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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

PORT ALBERNI PAPER MILL FIRE

by Tom Irving, Forest Industries Flying Tankers Limited

During the afternoon of August 12, 1989, an urgent request for assistance was received from the MacMillan Bloedel Ltd. Pulp and Paper Mill, Port Alberni, British Columbia, by the nearby Forest Industries Flying Tankers (FIFT) Ldt. The mill manager requested the services of the FIFT Martin Mars waterbombers (see Vol. 1, No. 3, p. 6 of this publication) to suppress an active fire burning in a hogfuel pile immediately adjacent to the mill structure.

High winds blowing toward the mill were causing spotting, which had already ignited a chip pile that was out of the range of fire hoses and ground equipment. Four fire departments (from the mill, from Port Alberni, and two volunteer fire departments from nearby communities) were fighting the fire—but were losing ground. A FIFT helicopter was sent to the mill site to assess the situation. The pilot quickly confirmed the mill to be in "grave peril." A FIFT management decision was made to dispatch the Mars and while they were enroute, the FIFT Birddog would determine the safety of the operation. The Birddog reported that, in spite of wires and 245-ft high stacks, the Mars could safely operate in the mill area.

The Birddog flew several dummy approaches onto the fire while the FIFT Operations Manager arrived at the mill to set up communications with the aircraft. Shortly thereafter, the first Mars arrived and made its foam drop, which was assessed to be "dead on target" by the Fire Boss.

It was later reported by an expert observer above the fire that the first drop knocked down the flames and replaced them with steam for about 15 to 20 sec, at which time the flames vigorously broke out again. Then the second foam drop was made, and the fire was stifled. Four more foam drops were called in by the Fire Boss for insurance, and the FIFT helicopter was used to mop-up several small spot fires at the mill retaining wall.

Sixth and final foam drop by the Martin Mars on the Port Alberni mill fire.

All six Mars drops were made with foam concentrate added to the payload at a rate of 0.4 percent. Normally, the Mars dispenses 7,200 U.S. gal of foam per drop but, because they had a heavy fuel load, the six drops were about 5,500 gal each. The results, given the the 0.4 percent solution, provided the "wet and sloppy" mixture needed for deep penetration into the hogfuel. The first two drops were made with fresh water, and the last two with sea water, but there was no appreciable difference in the quality or consistency of the foam.

Although FIFT does not particularly relish operating in industrial areas or near converting plants, this fire was a unique circumstance demanding extraordinary action and it has been established that the mill manager was wise to request the Mars air attack. With the four aircraft dropping 33,000 gal of foam in a 40-min time span, an out-of-control situation was quickly contained and an extremely high potential for loss was averted. For further information about foam use in this type of incident, contact Tom Irving, General Manager, Forest Industries Flying Tankers Ltd., R.R. No.3, Port Alberni, British Columbia, Canada V9Y 7L7; 604/723-6225.

SINGLE ENGINE DRIVEN COMPRESSED AIR FOAM SYSTEM

by Dan McKenzie, USDA Forest Service

In the San Dimas Technology and Development Center (SDTDC) October 1987 report No. 8751 1202, "Engineering Analysis of Threshold Compressed Air Foam Systems (CAFS)," I discussed a number of ways of to power a CAFS system—truck engine driven hydraulic system; side-mounted transmission PTO; slip-on centrifugal pump unit in conjunction with an under-the-hood, truck engine mounted and driven air compressor; and one or two auxiliary engines. When powering a CAFS unit with a single auxiliary engine, a pressure reducing valve was recommended.

Additional information has been developed since the report was published, and single auxiliary engine units have been built that do not need a pressure reducing valve to achieve and maintain constant water pressure. These newer units use engine rpm to control and produce required constant water pressure; they work very well. They have large water flow capability, which would have required a large (and expensive) pressure reducing valve. In a single auxiliary engine powered CAFS unit there can be four major components in the power system—engine, centrifugal water pump, air compressor, and possibly the foaming agent proportioning system. In my report, a high emphasis was placed on efficiency of individual components. However, what is really wanted is the highest overall efficiency of the system, which will not necessarily be the highest efficiency of each individual component. Such may be the case when assembling a CAFS unit using a single auxiliary engine without a pressure reducing valve.

A single engine can be used to power a CAFS unit by carefully selecting and matching components. In selecting components, the following relationships should be considered: At up to about one half of maximum flow of a centrifugal pump, centrifugal pump water pressure is very close to being proportional to pump rpm squared. This makes it possible to control water pressure by controlling pump rpm. Also, because pump pressure at high rpm is proportional to rpm squared, a small increase in rpm's will result in a large increase in water pressure. This gives a concave curve for water pressure verses engine rpm, as shown in figure 1.

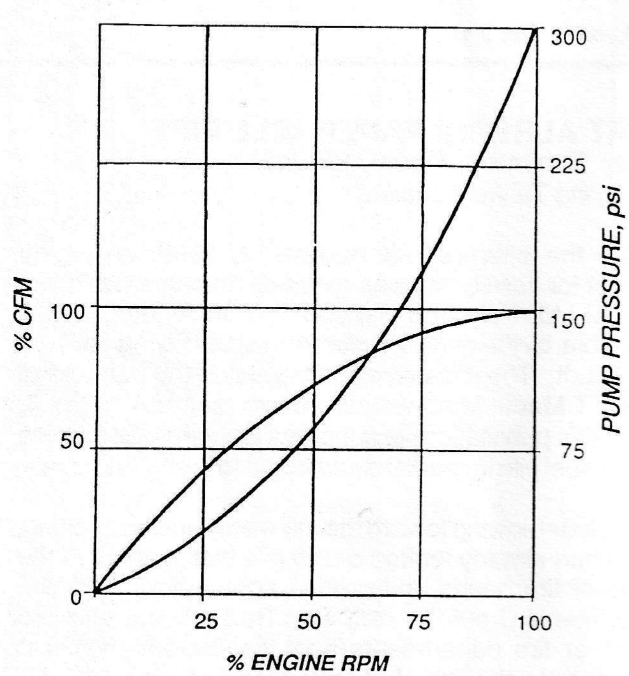


Figure 1. Relationshp of engine rpm, centrifugal pump pressure, and cfm of air compressor.

On most of the auxiliary engines used for powering fire equipment, setting the throttle is really setting engine rpm and, when driving a centrifugal pump, this is really setting pump pressure. Theoretically, air compressors are positive-displacement machines, which should mean output is directly proportional to rpm. But, in practice, output falls off at higher rpm's and increased pressures, resulting in a convex output curve for cfm verses engine rpm (fig. 1).

In general, a CAFS unit is operated at about 150 psi, but may require higher operating pressures (say up to 175, or a maximum of 200 psi). One of the guidelines for CAFS units from the report was, "With the CAFS in place, there should be no deterioration of the water handling capability or reliability of the engine." This means that water pressures of 300 psi or more should be achievable. This would require the pump gearing to be selected such that the engine would run at about 71 percent of rated engine speed when producing 150 psi. The air compressor would also have to be selected to produce the desired volume of air at 71 percent of engine speed, yet be capable of operating at 100 percent of engine speed. In selecting the engine, adequate horsepower must be provided to power (1) the pump at 300 psi, (2) the compressor at 100 percent of engine rpm, if this is desired—e.g., in making foam some distance from the engine and up hill, and (3) the proportioning system (which does not require very much power and can be run at a wide range of rpm); and also to compensate for power loss when operating at higher elevations (say, up to 7,000 ft).

When engine horsepower, pump gearing, and air compressor gearing are properly selected and well matched; the single engine driven CAFS unit not only meets the requirements of the guideline "no deterioration of the water handling capability or reliability of the engine," but also two other guidelines, "the engine should be able to make a moving attack" and "operation of the engine equipped with CAFS should be easy and simple."

Production units using a single engine to power a CAFS unit are commercially available. For further information on these, or to obtain any technical details on foam concentrate delivery systems, contact Dan McKenzie, mechanical engineer, USDA Forest Service, SDTDC, 444 East Bonita Ave., San Dimas, CA 91773; FTS, 793-8000; 714/599-1267 or 818/332-6231; FAX, 714/592-2309; DG, D.MCKENZIE:W07A.

