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FOAM APPLICATIONS FOR WILDLAND & URBAN FIRE MANAGEMENT

Prepared by: **NWCG Fire Equipment Working Team's Task Group for International/Interagency Foams and Applications Systems**

Canadian Committee on Forest Fire Management | Comité canadien de gestion des feux de fôret

THE LANGUAGE OF FOAM

by Paul Schlobohm, Forester,
USDI Bureau of Land Management

The state of Class A foam technology is at a crucial juncture point. Most wildland firefighters have been introduced to Class A foam and its foam generating systems. Many are able to produce and apply foam to their satisfaction. However, because of scarce and often incorrect information, few firemen can speak intelligently about their new resource. Nomenclature exists but is not yet well understood. I wish to use this opportunity to establish common terms to reduce confusion and misinformation.

A common misunderstanding is the relationship of concentrate proportioners and foam generating devices. Proportioners add foam concentrate to the water supply, thus creating foam solution. Foam generating devices agitate the solution to create foam. The two concepts are distinct. Any proportioning method can be used with any foam generating hardware.

For some, **foam solution** is a confusing term used to describe surfactant-treated water. The more familiar term, **wet water**, might seem adequate, but it is not. Wet water is a mixture of wetting agents and water. Since wetting agents are designed to prevent foaming, wet water can not be made into a foam. Foam solution (surfactant-treated water) has the ability to act as a wet water, unfoamed, or to be turned into a foam. Most foam solutions also have a lower surface tension than wet water.

Many definitions should be taken from established sources. The National Fire Protection Association's (NFPA) standard 298, "Foam Chemicals for Wildland Control," defines foam, foam concentrate, foam solution, expansion, drain time, and surface tension. Other fire texts define terms such as wetting agents, foaming agents, and fire classes. New technology has also evolved with the introduction of Class A foam. For example:

A *low-energy system* uses only the energy of the water pump to educt air into the foam solution—nozzle aspirated foam systems are low energy. (See fig. 1.)

Figure 1. Low-energy nozzle aspirated foam system makes medium expansion foam.

A *high-energy system* is a foam generating device that adds the energy of the air source to the energy of the water pump—the compressed air foam system (CAFS) is high energy. (See fig. 2.)

Figure 2. CAFS adds air from trailer compressor to foam solution pumped from portable tanks in order to foam the log deck.

Slug flow is a plug of water in a hose filled with compressed air foam and is the result of too little foam concentrate in the solution to hold water in bubble form.

The *rope effect* describes a discharge of foam that looks like a taut rope, allowing very little separation of product from the projection until gravity overcomes horizontal velocity. (See fig. 3.)

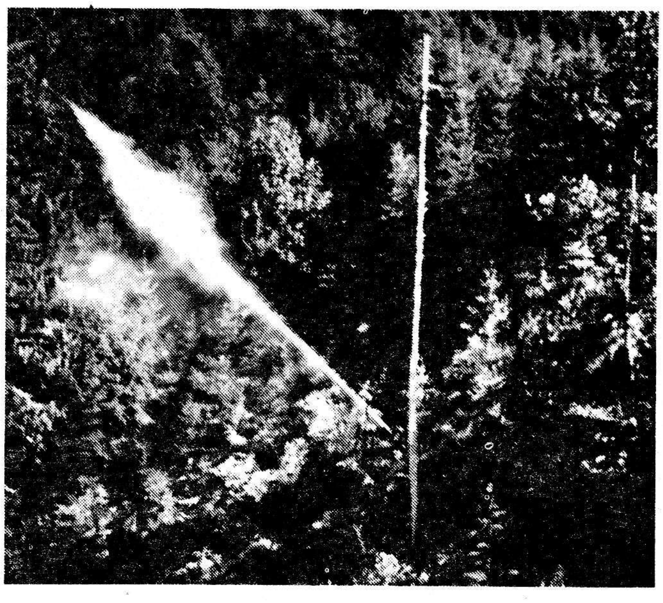

Figure 3. Rope effect produced by high-energy CAFS to reach the target with most of its foam product.

Foam type describes the consistency of foam as a function of expansion and drain time; foam type gives the firefighter a means of characterizing the variety of foams that can be produced.

Confusion about terminology is sometimes the result of inaccurate attempts to promote the concept of foam. For example, to demonstrate relative efficiency, 10:1 expanded foam has been said to expand 200 gallons of water to 2,000 gallons of water, or to replace 100 gallons of water with 10 gallons of water. The fact is making foam out of water does not increase the volume of water. Two hundred gallons of water is only 200 gallons no matter what form it takes. Creating a foam makes water more efficient at absorbing heat and wetting. To extinguish a given fire, less water as foam may be needed, enabling more results per volume than plain water.

As participants in a rapidly developing technology, we have the opportunity to develop a common language to facilitate the advancement of foam. Commitment will result in understanding and use. Apathy will lead to confusion and ignorance.

The glossary that follows is presented as a start in the development of this common language. It is a composite of several glossaries and terms from various publications. It forms part of a draft basic foam training document from an ad-hoc training committee, Foam Task Group, Fire Equipment Working Team (FEWT), National Wildfire Coordinating Group (NWCG)

Glossary of Terms

Absorption The act of absorbing or being absorbed.

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

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

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

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

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

Biodegradation Decomposition by microbial action, as with some detergents.

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

Carcinogenic Cancer causing.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Foam Blanket A body of foam—used for fuel protection—that forms an insulating and reflective layer from heat.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Short-Term Retardant A viscous, water-based substance wherein water is the fire suppressing agent.

Slug Flow In CAFS only, when foam solution is not rich enough to mix with air, inadequate mixing occurs; this sends pockets (or plugs) of water and air to the nozzle.

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

Surface Tension The elastic-like force in the surface of a liquid, tending to minimize the surface area and causing drops to form. (Expressed as Newtons per meter or dynes per centimeter; there are 1000,000 dynes per Newton.)

Surfactant A surface active agent; any wetting agent.

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

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.

VENTURI FOAM PROPORTIONING SYSTEM

by Dan McKenzie, Mechanical Engineer, USDA Forest Service

When using foam to fight fire, proportioning the foam concentrate directly into the high-pressure, or discharge, side of the pump is very desirable. This eliminates problems associated with adding the foam concentrate directly into the water tank, drafting the foam concentrate into the suction side of the pump, or using an around-the-pump proportioner. Possible problems eliminated by the injection of foam concentrate, using a proportioning system, directly into the the discharge side of the pump are:

- Corrosion (caused by the foam concentrate clearing the tank, pump, and plumbing)
- Pump priming difficulties
- Water-level gauge troubles
- Foaming in tank
- Foam proportion cannot be conveniently changed while operating—it can be increased by adding more foam concentrate to the water tank
- When refilling a partially used tank of water, dip sticking or gauging is required
- Fire engine can not draw water directly from a nurse tanker or hydrant and make foam solution
- Foam solution biodegrades over time, tends to lose potency, and does not foam as well
- Contamination of the water tank—making water from the tank unusable for other purposes (such as drinking or supplying water for look out towers)
- Use of more foam concentrate than required
- Problems with pump and valves caused by the foam concentrate washing out their lubricants.

Ideally, a foam concentrate proportioner should:

1. Be proportional over the entire range of use. When the percent of foam concentrate is set, it should not change over the range of operation of the water pump (both flow and pressure), be proportional down to almost zero flow, and stop flowing when the water is completely shut off.

2. Not require that chemicals be added to the water tank; run through the pump; nor be recirculated back to the tank or through the pump. This is important because most centrifugal fire pump installations have [if they do not, they should] a continual small bleed back to the tank for pump cooling when the water is shutoff in the hose line.

3. Inject on the discharge side of the pump in the correct proportion such that foam concentrate is injected into the water stream to make foam solution and immediately flows out of the engine and into the hose line with no possibility of the foam solution recirculating and thereby contaminating the engine tank or plumbing.

4. Be low in cost and simple in design; have both very high reliability and very high availability (i.e. work almost all the time); and have very high maintainability (i.e., if it does not work, can be repaired very quickly).

5. Be able to use different types of foam concentrates at up to 1 percent concentration—even higher percentages may be desirable—and be able to change percentage while operating.

6. Be able to gauge how much foam concentrate is left in the foam concentrate tank.

7. Cause no, or low, water pressure loss.

A proportioner that can be fabricated and that will have all seven of these desirable characteristics is a venturi proportioning system. The San Dimas Technology and Development Center (SDTDC) has developed, and placed in the field, demonstration/validation venturi units. A fully engineered, commercial production unit is available.

To understand how the venturi direct-injection proportioner system works, see the schematic of the essential elements (fig. 4), which are (1) venturi, (2) check valve in the flow line in front of the venturi, (3) foam concentrate positive-displacement pump, (4) pilot operated relief valve, (5) variable orifice (ball or needle valve), (6) check valve in foam concentrate injection line, and (7) foam concentrate reservoir or tank. With these elements, the system will work, without any one, the system will not work with the possible exception of the check valve (2) in the flow line in front of the venturi (1).

Foam concentrate is drawn from the foam concentrate tank (7) by the small, positive-displacement pump (3), which raises the pressure of the foam concentrate to the same pressure as main line or water pressure. Foam concentrate pressure is

