A Publication of the
National Wildfire Coordinating Group

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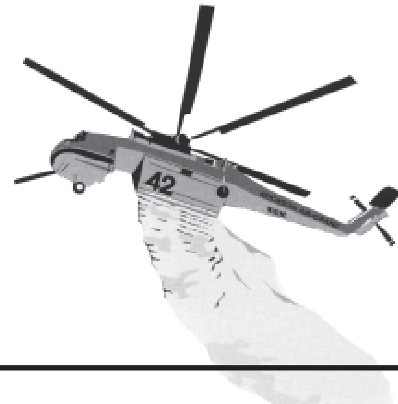
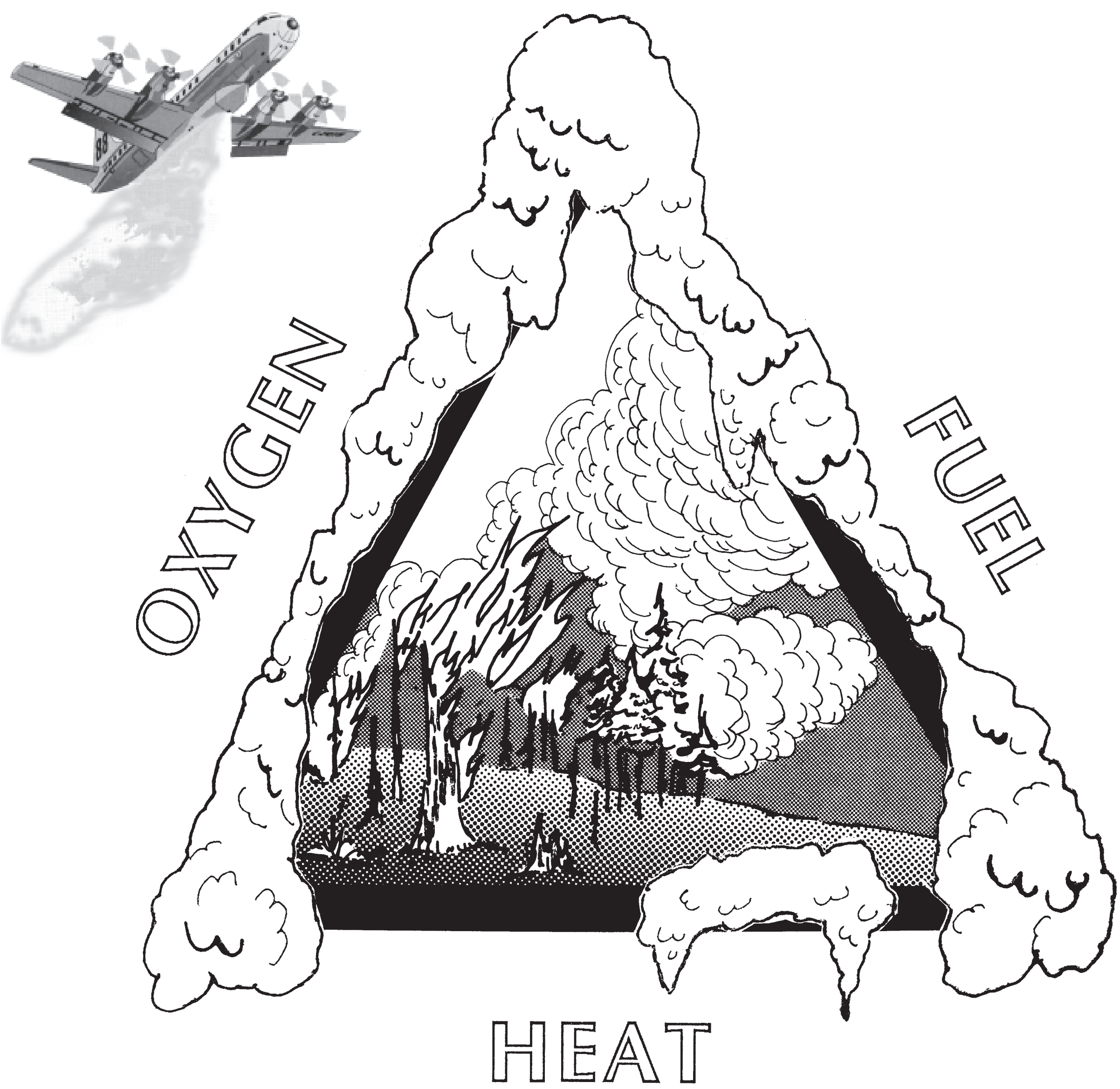
FOAM VS FIRE
Aerial Applications



PMS 446-3 **October 1995**

NFES 1845 **Third in a Series**



Additional copies of this publication may be ordered from:

National Interagency Fire Center
ATTN: Supply
3833 South Development Avenue
Boise, ID 83705-5354

Order NFES #

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
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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

Interest in chemical applications for range and forest fire fighting has accelerated greatly. Many documents have been published concerning the application of class A foams. In recent years two publications were developed by the Foam Task Group of the Fire Equipment Working Team (FEWT) to assist the user in foam applications. This publication addresses the aerial application of class A foams.

NOTE:
This document is one of a series of three "Foam vs Fire" publications that are available. These are:
Primer
Class A Foam for Wildland Fires
Aerial Applications

Readers are advised to refer to the other publications for additional detail as required.

INTRODUCTION

Water has always been the mainstay for fire suppression. The big question has always been, "How do we make water last longer and do a better job?" Adding chemicals to water helps to accomplish this purpose.

