United States Fire Administration

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Compressed Air Foam for Structural Fire Fighting: A Field Test Boston, Massachusetts

Federal Emergency Management Agency

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National Fire Data Center

Compressed Air Foam for Structural Fire Fighting: A Field Test Boston, Massachusetts

Report by The Boston Fire Department

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Compressed Air Foam for Structural Fire Fighting: A Field Test
Boston Fire Department Engine Company 37

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OVERVIEW

Compressed air foam, which is a relatively new development in the realm of fire suppression technology, has gained wide acceptance in the wildland and rural fire protection environments. Several of the characteristics and capabilities that have been reported by users of compressed air foam suggest that it could be a valuable addition to the arsenal of urban as well as rural fire departments. The potential benefits of a transfer of compressed air foam technology to the urban environment were recognized by the United States Fire Administration, which provided the opportunity to conduct the field evaluation program that is described in this report.

During most of 1992 and the early part of 1993, the Boston Fire Department participated in a field test of a compressed air foam system (CAFS). Partial funding for the program, including the equipment, analysis and reporting, was provided by the United States Fire Administration (USFA), part of the Federal Emergency Management Agency. The overall objective of the project was to evaluate the applicability of CAFS technology to an urban fire suppression environment.

SUMMARY OF KEY ISSUES	
Issues	**Comments**
Strategy	Immediate attack with tank water. Hydrant water supply secured as needed.
Fire Control	CAFS performance superior to water in test experiments. Field tests indicate CAFS equal or superior to water as extinguishing agent.
Equipment Reliability	Needs improvement.
Water Use	Reduced water usage.
Handline	Lighter and easier to handle. Hose line kinking not a problem.
Heat Absorption	No appreciable difference noted by users. Cools fuels below ignition point; moistens fuels to prevent reignition.
Stream	Throw distance shorter than comparable water stream. Reduced stream penetration capability.
Exposures	Excellent exposure protection capability.
Overhaul	Reduced need to overhaul due to superior water penetration into Class A fuels.
Water Damage	Significantly less.
Investigations	Foam needs to breakdown first. May need improved chemical analysis techniques to differentiate from accelerants.

This report is primarily based upon the observations of the crews on Engine 37 who used the CAFS equipment during the test period. They had the closest contact with the project and obtained the actual “hands on” experience that was desired to evaluate CAFS. The results of a series of small-scale tests of the CAFS conducted during the evaluation period at the Massachusetts Firefighting Academy are also presented and discussed. Additional information is provided as background, along with comments from the District Chiefs in District 5, other officers and firefighters, and additional observers who were requested to assist in the evaluation and report development.

BACKGROUND

The test evaluation project involved Engine Company 37, Boston's busiest fire company, which serves a densely populated and highly diversified district west of the downtown area. Engine 37's first due area includes hundreds of multi-family residential buildings, busy commercial areas, major medical facilities, college and university buildings, and numerous other occupancies, including Fenway Park, the home of the Boston Red Sox. It has the potential of responding to almost any type of urban fire situation in its first due area or in the surrounding areas where it normally responds as the second or third due engine company.

To increase the opportunities to use the CAFS at structure fires, Engine 37 was dispatched as an extra company to any working structure fire in the City of Boston for the duration of the project. Engine 37 was dispatched as soon as any company reported "smoke showing" or "fire showing" from a structure. This provided several additional opportunities where the system could be used and tested in real interior fire fighting situations.

Compressed air foam was developed in the 1970s in Texas as an innovative approach for fighting grassland fires in areas where water is extremely scarce. The system combines two technologies, an agent to reduce the surface tension of water and compressed air, to produce an expanded volume of fire extinguishing agent. The surface tension reduction, which makes water much more efficient as an extinguishing agent, is accomplished by introducing a small percentage of Class A foam concentrate into the water stream. Compressed air is then injected into the solution to expand the foam, creating a mass of foam bubbles to provide a much greater volume of extinguishing agent in a form that has the ability to stick to vertical surfaces and flow over horizontal surfaces, forming an insulating layer. The foam bubbles are more efficient at absorbing heat than plain water, whether it is in the form of a solid stream or small droplets. CAFS can be discharged from both handlines and master stream devices.

Class A foam, which is itself a new and advancing fire suppression technology, acts primarily as an agent to reduce the surface tension of water. Reducing surface tension makes water more efficient as an extinguishing agent, particularly on cellulosic materials, because the water can easily soak into porous materials instead of running off. Additives to reduce surface tension are not new; “wet water” has been used for decades to fight fires in baled cotton, hay, and other densely packed natural products, as well as mattress and cotton-stuffed furniture fires. Modem Class A foams have improved the efficiency and effectiveness of surface tension reduction agents and are rapidly gaining acceptance in the rural environment where water supplies are often limited to the amount of water that can be delivered to the scene of a fire on fire suppression vehicles. Where water is scarce, an agent that improves the efficiency of each gallon of water can be very valuable.