EVALUATION OF FLOW PROPORTIONER WITH A MEDIUM EXPANSION FOAM NOZZLE

by Larry McCoy, Lowell Kendall, and Steve Dudley, USDA Forest Service

With the beginning of a potentially dangerous fire season in the southwest, and the proliferation of the wildland/urban interface in and around the Flagstaff, AZ, area, the Mormon Lake Ranger District, Coconino National Forest, decided to incorporate a viable foam production system on its type 6, model 71 engine stationed at Flagstaff. Up to 50 percent of our current fire load is occurring in and around interface structures. This particular engine has responded to an average of 112 incidents a season. Foam and foam technology offer new tools to assist firefighters effectively employ additional strategies and tactics.

Our fire crews have been experimenting with the use of foam for 3 years and have developed numerous aspirating nozzles for field use. Until this season, our engines batch-mixed foam concentrates into the water tanks and relied on aspirating nozzles for ground foam production; results were only fair. The foam quality and lasting abilities did not match CAFS foams nor meet the claims of manufacturers of foam concentrates. We considered a CAFS system for integral incorporation into a new heavy engine we had on order. However, disadvantages to incorporation of CAFS into an engine whose tactics employ the regular use of progressive hose lays were deemed to include:

A. Space availability on a model 70/71 engine for a compressor is limited

B. Need for an auxiliary engine and a place to put it

C. Foam concentrate tank and accessory storage space is limited

D. Need to carry gasoline, on a diesel-powered vehicle, for the auxiliary engine

E. Heat dissipation; unit servicing; prohibitive costs

F. Potential design shortfalls, resulting in increased maintenance costs down the road

G. Need for additional operator training.

With these obstacles in mind, we began looking at alternatives. After researching products in the winter of 1988, we arrived at a system that functions efficiently and adequately for our purposes. We requisitioned a Flow-Mix model 500 foam proportioner from Flameco/Robwen. With the proportioner mounted on the engine, we are able to control insertion of foam concentrate (0.2 to 1.0 percent) into the discharge flow. The advantages of utilizing a discharge-mounted proportioning system enable us to introduce foam concentrate into discharge flow without having to put foam concentrate in the water tank or having it pass through the fire pump. The proportioner tank holds 5 gal of concentrate isolated from the engines' pump and plumbing. This results in a vehicle that is remaining clean and a fire pump unsusceptible to cavitation caused by water being churned into foam. The injection of foam concentrate is based on gpm flow through the proportioner and is proving accurate within its selection of ranges from 0.2 to 1.0 percent.

To compliment the proportioning system and deliver the ground foam we desired, we bought an Ansul/Wormald model KR2-75 medium expansion foam nozzle. This is a large nozzle that effectively maximizes the foam concentrate in a volume of water. This nozzle can produce large volumes of foam and loft it for distances up to 16 ft vertical and 25 ft horizontally. At engine pressures of 125 to 150 psi, we are able to rapidly cover a single-level dwelling with foam. The foam quality is far superior to any other product generated through aspirating nozzles that we've seen. Consistency ranges from a dry quality, which readily adheres to vertical and upside-down surfaces, to a wet product, which readily flows over land forms and obstacles. At lower engine pressures, the nozzle continues to perform with a quality product level, but without the lofting distance.

Flow-mix model 500 foam proportioner mounted on model 71 engine.

A medium expansion foam nozzle applying foam.

The nozzle can safely be operated by a single individual. Due to the amount of foam produced, and the mobility of the nozzle operator, we recommend the the use of knee- or waist-high boots to keep the nozzle operator dry. With the investment of approximately $1,700, we have a system that has given us most of the advantages of foam use. The system is capable of covering a 1/2-acre fire with 4 in of foam in 30 min. The advantage to this is that it allows firefighters to work in a healthier, smoke-reduced environment. The foam also caps off involved flammables—on a windy day it prevents embers and debris from the fire from being carried over the firelines—and provides a slowly penetrating moisture application on duffy and heavy fuels.

Current wildland tactics employed include starting at the far end of a fire and applying a foam blanket as the nozzle operator proceeds back toward the engine. This prevents disruption of the foam blanket by ensuring that people aren't walking in it or the hose isn't dragged through it. One crewmember is assigned to assist the nozzle operator in moving the hose. The foam can be applied at the top of a hill to flow downward to parts of the fire below. In pine duff we have found that 0.2 percent applied in two applications (one after the first breaks down) is effective in reducing mop-up time and labor. Where heavy fuels are involved, the pump operator changes the proportioner to 0.5 percent. This makes a wetter, denser foam that is quite effective in extinguishing heavy, involved fuels. When the nozzle operator moves out of the heavy fuels, the engine operator switches the proportioner back to 0.2 percent.

When two blankets are applied, they are laid down prior to the beginning of mop-up. While handline is being constructed, the first foam blanket is applied and allowed to decompose—decomposition takes about 15 min on a 90-degree day with low relative humidity. A second blanket is then applied and allowed to decompose. After the second blanket decomposes, mop-up is reduced to handtool mixing of deep, involved duff pockets; deep roots; and other areas that were heavily involved at the time of foam application. The remaining mop-up is often accomplished by personnel with a few backpack pumps and handtools wandering through the fire or handlines off the engine. When the foam blankets are applied to the fire, it is important to leave the foam undisturbed and allow it to slowly release water onto the involved materials. Mixing the foam in, instead of allowing it to decompose slowly, seems to be an inefficient use of foam and labor.

Since the foam concentrate is introduced into the discharge hose stream, it is a simple matter to remove the foam nozzle from one lateral and move it to another. There is no distance limitation, other than that created by friction loss and elevation gains or loss and pump capabilities. The discharge line through the Flow-Mix foam proportioner is a full-flow, 1-1/2-in orifice. Should foam not be needed, the proportioner is easily switched to the off position and water is supplied with about a 5 psi friction loss to the hose lay. No disconnection or reconnection of hose is needed.

A comparison of the various water additive costs in our use breaks down as follows:

A. Chemonics Fire-Trol FireFoam 103 @ $11.20/gal.

0.2% rate = 1.2 gal concentrate/600 gal of water
Cost = $13.50/tank, *or 3 cents/gal water.*

0.4% rate = 2.4 gal concentrate/600 gal of water
Cost = $27.00/tank, _or 5 cents/gal water._

0.6% rate = 3.6 gal concentrate/600 gal of water
Cost = $40.00/tank, _or 7 cents/gal water._

1.0% rate = 6.0 gal concentrate/600 gal of water
Cost = $67.00/tank, _or 11 cents/gal water._

B. Firechem Wetting Agent @ $15.60/gal.

1:4000 rate = 19 oz concentrate/600 gal of water
Cost = $2.28/tank, _or 0.4 cent/gal water._

1:2000 rate = 38 oz concentrate/600 gal of water
Cost = $4.56/tank, _or 0.8 cent/gal water._

1:1000 rate = 76 oz concentrate/600 gal of water
Cost = $9.12/tank, _or 2 cents/gal water._

C. AFFF @ $18.00/gal.

3% rate = 18 gal concentrate/600 gal of water
Cost = $324.00/tank, _or 54 cents/gal water._

The disadvantage to the system is the significant use of water. At 100 psi engine pressure, a 600-gal tank of water will last 11-3/4 min. This calculates out to a 52-gpm flow from the KR2-75, which is what the nozzle is rated at. For extended applications, we utilize tender support behind initial attack engines. We feel the water use is offset by the production of a 4-in thick foam blanket that slowly decomposes onto combustibles involved in the fire. Additionally, the foam blanket is often so thick that it obscures rocks, branches, and other things detrimental to sound footing. Use caution if you must walk through a foam blanket.

For further information, contact any of the authors at the Mormon Lake Ranger District, 4825 S. Lake Mary Rd., Flagstaff, AZ 86001; FTS 527-7474 or 602/527-7474; DG:R03F04D05A.