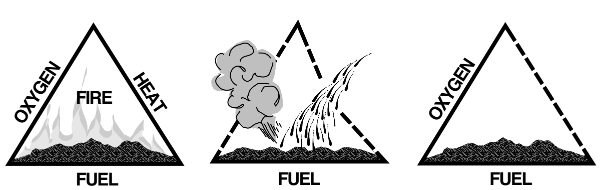
Applying fire chemicals that coat and penetrate fuels is not new. Early experiments by the USDA Forest Service during the 1930's and the 1940's dealt with the problems and advantages of aerial application strategies. In 1954, the first "Operation Firestop" evaluation program field tested chemicals for wildland fire control which paved the way for use of chemicals in aircraft.

In terms of effectiveness, foam by acting as a carrier for water affects all three parts of the fire triangle by:

1. Removing **heat** from the fire as moisture drains from the foam.

2. Blanketing **fuels** with foam temporarily alters fuel availability.

3. Depriving the fire of **oxygen** through the same blanketing action.



Ongoing evaluation of foam effectiveness has resulted in its use in many initial attack situations, and is often used during support actions. Increased visibility of foam has enhanced the efficient use of aircraft by assisting fixed wing and helicopter coordinators to more accurately place subsequent loads.

Ground forces have grown very enthusiastic about aerial use of foam as a method to "buy time". In ground evaluation tests performed in 1989, a foam drop using 0.5 percent solution removed all open flame from a torching spruce and surrounding fuels. Subsequently, it held the fire for 45 minutes before a very low-intensity flame appeared at the bole of the tree. Moisture penetration of the dense duff layer was 50 mm after 38 minutes, with a fair amount of foam still visible on the surface fuels.

Foam will continue to be a vital part of aerial suppression operations, based on significantly increased efficiency when compared to straight water.

FOAM CHARACTERISTICS AND PROPERTIES

Class A foam is a relatively stable aggregation of small bubbles that can adhere to wildland fuels. Foam is made by forcing air into a water solution containing a foam concentrate. The air is introduced by means of suitably designed equipment or by cascading the water and foam mixture through the air at high velocity.

The foam adheres to class A fuels excluding the air and enveloping the volatile combustible vapors at the fuel interface. The foam 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, heat, or flame attack, and is capable of re-sealing. Fire fighting foams retain these properties for varying periods of time, depending on the foam solution and the fire environment.

Foam is a suppressant not a retardant, and should be used in conjunction with ground forces to be successful in all methods of attack.

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, stabilize the foam, and 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 and approved by USDA Forest Service Interim specifications) to produce a foam solution which, when aerated, produces foam. Foam is a relatively stable mass of small bubbles made by forcing air into 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.

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

Note: Low end is commonly achieved, upper end needs special nozzles to achieve.

In aerial applications, low expansion foams are made. The expansion rate is affected by drop height, air speed, tank or bucket configuration, and percent concentrations of the foam agent. Physical mechanisms are explained further under Applications on pages 6 and 7.

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.

The use of cold water and cold concentrate reduces the expansion rate of the foam generated. 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 foam holds together when applied from a delivery system 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.

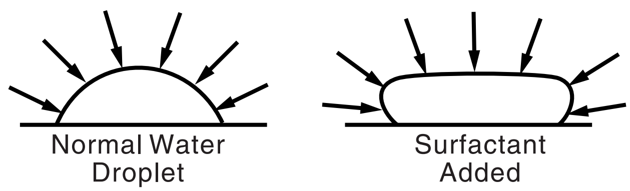
Drainage/Drain Time

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.

As the foam drains and the solution is released, it becomes available for wetting of fuels. Foams with short drain times provide solution for rapid wetting. Foams with long drain times release solution over a longer period while maintaining an insulating capability.

Surface Tension

The foaming agent component of the foam concentrate facilitates the formation of bubbles and the stabilizer strengthens the bubble wall to maintain their structure. The wetting agent (surfactant) reduces the surface tension of the draining liquid so that the fluid can spread more readily, and penetrate deeper into organic fuels at a faster rate when compared to water.



Foam Type

Foam type is a term used to describe the consistency of foam by drain time and expansion ratio. 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 low expansion types and are as follows:

Expansion — **Drainage**

1:1 — **Rapid**

FOAM SOLUTION (0.1 - 0.3%)
- **A clear to milky fluid**
- **Lacks bubble structure**
- **Mostly water**

WET FOAM (0.3%)
- **Watery**
- **Large to small bubbles**
- **Lacks body**
- **Fast drain times**

FLUID FOAM (0.5%)
- **Similar to watery shaving cream**
- **Medium to small bubbles**
- * **Flows easily**
- * **Moderate drain times**

DRY FOAM (0.8 - 1.0%)
- **Similar to shaving cream**
- **Medium to small bubbles**
- * **Mostly air**
- * **Clings to vertical surfaces**
- **Slow drain times**

20:1 — **Slow**

** These are the most important characteristics for the firefighter.*

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 attacking 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 Ratios

The user's specific needs and objectives must be identified before determination of a suitable mix ratio. Since each foam tank or bucket system produces an 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 adhering—should be used. For the pretreatment of the perimeter of a prescribed burn area, a slow draining to moderately rapid draining foam is required. 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 affect the type of foam produced, these suggestions should only be considered as a starting point.