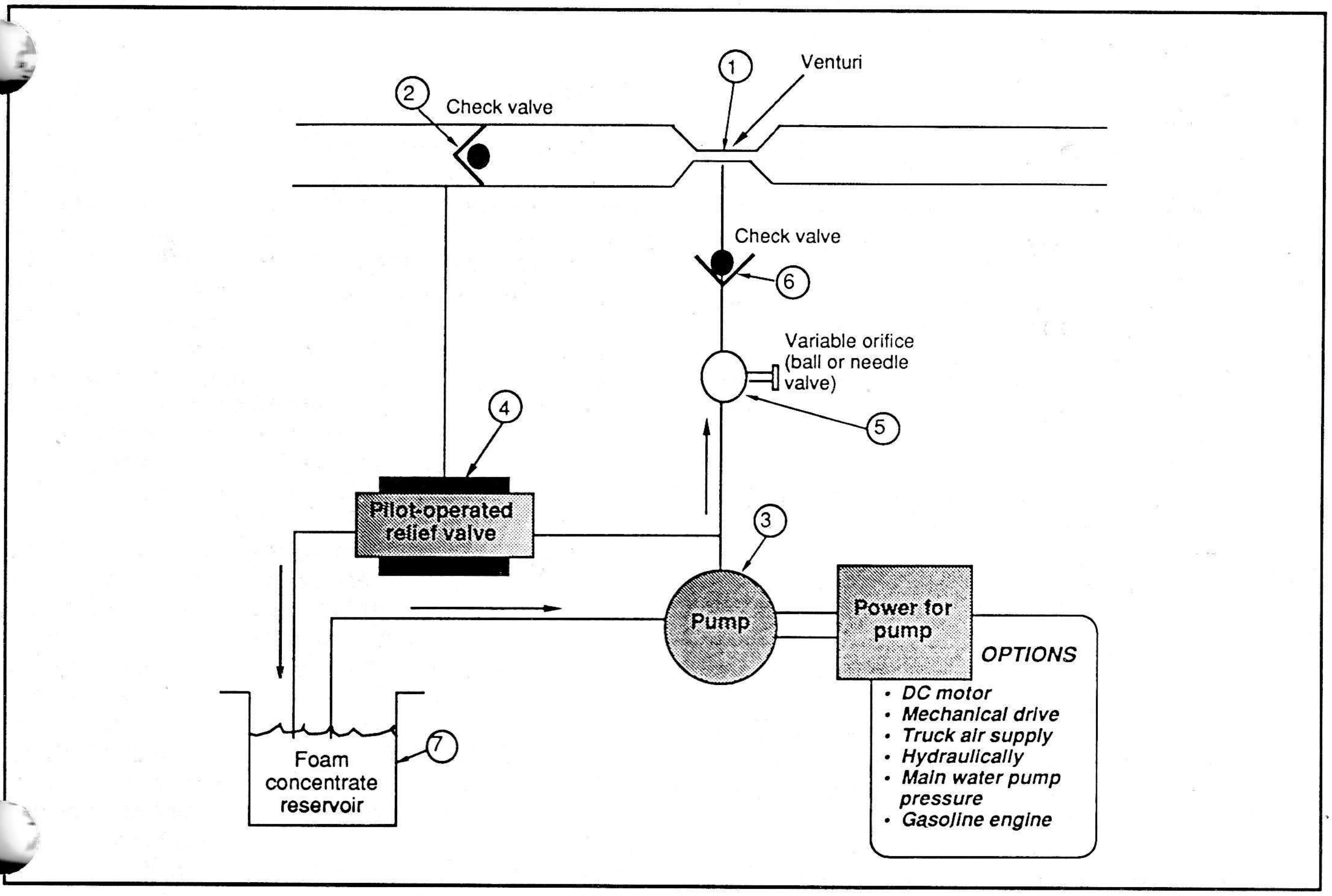

Figure 4. Essential elements of direct-injection venturi foam proportioning system.

controlled by the pilot-operated relief valve (4), which maintains foam concentrate pressure at the same pressure as water pressure. (In practice, foam concentrate pressure is set a little higher than water pressure.) With no water flowing, pressure is the same at the venturi inlet and its throat, resulting in no flow of foam concentrate into the water stream at the venturi throat.

When water is flowing, there is reduced pressure at the venturi throat. Foam concentrate pressure, which is controlled by the pilot-operated relief valve (4), is the same as inlet water pressure to the venturi (2); therefore, foam concentrate flows from high pressure (pressure equal to the water pressure) into the throat of the venturi. The rate of flow of the foam concentrate into the throat of the venturi is controlled by the difference in pressure from the venturi inlet and venturi throat and by the setting on the variable orifice (5). The more the orifice is opened, the greater the foam concentrate flow; as the orifice is closed, less foam concentrate flows. As water flow is increased, pressure at the venturi throat is decreased. As water flow is decreased, pressure at the venturi throat is increased; therefore, foam concentrate flowing into the water stream is increased or decreased as water flow is increased or decreased. Thus, the injection of foam concentrate remains proportional to water flow (or the percent of foam concentrate in the water stream remains constant).

Pressure decrease in the venturi throat is proportional to flow squared. If the water flow is doubled, pressure at the venturi throat will decrease by a factor of four. This results in excellent operation in the upper one-half of optimum design flow, and good operation in the upper two-thirds of optimum design flow. This means that, if the system were designed and sized for 50 gpm, it would work very well from 25 to 50 gpm and well from 16 to 50 gpm. The system could also be operated and work well at 100 percent over optimum design flow, and even up to 150 percent over optimum design flow.

Optimum design flow is considered to be the flow when the venturi throat pressure is 20 psi below venturi inlet pressure. In a well designed venturi, 80 or 90 percent of this differential pressure will be recovered in the divergent cone or diffuser section of the venturi, resulting in only a permanent pressure loss of 2 to 4 psi at optimum design flow. At 100 percent over optimum design flow, the differential pressure will be approximately 80 psi, resulting in a permanent pressure loss of 8 to 16 psi. At 150 percent over optimum design flow (which would not be considered as pushing the system too far), the differential pressure would be 125 psi, with a permanent pressure loss of somewhere in the order of 15 to 30 psi.

To make the system work well down to zero flow, a check valve is placed in the flow line ahead of the venturi that has a 1/2 psi cracking pressure. This results in the foam concentrate being injected into the water stream at near zero flow. We now have a system that will inject foam concentrate into a water stream from almost zero flow up to 250 percent of optimum design flow. It is of interest to note that the operating principle of this foam concentrate venturi direct-injection system is the same as a carburetor on a gasoline engine, which injects fuel into the air intake at a constant air/fuel ratio. The foam concentrate venturi direct-injection system is:

1. Proportional from near zero to maximum flow (250 percent or more of optimum design flow)
2. Free of the requirement that chemicals be added to the main water tank or be run through the pump
3. Capable of injection on the discharge side of pump
4. Very reliable, when well designed and operated correctly
5. Able to draw foam concentrate from different tanks that can be easily gauged, and the percent foam concentrate in the foam solution can be easily changed
6. A low pressure loss system at optimum design flow.

Elements that are absolutely essential for the venturi direct-injection foam concentrate proportioning system to work are shown in figure 4. There are a few other items that should be included in the system; these are shown on the complete system in figure 5. They provide a method to determine foam concentrate usage rate, such as a flowmeters to show rate of injection and rate of return to tank, which shows that the system is working. Also, a pressure gauge may be installed to show water pressure and foam concentrate pressure, and a suction filter to remove large particles. Three other items probably should also be installed. They are an emergency relief valve for the foam concentrate, a primer valve, and a water relief valve to the pilot-operated relief valve.

The purpose of the emergency relief valve is to relieve foam concentrate pressure if, for some reason, it should become too high—this is considered good practice. The primer valve relieves foam concentrate pressure so that the foam concentrate pump is more easily primed and can also be used to stop foam concentrate injection. With the primer valve open, the foam concentrate will only be circulated and will not be injected into the water stream because it is at near zero pressure. The water relief valve on the pilot-operated relief valve line prevents foam concentrate pressure from raising too high if the water pressure is higher than rated pressure of the venturi direct-injection proportioning system.

Another way of providing the foam concentrate at line or water pressure is to replace the pilot-operated relief valve, foam concentrate positive-displacement pump, primer valve, pressure gauges, emergency relief valve, return flowmeter, and emergency relief valve with a bladder pressure tank. This places water pressure on one side of the bladder and foam concentrate on the other side of the bladder (see the fig. 6 schematic). With water pressure inside the tank, the foam concentrate is now at the same pressure as water pressure. This system works just as the pump and pilot-operated relief valve system works. There is a commercially available pressure tank foam concentrate direct-injection system.

For further information on foaming agent delivery systems contact the author or Steve Raybould, Fire Specialist, at SDTDC, 444 East Bonita Avenue, San Dimas, CA 91773; 714/599-1267; FAX 714/592-2309.

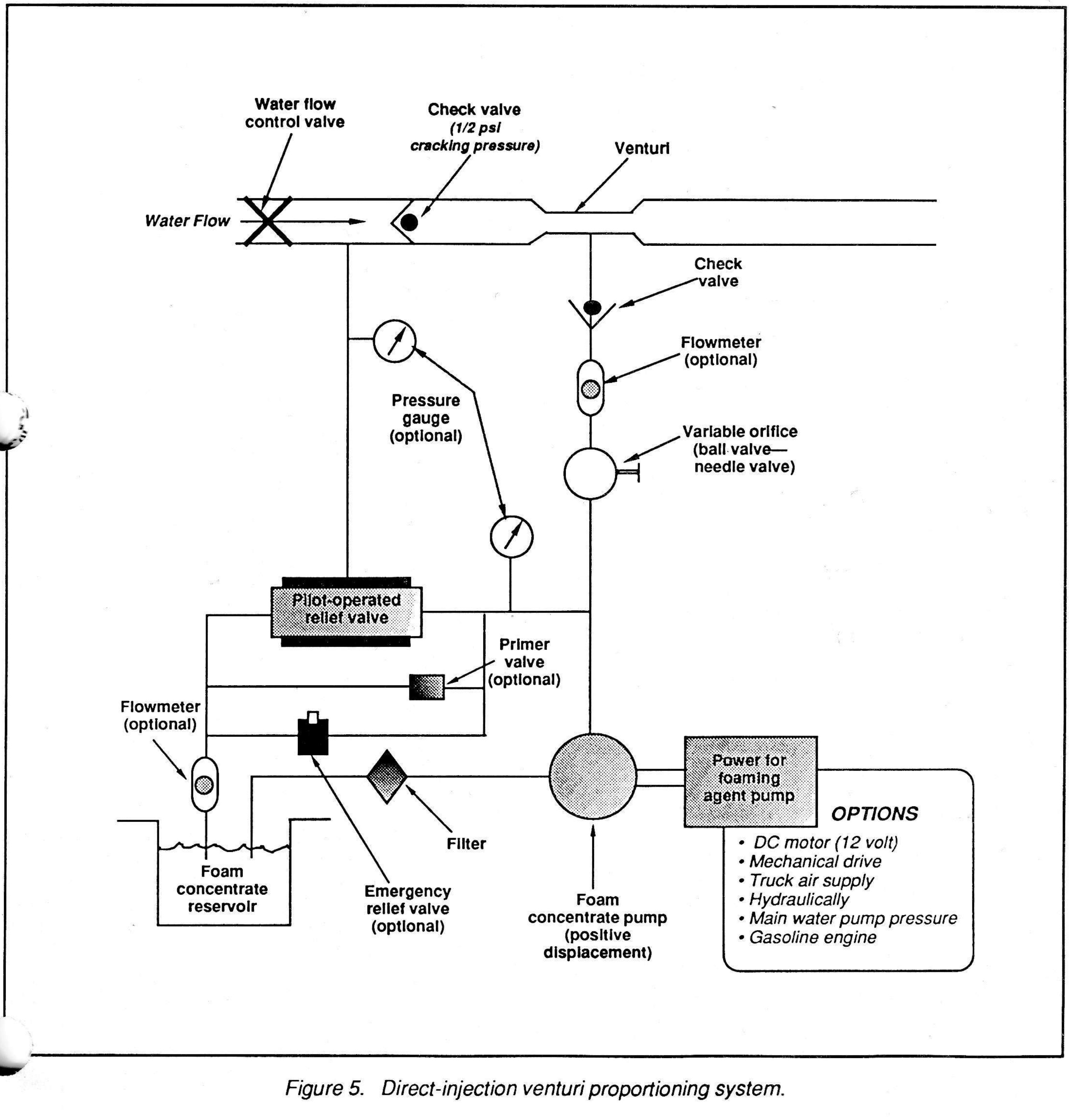

Figure 5. Direct-injection venturi proportioning system.