Foaming agents are normally associated with Class B fires, where they are used to form a bubbly insulating blanket that can float across the surface of a burning flammable liquid, insulating the fuel from radiant heat and preventing flammable vapors from escaping to the atmosphere. Surfactant agents are introduced in Class B foams to create a durable surface membrane while the mass of bubbles adds insulating qualities. The formulation of Class B foams depends on the particular fuels it is intended to be used on, since the agent must be able to resist breakdown by the product.

Class A foams have several similar properties to Class B foams, but they do not have to be formulated to form a vapor tight surface over a hydrocarbon or other type of flammable liquid. Both types of foam solutions are created by introducing a percentage of foam concentrate into a water stream. Class A foams can be produced with a much lower ratio of foam concentrate to water, when compared to Class B foams, and have many properties that are quite similar to dishwashing detergents. While Class B foam concentrates are used at mixing rates of 3 to 6 percent, (3 to 6 gallons of concentrate per 100 gallons of mixed foam solution), Class A foams are normally used at rates of less than 0.5 percent (one half gallon per 100 gallons of mixed foam).

When used in a wildland environment, CAFS has been very effective as an extinguishing agent and as a barrier to protect exposed fuels from ignition. The reduced surface tension allows the moisture to soak into burning trees and other forms of vegetation, cooling the burning fuels below their ignition point and moistening the fuel to inhibit reignition. On exposed fuels the moisture penetrates the surface while the foam bubbles form an insulating layer to shield the fuel from radiant heat. Applied ahead of a fire it can be used to form a moist fire break in grass or brush, or it can be applied to structures to protect them from ignition as a fire passes over or flaming brands land on rooftops.

The agencies that protect wildland areas have quickly adopted CAFS as one of their most effective weapons, recognizing its ability to make the most efficient use of the limited amounts of water they can carry on their vehicles. The first CAFS units were wildland fire vehicles, modified by adding foam proportioners and air compressors. Newer designs for wildland vehicles were developed around more advanced proportioning systems and improved foam concentrates, particularly to address the mission of wildland interface fire control. CAFS has proven to be particularly effective in protecting exterior surfaces of exposed structures in areas where the water supply is limited, since it can be proportioned to create a sticky mass that will adhere to walls and roofs to create a durable moist insulating barrier.

The application of CAFS to interior structural fire fighting is a spin-off from wildland fire suppression. The crews that protect wildland areas are often called to fight structural fires in the wildland areas and adjacent communities. They soon discovered that CAFS, as well as non-aerated Class A foams, were extremely effective agents for interior fire fighting, reducing the time to control fires, reducing the amount of water that is needed to control and extinguish the fire, and successfully inhibiting rekindles, even with minimum of overhaul after the fire is controlled. Exactly how CAFS extinguishes Class A fires is not well understood, that it can act as an effective extinguishing agent gives it promise for use outside of the wildland arena.

THE FIELD TEST PROGRAM

The technology transfer of both Class A (non-aerated) and CAFS has brought these systems from the rural and wildland environments to the urban environment. The invitation to test CAFS was extended to the Boston Fire Department from the United States Fire Administration, as a demonstration project to evaluate the effectiveness and limitations of CAFS in a high activity urban environment. The department was considered for several reasons:

- Boston is a large city, densely populated, with a mixture of building construction types and styles, ranging from old to new.

- The relative extremes in climate would permit an examination of the influence of climate on CAFS performance.

- The number of working structure fires in Boston is such that, if properly situated and assigned, a CAFS unit would get a sufficient workload for a reliable examination of the system.

- The Boston Fire Department has demonstrated a history of experimenting with technologically progressive fire suppression efforts. In 1992, the Boston Fire Department conducted a field evaluation of non-aerated Class A foam with Engine Companies 5 and 16.

- The Department had already completed other projects and cooperative undertakings with the USFA.

Test Objectives

The overall objective of the test program was to evaluate the effectiveness and suitability of CAFS as a fire fighting agent in an urban environment. The analysis was intended to weigh the costs and benefits of installing CAFS on urban apparatus, the relative effectiveness of CAFS versus water for interior and urban fire suppression, and the positive and negative operational characteristics of CAFS that would influence a decision on whether or not to install CAFS on new vehicles.