INTERIM GUIDELINES FOR AERIAL APPLICATION OF FOAM ON FOREST FIRES

by C.J. Ogilvie, M.E. Alexander, R.J. Lieskovsky, & J. Bird, Canadian Forestry Service

A 3-day workshop was held at the Northern Forestry Centre,Edmonton, Alberta, late in November 1988. Fire management agencies served by the Northwest Region of Forestry Canada met to identify research and technology needs related to the use of foam as a suppressant in aerial wildfire control operations. A major recommendation of the participants concerned the establishment of interim guidelines for air attack officers (AAO) or birddog officers (BDO) with respect to the aerial application of foam. The guidelines presented here were formulated by a group comprised of Forestry Canada fire researchers and fire operations personnel from the Alberta Forest Service (AFS) and the Government of Northwest Territories' (GNWT) Department of Renewable Resources.

The guidelines were prepared based on the following considerations:

- That they only refer to the initial application of foam, due to the lack of information on "burn-through" situations.

- Foam effectiveness is generally limited to fires or fire perimeters with flame lengths of less than 2.5 m, or frontal fire intensities of about 2000 kW/m (i.e., low- to high- intensity surface fires with torching or candling).

- The availability and arrival time of ground support will alter the aerial tactics by placing different emphasis on the required effectiveness of foam.

- A very simple fuels classification scheme based on readily observable characteristics of the tree canopy, if present, and forest floor as related to the delivery and dispersion of foam properties.

- Foam consistency will be limited to three broad categories generally recognized by AAO's or BDO's (i.e., "wet," "dripping," and "dry").

Wet foam penetrates the tree canopy well and drains into the forest floor quickly—however, its presence is short lived. Dry foam, on the other hand, tends to be intercepted by the tree canopy. It coats and insulates well, but releases water slowly. Dripping foam exhibits characteristics intermediate in performance between wet and dry foam.

The guidelines presented here reflect the current "state-of-our-knowledge;" comments from readers are welcome. Inquiries should be directed to the first author. Plans call for an interagency evaluation team to study the operational use of foam in western and northern Canada during the 1989 fire season. These interim guidelines may well be revised as a result of their findings.

Affiliations of the authors are as follows: C.J. Ogilvie and M.E. Alexander, Forestry Canada; R.J. Lieskovsky, AFS; J. Bird, GNWT. For further information contact Northern Forestry Centre, 5320 - 122nd Street, Edmonton, Alberta, Canada T6H 3S5; 403/435-7210. Request Technology Transfer Note A-010, April 1989, to obtain a table on recommended foam consistencies for aerial attack.

SDTDC PROTOTYPE FOAM PROPORTIONER IN ACTION

by Roger Dahlen, USDA Forest Service

During the August 1989 Balch Fire on the Sierra National Forest, CA, the engine from the San Marcos Station, Los Padres National Forest, CA—equipped with the first prototype foam unit designed and built by San Dimas Technology and Development Center (SDTDC)—was instrumental in saving pine trees and brush surrounding the Fence Meadow lookout. Foam was applied to the vegetation just prior to setting a backfire immediately west of the Dinky Creek drainage. The backfire worked; and, due to the foam layer application, no pine trees or brush were burned or scorched.

Los Padres National Forest San Marcos Pass engine with SDTDC foam proportioner installed.

The branch director was so impressed by the "show" at the lookout, the Los Padres engine crew was asked to demonstrate the unit numerous times to overhead and engine crews interested in the compactness of the unit and its application.

For further comments on the proportioner, contact Roger Dahlen, Captain, San Marcos Engine, Los Padres National Forest, 805/964-1313, and for the latest description of the proportioner, see the article by Dan McKenzie, Vol. 2, No. 2, p. 1.

THANK YOU, BLM-BOISE INTERAGENCY FIRE CENTER

by Randy Lafferty, MacMillan Bloedel Limited, Nanaimo, B.C., Canada

Experts were invited to British Columbia, Canada, to transfer Compressed Air Foam System (CAFS) technology to the British Columbia Forest Service and forest industry personnel. Ron Rochna and Paul Schlobohm, Fire Management Specialists, USDI Bureau of Land Management (BLM), who are stationed at the Boise Interagency Fire Center (BIFC), brought the Roseburg, OR, Fire Department's engine No. 107 —equipped with CAFS—to Canada on April 27, 1989.

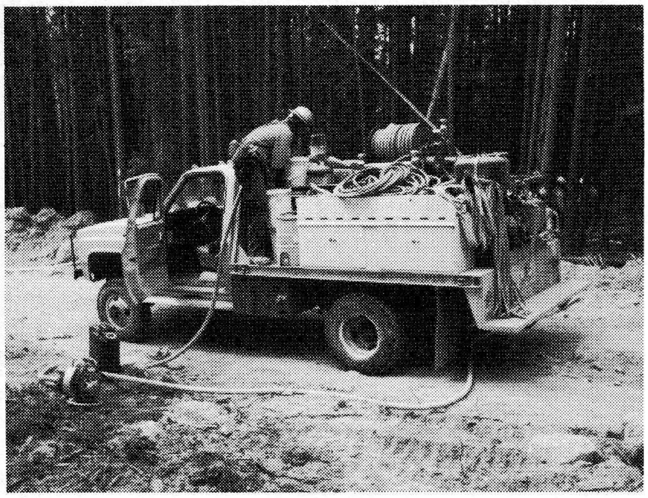
Two very impressive demonstrations/lectures were given to over 85 MacMillan Bloedel Ltd. employees on Vancouver Island. "After hours," Ron and Paul visited several volunteer and city municipal fire departments and outlined the use of class A foam, and foam generating equipment, in wildland/urban fire scenarios. Ron and Paul's tour concluded after another 2 days of demonstrations/ lectures at a British Columbia Forest Service-sponsored workshop in Vancouver and at the University of British Columbia forest in Haney. The field session also included field demonstrations by commercial foam concentrate and foam equipment suppliers, as well as Roseburg's engine 107. More than 100 people attended.

Support by BLM and its staff in this type of operational research and development and technology transfer is much appreciated. For further information on foam activities in British Columbia, contact Randy R. Lafferty, Fire Management Officer; MacMillan Bloedel Limited, Woodlands Services Division, 65 Front Street, Nanaimo, B.C., Canada V9R 5H9; 604/755-3500, FAX 604/755-3550.

TEXAS FOREST SERVICE CAFS STRIKE TEAM

by Mark Stanford, Texas Forest Service

During the 1989 fire season, the Texas Forest Service mobilized a CAFS strike team for duty on large fire incidents. Assignments the team received included the Everglades Fire, Florida; Muave Fire, Arizona; Powerline Fire, Idaho; and Unita Flat Fire, Utah. The strike team consisted of five type 4 engines—each with a crew of three firefighters, and a strike team leader vehicle—which also served as a support truck for supplies and equipment. Although the strike team engines technically fit the type 4 engine category, the CAFS capabilities far exceeded those of a standard brush truck.



CAFS vehicle shuttling water for progressive hoselay on the Powerline Fire, Idaho.

CAFS vehicle supporting a simple hose lay in a mop-up operation on the Unita Flat Fire, Utah.

Strike team vehicles were 1-1/4-ton, four-wheel drive, flat-bed trucks equipped with CAFS modules. The modules had 300-gal fiberglass water tanks with 40-cfm compressors, and 30-gpm positive displacement pumps powered by 23-hp engines. Each vehicle carried a full compliment of hose and appliances; this allowed the strike team to work independently or in conjunction with cooperating agencies and fire departments.

Although CAFS units are best known for their foam capabilities, a majority of the strike team's actions involved expanded wet-water applications. Expanded wet water was created by using a combination nozzle tip with a standard shut-off bale. The nozzle tip broke up the foam, creating an air-saturated, wet-water solution. This application provided for a low delivery rate with extended discharge distance.

Expanded wet water was particularly effective when rapid penetration of fuels was necessary. By simply removing the nozzle tip, the wet-water delivery could be converted to a foam application for direct attack, pre-treatment of fuels, support of existing fire lines, and structure protection.

One point that was well illustrated by the assignments was the versatility of a strike team of small CAFS engines. The relatively small size of the trucks allowed access to remote areas in difficult terrain, while the CAFS units provided capabilities equal to larger, conventional water engines. Water expansion by the CAFS modules extended the pumping times so that the 300-gal water tank was equivalent to 1,200 to 3,000 gal of water. This allowed the engines to remain in service longer between refills, greatly increasing their efficiency.