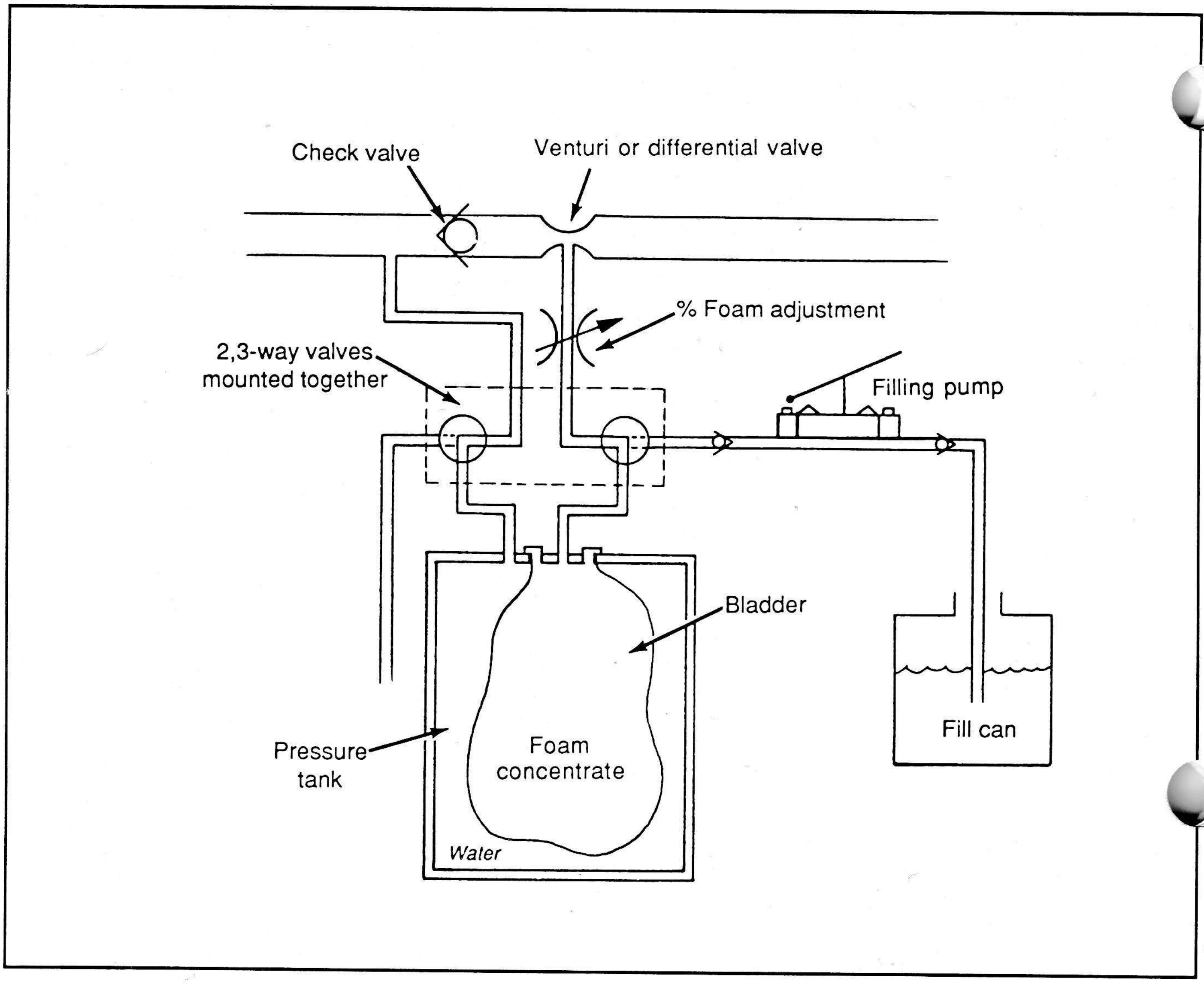

Figure 6. Direct-injection venturi proportional system with a bladder in pressure tank.

APPROVED, AVAILABLE FIRE CHEMICALS

by Steve Raybould, Fire Specialist, USDA Forest Service

A wildland chemical qualification, testing, and approval program is carried out by the agency's Intermountain Fire Sciences Laboratory, Missoula, MT, and Technology and Development Center, San Dimas, CA. The program covers all fire chemicals, including long- and short-term retardants, as well as wildland foam concentrates. Table 1 contains the latest list of approved wildland fire foams and their status.

FOAM USE IN BACKPACK PUMPS

by Lynn R. Biddison, Agency Liaison, Chemonics Industries

The Fire-Trol(™) Division of Chemonics has developed, and is marketing, an aspirating foam nozzle known as FT-BP (BAKPAK) for use with back pumps. This aspirating nozzle fits nearly all back pumps in use (see fig. 7). An adapter is available to fit the new Hudson back pump.

Along with the FT-BP (BAKPAK) nozzle, Chemonics is packaging and marketing its Fire-Trol FireFoam 103 chemical in 4-oz packets (FOAMPAK) for use in back pumps. One of these packets, emptied into a back pump equipped with the GT-BP (BAKPAK)

FIRE CHEMICALS
(Approved and commercially available)

Chemical	Mix Ratio	Status	Approved Applications[1] Fixed-Wing Airtanker	Fixed-Tank Helicopter	Helicopter Bucket	Ground Engine
WILDLAND FIRE FOAM (Approved under Interim Requirements for Wildland Fire Foam)						
Phos-Chek WD 861	.1-1%	Approved			•	•
Ansul Silv-ex	.1-1%	Approved			•	•
Fire-Trol FireFoam 103	.1-1%	Approved[2]		o	•	•
Phos-Chek WD 881	.1-1%	Approved[2]		o	•	•

[1] • Fully qualified   o Conditional Approval

[2] Conditional approval for use from fixed-tank helicopters until a new or modified formulation meets magnesium corrosion requirements.

Table 1. Fire chemicals (approved and commercially available).

Figure 7. Backpack bag and pump with FT-BP aspirating nozzle.

nozzle, results in foam having an expansion rate of ± 5 to 1. This means that the 5 gal of water with 4 oz of foam concentrate becomes equivalent to 20 to 25 gal of plain water.

The FT-BP (BAKPAK) nozzle and FOAMPAK's were used extensively on wildland fires in 1989. Firefighter reports were all very positive on the effectiveness of the nozzle and foam for fire suppression, and for speeding up and simplifying mop-up operations. Anyone with questions on these products should contact Chemonics Fire-Trol at P.O. Box 277, Orland, CA 95963; 916/865-4932; FAX 916/865-5479.

CLEARING THE AIR ON PHOS-CHEK(™) WD 861 FOAM CONCENTRATE

by Mike Mertens,
Marketing & Tech Service Mgr., Monsanto Co.

Old habits are hard to break. The same can be said of reputations. Does Monsanto's Phos-Chek WD 861 foam concentrate exhibit a problem with crystal growth? No, it definitely does not have a problem with crystals. Did this foam concentrate used to exhibit a problem with crystal growth? Yes. The following is a short history of Phos-Chek WD 861 foam concentrate and what was done to solve the crystal growth problem.

Our foam concentrate was developed during the winter of 1985-86. It was introduced in France in the early spring of 1986 and was utilized in France's fixed-wing air program. After this successful debut, the foam concentrate was made commercially available in the United States in time for the 1986 fire season. The product performed well with no apparent problems through the summer of 1986.

The first indication of a problem came from France during late summer of 1986. It was reported that crystal formations had been observed in the foam concentrate inventories which had been left over from the previous year. Shortly thereafter, the same problems were being reported here in the States. Monsanto had a real problem on its hands. The first step in solving this problem was to determine the cause of the crystals.

The crystal formations were analyzed. The results of this analysis revealed that the crystal formations were comprised of sodium sulfate decahydrate. Upon further analysis, it was discovered that the sodium sulfate was present as an impurity in one of the raw materials utilized in formulating Phos-Chek WD 861 foam concentrate. It was imperative that this situation be remedied. Our raw material supplier was contacted and appraised of the situation. We jointly reviewed our raw material specifications. The specifications were tightened to reduce the impurities present in the raw materials.

Since we have been using the higher quality raw materials, Phos-Chek WD 861 foam concentrate has not experienced problems with crystals. Another Class A foam, Phos-Chek WD 881 foam concentrate, which is specifically formulated for improved cold water mixing, has not experienced problems with crystal formation. ***With three fire seasons behind us, crystals are no longer a problem for Monsanto's Phos-Chek foam concentrates.***

As a final note, if you have on hand any pre-1987 Phos-Chek WD 861 foam concentrate with crystal formations present, the Monsanto Wildfire Division will replace it free of charge. A Monsanto Wildfire Division representative can be contacted at 714/983-0772.

FOAM DISPENSING EQUIPMENT REQUIREMENTS FOR CONTRACT HELICOPTERS

by John Seevers, Ph.D., Under contract to San Dimas Technology & Development Center, USDA Forest Service

Call-when-needed (CWN) contracts permit helicopter contractors to furnish equipment for dispensing foam and retardant concentrates into buckets. Since the equipment is relatively new to the USDA Forest Service, detailed design or performance specifications are not yet available. What follows indicates interim measures, until it is decided what equipment we will standardize on. Thus, until specifications are developed, the evaluation criteria presented here can be used—along with good judgement.

General Requirements

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

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

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

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

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

Containment: Any unit mounted inside the helicopter (other than those that have STC's or 337's), must have a containment vessel around the pumping unit and concentrate storage supply. The containment vessel must be able to hold 125 percent of the concentrate supply. Even in moderate turbulence, the containment vessel must be able to contain the foam concentrate. The discharge hose and fittings must be able to withstand 150 psi, or two times the rated maximum pressure output of the pump, whichever is greater. The discharge hose that is inside the cabin must have a containment sleeve of clear hose so that leaks will be visible.

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

Weight: The foam dispensing system empty weight shall not exceed 40 lb.

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

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

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

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

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.