PERSONAL SAFETY

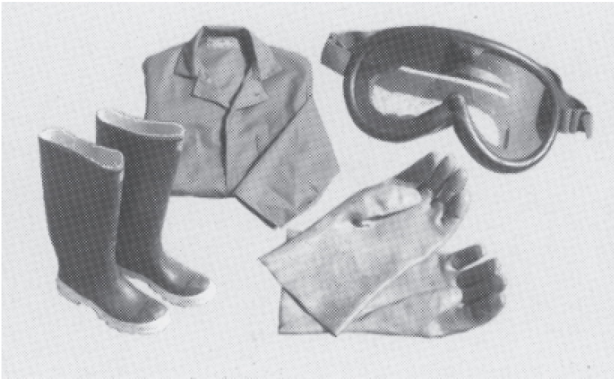
The U. S. Department of Agriculture (USDA) Forest Service approved foam concentrates have met the standards for skin and eye irritation. Additional requirements include oral and dermal toxicity.

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 by applying a topical cream or lotion to the exposed areas. A small number of people may experience allergic reactions when they come in contact with the foam.

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

Recommended Foam Consistencies for Aerial Applications

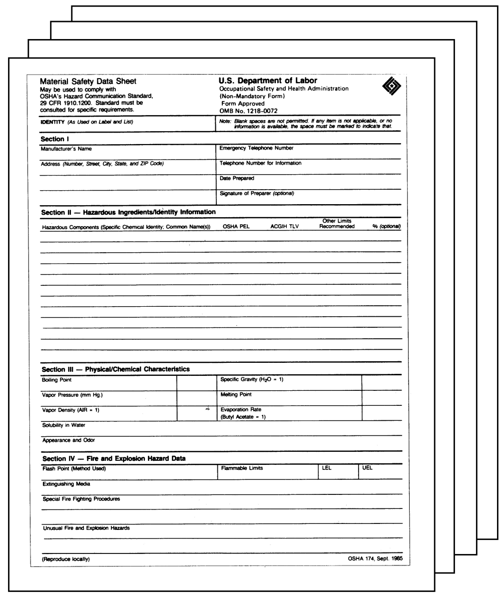
Ground Support (within 30 minutes			***No Ground support***		
Tree Canopy	Forest Floor		Tree Canopy	Forest Floor	
	Shallow	Deep		Shallow	Deep
Open	WET (FBP System fuel types C-1, C-7, S-1, O-1	DRIPPING (FBP system fuel types C-2, S-2, S-3	Open	FLUID (FBP system fuel types C-1, C-7 S-1, O-1)	DRY ()FBP System fuel types C-2, s-2, S-3)
Closed	DRIPPING (FBP system fuel types C-4, C-5 C-6, D-1)	WET FOLLOWED BY DRIPPING* (FBP system fuel types C-3, M-1, M-2, M-4)	Closed	WET FOLLOWED BY DRY-operational* (FBP system fuel types C-5, C-6, D-1)	WET FOLLOWED BY DRY* (FBP system fuel types C-3, M-7, M-3, M-4)



To minimize the problems from prolonged exposure to the skin and eye the following precautions should be taken:

* Review and follow information provided in Material Safety Data Sheets.
* When mixing concentrates, goggles, waterproof gloves, and rubber boots should be worn.
- Clothing soaked in concentrates should be removed and rinsed with water.
- Inhalation of foam vapors can be irritating to the upper respiratory tract, and should be avoided.
- Eyes splashed with concentrate or solution should be flushed with clean water for at least 15 minutes.
- Users should be aware that spilled concentrate is very slippery.
- Hand lotion should be used to avoid chapping.
- Avoid contaminating potable water sources with concentrate or solution.
- Make sure concentrate container is empty prior to opening a new one.
- Portable eyewash stations should be considered for aircraft operating sites.
- All safety precautions associated with ground crews near retardant drops also apply to aerial foam drops.
- Properly secure (or remove) used containers from the aircraft operating area.

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 should be labeled to alert personnel that they MUST NOT be used for drinking purposes. If a foam concentrate is ingested, the individual should seek medical attention as soon as possible. Caution should be taken to prevent the mixing of class A and class B foam concentrates. Personnel must follow the manufacturer's recommendations as found on the product label and product material safety data sheet (MSDS).



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

IDENTITY *(As Used on Label and List)*

Note: Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

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

Hazardous Components (Specific Chemical Identity; Common Name(s))	OSHA PEL	ACGIH TLV	Other Limits Recommended	% *(optional)*

Section III — Physical/Chemical Characteristics

Boiling Point

Specific Gravity (H_2O = 1)

Vapor Pressure (mm Hg.)

Melting Point

Vapor Density (AIR = 1)

Evaporation Rate (Butyl Acetate = 1)

Solubility in Water

Appearance and Odor

Section IV — Fire and Explosion Hazard Data

Flash Point (Method Used)

Flammable Limits | LEL | UEL

Extinguishing Media

Special Fire Fighting Procedures

Unusual Fire and Explosion Hazards

(Reproduce locally)

OSHA 174, Sept. 1985

Note: Some agencies may have additional regulations and policies that apply to the safe handling and utilization of foam.

Working Conditions

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 spill occurs or concentrate enters a water supply, contact your local authorities immediately. Be prepared to provide appropriate manufacturer's information.

Care should be taken during planning and application 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

As our nation strives to reduce human impacts to forest and range and ecosystems, it is important that we know about the environmental effects of class A foam products.