There is a need for a separate category under the Incident Command System (ICS) to identify the capabilities of CAFS engines. The present system, which groups water and CAFS units together by tank and pump size, underrates the capacity of CAFS engines. In addition to a separate category for typing CAFS engines, there are important valid reasons for treating CAFS units as special resources during periods of high fire incidence. The unique structure protection capabilities of CAFS might be better utilized if CAFS engines were assigned to regional dispatch centers. The units could then be used to protect improved property wherever needed, rather than being assigned to a specific incident until completion of operations.

The 1989 strike team's assignments demonstrated that there is a role for small CAFS engines beyond those traditionally held by brush trucks. The capabilities of the CAFS modules far exceed those of a water unit of equal size. Off-road access provided by the trucks, coupled with the water expansion of the CAFS modules, provides a versatile tool to fire managers. For further information on the TFS CAFS strike team, contact Mark Stanford, Staff Forester, Texas Forest Service, Fire Control Department; P.O. Box 310, Lufkin, TX 75901; 409/639-8100.

LOWMAN COMPLEX INCIDENT—STRUCTURE PROTECTION

by Bill Williams, USDA Forest Service

[The following letter—from the Incident Commander of the Lowman Complex Fire— is of interest to all who are involved with foam use.]

United States Department of Agriculture — Forest Service — Payette National Forest, 106 W. Park, McCall, ID 83638, *208/634-8151*

Reply to: 5130 — Date: August 24, 1989

Subject: Structure Protection on the Lowman Complex

To: Regional Forester, Intermountain Region

I have just returned from the Lowman Complex, where many structures were threatened and some were lost. One reason that more were not lost is that we had two large structural protection engines, called the Odin Foamers. They are produced by Odin Fire Service, Newport,OR, and crewed by BLM engine crews from the Boise Interagency Fire Center (BIFC). Mr. Clarence Grady of Odin Industries Fire Services accompanied the engines. The engines are large, type 1 rigs with 2,800 gal of water, 120 gal of foam concentrate, and a deck monitor on top that can shoot foam onto a structure from a distance. The engines have a 4,000 gpm compressed air foam capability, and can discharge foam up to a distance of 280 ft using the deck monitor.

These two engines, and their crews (including Mr. Grady), were instrumental in saving numerous structures along Highway 21 in the Lowman area and in Enchanted Valley. My entire team was very impressed by the capability of the equipment and the effect of the foam produced, plus the top quality work of Mr. Grady and the BLM crews. Without those two engines and the outstanding work of their crews, we would have lost more homes on the Lowman complex.

Incident Commanders should have rapid access to this type of large engine with foam capability when structures are threatened by wildland fires. This type of equipment can make the difference in saving or losing homes. Considering the amount of urban interface we now have, we need to encourage development of strike teams of large engines with foam capability in the Great Basin Area, and then mobilize them immediately when we have a fire that threatens structures.

If you have any questions, or need more information, please give me a call.

/s/Bill E. Williams
BILL W. WILLIAMS
Incident Commander, Lowman Complex

LOWMAN FIRE—HAVEN LODGE BURNOVER

by Ron Rochna, USDI Bureau of Land Management

On July 29, 1989, I was given an assignment to take the two BIFC compressed air foam engines and best use them after assessing structure protection needs on the Lowman Complex Fire, Boise National Forest, ID, from Lowman, east on Highway 21, to the Enchanted Valley—a distance of approximately 9 mi. The foam engines each had 2,800 gal of water, a 500-gpm water pump, a 265-cfm air compressor, two 2-1/2-in deck cannons, and a two-man crew. The system, at full performance, can deliver 4,000 gal of foam 280 ft. The crew members were Ron Rochna (BIFC Foam Project Leader), Clarence Grady (Odin Industries, fire instructor) and Dean Philstrom (Owner, Odin Industries) on one engine and Carl Dorsey (BIFC Engine Foreman), Al Olson (BIFC), and Randy Webb (BIFC) on the other. A narrative of what happened follows.

We arrived at the Lowman USDA Forest Service Ranger Station to obtain area maps. These did not indicate locations of structures, etc., so our first task was to mark the entire area on the maps to show roads, bridges, structures, propane tanks, powerlines, etc. Then each structure was to be assessed on its ability to be defended from fire. We were also to make contact with the local residents on measures they could take to reduce the risk around their home and about a possible evacuation if the fire moved towards them. I was to take all this information to the incident commander (IC) with recommendations on additional engines, crews, etc. that might be needed to defend the area.

The six of us split into three two-person teams—one to work in Lowman, Miller Estates, and the Long Valley summer homes; the second in the Haven Lodge area that included a Post Office; the third (myself plus another) in the Enchanted Valley. The three teams finished the assessment and met in Lowman to finish marking in the maps and writing up recommendations. Our collective opinion was that we needed at least four strike teams consisting of type 1 structural engines, plus four hand crews with portable pumps, hose, and ancillary equipment.

We felt that the 20 homes in the Enchanted Valley subdivision were in the greatest danger; the eastern edge of the fire was only 1-1/2 mi away. I moved the two foam engines in that direction to apply foam to preserve structures, wood piles, and vegetation. I stopped at the Haven Lodge to inform the owners to prepare for a possible evacuation and to pass it on to anyone who stopped by. (I don't think that they took me seriously; the proprietor's expression was that of bewilderment.)

Looking to the west I could see a billowing smoke plume rising over the ridge. I tried to contact the operations chief; then the fire camp; and finally made contact with Jackson Peak and asked what the fire was doing. Reply was that the fire would not reach the Enchanted Valley before sunset, at the earliest. I sent a team in a pickup to the top of Banner Ridge to scout the fire. They returned and said that the fire was running towards the Haven area (north). The Enchanted Valley was east and two drainages away from the fires edge. We recommended that someone go and check out the Haven Lodge area.

I told the other team that my team was going to the Haven area and for them to keep their ear to the radio and keep applying foam to the structures. The plume was building in height and slanting towards the north. (Enchanted Valley was approximately 1-1/2 mi south of Highway 21.) I met the Sheriff at the mouth of the valley. He was very excited; said that the fire had blown up and that all residents in the valley must evacuate. I said that most of them had already left and only five families remained. I told him to inform them that my engine was moving to the Haven area.

We were approximately 1 mi east of the Haven on Highway 21 when we could see the base of the smoke plume. The funnel was approximately 1/4-mi across at the top of the ridge on the south side of the Haven. It was rotating like a tornado and was dark red. There were numerous spot fires below the ridge on the upper half of the slope.

I arrived at the Haven and drove up to the lodge building. There were many people standing about looking at the fire directly across and above them on the slope. There was a lot of confusion. My intent was to foam the Haven Lodge; however, the Lowman Forest Service Assistant Fire Management Officer (AFMO) yelled for me to take my engine up to the homes above the lodge to evacuate residents.

There were approximately 10 homes. I noticed a spot fire approximately 1/4 acre in size within 100 ft of a home in the upper northeast corner of the subdivision. We drove up the driveway and saw the owner (a man in his 60's) pulling a garden hose along to wet down his property. I yelled at him that he must leave; he looked at me and said that his house was all that he owned and that he would have no reason to live if he lost it and its contents. I contacted the AFMO and told her of the situation; she told me to get him out and didn't care how I did it. The weather was still clear, wind was down canyon, the temperature was 95 degrees, and the relative humidity was near 15 percent. The fire was approximately 75 ft from the house and spreading down the slope to both the east and west.

Clarence Grady was instructed to engage the foam system and give me 300 gpm water, 200 cfm of air, and 0.3 percent of foam concentrate. I climbed up on top of the truck and manned a deck monitor. It discharged 1,600 gal of foam per minute at the fire's edge and slowed it down. Then I shot foam onto the house, completely turning it white. After about 30 sec the owner got into his truck and left.

Carl Dorsey, on the other foam engine, called to say he was enroute to assist. I told him where we were and that we needed some help. After 5 min of foaming the structures and all vegetation within 100 ft, we moved to the four buildings that were approximately 150 yd to the west; this took approximately 1 min. We pulled into the driveway and parked facing out. I noticed a powerline and observed a 500-gal propane tank within 8 ft of the home with a spot fire burning between them. I pulled 100 ft of hose and doused the spot and checked to see if anyone was there. They had left.