Operational Requirements

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

Flow Rate: The system must be capable of dispensing a variable amount of concentrate, in flight, to achieve a mixture ratio ranging from 0.1 to 1.0 percent by volume, in 0.05 percent increments. (Example: For a water bucket load of 250 gal, a mixture ratio of 0.50 percent would require 1.25 gal of injected concentrate; the next selected increment of 0.55 percent would require 1.375 gal of injected concentrate.)

Concentrate Loading: Loading of 5-gal containers is preferred. If bulk loadings 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.

EFFECTIVENESS OF FOREST FIREFIGHTING FOAMS

by Edward Stechishen, Research Forester, Forestry Canada

Suppression of forest fires is dependent on breaking the links in the fire triangle; that is, isolating either air, fuel, or heat from the other two. Water has been used extensively to attain this goal and, in more recent times, retardants have played a major role in aerial suppression. The need to apply copious quantities of water has been the driving force in the search to enhance water's suppression capabilities. Currently, the answer seems to be the use of a foaming agent. The conversion of water from a liquid to a bubble state imparts new characteristics to the water and results in superior suppression qualities. The foam affects all three sides of the triangle, and also produces side benefits which are an aid to suppression. In some instances, a particular function performed by the foam modifies more than one of the fire parameters—thereby giving a compounded net benefit.

The least complicated relationship is that of the foam and air. The viscosity of water is such that very little adheres to the surface that it lands on. Water immediately drains off, and only a miniscule amount is retained if the surface is not very rough and porous. In most cases, foam is semifluid; consequently, gravitational forces are primarily responsible for the gradual flow that is set up after foam comes to rest. As a result, more water adheres and remains on site for a much longer period of time in the foam state. During this interval, the foam acts as a durable barrier and excludes the oxygen-enriched air from the fuel's surface. Vaporized water is trapped at the fuel interface by the foam layer and air pockets in the fuel's proximity attain high relative humidities. Foam impedes the free movement of air and moisture-laden air is not replaced by dry air. When water is applied to live coals, the skin-thin layer of water that adheres is readily evaporated and oxygen-enriched air is permitted to enter and foster combustion. But, when this same volume of water is expanded ten times, the resulting foam layer forms a protective envelope.

The heat segment of the tripartite making up the fire triangle is severed by foam in several ways. The brilliance of the foam blanket reflects some of the energy that impinges on it; the balance is absorbed. The sphere-like structure of the bubbles causes incoming energy to dissipate laterally, and localized preheating is minimized. The pathway through the bubble mass is made up of the fluid in the bubble skins and the air within these bubbles. These air cells act as pockets of insulation and, as a consequence, radiant energy becomes highly diffused when it enters the foam. The energy that is absorbed is used to evaporate water trapped in the foam structure. The net result is slower evaporation per unit of surface area and an overall delay in the exposure of the fuel's surface to oxygen and heat. The foam physically insulates burning fuel from the surrounding environment. The energy released at the combustion interface is dissipated, and cooling takes place while this barrier starves the burning fuel of oxygen. These inhibiting factors reduce the potential for rekindling; rekindling only takes place where the energy output exceeds that needed to totally dissipate the foam cover.

The fuel segment of the fire triangle is affected by foam in diverse ways. A heavy application of foam does not drain off instantaneously like water but flows gradually, thereby enveloping the fuel particles on which it lands. This results in much more water being held in the bubble structure per unit of fuel surface. The increase in amount means there is more water available both for wetting and to absorb heat. The surface-active agent in foam reduces the surface tension of water from approximately 72 mN/m to less than 33 mN/m, the level specified for wetting agents. A typical relationship between surface tension and mix ratio is:

Foam concentrate (%)	Surface tension (mN/m)
0.00	72.1
0.01	43.6
0.05	34.2
0.10	30.3
0.50	28.9
1.00	28.9
100.00	32.5

Water in its pure form maintains a strong molecular bond; consequently, its surface resists rupture. The addition of a wetting agent to water weakens this molecular bond, and the water's ability to wet and to penetrate porous materials is greatly enhanced. Because foam stops where it lands and releases its liquid component at a regulated rate, wetting of the fuel is achieved much more efficiently. Hard-to-wet surfaces shed water but foam adheres to them, and the foam wets these surfaces via the wetting agent. Vertical surfaces are also difficult to wet with water—even if they are receptive to water—but, in the foam state, a substantially greater amount of water can be entrapped and rendered available for wetting and heat absorption of such surfaces.

The rigidity of the bubble structure depends on bubble uniformity, mix percentage, exposure to sunlight and wind, and the efficiency of the foam generator. The rate at which the bubble mass reverts to liquid depends on these factors. The slow release of fluid from the foam makes liquid water available for a longer period of time to wet the fuel. Changing water from a liquid state to a foam state also enhances the suppressant's ability to penetrate fuel complexes. Water travels along the path imposed on it by gravity and that imparted to it by the delivery vehicle. These forces also apply to foam but, once the liquid aerates to form a bubble mass, it becomes buoyant and its descent path is influenced by air movements.

The end result is that foam penetrates through openings to envelop fuels which might otherwise not be wetted. This enveloping of fuels results in an isolation of volatiles emanating from the fuel particles or, as a minimum, a dilution of these volatile substances to a level where the ignition threshold is greatly altered; i.e., the ignition temperature is elevated. The breakdown of the foam at a controlled rate not only enhances wetting but also modifies the microclimate within the fuel complex and in the stand, where the escape of liquid sets up a drizzle-like condition.

Forest firefighting foams are currently the best instruments available to suppression agencies to break the air, heat, and fuel relationship.

FOAM GENERATING EQUIPMENT

by Dan McKenzie, Mechanical Engineer, USDA Forest Service

On-Hand Equipment/Aspirating Nozzles/Compressed Air Foam Systems

When fighting wildfire with foam, the foam generating equipment can range from the use of current equipment (tank, pump, and plumbing) on hand to specially developed, high-performance compressed air foam systems (CAFS). To use on-hand equipment, one just pours a foam concentrate into the water tank, to the desired proportion to make foam solution, and then go at it. To make improved foam, an aspirating nozzle can be added for a cost of some as low as $20. CAFS is the next step up from the aspirating nozzle. CAFS is the injection of compressed air into foam solution, generally at the engine, and running the produced mixture through a length of hose or mixing device to produce a uniform foam. The advantages of a CAFS unit over an aspirating nozzle include (1) the foam can be projected further, (2) less foam concentrate is used, and (3) smaller more uniform bubble, longer lasting, foam can be made.

An added advantage of CAFS over an aspirating nozzle is that the aspirating nozzle can only make one type of foam—wet sloppy, while a CAFS unit can make different types of foam—all of which generally last longer than aspirating nozzle made foam. For a number of reasons it is not desirable to add foam concentrate directly to the water tank. Therefore, both when using an aspirating nozzle and CAFS, proportional direct injection of the foam concentrate into the discharge side of the pump is what one should use.

Aspirating Nozzles: Aspirating nozzles create foam by (a) atomizing the foam solution stream, (b) drawing air into the stream, generally by venturi action, to create a froth, (c) mixing the froth in an expansion chamber to enhance and strengthen the bubbles, and (d) discharging the foam. The aspirating nozzle is a low-energy system for making foam; for only the energy in the water stream is available. In general, aspirating nozzles which have a long reaches, by using the water stream energy to project the foam, will only produce wet, frothy foam. Aspirating nozzles which use most of the water stream energy in making bubbles, will create a drier, more uniform bubble, foam that is only projected short distances. For there is only a given amount of energy in a water stream—

if you want to educt air to create foam, this will require the use of energy from the water stream reducing the amount of energy for projecting the foam resulting in reduced discharge distances. Aspirating nozzles normally require at least a 0.5 percent foam solution to operate well.

Compressed Air Foam System (CAFS): CAFS—at one time known as the "Texas Snow Job"—was first put into service by the Texas Forest Service in 1977. CAFS feature the injection of compressed air (or other pressurized gas) into foam solution (foam solution is water and foam concentrate in the correct mix ratio). In CAFS, less foam concentrate is generally used (0.3 percent) than with an aspirating nozzle. CAFS is a brute force method of producing foam; therefore, almost any foam concentrate will "work." Injection of air usually takes place at the engine, mostly at operating pressures of 80 to 100 psi. Higher or lower pressures are also used—depending on hose size and length.

Direct Injection/Equipment Components

Both the aspirating nozzle and CAFS should use proportional, direct injection of the foam concentrate into the exiting water stream to make foam solution, since adding the foam concentrate directly to the water tank or passing it through the pump (suction side proportion devices) is not desirable for the following reasons:

- Corrosion (caused by the foam concentrate clearing the tank, pump, and plumbing)
- Pump priming difficulties
- Water-level gauge troubles
- Foaming in tank
- Foam proportion cannot be conveniently changed while operating (It can be increased by adding more foam concen trate to the water tank)
- When refilling a partially used tank of water, dip sticking or gauging is required
- Fire engine can not draw water directly from a nurse tanker or hydrant and make foam solution
- Foam solution biodegrades over time, tends to lose potency, and does not foam as well
- Contamination of the water tank—making water from the tank unusable for other pur poses (such as drinking or supplying water for lookout towers)
- Use of more foam concentrate than required
- Problems with pump and valves caused by the foam concentrate washing out their lubricants.

For these reasons and others, proportional, direct injection of the foam concentrate on the discharge side of the pump is very desirable in both aspirating nozzles and CAFS units. There are a number of direct-injection proportioning systems on the market (or under development), for use with both aspirating nozzles and CAFS units, which proportionally inject foam concentrate into the discharge or high pressure side of the pump for use with both new and existing water pumping equipment.

Pumps: Both types of pumps used in firefighting can be used with foam generating equipment. Early CAFS used the positive-displacement pump. However, a method of using the centrifugal pump was developed—allowing the centrifugal pump to work very well with CAFS. There are major advantages to using a centrifugal pump with CAFS, for there is no deterioration of the water handling performance nor of the reliability of the fire engine related to water handling.

Air Compressors: There are several types of positive-displacement air compressors—piston, rotary van, rotary helical screw, and rotary lobe. The piston type is by far the lowest cost and simplest. The rotary screw has a major advantage over the piston air compressor in that it can modulate output. Because of this, the rotary screw compressor is becoming popular for use in CAFS, despite its higher cost. Very little if any air storage is required for CAFS, for the system will generally use all the air that is produced and at the rate at which it can be produced. In the larger systems, using the rotary screw type air compressor which will modulate output, no air storage is necessary.