Aquatic toxicity is perhaps the most scrutinized effect of class A foam products because the surfactants in the foam products interfere with the ability of fish and other aquatic organisms to obtain oxygen from water. Aquatic toxicity is determined by measuring the survival or reproductive impairment of an aquatic species (commonly a fish or invertebrate) at several concentrations (or mix ratios) of a chemical over a specified time period. The results from these exposures can be used to estimate the amount of chemical that will result in 1 to 100% mortality of a species. The concentration of chemical that results in 50% mortality (LC 50) is commonly used in reports or Material Safety Data Sheets because it can be compared with the same 50% value for many other chemicals. This indicates how toxic one chemical is relative to another. Using the 50% mortality value is not appropriate for determining an acceptable level of effect in the field. This is especially true when one considers that the current acceptable risk for an endangered species is zero.

Fire suppressant foams diluted for use in fire fighting are more than 99 percent water. The remaining one percent contains surfactants (wetting agent), foaming agents, corrosion inhibitors, and dispersants.

Approved fire suppressant foam concentrates, and the solutions resulting when the concentrate is mixed with water, have been tested and meet specific minimum requirements with regard to mammalian toxicity:

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

Because a very small amount of foam concentrate retains very good wetting capabilities, extra precautions should be taken to avoid getting any concentrate into the water.

Prior to any application of chemical products get approval from the responsible land management agency.

Follow these guidelines and precautions to minimize the possibility of foam concentrate or solution entering a stream or other body of water:

1. During training or briefings, inform field personnel of the potential danger of fire chemicals, (especially concentrates) in streams or lakes.

2. Locate foam mixing and loading points where contamination of natural water, especially with the foam concentrate, is minimal.

3. Pumping systems are recommended for refilling reservoirs with concentrate to reduce spillage. Commercial pour spouts for 5 gal tanks are available that reduce spillage.

4. Maintain all equipment and use check valves, where appropriate, to prevent release of foam concentrate into any body of water.

5. Exercise particular caution when using any fire chemical in watersheds where fish hatcheries are located.

6. Locate dip operations to avoid run-off of contaminated water back into the stream.

7. Use a dip tank, rather than dipping directly from a convenient body of water, to avoid releasing any foam into these especially sensitive areas.

8. Use a pump system equipped with check valves to prevent flow of any contami-

nated water back into the main body of water.

9. Avoid direct drops of foam into rivers, streams, lakes or along lake shores, domestic wells or agricultural lands. Use alternative methods of fireline building.

10. Promptly notify proper authorities if any fire chemical is used in an area where there is likelihood of negative impacts.

11. Whenever possible set up dip tanks within a containment area instead of dipping directly from bodies of water.

AERIAL APPLICATION PROPORTIONING SYSTEMS

Proportioning

The first step in creating foam is adding the required amount of foam concentrate to water to create foam solution. This process is known as proportioning. In aerial applications there are two methods of proportioning foam concentrates; batch mixing and direct injection.

Batch Mixing

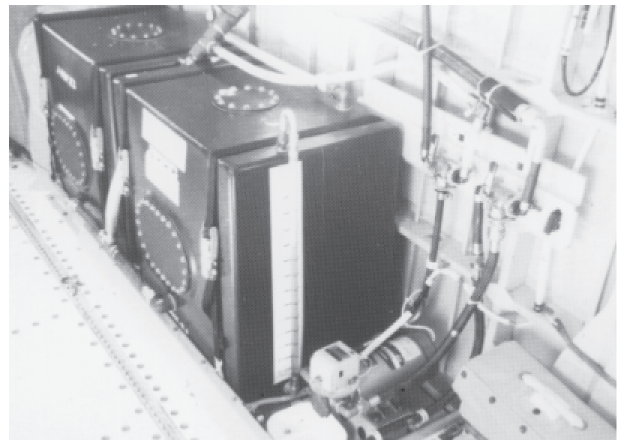
The simplest method of making a foam solution is to manually add foam concentrate to the water supply. This method, called batch mixing, is commonly used with portable tanks in helicopter bucket operations. It is also used with fixed wing tankers that are not equipped with direct injection proportioners. A measured volume of concentrate is poured into a measured volume of water to yield a foam solution of the recommended strength.

Batching can be wasteful, the required volumes of both water and concentrate are estimated, especially when refilling a partially full tank. It is difficult to change mix ratios. Dip sticks or sight gauges may be useful for more accurate batch mixing.

The concentrate should be added to water, because adding water to the foam concentrate causes excessive foaming in the tank when water is added. Bucketing operations generate rotor downwash which can cause foam generation and blow foam around the site. Since foam concentrate is heavier than water, mixing or recirculation of the concentrate/water mixture is required to obtain a homogeneous solution. To improve mixing in cold water, use relatively warm concentrate. The solution should be used as soon as possible for optimum performance.

Direct Injection

The proportioning systems used to produce foam solution in airtankers and helitankers inject the foam concentrate into a tank or bucket using a pump and timer system triggered by the pilot. Circulating systems have been devised for some helibuckets but dispersion of the foam concentrate 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.

Many exclusive use contracts require helicopter contractors to furnish equipment for dispensing foam concentrates into buckets. Call-When-Needed (CWN) contracts have provisions allowing the contractors to furnish equipment for dispensing foam concentrates.

APPLICATIONS

Foam has no long-term retardant effect. It is the water component that suppresses the fire. When the water drains away or evaporates it is not effective. 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.

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. Usually, 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 thoroughly 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 width and depth of foam drop pattern depend primarily upon aircraft attitude, drop height and drop speed.