An important consideration of the study was to identify any critical deficiencies or potential hazards that would cause CAFS to be considered unsuitable for urban use or that would require special precautions.

Anticipated Advantages and Disadvantages

Current users and proponents of CAFS have identified several positive characteristics that, if valid, could make it a very attractive addition to the arsenal of urban fire departments. On the other hand, several issues of concern have been raised regarding potential drawbacks. The study was designed to evaluate the practical and operational validity of the positive attributes, to see if they were accurate and significant, and to determine whether any of the potential negatives were major problems or disqualifiers.

The anticipated positive characteristics were:

- Faster attack using tank water
- Faster knockdown of fires
- Fire control with fewer gallons of water
- Reduced need for overhaul to prevent rekindles

- Reduced water damage
- Reduced exertion by firefighters to advance and operate handlines
- More efficient exposure protection

Other considerations for evaluation included:

- Since heat absorption is the principal fire control mechanism of both water and foam, is there a concern that the reduced water volume flowing from a CAFS attack line could be insufficient to knock down a challenging fire or to prevent flashover in a dangerous situation?

- Would the hose line be vulnerable to kinking, resulting in a loss of flow to the nozzle?

- Would a compressor failure leave firefighters in a vulnerable position without an adequate flow and discharge pressure to attack the fire?

- Is the hardware reliable enough for heavy duty use?

- Are maintenance requirements or costs excessive?

- Is the total cost of the system, including maintenance, plus the cost of the foam concentrate, excessive compared to the potential benefits?

Each of these issues, with the exception of cost calculations, was considered in the evaluation. Since the focus of this first field test project was operational characteristics rather than costs, installation and maintenance costs were not tracked and the cost of the foam was not calculated. There was also no attempt to quantitatively compare actual or potential differences in fire or water damage, although qualitative observations of these characteristics were recorded.

System Components and Installation

The CAFS equipment was retrofitted at the Boston Fire Department's Maintenance Division on Engine 37, a 1987 Emergency One, 1250 gpm pumper, equipped with a 750 gallon water tank. This particular vehicle has a short wheelbase, with limited hose load capacity, to allow maneuvering through the narrow streets of the city. The foam system was designed to discharge through two 2-l/2 inch outlets and through the deck gun. An existing rear 2-l/2 inch discharge and a new discharge, added at the Officer's side panel, were used for the CAFS handlines. A special manifold was also added and connected to the deck gun on top of the vehicle.

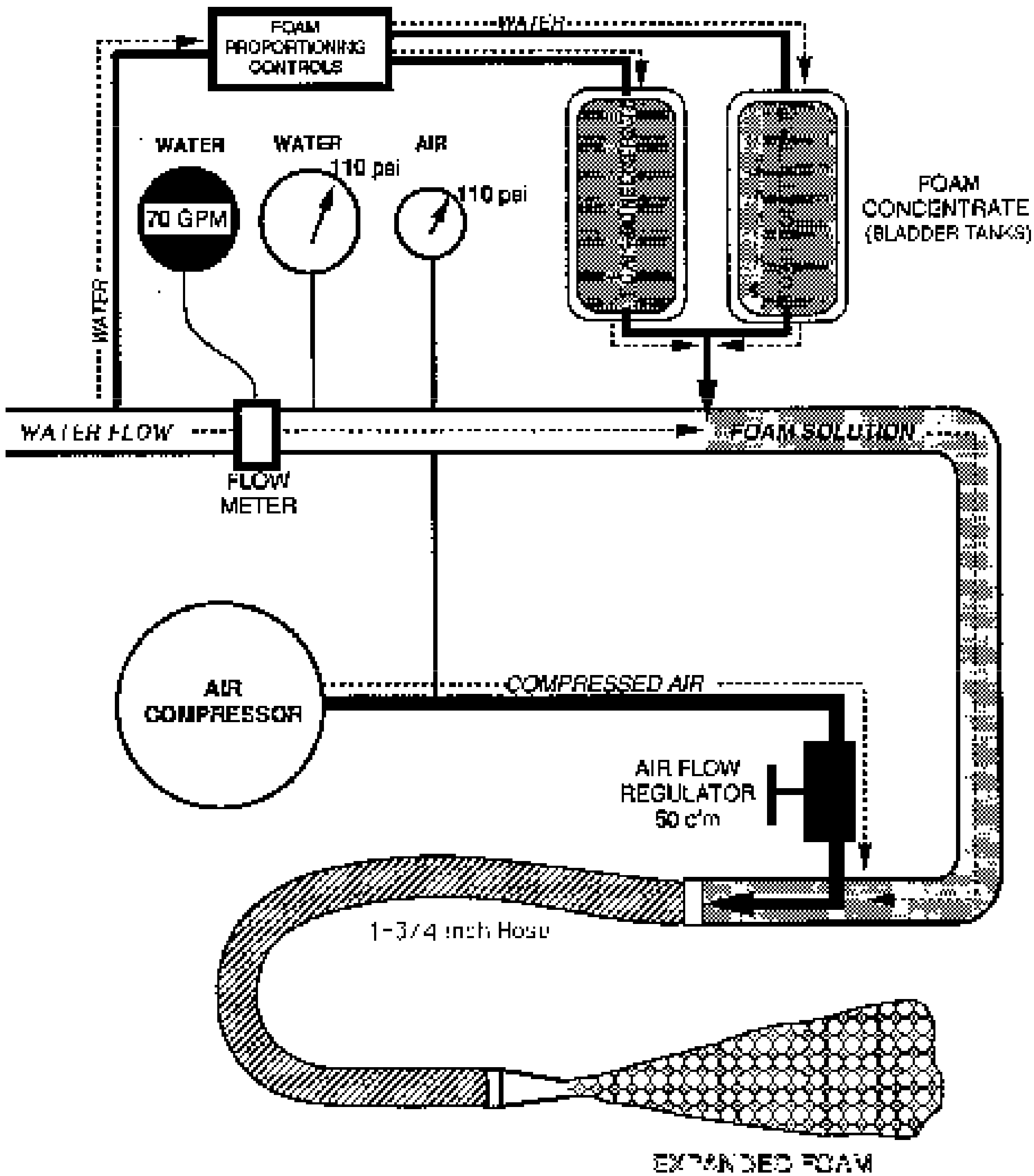
The 2-l/2 inch discharges were configured to supply l-3/4 inch handlines equipped with l-1/8 inch straight bore nozzles. The side discharge was connected to a crosslay with 150 feet of l-3/4 inch hose, backed-up by 100 feet of 2-l/2 inch hose. The rear discharge was connected to a 400 foot l-3/4 inch line.