Power Sources: When using aspirating nozzles, the power for the foam generating equipment can be a power takeoff (pto) from the truck transmission or an auxiliary engine. CAFS can also be powered by the truck engine or an auxiliary engine; however, special methods must be used. When using the truck engine to drive a CAFS unit, a hydrostatically driven system should be used to drive the centrifugal pump and air compressor. If CAFS is to be driven by an auxiliary engine, a single auxiliary engine can (and probably should) be used. For, when a single auxiliary engine is used—and engine horsepower, pump gearing, and air compressor gearing are properly selected and well matched—the single-engine CAFS works very well.

Equipment Selection/Flowmeters

Major components of foam generating equipment have just been covered; however, the question is what should be used. For aspirating nozzles usually the standard water handling equipment can be used with the addition of a pump discharge, direct-injection, foam concentrate proportioning system. For CAFS, a little more guidance is needed.

For CAFS or aspirating nozzles the pump should be a centrifugal pump because of the major advantage of no deterioration of the water handling performance nor of the reliability of the fire engine related to water handling. For wildfire, the pump performance should probably fall in the following ranges—50 to 70, 90 to 120, and 190 to 250 gpm.

The air compressor could be either a piston or rotary screw. The rotary is becoming preferred because it modulates output. For wildfire, the compressor output should fall in the range of a minimum of 40 to 100+ cfm. The minimum flow will operate well a short (up to 200 ft) 1-inch diameter hose; 100 cfm will operate very well a short (up to 200 ft) 1-1/2-inch hose. The power source should be the truck engine or a single auxiliary engine; in either case the unit should be able to make a running attack.

A CAFS unit should have a system that proportionally injects foam concentrate into the discharge side of the pump. This means that no foam concentrate has to be added to the tank nor run through the pump.

One more area of guidance for a CAFS unit is to have flowmeters on the water, air, and foam concentrate lines. When the end of the hose is close to the engine, and the engine operator can see the discharge, these may not be very important. But, when fighting wildfires, frequently the hose ends up going over the top of the hill; then the engine operator cannot see what is happening at the end of the hose. For, when supplying a long hose lay, it is a long time before a change at the end of the hose is seen after an adjustment is made at the engine—sometimes as long as 15 to 20 minutes. For these reasons, flowmeters on a CAFS unit are very important; they show the operator what the unit is doing and, when an adjustment is made, the operator can see whether the adjustment is producing the desired effects. Flowmeters also help in training the operator to produce foam quickly and change the foam on demand.

NEW FOAM CONCENTRATE PROPORTIONING SYSTEM

by Rod Carringer, General Mgr.
KK Products, Valparaiso, IN

As Class A foam technology progresses from the wildland to the structural/urban environment, the demand for new application and proportioning equipment has reached an all time high. Interest in aspirated and compressor assisted foam comes from the industrial and structural fire services, as well as wildland/rural interface professionals. To answer these diverse needs, KK Products has undertaken a complete and extensive evaluation program of discharge-side foam injection systems. Agencies such as California Dept. of Forestry & Fire Protection (CDF) in Davis, CA; the Forest Service Technology & Development Center (T&DC) in San Dimas, CA; Petawawa National Forestry Institute, Forestry Canada; Bureau of Land Management, Boise Interagency Fire Center (BIFC) in Boise, ID; Texas Forest Service; Florida Division of Forestry; and New Brunswick Division of Forestry have been instrumental in the development of the KK Products PRO/portioner over the last 7 mo.

Designed to be rugged and durable in constant heavy field use, the PRO/portioner (fig. 8) uses no electronic monitors or flow-sensing equipment. The original design was adapted from development work by Dan McKenzie of T&DC, San Dimas, CA. Using a unique proportioning block, developed by the KK engineering staff, the PRO/portioner is capable of accurately metering Class A or 1 percent AFFF from 0.1 up to 1 percent into the discharge or high-pressure side of the pump. Flow ranges from 5 to 250 gpm, and pressure ranges up to 450 psi, allow these units the flexibility of use with structural engines, brush trucks, and fixed hydrant systems.

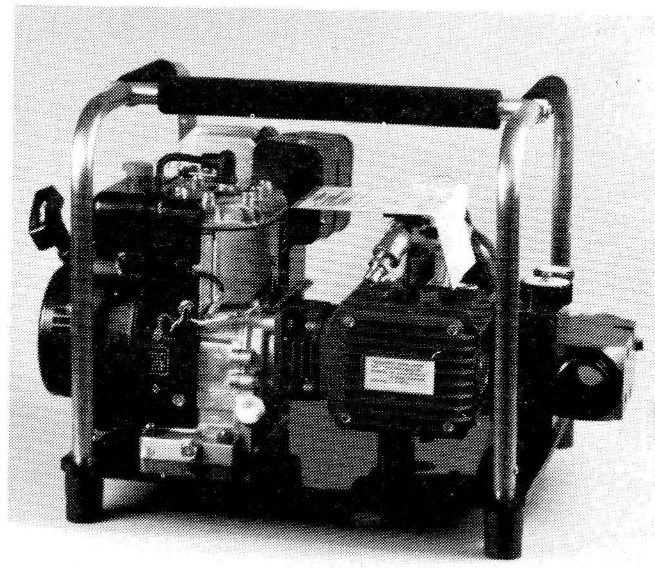

Figure 8. PRO/portioner powered by four-cycle engine.

PRO/portioners are available with a choice of power options. Twelve-volt DC electric motor units are ideal for truck-mounted applications when a fixed or running attack must be made with the engine. Two- and four-cycle engine models can either be mounted on engines or used for applications with portable pumps or when water relays require remote injection of foam concentrate. Also, the portioner can be mechanical driven by the centrifugal water pump drive line (not adding to the electrical system load of the fire engine).

Foam proportioners eliminate many problems commonly associated with the use of low proportioning Class A foam concentrate, such as:

• The elimination of foam concentrate from the pump or water tank means no more corrosion or pump maintenance concerns.

• The unit accurately meters as low as 0.1 percent, assuring no wasted foam concentrate into the discharge or high-pressure side of pump.

• The wide range of operating flows and pressures permits use with a wide variety of pumps and initial attack operations.

• There are no hose length or combination restrictions, high-pressure requirements, or nozzle flow matching, as is necessary with common educators.

Proportioners with Class A foam concentrate and an aspirating nozzle provide a simple systems approach to any fire professional concerned with initial attack, exposure protection, or saving time and effort in mop-up and overhaul situations. Fuels that for years have been considered the most difficult to suppress can now be more easily extinguished without the problem of rekindling. Remarkable results have been attained in the suppression of some of the following fire scenarios:

Wildland	*Structural*	*Industrial*
* Direct attack	* Initial attack	* Fixed sprinkler systems
* Wet line	* Exposure protection	* Coal bunker fires
* Mop-up Operations	* Tire fires	* Dump fires
* Exposure protection	* Peat moss	* Salvage/overhaul

For additional information please contact Rod Carringer, KK Products, 800/537-7553.

LONG-TERM FOAM USE IN NEW BRUNSWICK

by Dave Ingersoll, Air Operations Mgr.,
Dept. of Natural Resources & Energy,
New Brunswick, Canada.

During the summer of 1987, Ed Stecishen of Forestry Canada assisted New Brunswick in evaluating the PZL M-18 Dromader used as an air tanker to drop foam. Several drops were made on both an open field grid system and on a mature Jack Pine stand with a dense canopy. Among these drops, there were a few loads of long-term retardant for comparison of recovery rates for various retardants. It was during these test drops that the subject of mixing the foam concentrate with long-term retardant was discussed. It was decided to try one long-term retardant drop with foam concentrate added at a concentration of approximately 0.8 to 1 percent to see what would happen.

The test drop was carried out, using the same altitude and air speed at release, as with long-term retardant. Recovery rates using the long-term retardant and foam mixture appeared to be better than with long-term retardant alone in the closed canopy test. Some other improvements caused by adding foam concentrate to the long-term retardant were better wrap-around capabilities than ordinary long-term retardant slurry. It was also observed that the long-term foam slurry formed a film over the ground fuels and horizontal aerial fuel. When long-term retardant alone was dropped under the same conditions, ground and horizontal aerial fuels were spotted with retardant droplets.

Due to the lateness in the fire season (1987), the use of long-term foam was not carried out under actual fire conditions, as very few fires occurred and a system has not been perfected to introduce the foam concentrate into the long-term retardant during the loading process. In 1988, long-term foam was used on a small number of fires, with reports of good results coming from the Birddog officers involved. Introducing the foam concentrate to the retardant load was done by hand, which proved tedious and discouraged regular use. It was felt that an injection system had to be developed that would accurately measure the foam concentrate and inject it into the long-term retardant when the aircraft was being loaded.

During the winter of 1988-89, Chemonics Industry Ltd. of Kamloops, British Columbia, developed a portable injection system to be used in New Brunswick. This system was simple to use, and allowed the mixing of long-term foam whenever it was desired. The 1989 fire season saw the use of long-term foam on initial dispatch on a large number of fires and, although not scientifically documented, reports from Birddog officers and ground crews were very positive. The long-term foam was said to be more effective in stopping fire spread than long-term retardant alone.

During the winter of 1989-90, New Brunswick acquired a smaller foam injector to be carried in the Birddog aircraft to improve foam use at satellite airstrips. It is hoped that more long-term foam will be used during the 1990 fire season since past results have been encouraging. New Brunswick Air Operations will be trying to document some of the benefits of this mixture during the 1990 fire season. For further information on long-term foam retardant use in New Brunswick, feel free to contact Dave Ingersoll, Air Operations Manager, Department of Natural Resources and Energy, Forest Fire Protection Branch, P.O. Box 6000, Federation, New Brunswick, E3B 5H1, Canada; 506/453-2530; FAX 506/453-3322.

USDI BUREAU OF LAND MANAGEMENT FOAM PROJECT 1990

by Paul Schlobohm, Forester,
USDI Bureau of Land Management

The Foam Project at the Bureau of Land Management (BLM), Boise Interagency Fire Center (BIFC), Boise, ID, is actively involved in four phases of Class A foam technology development: Education, equipment development, research, and technology transfer.

As part of its 1990 education plan, the project will conduct five foam workshops, presented at two engine academies, using the pilot NWCG engine academy package, and will visit four BLM sites by July 1990. Also, the content of the workshops is being updated and abridged for special short presentations. To supplement our oral presentations, three new videos about Class A foam are being produced. These follow "An Introduction to Class A Foam" of 1989 and will cover the properties of foam (fig. 9), foam proportioners, and nozzle aspirated foam systems.

Figure 9. Foam has cooling, wetting, and other fire-extinguishing properties.

Equipment development work will include an evaluation of the latest aspirated nozzles. Since our report of 1988, several nozzles have been introduced. As part of our study of the optimum BLM foam engine, the project will evaluate a compressed air foam system (CAFS) module capable of producing 130 gal/min of water and 65 cu ft/min of air, using a single auxiliary engine driving a centrifugal water pump and a rotary screw air compressor.