Foam durability depends on the weather. Foam will be visible in exposed areas for at least 15 minutes in hot weather, up to several hours in cool weather, and in shaded areas it will be visible even longer.

Drainage information should be a key consideration when delivering foam. The objective being the most cost effective method to suppress the fire. If the user knows the fuels and can read the fire's activity from a vantage point, the most efficient use of each measure of foam delivered by fixed wing and helicopters will be made. This can be achieved by specifying the mix ratio that yields a foam draining at a rate that is most beneficial. Matching foam with the fire fighting needs increases the effectiveness of the water being applied, and decreases the effort necessary to accomplish the mission.

Air shear is the main 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 the tank or bucket, 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 generated. The rate at which the outer boundaries of the fluid mass are aerated depends on the velocity of the solution through the air.

General Tactical Considerations:

- Wind drift is higher with drier foams (>0.3%).
- Deep fine fuels such as grass require foam solution or wet foam to penetrate the fuel bed—foam solution (0.1-0.3%).
- Exposed medium fuels such as chaparral or southern rough require wet foam (0.3%).
- Heavy fuels such as slash piles—Wet foam (0.1% to 0.3%).
- Hover drops where you want foam to cling to snags, down logs or brush piles—increase concentrations but not to exceed 1.0%.
- Surface fines under canopy—wetter foams at lower concentrations to penetrate canopy.
- When working closely with ground forces - use lowest effective concentration to minimize impact on crews (ie. slippery conditions, masking fire from ground crews). Communications with ground forces is essential in this type of operation.
- Use foam with care in steep rocky areas where footing can be hazardous for crews.
- Consider use of foam drop on helispot for dust abatement—more effective than water (0.3-0.6%).

Rotary-Wing Operations

Airspeed and height above the ground will directly effect the length of line and coverage level. Variations in airspeed and altitude can be used to change coverage and pattern. Drops generally will be made directly on the fire line, at the head of fires with short flame lengths, or on the flanks working toward the head on fires with longer flame lengths. Caution should be used when performing hover drops to avoid rotor down wash fanning the fire.

Close coordination between the crew leader and pilot is absolutely essential. Using the pilot as an observer/scout, the risk can be minimized and the time to control a fire greatly reduced. Caution must be used when applying direct attack techniques.

There appears to be adequate air shear from 60 feet with helicopter hover drops. An increase in the mix ratio generally works the same as increased aircraft speed or increased drop height for increased aeration of foam.

Fixed-Wing Tanker Operation

Aircraft velocity, drop height, tank system flow rate and drop volume, aircraft attitude, wind conditions and fuel arrangement will affect the ground pattern or footprint of the foam drop. The affect will be more pronounced as foam concentrate mix ratios increase (drier foams). Knowledge of how these parameters effect foam delivery can be used to increase the effective use of foam. The mix of techniques used will depend on individual fire situations encountered. Fixed wing delivery of fluid or wet foam will have similar drop characteristics to water-like retardant. Recommended literature can be found in the Sources of Information section.

Aircraft Velocity

Aircraft velocity can have a significant effect on the shearing (foam generation) of the load and ground pattern placement. Increased velocities lengthen patterns, decrease the coverage level on fuels and also produces drier foam.

As fire intensity increases, the foam coverage level should be increased.

Making drops at a consistent ground speed should increase the accuracy of the drops.

Fixed wing tankers are limited to a narrow range of drop speeds as compared to rotary wing tankers (the CL-215 normally drop at 100-110 kts).

Drop Height

Foam drops from lower than recommended height are unsafe and will reduce the patterns effectiveness. This will have significant potential to cause injury to ground personnel, break out the overstory, damage equipment and dislodge rocks, logs, and tools from the large unbroken mass of foam solution (not generated foam) impacting velocity and force.

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 above canopy to achieve foam formation. As fire intensity increases a lower drop height can be used to form a more dense, compact and wetter foam load. A lower drop height will also increase the forward momentum of the load which can be used to penetrate thicker canopies.

For lower intensity fires a higher drop produces a larger, less dense drop cloud (greater foam generation). The most efficient and uniform coverage of foam on fuels is realized when near vertical fall of the suppressant is achieved if the canopy is not too dense.

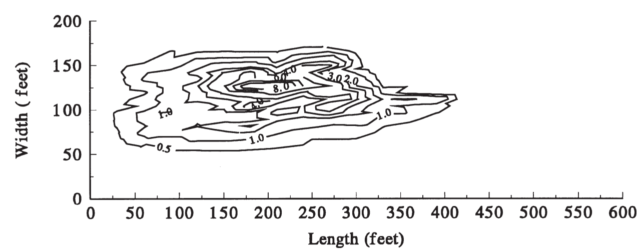
Recommended drop heights vary with the aircraft used. The CL-215/415 aircraft drops range between 100-175 feet above canopy. Single engine agricultural aircraft have recommended drop heights between 40 to 120 feet above canopy.

Drop heights will also vary with vegetation cover and terrain. If drop heights are too low, there will be considerable movement and breakage in the canopy. If drop heights are too high, the drop cloud will tend to break up and drift away from the target. The suppressant cloud "breakup" will decrease the level of foam coverage on the fire.