The installation included twin variable rate, bladder type foam proportioners and a 200 cfm, oil operated, water cooled air compressor. (See diagram of complete system on the following page.) This equipment was installed in the midship area of the vehicle above the pump. A 13 gallon concentrate holding tank was installed adjacent to the crosslays. Four S-gallon cans of Class A foam were also carried on board the apparatus, to provide a total capacity of approximately 53 gallons of concentrate (10 gals. each proportioner, 13 gals. holding tank, and 20 gals. in S-gallon cans). The foam concentrate was injected from either of the bladder type proportioners into an add-on discharge manifold that was attached to the pump casing. The water/foam mix could then be discharged through both of the outlets and the deck gun. The compressed air was injected into the stream just prior to the mixture leaving an outlet. Check valves were used in both the liquid and air lines to prevent any backflow.

To place the system into operation was a simple three step process. The pump operator would:

1. Engage the pump prior to exiting the cab. At the same time, the air compressor would be engaged, with the pressure preset at 110 psi.

2. The operator would then choose either one of the two proportioners and turn the operating valve to the "FOAM" position, allowing foam concentrate to enter the pump. A metering valve allowed the concentrate flow to be modulated between 0.1 percent to 0.8 percent, with 0.3 percent the normal setting. The pump was used to raise the water pressure to 110 psi, equaling the air pressure. Air and water pressures were always maintained at equal levels to ensure that the check valves would open. The flows would be



CAFS - System Design & Major Components

adjusted by volume, depending upon the consistency of foam desired.

3. Using a digital gauge to indicate the liquid flow rate, the appropriate discharge gate would be opened to allow the water/foam solution to charge the hoseline. The operator would wait 10 seconds before opening the compressed air discharge valve, adjusting the pressure on an analog gauge. The delay was added to avoid a long wait for liquid to be discharged at the nozzle.

The compressed air had the tendency to travel much faster than the liquid, thus the air raced ahead and would have to be bled off.

The consistency of the foam could be adjusted from "wet" to "dry" by varying the settings to provide a lower proportion of water to expanded foam. Wet foam could be described as soapy looking water while dry foam would appear more as a shaving cream consistency. Wet foam was used initially for attacking interior fires, while dry foam was used during the overhaul stages. Dry foam was also used to extinguish dumpster fires, auto fires, compactors, and outside fires. Dry foam has to be closely monitored since insufficient water content may not extinguish a fire. Either way, it was the water content carried by the foam that knocked down flames or was absorbed into hot spots to extinguish the fire.