Due to an increasingly popular structure protection role for foam, a feasibility study of foam/retardant mix ground applications will be conducted. Many situations warrant a single application of a long-term product rather than multiple short-term applications of pure foam (fig. 10). The Foam Project is also working with several Federal, international, and industry research groups to quantify foam behavior. We are pursuing how foam works. How does foam compare to water by volume at extinguishment? Does the vapor cloud created by the initial discharge of compressed air foam (fig. 11) provide a mechanism for the interruption of fire's chemical chain reaction? What is the importance of surface tension?

Figure 10. Single foam/retardant treatment may be preferable to this type of foam application repeated over several days.

Figure 11. Investigation should determine how effective this 12-gpm CAFS stream is vs. 12 gpm of plain water.

The fastest growing task for the project is technology transfer. Requests for information have doubled over last year. Four conference presentations are scheduled before mid-year. We continue to serve as a foam information source. Contact the project through Ron Rochna, Project Leader, or Paul Schlobohm, at BLM-BIFC, 3905 Vista Avenue, Boise, ID 83705; 208/389-2432.

FOAM USE IN FIXED-WING AIRTANKERS

by L. A. Amicarella, Dir., Fire and Aviation Management, USDA Forest Service

[The following letter is of interest to all who are involved with foam use.]

United States Department of Agriculture **Forest Service** **WO**

Reply to: 5160 **Date:** December 18, 1989

Subject: Foam Use in Fixed-Wing Airtankers

To: Regional Foresters, Area Director, BIFC Directors, IFSL, SDTDC

Aerial foam evaluation has been ongoing with the ORE program at Redding since 1986. The analysis of the data collected from the foam study has been partially completed, summarized and recommendations for future use and direction made. The greatest benefits from foam (applied aerially) result when foam is used with close support of ground personnel. In helicopters, foams provide a significant payoff as compared to water, providing: 1) more efficient knock down; 2) reduced rekindling; 3) quicker containment; 4) less time and effort for mop-up. In fixed-wing (land based) aircraft, foams sometimes provide a payoff. Foams may fill a significant niche in the wildland interface areas when used in close support of ground forces. They also result in minimal chemical/aesthetic damage. Foams can sometimes be used effectively in early fire season or at other times when fire severity is at lower levels. They are less costly at those times than long term retardants.

From the above findings, we know that foam in airtankers has limited application. Foam is not a replacement for long-term fire retardant (tactics, fuel, fire intensity considered), but it is a low cost alternative in specific instances. We need to continuously consider the tactics, application, conditions, and expected results.

Early in 1989, we prepared to approve foams for fixed-wing airtankers and helicopters with fixed tanks. Just prior to that approval, we received reports of excessive corrosion in the tanks of aircraft operating under the auspices of the ORE program at Redding, California. A team was assembled to investigate the problem. Several reports were subsequently issued by Ocean City Research Corporation and the Intermountain Fire Sciences Laboratory defining exposures, corrosion damage, and analysis of corrosion products and affected alloys (distributed to you 7/21). The reports were inconclusive, but they did flag some preventative measures that could be employed to reduce further risk, identify needs for further investigation of the cause of the corrosion, and offered several hypotheses as to the cause.

To reiterate our July report to you, it is clear that a tie exists between the corrosion damage occurring to Tankers 01 and 92 and the use of wildland fire foam during the conceptual foam evaluation being conducted as part of the ORE study in 1987 and 1988. There is also an apparent relationship between the corrosion damage and airtankers being parked loaded with water during the season (active corrosion pitting during exposure to water was positively identified). It is possible, however, that one or more of the foams or perhaps an interaction of the foam and retardant could have initiated pitting, which continued during the season (while exposed to water).

Since the cause of significant corrosion damage to Tanker 01 has not been isolated, it is important that the recommendations be considered and preventative measures be taken. They include, but are not necessarily limited to, the following actions:

a. Do not allow the airtankers to sit loaded with water for long periods (especially those that have been exposed to wildland fire foams).

b. Maintain close corrosion surveillance of the airtanker fleet during the fire season to detect the occurrence of further pitting incidents like those noted in the report on Tankers 01 and 92. This is especially important since the efforts of the survey and follow-up analysis were completed. Even though considerable effort was taken to arrest corrosion, continued pitting in Tanker 01 has been identified.

The above two paragraphs, which were a part of our report to you on July 21, are still valid and need to be followed for future aerial chemical program action. You need to recognize that there are risks involved in setting up multitudes of conditions to which metals are exposed to corrosion. As a result of this situation, a significant claim was settled with the contractor. Future aerial use of foams in situations other than with buckets may set up the same scenario for you.

As a minimum, an elaborate inspection process to monitor corrosion in airtankers will be necessary if foams are used. With this in mind, at this time we question whether the use of fixed-wing aircraft for delivering foam is practical or advisable and potential applications and advantages are worth the risk.

For the present, we do not plan to authorize the use of foams in airtankers beyond further determination of results forthcoming from the foam conceptual evaluation conducted as part of the ORE program.

/s/John W. Chambers (for)

L. A. AMICARELLA, Director
Fire and Aviation Management

HELICOPTER COMPRESSED AIR FOAM SYSTEMS (HCAFS)

by Mark P. Kovaletz,
Southern California Edison Co.

In response to today's firefighting needs, Southern California Edison (SCE) Company has developed a new system that allows aerial application of the foam fire retardant by helicopter (fig. 12). USDA Forest Service utilization of compressed air foam systems (CAFS) for firefighting has proven its value as an efficient and cost-effective tool. However, expanding the value of this type of system has been limited by the heavy, truck-mounted application system in use today. Slow-moving, land-based vehicles are unable to assist in situations that require quick response or in remote or roadless locations.

The primary obstacle to developing a helicopter-mounted CAFS system has been reducing the weight of necessary components. For example, current truck-mounted CAFS utilize an air compressor having at least 15 hp, often weighing in excess of 750 lb. Additional components required for an aerial system included engine, torque convertor, boom assembly, a fire retardant holding tank of

Figure 12. Demonstration of SCE's HCAFS for Forest Service employees.

sufficient volume, and a pilot and a crew member to operate the system. The excessive weight of these "components" effectively prevented successful development of an aerial foam application system.

In 1987, SCE began development of a lightweight, helicopter-mounted compressor system for precision application of dry media. Although not originally conceived for firefighting, a major 1989 fire in Hacienda Heights, CA, underscored the critical need for structure protection in wildfire situations. In the Hacienda Heights situation, firefighting equipment was on hand but road access problems prevented response to many homes. Similar access problems exist throughout Southern California and nationwide. SCE subsequently adapted its helicopter-based media-delivery system to accurately direct a stream of fire retardant foam.

The key element in achieving a lightweight HCAFS system was careful selection of components and innovative applications of structural materials. Key components included a Bauer Roto-2S air compressor rated at 30 hp; a Hirth 55-hp, two-cylinder, two-cycle aircraft engine; and a Salsbury Industries torque converter. Large-diameter, thin-wall, steel-alloy tubing was used for frame construction, and the boom assembly utilized composite construction with nozzle servos. The entire system weighs just over 600 lb, or about half of the operating payload of a light, single-engine helicopter.

Another major design constraint involved eliminating the need for a crew member to operate the boom and nozzle. The unique media spray boom developed for the system offers exceptional control during media application, and can be operated easily by the pilot alone. This eliminates the weight of a crew member, increasing overall safety. Safety is further enhanced by a cargo hook-mounted design that can be jettisoned in an emergency. Stability of the aircraft is increased by this cargo hook-mounted system, which makes positive contact with the landing gear, effectively lowering the aircraft's center of gravity.

A demonstration HCAFS system was held at the Forest Service T&DC, San Dimas, CA, in January 1990. For this demonstration, a water flow rate of 40 gal/min was selected, combined with 135 cu ft/min of air pressurized to 110 psi. The concentration of fire retardant surfactant used was 0.75 percent. Using a boom about 20-ft long with an inside diameter of 1.25 in, excellent quality foam was horizontally thrown more than 100 ft. Based upon this demonstration, it was determined that a true prototype would be constructed with 125-gal capacity, for evaluation in July 1990.

A spin-off of SCE's development was a helicopter external-load stabilization system, mounted to the helicopter skids and cargo hook. This system greatly increases the stability of external loads during flight, and has demonstrated it's effectiveness stabilizing loads such as the Forest Service Helitorch.

HOW HIGH CAN YOU PUMP WILDLAND FIREFIGHTING FOAM?

by R. R. Lafferty, MacMillan Bloedel Ltd., and C. Grady, Odin Fire Service Inc.

A pumping test on compressed air foam systems (CAFS) was done November 1989 by personnel from Odin Fire Service Inc. of Newport, OR, and the Kelsey Bay Division of MacMillan Bloedel Ltd. at Sayward, British Columbia, Canada. The authors, plus Ian Halowaty and Chris Swinamer of Kelsey Bay, and Hal Ross of Odin, conducted the test. Personnel from the British Columbia Ministry of Forests and the MacMillan Bloedel management staff observed the test.

CAFS generate foam at the pump and push it through the hose lay. The solution is expanded (up to 30 times) by compressed air and, therefore, weighs proportionately less than untreated water. Compressed air foam bubbles change their shape as they go through the hose. Bends, restrictions, mechanical mixers, and time affect the size and consistency of foam bubbles.

Test Program

The objective of the test was to determine the limits of a CAFS in delivering a working fire stream through a 1.5-in (38 mm) forestry hose to high elevation. Twenty-one hundred feet of 1.5-in forestry hose was laid on a mountain slope to a pump site. A wye was placed on a landing—900 ft (275 m) of hose and elevated 335 ft (102 m) from the pumper. The top end of the hose was another 1,200 ft (366 m) up the hill and elevated another 485 ft (148 m).

A Kelsey Bay fire truck was used to supply the Odin diesel-powered screw compressor and centrifugal water pump. Variables were:

Air temperature.... ....41°F (7C°)
Relative humidity.. ....67%
Water temperature.. ....37°F (2.7C°)
Solution. ....0.5% foam solution
55 cfm of air at 170 psi ....(1.56 m^{3}pm at 1173 kPa)
55 gpm of water at 170 psi..(248 Lpm at 1173 kPa)

Three observations were made during the test:

A. Hose length - 900 ft
Head gain - 335 ft
System pressure - 150 psi (1035 kPa)

At this elevation, the foam stream reached 50 to 75 ft (15 to 23 m) using a 1-in (25 mm) and a 0.75-in (18 mm) bore nozzle, respectively.