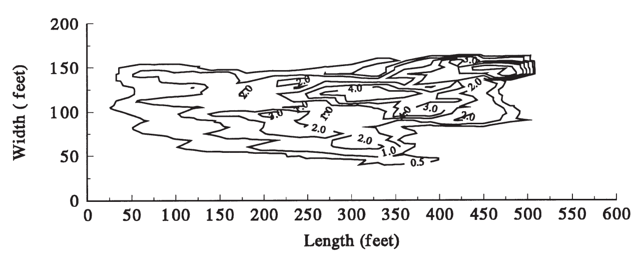
Aircraft Attitude

Aircraft attitude is more a function of load placement than a planned influence on the shape of the footprint:

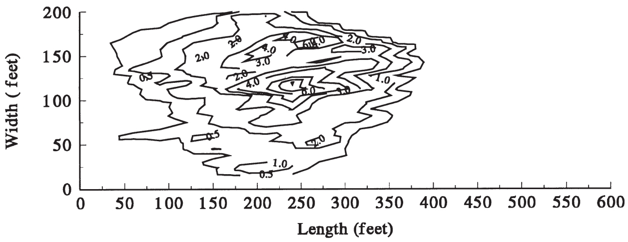
1. **Level** attitude normally produces a uniform elliptical pattern



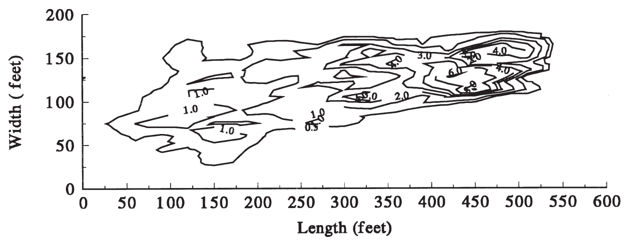
2. **Diving** tends to shorten the pattern and brings the core of the load forward reducing the available effective length.



3. **Lofting** or lifting tends to elongate the pattern increasing the line length in trace amounts at the tail end of the load.



4. **Banking** tends to force the core of the load to the outside on the turn due to the centrifugal force. The effects on the pattern is usually minimal. This can be effective for "throwing" a load into a section of the fire where the airtanker cannot fly.



5. Dropping loads on a downhill run tends to elongate the pattern.

Diving and lofting are not commonly used in fixed wing tanker foam operations.

Wind

The effect of wind on foam suppressant can be significant and can be used to advantage:

1. Headwind has a similar effect on the pattern as diving.

2. Downwind affects the pattern similar to lofting by elongating the drop.(Less intense fires—longer line increased coverage).

3. Crosswind can have the most significant effect on pattern placement. Crosswind drops are subject to drift and will diffuse the patterns core. The effect is relative to wind velocity and can be considerable. The flight path needs to be moved upwind to compensate for the drift.

Thermal Updrafts

High intensity fires often generate thermal updrafts which erode foam drops and reduce their effectiveness. To compensate, use a combination of wetter loads, lower drop heights, or headwind drops.

Fuel Arrangement

Canopies intercept foam preventing it from reaching surface fuels and fires. When attacking surface fires mix ratios should be reduced to make a wetter foam to penetrate the canopy.

In canopies with laddered fuels, foam can be used to treat all fuel levels by dropping progressively drier foams.

Single Engine Agricultural Tankers (SEAT)

These aircraft are best used with short turnaround times. To maintain short turnaround times, airfields closest to the fire or fires in need of aerial suppression should be evaluated for suitability and avenues secured for SEAT operations prior to emergency needs. This can include, road access to enable the support truck to move to the closest airfield to supply foam concentrate and fuel. Available water supply at the remote airfield to support SEAT operations is preferred, but this can be replaced or supplemented by a water tender or nurse tanker. Agency oversight may be needed at these remote operations. This should be someone familiar with SEAT, foam and fire suppression operations.

The SEAT aircraft must be able to communicate with ground firefighters, other aircraft, and with dispatching centers assigned to the incident. A radio system to meet this need should be utilized in all SEAT aircraft. The radio system used to contact ground personnel should be separate from radio systems required for air to air transmissions.

SEAT pilots should have working knowledge of wildfire terminology, size up, strategy and tactics prior to being assigned any operational missions. A pilot of a SEAT aircraft that is dispatched to an area they are not familiar with should require a briefing addressing dispatching procedures, flight hazards, fire behavior, fuel types, and local policies. As pilots gain experience in aerial attack of wildfires, they can be dispatched as initial attack without other aerial or ground forces directing them. This type of use is an agency organization decision and should be predicated on the level of performance required for such operations.

EQUIPMENT RECOMMENDATIONS, MAINTENANCE AND CLEAN-UP

Rotary-Wing Recommendations

Fixed Tanks and/or Buckets

Compatibility of Materials: The materials used in construction of any foam dispensing unit must be compatible with all foams, and resistant to corrosion, erosion, pitting, etching, or softening.

Installation: The foam pumping unit and concentrate reservoir must be affixed to the helicopter in a way that prevents injury to personnel or damage to the helicopter. The design must meet the ultimate inertia forces specified in Federal Aviation Regulations (FAR) 23.56 1(b)(2). All parts of the foam pumping unit must be designed so that no abrasion or damage occurs at points of contact with the helicopter.

Location of Unit: The preferred mounting location of the foam pumping unit and concentrate reservoir is external to the helicopter and attached to (or within) the water supply.

Maintenance: The foam dispensing system is expected to require no major maintenance during each fire season. In the event that maintenance is required it is the contractor's responsibility, unless furnished by the government or agency.

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 mix ratio ranging from 0.1 to 1.0 percent by volume. See page 23.

Concentrate Loading: 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.

