sill needs to be observed around air tanker drops. If there is a failure in the system and enough soap is not injected into the water before it leaves the plane, it will impact as a heavy water mass, not a dispersed foam.

In ground application of foam, the mixing of air with the wet water can be more controlled than with aerial application. Although there are numerous units being developed that produce foam, basically there are two systems that produce the mechanical foams currently in use in wildland firefighting. The first, a low energy foam system, uses the energy of the streaming flow of foam solution through a venturi at the nozzle to draw in air to produce foam. Several kinds of aspirating, or aerating, nozzles are available. All of these use energy to expand the water stream from a small stream to a larger cross section of foam, leaving less energy available to project the stream over a horizontal or vertical distance. Because of the reduced nozzle velocity, low energy systems can only blanket the fuels near at hand. They do, however, produce foam and enable wet water to become 3 to 5 times more efficient at putting out the fire. Different nozzles can be used to produce low, medium, or high expansion foam. Remember that the more energy you use to expand the foam results in less energy for discharge.

High energy foam systems use an air compressor to add air to the water stream under pressure, adding energy to the stream. A simple way to estimate the added energy in the hose stream is to add the horsepower of the air compressor to that of the water pump. As in low energy foam systems, energy is required to draw in air to produce a foam. Here this is compensated by the addition of energy that brings discharge performance up to that needed for effective reach to a flaming front. You can expect to increase discharge distance by 50% as compared to a conventional water nozzle flowing a equal volume of water. In these compressor assisted foam systems (CAFS), foam is made in the hose between the pump and the nozzle. Hose used must prevent water from escaping through its walls. Foam solutions cause an appliance; i.e., piping, hose, etc., that weeps or leaks with plain water to flow three times more water. (Surfactant allows water drops to be three times smaller.) Over 50 feet of hose may be needed to produce foam unless special mixing devices are in the line. Hose may become very light since there is less water in the hose. Kinks in the hose cause water to break out of the foam disrupting discharge distance and quality. Durable woven hose is used to reduce kinking. Hose which is porous to water or has an irregular lining will decrease discharge performance.

CAFS-produced foam bubbles are smaller and more consistent than those produced by aspirating nozzles, reaching close to 90% efficiency of water conversion to foam. CAFS expands water 5 to 20 times, and is usually used with a smooth bore valve at the end of the hose, rather than a nozzle. Restricting the flow at the tip tends to make the foam wetter, since it squeezes the bubbles out of the line. Foam in a hoselay can be pumped twice as high as water, since there is greatly reduced head pressure, despite somewhat greater friction loss. Foam cannot be pumped through a pump of any kind since it will cavitate the pump, so a relay system or tandem system cannot be applied.

III. APPLICATION TECHNIQUES

While generating and using foam is a simple technique in principle, as with any new system, it warrants proper education and training at all management levels if its fullest potential is to be exploited.

If a firefighter understands the principles of proper water use and then performs tasks using foam he will experience an increase in the efficiency of water.

Rates of application depend primarily on wind, temperature, fuel moisture, and fuel loading. The width and depth of foam application necessary for the task changes as the above factors change. In general, enough foam is required to provide adequate water to the fuels. One important feature of foam is that the applicator can see when enough has been applied because it is visible and stays where it is applied.

Direct Attack

Use 0.3% agent solution for CAFS, 0.5% for nozzle aspirating systems. Apply foam to the base of a linear flame front. On wide hotspots secure the edge and move toward the center. While attacking the edge, direct a portion of the foam stream onto immediately adjacent unburned fuels.

For pump and roll attack from engines, apply as you would a water stream, long enough to ensure extinguishment. This will not take as long as with water. As soon as steam is visible, and a reduction in smoke, move on. Vapor suppression, cooling and wetting have occurred. Leave a foam blanket over the hot fuels to smother and continue to wet the fuel. Remember to use a wet foam.

Foam's ability to continue to wet and cool fuels long after the applicator has left the area is a key to effective foam use. Greater efficiency results as the applicator moves on to a new area because he/she knows the foam will continue to work where applied. Once the capabilities of foam become familiar, do not be surprised that foam puts out fires when this was not a consideration with just water. Fire inside and at the top of snags and fire within harvested log decks can be extinguished with foam.

Indirect Attack

Use same mix ratios as for direct attack. Apply foam as a wetting barrier adjacent to the backfire or burnout. The most effective ground fuel foam barrier is medium expansion foam 50 to 1 up to 100 to 1 expansion ratios. However, low expansion generated foam will also work. Apply at least 5 minutes ahead of lighters. (Foam needs times to drain to make water available for fuel wetting.) The foam line should be a least two and half times as wide as the flame lengths. Coat all sides of the fuel whenever possible. Apply foam directly at close range as water would be applied for penetration into ground and surface fuels. Then apply foam softly to the aerial fuels by lofting onto brush, tree trunks, and canopies to add an insulating barrier.