B. Hose length - 2,100 ft (640 m)
Head gain - 820 ft (250 m)
System pressure - 180 psi (1242 kPa)

The foam was able to reach the 820-ft elevation (fig. 13); however, nozzle pressure was basically zero and foam stream was less than 1 ft (30 cm).

Figure 13. Chris Swinamer releases stored hose pressure at 820-ft vertical elevation above the pump.

C. The third scenario—air and water were pumped separately to the 335-ft level, reconnected there to create foam, and continued pushing foam up the hill to the 820-ft level. The air and water pressure were balanced at 150 psi at the 335-ft level.

A very lathery foam was produced at 820 ft, but it was considered below standard and unusable (fig. 14).

Figure 14. Dynamic foam flow at 820-ft vertical elevation above the pump.

Conclusion

Foam can be pushed more than twice as high in elevation than water with similar pump pressures. Due to pressure limitation of 180 psi that the authors placed on the CAFS, they were only able to pump foam to a static head of 820 ft. To pump water that high would require about 400 psi, or slightly less than 50 psi per 100 ft. Our test showed that foam requires 22 psi per 100 ft of elevation.

OPERATION OF IN-LINE EDUCTOR PROPORTIONING SYSTEM

by Dan McKenzie, Mechanical Engineer, USDA Forest Service

In-line eductor foam concentrate proportioning systems have been used by fire services for many years; however, their operation has limitations and the principle of their operation is not well understood. While it is true an in-line eductor proportioning system can be made to work well in a given situation, any change in the operating conditions (such as engine pressure, reduced flow, added hose, or nozzle changes) can result in a change in the proportioning (percent of foam concentrate in the foam solution) or the system not working at all. For these reasons it can be said that an in-line eductor is very situation sensitive. To explain why an in-line eductor proportioning system is so situation sensitive, an understanding of how it works is required.

An in-line eductor proportioning system (fig. 15) is made up of (1) an eductor (or venturi), (2) a reservoir, (3) a check valve, and (4) a flow control device for the foam concentrate (a needle valve or an orifice). The eductor (fig. 16) is make up of (1) the convergent cone, (2) throat, (3) the divergent cone or diffuser, and (4) an eductor metering orifice.

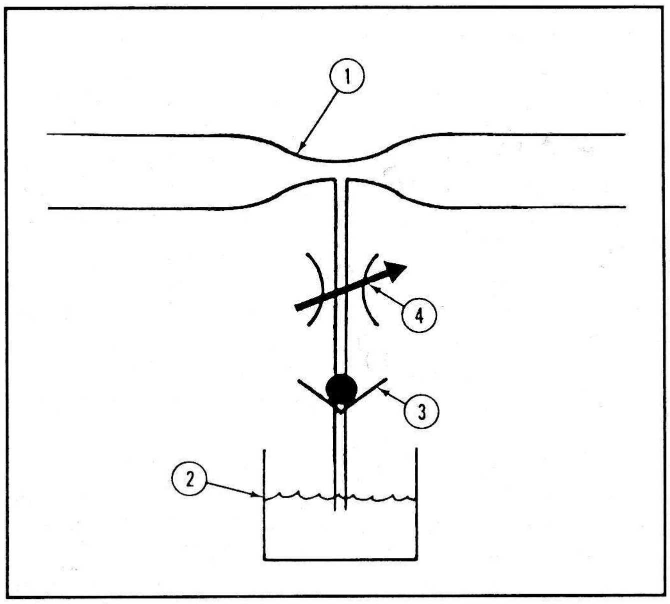

Figure 15. In-line eductor proportioning system.

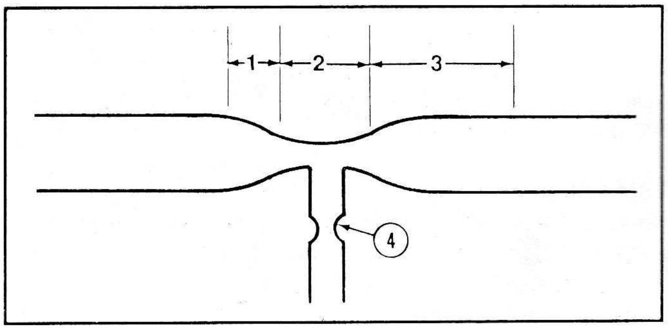

Figure 16. An eductor.

As water is forced through the eductor, the water velocity is increased at the throat—resulting in reduced static pressure. As water leaves the throat, the water velocity is reduced—resulting in increased static pressure. For an eductor to work, the velocity through the throat must be increased until a negative pressure is created in the throat area (fig. 17). A negative pressure of up to 14.7 psi can be created depending on elevation (14.7 psi at sea level, less at higher elevations).

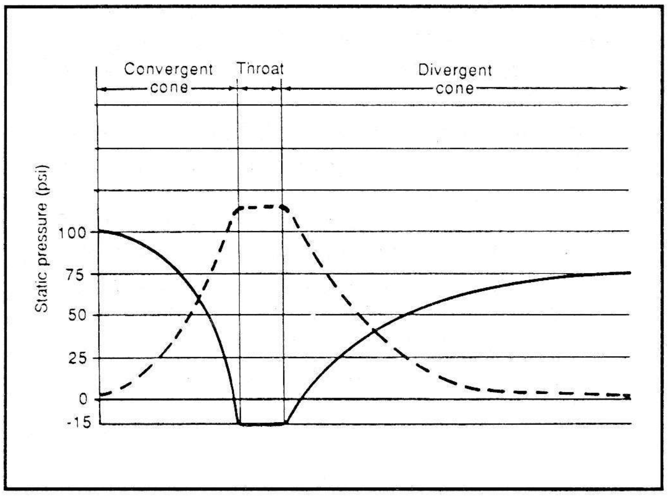

Figure 17. Static and dynamic pressure as water flows through an eductor—static pressure is solid line and dynamic pressure is broken line.

An explanation of this is that when a fluid (such as water) is under pressure, the total pressure is made up of two parts—static and dynamic pressure. The static pressure is what shows on a pressure gauge. The dynamic pressure is the pressure of the moving fluid and is the pressure that would be produced if the fluid were stopped. The dynamic pressure is proportional to the velocity squared, so if the velocity is doubled the dynamic pressure is increased four times. Static pressure and dynamic pressure can be interchanged, since when a fluid is moving down a large diameter pipe slowly, the static pressure can be high—but it will not have a very high dynamic pressure. If the pipe diameter is decreased, the velocity of the fluid will be increased, increasing the dynamic pressure and decreasing the static pressure. If the pipe diameter is now increased, the dynamic pressure will decrease and the static pressure will increase.

These pressure changes, from static to dynamic and then back to static are not without cost; there is an overall decrease in total pressure. Since dynamic pressure is fixed, the pressure loss shows up in the static pressure. This is what is done in an eductor; it is possible to push the velocity so high that the static pressure goes to zero pressure gauge and even to push velocity farther, so the pressure goes to a negative gauge pressure—or vacuum or near absolute zero pressure, which is -14.7 psig (or 30-in Hg vacuum) at sea level. A pressure gauge pressure reading is correctly referred to as psig or psi gauge. For, a pressure gauge shows the pressure above or below atmospheric pressure (which is 14.7 psi at sea level). Total pressure is psig plus atmospheric pressure.

The negative gauge pressure that can be created in an eductor is what causes the foam concentrate to move from the reservoir to the eductor throat and into the water stream to make foam solution. As the water and foam concentrate move through the eductor, out of the throat area into the diffuser section, static pressure is regained; however, for an eductor operating near absolute zero pressure only about 40 to 75 percent of the inlet static pressure can be regained.

For a venturi, where the static pressure does not change as much, 80 to 90 percent of the static pressure can be regained. An eductor (fig. 16) is made up of three sections—convergent cone, throat, and divergent cone. The convergent cone section is basically a nozzle; fire nozzle tables can be used to predict the convergent cone section performance. However, total pressure must be used. If you have a static pressure of 100 psig at the entrance of the convergent cone section, the total pressure change from this entrance to the throat section can be up to 114.7 psi (100 psig plus 14.7 psi of atmospheric pressure). As an example, if we have an eductor with a 3/8-in throat diameter and 100-psig static pressure at the entrance to the eductor we can have up 114.7 psi pressure driving water through the eductor which will force up to 45.1 gpm through the eductor (see table 2).

The throat section is the reduced pressure area where the foam concentrate is injected at up to 14.7 psi pressure. We can control the foam concentrate injection rate by placing flow resistance (a needle valve or orifice) in the foam concentrate line from the reservoir to the throat of the eductor. We can change the foam concentrate flow rate by changing the amount of resistance in the flow line. One reason why eductor proportioning systems are so situation sensitive is that if static pressure to the inlet of the eductor is increased, increased water flow will result. But there can be no increase in the pressure causing the foam concentrate to flow into the throat of the eductor, so there can be no change in the flow rate of the foam concentrate—resulting in a decrease in the percentage of foam concentrate in the foam solution coming out of the diffuser section of the eductor. To keep the percentage of the foam concentrate in the foam solution the same, the flow resistance in the foam concentrate line must be decreased.

If static pressure to the inlet of the eductor is lowered (resulting in a reduced water flow), static pressure at the eductor throat will be reduced. In fact, it can be reduced below 14.7 psi, resulting in positive static pressure at the eductor throat. When this occurs, no foam concentrate will flow into the throat—resulting in no foam concentrate being added to the water stream. The same thing can happen if, for some reason, the water flow is reduced, by say, cutting back water flow at the nozzle. The inlet static pressure at the entrance to the eductor can be the same, but the water flow is decreased to where the velocity through the throat of the eductor is not enough to create a negative pressure. In our example (100-psi inlet and 3/8-in throat diameter) this would be a cut back of flow from 45 to 42.2 gpm. At 45 gpm, the system would be working well; at 42.2 gpm the system would not be working at all. This is what is meant by situation sensitive.