Buckets Only

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 or Connectors: All hose or electrical connections 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 or electrical cables 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 so 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 Standard Technical Approvals or 337's), must have a containment vessel around the pumping unit and concentrate storage supply. The concentrate reservoir 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 or inside the bucket itself.

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

Vibration: The unit must be designed and constructed so as not 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.

Fixed-Wing Recommendations

The foam concentrate pumps should have bronze or stainless steel body housings. Aluminum pump housings will not last very long.

The electric motors used in the aircraft should be of sufficient horse power to drive the pump. The motor should be reversible to allow filling of the foam concentrate holding tank.

The use of plastic fittings or plumbing (rigid tubing or flex hose) should be limited to areas where the risk of being damaged is low or if the plastic plumbing fails, the resulting foam concentrate spillage will not cause damage to the aircraft. Plumbing should be routed so that maintenance personnel and flight crews can visually monitor the system so that any leaks can be dealt with immediately. The use of plastic fittings mounted above water tanks would be acceptable.

Maintenance and Cleanup

Scheduled calibration checks and adjustments should be included in maintenance schedules to ensure the systems are operating correctly.

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.

The CL-215/415 tanks can be flushed at the end of each mission by picking up and dropping 1 or 2 loads of fresh water. Loads can be dropped ahead of the fire, on hotspots or flaming brands that have been missed, or in the center of the fire to aid with smoke abatement. They should not be dropped on the foam line or into the water source. The aircraft can also be washed on its return to base.

APPROVED, AVAILABLE FIRE CHEMICALS

A wildland chemical qualification, testing, and approval program (Interim Requirements for Wildland Fire Foam) is carried out for the various agencies by the National Wildfire Suppression Technology (NWST) Group, Missoula, MT, and the Technology and Development Center, San Dimas, CA (SDTDC). The program covers all fire chemicals including long and short-term retardants, as well as foam concentrates. For use in Canadair CL-215/415 aircraft, Canadair carries out a qualification testing and approval program. In the future all foams are expected to be approved under an International Wildland Fire Foam Specification.

The Qualified Products List (QPL) for approved class A foams is updated annually and made available to the field by mid January of each year. Current QPL's can be obtained from either NWST or SDTDC.

STORAGE AND SHIPPING

It is recommended that concentrates be stored in the original polyethylene containers only. Do not store concentrates in steel tanks. The concentrates are corrosive (as are foam solutions); however, they meet USFS requirements for corrosion limits.

All concentrate being shipped is required to be transported with Material Safety Data Sheets(MSDS).

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

Automatically Regulated A proportioning method or device that readily adjusts to changes in water flow and or pressure to maintain a desired mix ratio.

Balanced See Automatically Regulated.

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

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

Biodegradation Decomposition by natural biological processes.

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.

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 A Foam Foam intended for use on Class A or woody fuels; made from hydrocarbon-based surfactants, which possess excellent wetting properties.

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

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 Systems (CAFS) 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 A generic term used to describe foam systems which combine air under pressure with foam solution to create foam in the hose.

Concentrate A substance that has been concentrated. The form in which foam suppressant is transported and stored. Water is added to prepare it for use.

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 foam degrading or being reduced in rank, status, or condition.

Density The weight of a specific volume of material.

Drain Time The time (minutes) it takes for foam solution to drain 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.

Dry Foam **A low expansion foam type with stable bubble structure and slow drain time which is used primarily for resource and property protection.**

Durability The effective life span of foam bubbles.

Durable Foam Foam products, as yet undeveloped, which, when mixed at 1 percent or less, will remain effective at preventing ignition for 12 hours; will work with current class A foam delivery systems including proportioners, aspirating nozzles, CAFS, fixed wing and rotor wing aircraft; will meet requirements for corrosion, health, safety and environmental impact.

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

Environment The complex surroundings of an item or area of interest, such as air, water, natural resources, and their physical conditions (temperature, humidity).

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.

Fire Suppressant Any agent used to extinguish the flaming and glowing phases of combustion by direct application to the burning fuel.

Fluid Foam A low expansion foam type with some bubble structure and moderate drain time, exhibiting properties of both wet and dry foam types, which is used for extinguishment, protection and mop-up.

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 Blanket A layer of foam which forms an insulating and reflective barrier to heat and is used for fuel protection, suppression and mop-up.

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

Foam Generation The foam production process of forcing air into or intraining air in foam solution, creating a mass of bubbles.

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.

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.

Foam Type A term used to describe the consistency and viscosity of low expansion foam as the combination of drain time and expansion.

High Expansion Foam with an expansion between 201:1 and 1000:1.

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

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

Low Expansion Foam with an expansion between 1:1 and 20:1.

Manually Regulated A proportioning method or device that requires the operator to make adjustments to maintain a desired mix ratio over a changing range of water flows and pressures.

Medium Expansion Foam with an expansion between 21:1 and 200:1.

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

Mixing Chamber A tube constructed with deflectors or baffles, that mixes foam solution and air to produce tiny, uniform bubbles in a short distance (1 to 2 ft).

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

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

Proportioner A device that adds a predetermined amount of foam concentrate to water to form foam solution.

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.

Slug Flow The discharge of distinct pockets of water and air due to the insufficient mixing of foam concentrate, water and air in a compressed air foam system.

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.

Surfactant A surface active agent; any wetting agent. A formulation which when added to water in proper amounts will materially reduce the surface tension of the water and increase penetration and spreading abilities of the water.