The other engine arrived and asked where to go. I observed black smoke 200 yd southwest and below us. If this fire grew, it would cut off our escape. Carl was directed to knock it down. By this time, the spot fires were numerous with the hillside above active with flame and the wind still blowing to the west, down canyon, 10 to 20 mph.

I told Clarence that we had better get out of there. At the same time Carl came on the radio: "Ron, get out of there, the fire is blowing up—we have to leave." Seconds later, the wind shifted to the east (up canyon) and knocked both of us to the ground, then everything burst into flames. The wind must have been between 70 to 90 mph. I picked up the hose line and foamed the ground around us; then Clarence disconnected the hose so we could leave.

Smoke and flames were everywhere. We couldn't see; breathing was difficult. I seized the full-face respirators out of the truck, and we put them on. We now could breath and our eyes were protected. We had to get away from the buildings; there was much heat and a concern that the propane and other contents in the buildings would explode. We had a safety zone 100 yd down the road, approximately 1/2 acre in size. It was a garden with sprinklers running; I decided to move to it.

The high winds blew a building apart right in front of the the engine and, at the same time, it caught fire; the powerlines broke and fell across the engine. It appeared the power (I hoped) was already off. Flames from the burning buildings were rolling over the truck—we had to get to the safety zone. I held onto the front bumper so Clarence could see my helmet as I guided him down the road. Clarence stopped twice when he lost sight of me, thinking I had fallen down. (He thought that he might have driven over me.)

At this time, eight buildings, and cars, boats, snowmobiles, tractors, wood decks, and firewood piles were on fire. The natural vegetation had already been vaporized. The wind let up for a moment and I could see the safety zone. I yelled at Clarence, "Let's get to the garden." We positioned the truck in the middle of a potato patch and rested.

At least five propane tanks were venting to the north and west of us. The closest one was within 100 ft, where explosions from the burning outbuildings were continuous—resulting in sharp metal falling. Clarence, a hazardous materials instructor from Oregon, stated that if a 500-gal propane tank blows (boiling liquid vapor explosion), the shock wave would kill you within 1,000 ft of it. Great! There were propane tanks all around us; several over 2,000 gal. By the way, the IC, Bill Williams, was talking to us continuously on the radio all this time. By now, the only fires were from buildings and their contents. Most propane tanks were within 8 ft of the structures and had direct flame impingement. This was not good!

We decided to try to make it to a river, which was approximately 250 yd to the west. We stopped at the highway and encountered many campers and trailers burning. We retreated back to a brick house that was not on fire and took shelter next to it on the downhill side. This house also had a detached garage made of stone, and a wood shed full of firewood (at least 5 cords). Both were northwest of the house. We sat there talking about what to do, what was going to happen, etc. Then the propane tanks below us at the Haven Lodge started venting. We decided to move back to the engine. Within 5 min the brick house was on fire and a log cabin below the old man's house we had foamed was burning.

We looked up at the old man's house. It was still there! As was a house next to the burning cabin. The propane tanks above us were not venting anymore, indicating all the fuel was gone. We decided to move the engine to the east to protect the old man's house and the house that was next to the burning cabin. (This structure had a main floor with a daylight basement.)

We laid a hose line up to it and knocked down the flame on the front porch (west side), then sprayed foam on the wall exposed to the cabin (north side), and put out the fire in the firewood pile (east side). I then entered the house to see if fire had entered. The structure was full of smoke. We did a search and concluded that there was fire on the main floor. I went outside and injected foam through a hole on the west end of the house, filling a portion of the floor. The fire was out. I contacted the IC and told him we were OK.

Summary: My mission originally was to foam the Haven Lodge and Post Office, but then I was directed to evacuate a stubborn resident from his home. This order came from the Lowman Ranger District AFMO. We succeeded in uprooting the resident homeowner and by chance, saved his home. As the fire storm calmed down, we were able to foam and save another house. It was reassuring to us to have Bill Williams, the IC, talking to us on the radio.

We feel that the full-face respirators kept us from panicking. Handkerchiefs are not effective in dense smoke. The respirators protect the eyes, nose, and mouth—the entire face; offering added protection from radiant heat. Full-face protection prevents panic.

For further information on the foam engines, or to enter into a dialogue on their use in structure protection, contact Ron R. Rochna, Foam Project Leader; USDI Bureau of Land Management, Boise Interagency Fire Center, 3905 Vista Avenue, Boise, ID 83705; 208/389-2432.

EFFECTIVENESS OF GROUND-APPLIED CAFS IN ALASKAN WILDLAND FIRE SUPPRESSION

by Frenchie Malotte, Alaska Division of Forestry

Wetting agents make water more effective as an extinguishing agent; but, does adding an air compressor further enhance their use during wildland fires to the extent that added costs are offset by benefits gained? As a research project, a test compressed air foam system (CAFS) unit was set up on an existing type 3 engine from the Fairbanks area within the Alaska Division of Forestry. We wanted to determine the effectiveness of CAFS when used in both direct and indirect suppression strategies in fuels encountered in the wildland/urban interface of interior Alaska.

The engine, built on a 4 x 4 Ford F-700 chassis (21,200-lb GVW) with a 300-gal fiberglass slip-on water tank, has a Wajax-Pacific model BB-4 water pump powered by a 16-hp, four-cycle gasoline engine. The BB-4 has a rated capacity of 87 gpm at 150 psi, and 31 gpm at 350 psi. The air compressor is a Mallory model 4400 with a Dayton Speedaire model 32183B compressor powered by a 18-hp, four-cycle gasoline engine. The air compressor has a rated capacity of approximately 40 cfm at 150 psi.

The engine was setup to deliver compressed air foam through 1-1/2-in hose lines, 1-in booster lines, and a 1-1/2-in deck-mounted monitor. (Note: Pump capacity can be exceeded by simultaneous use of all provided discharge ports.) Foam concentrate is injected into the intake side of the pump. After the solution passes through the water pump, compressed air is introduced and then passes through an in-line mixer pipe. Check valves prevent air from entering the water pump and water from entering the air compressor. This mixture then discharges through a variety of hose lines and nozzle openings as compressed air foam. Both the water pump and air compressor must be operated at equal static pressures of 150 psi. The system is designed to deliver plain water, surfactant-treated water, or compressed air foam, as determined necessary by the pump operator.

The main areas of safety concerns are to avoid contact of foam concentrate in the eyes and mucous membranes and understanding reactions of appliances opened rapidly under high pressure. The foam mixture appears to be no more harmful than household dish soap or shampoo. Eye protection should be worn, as when using any high-pressure water streams. Eye wash solution should be readily available in case of need.

Two types of foam concentrate were used during the evaluation period. They were Ansul Silv-ex and Monsanto Phos-Chek WD 861. It appears that Silv-ex is least affected by cold weather storage, although Monsanto claims their WD 881 has undergone changes to correct problems of ingredient separation. We were unable to determine any noticeable difference in foam quality between the two foams tested.

The following are prices for foam concentrates maintained in our warehouse inventory (shipping costs not included):

Manufacturer/Brand/Size (gal)	Price ($/gal)	Source
3M FB100 Firebreak, 55	8.50	Alaska Branch of 3M Co.
Chemonics Fire-Trol, 55	12.50	General Services Admin (GSA)
Monsanto Phos-Chek WD 861, 55	10.50	Monsanto Co.
Monsanto Phos-Chek WD 881, 55	11.25	Monsanto Co.
Ansul Silv-ex, 55	11.60	Wajax-Pacific

These foam concentrates are mixed with water at 0.3 percent. Three gallons of foam concentrate makes 1,000 gal of surfactant-treated water. A 55-gal drum of foam concentrate makes approximately 18,300 gal of surfactant-treated water. Using the above prices, the average cost of surfactant-treated water is $0.03 per gal.

CAFS equipment operator proficiency was readily attained by experienced firefighters within 2 to 3 days. For this system, the best foam production and stream reach was achieved by using a 3/4-in ball shut-off valve or a 5/8-in opening on a forester nozzle with the straight tip removed. Use of smaller nozzle openings, or fog nozzles, causes the compressed air foam to break up or separate. Use of smaller nozzle openings causes the reach of the stream to be considerably reduced. The deck monitor, with a 3/4-in ball shut-off, has a maximum horizontal reach of approximately 125 feet. The handlines with a 3/4 inch ball shut off have a maximum horizontal reach of approximately 100 ft. Surfactant-treated water under the high pressure of the BB-4 pump through an aspirating nozzle produces a stream with a maximum horizontal reach of only 30 ft.