Another example of the eductor being situation sensitive is when the inlet pressure to the eductor is 100 psig and there is a 75 percent pressure regain, 71 psig will be available to flow water through the hose and nozzle (114.7 x 0.75 = 86, 86 - 14.7 = 71). From table 2, this requires a 1/2-in size nozzle to pass the 45 gpm at less than 71 psig (62.5 gal at 70 psi). A 1/2-in nozzle with 45-gpm flow requires only 36 psi to flow the 45 gpm, leaving 35 psi for pressure loss in the hose lay. A 35-psi pressure loss at 45-gpm flow in a 1-1/2-in hose would be a hose lay almost 400-ft long. So if four 100-ft lengths of 1-1/2-in hose were used, the eductor would just work. Now, if another length of hose is added and engine pressure is not raised, flow will be reduced—resulting in no foam concentrate being injected into the hose lay. If engine pressure is raised to maintain the 45 gpm, still no foam concentrate would be injected into the hose lay because there is no negative pressure being created at the eductor throat. For the system to work, the engine pressure and flow must both be raised to approximately 60 gpm and 200 psi engine pressure. At these conditions, the system should be working. As you can see, adding hose after the eductor can cause the eductor system not to work. (Again an example of "situation sensitivity.") One way to over come this problem is to:

- Operate at higher engine pressures (may be effective on short hose lays; may not be effective on long hose lays)
- Operate at higher flow rates (should be effective)
- Use larger flow nozzles (should be very effective)
- Move eductor system closer to the end of the hose lay or reduce the amount of hose after the eductor (should be very effective)
- Use larger diameter hose (should be very effective)

HEAD		Velocity of Discharge Feet Per Second	DIAMETER OF NOZZLE IN INCHES								
Pounds	Feet		1/16	1/8	3/16	1/4	3/8	1/2	5/8	3/4	7/8
10	23.1	38.6	0.37	1.48	3.32	5.91	13.3	23.6	36.9	53.1	72.4
15	34.6	47.25	0.45	1.81	4.06	7.24	16.3	28.9	45.2	65.0	88.5
20	46.2	54.55	0.52	2.09	4.69	8.35	18.8	33.4	52.2	75.1	102
25	57.7	61.0	0.58	2.34	5.25	9.34	21.0	37.3	58.3	84.0	114
30	69.3	66.85	0.64	2.56	5.75	10.2	23.0	40.9	63.9	92.0	125
35	80.8	72.2	0.69	2.77	6.21	11.1	24.8	44.2	69.0	99.5	135
40	92.4	77.2	0.74	2.96	6.64	11.8	26.6	47.3	73.8	106	145
45	103.9	81.8	0.78	3.13	7.03	12.5	28.2	50.1	78.2	113	153
50	115.5	86.25	0.83	3.30	7.41	13.2	29.7	52.8	82.5	119	162
55	127.0	90.4	0.87	3.46	7.77	13.8	31.1	55.3	86.4	125	169
60	138.6	94.5	0.90	3.62	8.12	14.5	32.5	57.8	90.4	130	177
65	150.1	98.3	0.94	3.77	8.45	15.1	33.8	60.2	94.0	136	184
70	161.7	102.1	0.98	3.91	8.78	15.7	35.2	62.5	97.7	141	191
75	173.2	105.7	1.01	4.05	9.08	16.2	36.4	64.7	101	146	198
80	184.8	109.1	1.05	4.18	9.39	16.7	37.6	66.8	104	150	205
85	196.3	112.5	1.08	4.31	9.67	17.3	38.8	68.9	108	155	211
90	207.9	115.8	1.11	4.43	9.95	17.7	39.9	70.8	111	160	217
95	219.4	119.0	1.14	4.56	10.2	18.2	41.0	72.8	114	164	223
100	230.9	122.0	1.17	4.67	10.0	18.7	42.1	74.7	117	168	229
105	242.4	125.0	1.20	4.79	10.8	19.2	43.1	76.5	120	172	234
110	254.0	128.0	1.23	4.90	11.0	19.6	44.1	78.4	122	176	240
115	265.5	130.9	1.25	5.01	11.2	20.0	45.1	80.1	125	180	245
120	277.1	133.7	1.28	5.12	11.5	20.5	46.0	81.8	128	184	251
125	288.6	136.4	1.31	5.22	11.7	20.9	47.0	83.5	130	188	256
130	300.2	139.1	1.33	5.33	12.0	21.3	48.0	85.2	133	192	261
135	311.7	141.8	1.36	5.43	12.2	21.7	48.9	86.7	136	195	266
140	323.3	144.3	1.38	5.53	12.4	22.1	49.8	88.4	138	199	271
145	334.8	146.9	1.41	5.62	12.6	22.5	50.6	89.9	140	202	276
150	346.4	149.5	1.43	5.72	12.9	22.9	51.5	91.5	143	206	280
175	404.1	161.4	1.55	6.18	13.9	24.7	55.6	98.8	154	222	302
200	461.9	172.6	1.65	6.61	14.8	26.4	59.5	106	165	238	323

Table 2. Theoretical discharge of smooth taper nozzles in U.S. gpm.

Another explanation of why an eductor system is so very situation sensitive is the nature of eductor operation. At some pressure there is a maximum flow that can be forced through an eductor. This maximum flow is largely determined by the diameter of the throat and also by the shape of the inlet to the throat. At 100 psi and a 3/8-in throat diameter with a smooth inlet shape, only 45 gpm can be forced through the eductor; this creates a negative pressure of 14.7 psi at the throat. This -14.7 psi is what moves the foam concentrate into the water stream. A slight cut back in flow rate (45 to 42 gpm) will result in no negative pressure at the throat and, thus, no foam concentrate moving into the water stream. This slight reduction in flow could be the result of added hose, reduced nozzle opening, or added elevation of the nozzle (fig. 18).

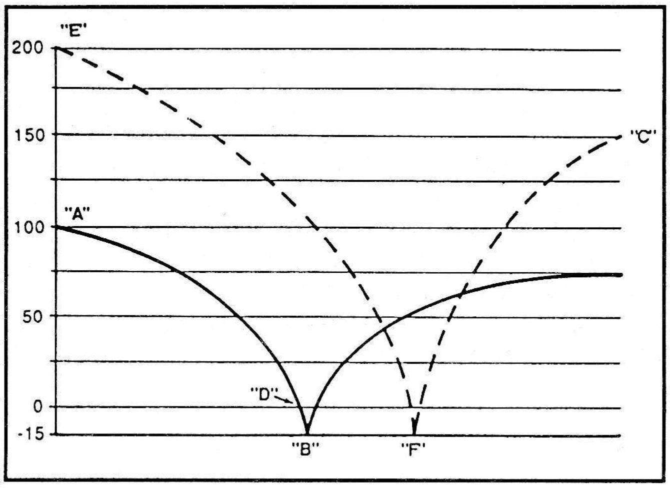

Figure 18. Flow through an eductor.

The solid line in figure 18 is maximum flow at pressure "A" that creates a negative pressure at "B" with a flow of 45 gpm driven by 100 psig inlet pressure. The eductor has regained 75 percent of the inlet pressure at "C" (or 71 psig). Now, when more resistance is add to the flow line—like closing down a nozzle or adding hose—so that flow is reduced to 42 gpm at "D," no negative pressure is created; and, therefore, no foam concentrate flows into the water stream. To make the system work, pressure must be raised to approximately 200 psi at "E." Flow is now 60 gpm at "F," and a negative pressure is created at "F"—again forcing foam concentrate to flow into the water stream.

In summary, in-line eductor proportioning systems can be set up and adjusted to work very and will continue to work well as long as no changes are made. If changes are made—such as reducing the size of the nozzle (like shutting down a nozzle when two are in use), adding hose, or adding elevation at the hose outlet—the proportion may change, or the system may not work at all. This results in the eductor proportioning system being very situation sensitive. Therefore, these systems should be used with caution in wildfire suppression conditions where low flows and long, small-diameter hose lays are used.

TRAINING AND SAFETY NOTES

THE SAFE HANDLING OF FIRE SUPPRESSANT FOAMS

by Lloyd Smith, Mixmaster,
USDI Bureau of Land Management

Since the approved fire suppressant foams currently being used by the Bureau of Land Management in Alaska have the potential to cause injury, the Alaska Fire Service has established rules to enable workers to safely handle foam concentrates. The Alaska Fire Service foam safety policy is as follows:

1. Splash-proof goggles must be worn at all times when handling concentrates.

2. Eye wash first aid solutions must be available at all sites.

3. A water source for eye flushing must be available at the work area.

4. Do not rub the face while working with the concentrates.

5. Latex gloves or their equivalent should be worn while handling concentrates. The disposable latex gloves are recommended because they do not have to be THOROUGHLY washed after each use.

6. Coveralls are recommended to prevent the concentrates from splashing directly on to the skin or clothing. Clothes that have been exposed to the concentrate must be removed and the skin thoroughly rinsed.

7. Always handle the concentrates in well-ventilated areas.

8. Spills in enclosed areas, such as aircraft interiors, must be washed out thoroughly to eliminate all concentrate vapors which should not be inhaled.

9. All demonstrations of foam products will be conducted at a safe distance from the spectators to prevent accidental exposure due to mechanical failure, spillage, or splashing.

10. All spills of foam concentrates will be reported to the Safety Officer and the Retardant Foreman. These spills require immediate clean-up so personnel will not slip on the ramp or equipment.

11. All contractors directly involved with fire suppressant foams will receive the same safety training as the retardant personnel before they come in contact with these products. (Many contractors were not aware of the injury potential prior to the safety briefing.)

12. All foam tanks and containers will be properly labeled with the product and manufacturer's name.

13. All fire suppressant foam concentrate tanks inside airtankers will be labeled with the type of foam and a Material Date Safety Sheet will be attached to the tank. The labeling insures that the different foam products will not be mixed together and cause product contamination. In the event that a crew member is accidentally exposed to the concentrate, the Material Data Safety Sheet can be removed and taken to the medical facility with that person.

14. Wash all equipment THOROUGHLY; e.g. bung wrenches, so when the equipment is handled in the future without gloves, personnel will not unknowingly be exposed to the concentrate.

These rules were formulated by following the information in the Material Data Safety Sheets and through 3 yr of field use with fixed-wing aircraft. During the 1988 fire season, over 400,000 gal of foam were dropped from airtankers on wildfires throughout Alaska. These safety guidelines have proven to be highly effective in the handling of all of the foam products. For additional information contact Lloyd Smith at 907/356-5528.

*****SPECIAL NOTICE*****

INPUT, INPUT, WE NEED INPUT

by Al Seltzer, Technical Writer/Editor, USDA Forest Service

See your name in print. Share your ideas, thoughts, facts on foam—its use and application. And, when available, provide photographs and/or graphs, drawings, and sketches to illustrate your text. As the editor of this publication, stationed at the USDA Forest Service San Dimas Technology & Development Center (SDTDC), 444 East Bonita Avenue, San Dimas, CA 91773; 714/599-1267; FTS, 793-8000; FAX, 714/592-2309; DG, A.SELTZER: W07A, I invite you to contribute any and all material on foam concentrates and their applications for future issues of this interagency, International document.

Steve Raybould (same address and numbers as the editor), who serves as the coordinator between authors and the SDTDC's publications group—and is program assistant to the Center's Program Leader for Fire and Residues—joins in this call for input. Do not be shy. If you have any inclination at all about submitting some material, and are hesitant about using the mails, at least PHONE/FAX/DG myself or Steve—let's talk and see if you too can become an author.