Toxicity The quality or state of being harmful, destructive or deadly, often expressed as a lethal concentrate or dosage necessary to kill a given percentage of a test population.

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

Vapor Suppression Creating a seal with foam which prevents a release of flammable vapors from fuels.

Viscosity A measure of a fluids resistance to flow, an indication of the ability of the foam to spread over and cling to fuels and to cling to itself.

Wet Foam A low expansion foam type with few and varied bubbles and rapid drain time which is used for rapid penetration and fire extinguishment.

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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Parminter, John 1989. *A Primer On Wildland Fire-Fighting Foams*. Ministry Of Forests, British Columbia, Canada.

Seevers, Melinda R. and John A., *Field Survey of Helicopter Foam Injection Systems.* Copies available from Technology & Development Center, USDA Forest Service, 444 E. Bonita Ave., San Dimas, California 91773.

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, 3833 Development Avenue, Boise, Idaho 83705-5354.

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

Tactical Applications with Class A Foam, 1994
NFES #2404

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 =	10 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 lite r=	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

To Change	To	Multiply By	To Change	To	Multiply By
inches	centimeters	2.54	ounce-inches	newton-meters	0.007062
feet	meters	0.305	centimeters	inches	0.394
yards	meters	0.914	meters	feet	3.280
miles	kilometers	1.609	meters	yards	1.094
square inches	square centimeters	6.451	kilometers	miles	0.621
square feet	square meters	0.093	square centimeters	square inches	0.155
square yards	square meters	0.836	square meters	square feet	10.764
square miles	square kilometers	2.590	square meters	square yards	1.196
acres	square hectometers	0.405	square kilometers	square miles	0.386
cubic feet	cubic meters	0.028	square hectometer	acres	2.471
cubic yards	cubic meters	0.765			
			cubic meters	cubic feet	35.315
fluid ounces	milliliters	29,573	cubic meters	cubic yards	1.308
pints	liters	0.473	milliliters	fluid ounces	0.034
quarts	liters	0.946	liters	pints	0.2113
gallons (US)	liters	3.785	liters	quarts	1.057
liters	gallons (US)	0.264			
gallons (Imp)	liters	4.546	liters	gallons	0.264
liters	gallons (Imp)	2.220	grams	ounces	0.035
gallon (US)	gallon (Imp)	0.333	kilograms	pounds	2.205
gallon (Imp)	gallon (US)	1.201	metric tons	short tons	1.102
ounces	grams	28.349			
pounds	kilograms	0.454	PSI	kilopascals	6.895
short tons	metric tons	0.907	kilopascals	PSI	0.145
pound-feet	newton-meters	1.365	acres	hectares	0.405
pound-inches	newton-meters	0.11375	hectares	acres	2.470

Temperature (Exact)

°F=Fahrenheit °C=Celsius

°F=(°Cx9/5)+32 °C=5/9x(°F-32)

Gallons of Water

Percent Foam	100	150	200	250	300	350	400	450	500	600	750	1000	1500	2000
.1	12.8 oz	19.2 oz	25.6 oz	32.0 oz	38.4 oz	44.8 oz	51.2 oz	57.6 oz	64.0 oz	76.8 oz	96.0 oz	1.0 gal	1.5 gal	2.0 gal
.2	25.6 oz	38.4 oz	51.2 oz	0.5 gal	76.8 oz	89.6 oz	102.4 oz	115.2 oz	1.0 gal	153.6 oz	1.5 gal	2.0 gal	3.0 gal	4.0 gal
.3	38.4 oz	57.6 oz	76.8 oz	96.0 oz	115.2 oz	134.4 oz	153.6 oz	172.8 oz	1.5 gal	230.4 oz	2.25 gal	3.0 gal	4.5 gal	6.0 gal
.4	51.2 oz	76.8 oz	102.4 oz	1.0 gal	153.6 oz	176.2 oz	204.8 oz	230.4 oz	2.0 gal	307.2 oz	3.0 gal	4.0 gal	6.0 gal	8.0 gal
.5	0.5 gal	96.0 oz	1.0 gal	1.25 gal	1.5 gal	1.75 gal	2.0 gal	2.25 gal	2.5 gal	3.0 gal	3.75 gal	5.0 gal	7.5 gal	10.0 gal
.6	76.8 oz	115.2 oz	1.2 gal	1.5 gal	1.8 gal	2.1 gal	2.4 gal	2.7 gal	3.0 gal	3.6 gal	4.5 gal	6.0 gal	9.0 gal	12.0 gal
.7	89.6 oz	1.05 gal	1.4 gal	1.75 gal	2.1 gal	2.45 gal	2.8 gal	3.15 gal	3.5 gal	4.2 gal	5.25 gal	7.0 gal	10.5 gal	14.0 gal
.8	102.4 oz	1.2 gal	1.6 gal	2.0 gal	2.4 gal	2.8 gal	3.2 gal	3.6 gal	4.0 gal	4.8 gal	6.0 gal	8.0 gal	12.0 gal	16.0 gal
.9	115.2 oz	1.35 gal	1.8 gal	2.25 gal	2.7 gal	3.15 gal	3.6 gal	4.05 gal	4.5 gal	5.4 gal	6.75 gal	9.0 gal	13.5 gal	18.0 gal
1.0	1.0 gal	1.5 gal	2.0 gal	2.5 gal	3.0 gal	3.5 gal	4.0 gal	4.5 gal	5.0 gal	6.0 gal	7.5 gal	10.0 gal	15.0 gal	20.0 gal