Application of compressed air foam into trees and brush allows a high percentage of the extinguishing agent to remain in place on the vegetation rather than run off onto the ground. Compressed air foam applied to moss and duff soaks in rapidly and holds moisture in place for periods of 2 to 3 hr.

Field trials, test burns, and five evaluations that were conducted from March to September 1989. These included:

- Evaluation of foam production with and without in-line mixer
- Evaluation of knock-down capability of compressed air foam on interior structure fire
- Application of compressed air foam on vertical structural surfaces
- Evaluation of compressed air foam for wetline construction on perimeter of hay field burn
- Evaluation of compressed air foam on brush and tundra/grass and brush/brush and tree fires and when torching spruce trees, plus on a flammable liquids pit fire and on a deep-smoldering berm pile
- Evaluation of plain water on mop-up of deep-smoldering duff fire.

From all these, we conclude:

1. The air compressor is more useful on direct attack of hot-line. The air compressor produces a much longer reaching fire stream, which allows firefighters to attack longer flame lengths without being subjected to intense heat and smoke. Compressed air foam is an excellent initial attack tool.

2. The air compressor is not needed for most mop-up operations. A lower energy surfactant-injected solution is sufficient. The high back pressure of compressed air foam is a disadvantage, because of splattering, when applying agent directly in front of firefighters using hand tools.

3. Injection of surfactant on the intake side of the pump does not allow recirculation of water for pump cooling nor pressure relief back to the water tank. Foam

created in the water tank will cause the pump to cavitate. Without these features, pump overheating occurs within 1 min of nozzle shut down.

4. The in-line (motionless) mixer produces better quality foam than 100 ft of hose line agitation. This mixer is mandatory for use of the deck monitor without pumping through a length of hose to produce compressed air foam.

5. The air compressor was quite useful in draining hose lines and permitted rapid demobilization.

6. The BB-4 pump and the Mallory model 4400 air compressor do not appear to be well matched. The water pump runs at low speed, and the air compressor runs at maximum speed to produce compressed air foam at 150 psi.

7. Surfactant-injected water and compressed air foam allow much greater penetration of extinguishing agent. A 50-percent reduction in workhours for mop-up time can be expected in most situations.

8. Compressed air foam allows approximately 90 percent of the extinguishing agent to remain on the applied surface rather than to run off. This greatly extends the use of limited water supplies.

9. Accurate determination of foam mixtures is not possible without the addition of a water flow meter.

10. The system worked much better with 1-1/2-in, rather than the 1-in piping used in 1988.

11. Use of non-weeping forestry hose is mandatory with compressed air foam.

12. Monsanto Phos-Chek WD 861 foam concentrate has to be strained after cold-weather storage to remove separated chemicals. Ansul Silv-ex foam concentrate exhibits minimal crystalization from cold-weather storage.

13. The weight of a 100-ft hose line full of compressed air foam is only 20 lb, compared to a hose line full of water, which weighs 90 lb. Several lengths of compressed air foam charged hose can be moved by one person using only one hand.

14. The control panel from the pump and air compressor is located where noise levels make radio operations nearly impossible.

15. Separate pump and air compressor controls make it more difficult to match up pressure for compressed air foam production.

16. There were no adverse environmental or health problems observed from use of the foam concentrates tested.

We, thus, recommend the following:

1. Each roadside area within the Alaska Division of Forestry should be equipped with a minimum of one CAFS engine. CAFS use for both hot-line and mop-up improves overall efficiency to the extent that its additional equipment costs are offset within one fire season.

2. All engines and water tenders within Alaska Division of Forestry should be equipped with surfactant injection.

3. Surfactant-injection systems should only be installed on the discharge side of the water pump to allow for pump cooling and pressure relief piping to be recirculated into the water tank. A Flow Mix model 500 surfactant-injection system would be suitable with an electric refill pump to eliminate the need to shut down the system after flowing 1,600 gal of water.

4. The in-line (motionless) mixer pipe should be installed on each CAFS engine to produce better quality foam for both handlines and the deck monitor.

5. A Mallory model 6600 with a Dayton Speedaire model 32410 compressor—powered by a Kohler 23-hp, four-cycle gasoline engine, would be a better match for the BB-4 pump. This compressor would produce 50 percent more air than the existing Mallory model 4400, and would allow greater utilization of the BB-4 pump with longer reaching streams than the existing set up.

6. A water flow meter should be installed to enable accurate and cost-effective mixing of foam concentrate. A digital "totalizer" manufactured by Foam Pro displays current water flow rate (gpm), cumulative volume of total water discharged, and foam concentrate percentage.

7. Use of non-weeping forestry hose, such as Wajax hot-line (test pressure: 450 psi) should be mandatory for compressed air foam.

8. Monsanto Phos-Chek WD 861 foam concentrate should not be used unless warm storage can be provided. This product needs to be strained after cold storage to remove separated chemicals. (Note: The manufacturer's technical service representative advises that their WD-881 product has undergone changes to correct problems of ingredient separation.)

9. A single pump and air compressor operator's panel should be designed and located away from high noise levels. A better exhaust system for the pump and air compressor could reduce noise levels, and the need for a remote-control panel to enable radio operations.

10. A pump-to-tank valve should be installed to allow tank refill while drafting, or while being supplied from a water tender.

11. The pressure relief valve should be vented back to the water tank. A small diameter (1/8-in) pump cooling line with filter screen should be installed to prevent pump overheating.

12. New engines should be equipped with 500-gal tanks to increase water carrying capacity by 65 percent. This, combined with compressed air foam, would increase the extinguishing capability considerably.

13. All CAFS engines should be set up in a standardized configuration, Statewide, to simplify training and operations.

14. The BB-4 pump is a good choice as it provides up to 250 psi and allows for pump and roll capability.

15. The existing pump discharge gate valve should be replaced with a 1/4-turn ball valve to allow more precise manipulation for creating different types of foam.

16. Water tank level gauges should be installed on the operator's panel, since it is difficult to see the water level through the fiberglass tanks.

17. A minimum of 3 days training and hands-on experience should be conducted for all persons working on CAFS; this training should be in addition to the proposed engine academy curriculum.

For further information, or to obtain a complete copy of the research project report from which this article was abstracted (or to inquire about video footage of the test program), contact Norman (Frenchie) Malotte, Equipment Committee Chair, State of Alaska Dept. of Natural Resources-Div. of Forestry, Fairbanks Area Office, P. O. Box 107005, Anchorage, AK 99501-7005; 907/762-2505.

SUGGESTED READING AND VIEWING

The following articles, papers, and reports on foam technology are for your suggested reading:

1. Alberta Forest Service. Wildland fire foam manual. Forest Protection Branch, P.O. Box 7040, Stn. M, Edmonton, Alberta, Canada T5E 589. Second ed., 1989.

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5. Parminter, John. Primer on wildland firefighting foams, with summary of experience to-date and recommendations for operational use. Protection Branch, Ministry of Forests, 1450 Government St., Victoria, B.C. V8W 3E7; August 1989.

The following video on foam technology is for your suggested viewing:

1. Introduction to foam. Boise Interagency Fire Center, 3905 Vista Avenue, Boise, ID 83705.

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by Al Seltzer, USDA Forest Service

Now that six issues of this publication have been distributed, the editor—Al Seltzer, Technical Publications Writer/Editor, USDA Forest Service San Dimas Technology & Development Center (SDTDC), 444 East Bonita Avenue, San Dimas, CA 91773; FTS 793-8000, 714/599-1267, 818/332-6231; FAX 714/592-2309; DG A.SELTZER:W07A—has compiled a bibliography for the articles that have appeared over the 2-year period. Steve Raybould (same address and numbers as the editor), program assistant to the Center's Program Leader for Fire and Residues, has served as the coordinator between authors and the SDTDC's publications group. In addition to the editor, the group includes John and Jeanne Irwin, who provide graphics, layout, and production for this series of Foam Applications documents.

The bibliography is presented in the following three tables, arranged alphabetically by author, by agency/firm, and by title of article.