Mop-up

If foam was used in the attack, this may enable mop-up to start earlier. Use of foam in mop-up soon after the flaming phase is over helps prevent fires from becoming deep-seated in the ground, requiring time-consuming mop-up. This also eliminates residual smoke, reduces reburn potential and soil erosion. The same mixture is used as noted above. Begin applying a wet foam on the edge of the burn and work in, concentrating on hot spots. Direct attack any flames. Apply foam as you would a water stream into burning material for best penetration. Before leaving the area, check for steam rising from the foam. Steam plumes indicate pockets of heat which may need more attention.

Frothy foam put on charred material early in mop-up does work usually done with water fog and a tool. It quickly penetrates the fuel and the ground where it lays, and as a blanket separates oxygen from any remaining smoldering fuel. This works extremely well on pitchy and punky material, duff, and litter.

For deep-seated fires in stumps, landings, and log decks, install a mop-up want or a Forester nozzle. Application technique is not different than with water, but the water used is more effective.

Fuels and Vegetation Protection

Foam's abilities to penetrate dead and live fuels quickly, to form an insulating blanket, to cling to vertical surfaces, and to reach distances from the nozzle make it very useful for fuel protection, whether for stands of timber, areas of brush and grass, wildlife trees, snags, fuel jackpots, endangered plants, log decks, or structures. Fuel protection is achieved with less water, less application time, and with less people than conventional methods.

The rate of foam application for fuel protection depends on air temperature, relative humidity, and fuel loading and moisture content. Foam is a short-term treatment in hot temperatures. Regardless of the conditions, medium expansion foam lasts three times longer than compressed air foam and compressed air foam remains twice as long as low expansion air aspirated. Under moderate conditions and using the appropriate foam generator, application time may be several hours before ignition time.

The characteristics of foam important to fuel protection are its wetting ability and its durability. The foam must break down to wet the fuels and remain stable to maintain a protective barrier. Foam expansion ratios can be guides to this apparent contradiction:

20:1	Very little wetting, too dry
10:1	Good for wetting and blanketing
5:1	Weak blanket, needed in mop-up

Use 0.2-0.3% solution for CAFS, 0.3-0.5% for nozzle aspirating systems. Apply the foam directly from a short distance at high pressure, as water might be applied, for penetration of foam mass to ground and surface fuels.

For fireline application, most work can be accomplished right from the line. The width of the foam line depends on fuel and fire behavior factors. In Western Oregon Model 13 slash fuels, 20-40 foot wide foam lines were used successfully. Apply foam to all sides of the fuel when possible. Apply foam to ladder fuels and crown fuels above the foam line. Apply as long as it is necessary to coat all fuels with the desired amount of foam. Be sure to direct the high pressure stream directly into the fuels where the fire line meets the foam line.

Structure Protection

Foam's ability to adhere to vertical, sloped, and upside-down surfaces is the key to structure protection. Without this characteristic, no barrier could be produced and wetting may not be complete. Use 0.3% agent solution for CAFS, 0.3-0.5% for nozzle aspirating systems. Apply foam to outside walls, eaves, roofs, columns, or other threatened surfaces. Loft foam from enough distance to avoid breakdown. Durability is consistent with weather and fire behavior. In general, CAFS foam lasts for an hour in hot weather, nozzle aspirated foam for 30 minutes. Quality foaming agents will leave at least one-half inch of foam on all surface, even if excess sloughs off. The objective is to wet all exposures, apply enough foam to meet the objective. It is recommended to treat all natural fuels within 50 feet of structures as well.

Vehicle and Equipment Protection

Vehicles and equipment can be outfitted with small, ready-to-use expanded foam fire extinguisher units. Vehicles and heavy equipment with pneumatic systems for brakes or other uses can be adapted to produce foam on demand.

Hazardous Materials (Flammable Liquids)

This subject requires the use of Class B foams. Refer to NFPA handbooks for guidance.

The table below gives the types of foam discussed in Part I. The air-to-water ratios are given at atmospheric pressure, comparing volume to volume. A cubic foot of water is 7.8 gallons.

TYPES OF FOAM	DESCRIPTION OF FOAM	AIR-TO-WATER RATIO
1	Mostly air, very "dry" and fluffy	40 to 80
2	Like shaving or whipped cream; holds peaks, does not immediately run on vertical surfaces	25 to 45
3	Like watery shaving cream; peaks collapse; immediately runs on vertical surfaces	10 to 30
4	Very wet; readily runs off vertical surfaces	7 to 15
5	Mostly water; no body	up to 10