Table 1. Alphabetical by Author.

AUTHOR	AGENCY/FIRM	ARTICLE TITLE	VOL	NO	PG
Abernarthy, David	Texas Forest Service	Texas Forest Service Foam Report	1	3	4
Adamson, Keith	Robwen, Inc.	New In-Line Proportioner System Supplies Accurate Mixture of Surfactants	2	1	4
Alexander, Martin, E.	Canadian Forestry Service	Foam Effectiveness in Relation to Quantified Fire Behavior	2	2	4
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Table 2. Alphabetical by Agency/Firm.

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Irving, Tom	For. Ind. Flying Tigers	Waterbombers Use Foam in British Columbia	1	3	6
Button, Chris	Los Angeles County	New Firefighting Foam Approved for Helicopter Use	2	1	1
Lafferty, Randy R.	MacMillan Bloedel, Ltd.	Foam Chemicals for Wildland Fire Control—NFPA Propsoed Standard No. 298	1	1	4
Lafferty, Randy R.	MacMillan Bloedel, Ltd.	Thank You, BLM—Boise Interagency Fire Center	2	3	6
(Foam Task Group)	NWCG FEWT Foam Task Grp.	Suggested Reading	1	3	11
(Foam Task Group)	NWCG FEWT Foam Task Grp.	Suggested Reading	2	2	10
(Foam Task Group)	NWCG FEWT Foam Task Grp.	Suggested Reading	1	1	11
(Foam Task Group)	NWCG FEWT Foam Task Grp.	Suggested Reading and Viewing	2	3	13
(Foam Task Group)	NWCG FEWT Foam Task Grp.	Suggested Reading, Foam Technology	1	2	11
Rondeau, Dick	Oregon State Dept. of Forestry	Foam Evaluation by Oregon State Department of Forestry	1	1	8
Conacher, Glen	Prov. of Saskatchewan	Firefighting Foam	1	1	10
Adamson, Keith	Robwen, Inc.	New In-Line Proportioner System Supplies Accurate Mixture of Surfactants	2	1	4
Stanford, Mark	Texas Forest Servcie	Texas Forest Service CAFS Strike Team	2	3	6
Abernarthy, David	Texas Forest Service	Texas Forest Service Foam Report	1	3	4
Ebarb, Pat	Texas Forest Service	Task Group for International/Interagency Foams & Applications Systems	1	1	4
Ebarb, Pat	Texas Forest Service	Texas Forest Service Foam Program Update	2	1	2
Ebarb, Pat	Texas Forest Service	Texas Forest Service Foams & Water Expansion Program	1	1	6
Stanford, Mark	Texas Forest Service	Texas Forest Service CAFS Strike Team Training Program	2	2	11
Madrzykowski, Dan	US Dept. of Commerce/NIST	U.S. Dept. of Commerce (NBS/now Nat'l. Inst. of Std. & Tech.) Foam Research	1	3	11
Amicarella, L.A., & Shenk, Bill	USDA Forest Service	USDA Forest Service Encourages Foam Use	1	3	11
Blakely, Dave & Johnson, Ceci	USDA Forest Service	USDA Forest Service Foam Research Activities	1	1	7
Dahlen, Roger	USDA Forest Service	SDTDC Prototype Foam Proportioner In Action	2	3	5
George, Chuck	USDA Forest Service	Foam Applications—A Presentation Outline	1	2	9
Hill, Paul R.	USDA Forest Service	Forms Available to Evaluate Foam Use	1	1	9

Table 2. Alphabetical by Agency/Firm (continued).

Hill, Paul R.	USDA Forest Service	Manufacturer Submission Procedures for Wildland Fire Foams	1	2	3
Hill, Paul R.	USDA Forest Service	USDA Forest Service Program Direction for Wildland Fire Foam	1	1	4
Johnson, Ceci	USDA Forest Service	All About Foam and How to Safely Use It	1	1	5
McCoy, L.; Kendall, L.; & Dudley, S.	USDA Forest Service	Evaluation of Flow Proportioner with a Medium Expansion Foam Nozzle	2	3	3
McKenzie, Dan	USDA Forest Service	New Proportioner Systems Supply Accurate Foam Concentrate Mixtures	2	2	1
McKenzie, Dan	USDA Forest Service	San Dimas Technology & Development Center Foam Project Activities	1	2	7
McKenzie, Dan	USDA Forest Service	Single-Engine-Driven Compressed Air Foam System	2	3	2
McKenzie, Dan & Costantino, Jim	USDA Forest Service	Pleasant Valley Ranger District, Tonto National Forest CAFS Unit	1	2	4
McKenzie, Dan & Warner, Dewey	USDA Forest Service	Deschutes National Forest Compressed Air Foam Systems (CAFS) Unit	1	2	3
Page, Jim	USDA Forest Service	Compressed Air Foam Systems (CAFS) Workshop	2	1	5
Seltzer, Al	USDA Forest Service	Bibliography, Vol. 1 & 2—Foam Applications for Wildland & Urban Fire Management	2	3	13
Shenk, B.; Hill, P.; & George, C.	USDA Forest Service	USDA Forest Service Develops Long- and Short-Range Plans for Wildland Foams	1	2	3
Smith, Doc	USDA Forest Service	Chairperson's Corner	2	1	2
Smith, Doc	USDA Forest Service	Chairperson's Corner—International Workshop on Foam Applications Announced	1	2	1
Smith, Doc	USDA Forest Service	Chairperson's Corner—Int'l Workshop on Foam Applications/Foam Task Group	1	3	1
Smith, Doc	USDA Forest Service	Chairperson's Corner—Why a Foam Task Group & How You Can Help	1	1	1
Smith, Doc	USDA Forest Service	Overview—June 1988 International Workshop on Foam Applications	1	3	10
Williams, Bill	USDA Forest Service	Lowman Complex Incident—Structure Protection	2	3	8
Rochna, Ron R.	USDI Bureau of Land Mgmt.	BLM Foam Project Fire Engine 1988	2	2	2
Rochna, Ron R.	USDI Bureau of Land Mgmt.	Lowman Fire—Haven Lodge Burnover	2	3	8
Rochna, Ron R.	USDI Bureau of Land Mgmt.	Training & Safety Notes—Safe Operation of CAFS	2	1	7
Rochna, Ron R.	USDI Bureau of Land Mgmt.	USDI BLM Experiences, Using Foam as Barrier in Prescribed Fire & for Mop-up	1	2	6
Rochna, Ron R.,Schlobohm, P.,et.al.	USDI Bureau of Land Mgmt.	Abstract of Performance Test: Low-Expansion, Nozzle-Aspirated Systems & Wildland Foam	2	2	5
Schlobohm, Paul, & Rochna, R.	USDI Bureau of Land Mgmt.	Evaluation of Foam as a Fire Suppressant is Available	1	2	6
Webber, Bob	USDI Bureau of Land Mgmt.	USDI Bureau of Land Mgmt. Foam & Compressed Air Foam Systems Development	1	1	8
Wilson, Jack	USDI Bureau of Land Mgmt.	Foam Project—Where Are We?	1	3	3
Butts, Dave	USDI National Park Service	USDI National Park Service Use of Foaming Agents	1	1	10
Seaman, Dick	Yukon Forest Service	1986 Season Ground Application Use	1	1	9

Table 3. Alphabetical by Article/Title.

AUTHOR	AGENCY/FIRM	ARTICLE TITLE	VOL	NO	PG
Seaman, Dick	Yukon Forest Service	1986 Season Ground Application Use	1	1	9
Rochna, Ron R.,Schlobohm, P.,et.al.	USDI Bureau of Land Mgmt.	Abstract of Performance Test: Low-Expansion, Nozzle-Aspirated Systems & Wildland Foam	2	2	5
Johnson, Ceci	USDA Forest Service	All About Foam and How to Safely Use It	1	1	5
Seltzer, Al	USDA Forest Service	Bibliography, Vol. 1 & 2—Foam Applications for Wildland & Urban Fire Management	2	3	13
Rochna, Ron R.	USDI Bureau of Land Mgmt.	BLM Foam Project Fire Engine 1988	2	2	2
Read, Bob	British Columbia FS	British Columbia Foam Health, Safety, Environment—Where It's At!	1	3	8
Read, Bob	British Columbia FS	British Columbia Forest Service Foam Use	1	3	7
David, Day	Calif. Dept. of Forestry/Fire	California Department of Forestry & Fire Protection Foam Studies	1	1	10
Trask, Art	Calif. Dept. of Forestry/Fire	California Department of Forestry & Fire Protection Helicopter Foam System	1	3	9
Machado, John	Calif. Dept. of Forestry/Fire	California Department of Forestry & Fire Protection Studies Aspirating Nozzles	1	2	4
Stechishen, Edward	Canadian Forestry Service	Canadian Forestry Service Current Research Work	1	3	7
Stechishen, Edward	Canadian Forestry Service	Canadian Forestry Service Wildland Foam Studies at Petawawa Nat'l Forestry Inst.	1	1	7
(Canadian Forestry Service)	Canadian Forestry Service	Canadian Provincial Foam Program—Canadian Air-Dropped Foams	1	1	9
Smith, Doc	USDA Forest Service	Chairperson's Corner	2	1	2
Smith, Doc	USDA Forest Service	Chairperson's Corner—International Workshop on Foam Applications Announced	1	2	1
Smith, Doc	USDA Forest Service	Chairperson's Corner—Int'l Workshop on Foam Applications/Foam Task Group	1	3	1
Smith, Doc	USDA Forest Service	Chairperson's Corner—Why a Foam Task Group & How You Can Help	1	1	1
Page, Jim	USDA Forest Service	Compressed Air Foam Systems (CAFS) Workshop	2	1	5
McKenzie, Dan & Warner, Dewey	USDA Forest Service	Deschutes National Forest Compressed Air Foam Systems (CAFS) Unit	1	2	3
Malotte, Frenchie	Alaska Div. of Forestry	Effectiveness of Ground-Applied CAFS in Alaskan Wildland Fire Suppression	2	3	10
McCoy, L.; Kendall, L.; & Dudley, S.	USDA Forest Service	Evaluation of Flow Proportioner with a Medium Expansion Foam Nozzle	2	3	3
Schlobohm, Paul, & Rochna, R.	USDI Bureau of Land Mgmt.	Evaluation of Foam as a Fire Suppressant is Available	1	2	6
Conacher, Glen	Prov. of Saskatchewan	Firefighting Foam	1	1	10
Blankenship, Paul	Calif. Dept. of Forestry/Fire	Firefighting Foam for Ground Application	2	1	6
George, Chuck	USDA Forest Service	Foam Applications—A Presentation Outline	1	2	9
Lafferty, Randy R.	MacMillan Bloedel, Ltd.	Foam Chemicals for Wildland Fire Control—NFPA Propsoed Standard No. 298	1	1	4
Stechishen, Edward	Canadian Forestry Service	Foam Drainage Vessel	2	2	4
Alexander, Martin, E.	Canadian Forestry Service	Foam Effectiveness in Relation to Quantified Fire Behavior	2	2	4
Rondeau, Dick	Oregon State Dept. of Forestry	Foam Evaluation by Oregon State Department of Forestry	1	1	8
Wilson, Jack	USDI Bureau of Land Mgmt.	Foam Project—Where Are We?	1	3	3
Greene, J.P.	Florida Div. of Forestry	Foam Use in Florida Everglades Region	2	1	5
Hill, Paul R.	USDA Forest Service	Forms Available to Evaluate Foam Use	1	1	9
Day, David J.	Calif. Dept. of Forestry/Fire	Injection Foam Systems and Aspirating Nozzles	2	2	3
Ogilvie, C.J., Alexander, M.E., et.al.	Canadian Forestry Service	Interim Guidelines for Aerial Application of Foam on Forest Fires	2	3	5
Read, Bob	British Columbia FS	Long-Term Fire Retardant Mixed with Foam	2	2	2
Williams, Bill	USDA Forest Service	Lowman Complex Incident—Structure Protection	2	3	8
Rochna, Ron R.	USDI Bureau of Land Mgmt.	Lowman Fire—Haven Lodge Burnover	2	3	8
Hill, Paul R.	USDA Forest Service	Manufacturer Submission Procedures for Wildland Fire Foams	1	2	3
Button, Chris	Los Angeles County	New Firefighting Foam Approved for Helicopter Use	2	1	1
Adamson, Keith	Robwen, Inc.	New In-Line Proportioner System Supplies Accurate Mixture of Surfactants	2	1	4
McKenzie, Dan	USDA Forest Service	New Proportioner Systems Supply Accurate Foam Concentrate Mixtures	2	2	1
Smith, Doc	USDA Forest Service	Overview—June 1988 International Workshop on Foam Applications	1	3	10

Table 3. Alphabetical by Article/Title (continued).

McKenzie, Dan & Costantino, Jim	USDA Forest Service	Pleasant Valley Ranger District, Tonto National Forest CAFS Unit	1	2	4
Irving, Tom	For. Ind. Flying Tiger	Port Alberni Paper Mill Fire	2	3	1
McKenzie, Dan	USDA Forest Service	San Dimas Technology & Development Center Foam Project Activities	1	2	7
Dahlen, Roger	USDA Forest Service	SDTDC Prototype Foam Proportioner In Action	2	3	5
McKenzie, Dan	USDA Forest Service	Single-Engine-Driven Compressed Air Foam System	2	3	2
(Foam Task Group)	NWCG FEWT Foam Task Grp.	Suggested Reading	1	1	11
(Foam Task Group)	NWCG FEWT Foam Task Grp.	Suggested Reading	2	2	10
(Foam Task Group)	NWCG FEWT Foam Task Grp.	Suggested Reading	1	3	11
(Foam Task Group)	NWCG FEWT Foam Task Grp.	Suggested Reading and Viewing	2	3	13
(Foam Task Group)	NWCG FEWT Foam Task Grp.	Suggested Reading, Foam Technology	1	2	11
Ebarb, Pat	Texas Forest Service	Task Group for International/Interagency Foams & Applications Systems	1	1	4
Stanford, Mark	Texas Forest Servcie	Texas Forest Service CAFS Strike Team	2	3	6
Stanford, Mark	Texas Forest Service	Texas Forest Service CAFS Strike Team Training Program	2	2	11
Ebarb, Pat	Texas Forest Service	Texas Forest Service Foam Program Update	2	1	2
Abernarthy, David	Texas Forest Service	Texas Forest Service Foam Report	1	3	4
Ebarb, Pat	Texas Forest Service	Texas Forest Service Foams & Water Expansion Program	1	1	6
Lafferty, Randy R.	MacMillan Bloedel, Ltd.	Thank You, BLM—Boise Interagency Fire Center	2	3	6
Rochna, Ron R.	USDI Bureau of Land Mgmt.	Training & Safety Notes—Safe Operation of CAFS	2	1	7
Shenk, B.; Hill, P.; & George, C.	USDA Forest Service	USDA Forest Service Develops Long- and Short-Range Plans for Wildland Foams	1	2	3
Amicarella, L.A., & Shenk, Bill	USDA Forest Service	USDA Forest Service Encourages Foam Use	1	3	11
Blakely, Dave & Johnson, Ceci	USDA Forest Service	USDA Forest Service Foam Research Activities	1	1	7
Hill, Paul R.	USDA Forest Service	USDA Forest Service Program Direction for Wildland Fire Foam	1	1	4
Rochna, Ron R.	USDI Bureau of Land Mgmt.	USDI BLM Experiences, Using Foam as Barrier in Prescribed Fire & for Mop-up	1	2	6
Webber, Bob	USDI Bureau of Land Mgmt.	USDI Bureau of Land Mgmt. Foam & Compressed Air Foam Systems Development	1	1	8
Butts, Dave	USDI National Park Service	USDI National Park Service Use of Foaming Agents	1	1	10
Madrzykowski, Dan	US Dept. of Commerce/NIST	U.S. Dept. of Commerce (NBS/now Nat'l. Inst. of Std. & Tech.) Foam Research	1	3	11
Irving, Tom	For. Ind. Flying Tigers	Waterbombers Use Foam in British Columbia	1	3	6
Stechishen, Edward	Canadian Forestry Service	You Need to Know a Foam's Drainage Rate	2	1	4

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