A simple chart with desired settings (see below) was attached to the pump panel to guide the pump operators. After some practice, all members could easily adjust controls to provide wet or dry foam when ordered.

FOAM TYPE CHART		
Hose Size	**Wet Foam**	**Dry Foam**
l-3/4 inch	70-90 gpm 50-70 cfm	50-70 gpm 70-90 cfm
2-l/2 inch	100-130 gpm 70-100 cfm	80-90 gpm 100-120 cfm
Deck gun	150-200 gpm 80-110 cfm	100-150 gpm 120-150 cfm

OPERATIONS

The primary attack capability that was used for the structure fires during CAFS evaluation was the 400 foot l-3/4 inch attack line with l-1/8 inch straight bore tip. This did not preclude the use of 2-l/2 inch hose where conditions warranted, such as well involved structures, large area warehouse type occupancies, or commercial occupancies which have greater fire loads than residential structures. The l-3/4 inch hose is quicker to stretch, lighter in weight, and flows approximately 150 gpm when proper pump pressures are supplied.

The effectiveness of this attack line was compared to a regular 2-l/2 inch hoseline flowing plain water.

Two firefighters could easily handle and advance a fully charged CAFS line. The flow through the hoseline is a mixture of foam solution and compressed air. The entrained air reduces the density of the flowing stream, which allows the hose to be more flexible, as well as lighter in weight, so firefighters can advance and maneuver the charged line more easily. A l-3/4 inch hose filled with water weighs approximately one pound per foot, while the same hose filled with CAFS weighs about half as much.

Nozzle reaction is reduced with CAFS because of the reduction in mass of the flowing stream. The compressed air adds energy to the stream, which helps propel the foam mixture through the hose, which results in a significant reduction in the apparent friction loss as compared with plain water.

Compressed air accumulates at the nozzle before it is opened, attaining the same pressure as the onboard compressor. When first opened, this volume of trapped air is rapidly released causing a jolt reaction that can pull the nozzle right out of the hands of an untrained firefighter. After the trapped compressed air is released, nozzle reaction is immediately reduced.

The nozzle used during the test was a l-1/8 inch straight bore tip. This gave the stream better projection and definition than the open hose butt that is commonly used in woodland fire suppression. The stream was directed efficiently with this nozzle. The “throw distance” is comparable to that of a water stream.

The flow through the hose is a mixture of water and compressed air. The compressed air expands rapidly as it leaves the nozzle creating a flow of expanded foam bubbles, as opposed to a dense and well defined water stream that would be expected from the same nozzle. The anticipated expansion ratio is in the 4:l or 5:l range, which delivers approximately 280 to 350 gallons of expanded foam per minute at a 70 gpm flow rate. (It might be helpful to picture the water as being carried on the surface of each air bubble, rather than as a solid mass.)

The friction loss characteristics for a CAFS line as compared to a hoseline delivering water are as follows: A water stream using a l-1/8 inch straight bore nozzle at 50 psi nozzle pressure would flow approximately 250 gallons per minute. The water stream would have a friction loss of almost 100 psi per 100 feet in l-3/4 inch hose, so with 400 feet of hose the pump discharge pressure would have to be in the order of 450 psi to deliver an effective stream. At this pressure the line would not be practical or safe to operate.

A more realistic comparison would be a 400 foot l-3/4 inch hoseline, with a variable pattern fog nozzle, operating at 100 psi nozzle pressure, flowing approximately 150 gallons of water per minute. To accommodate friction loss, this line would have to be supplied with a pump discharge pressure of 240 psi. To keep the pump discharge pressure below 200 psi, this line would have to be limited to 200 feet in length. During the CAFS test, pump pressures were kept at 110 to 150 psi and hose stretches of up to 400 feet were employed effectively. The volume of finished foam was on the order of twice the volume of water flowing from the nozzle.

The CAFS stream is easily projected through the air, but has very little physical penetration capability as compared to water. A straight stream of water has strong penetrating power due to the mass and velocity of the water, while expanded foam bubbles have very little mass and no appreciable penetrating power. The CAFS stream does not have the capability to “blast through” plaster walls and ceilings, for instance, to reach concealed fire within a void space, or to burrow into stacks of burning materials to get to a fire that is deep-seated in a pile. On the other hand, the foam in the “dry” form is much more effective when injected into a void space and can soak through stacked material much more efficiently to reach deep-seated fire in a pile. This may be attributed to the fact that the high surface tension of plain water resists soaking into materials. Water flows down hill, while fire bums upward. CAFS, in the “dry” form, clings and sticks to materials when applied. As the air bubbles break down, the water that formed them, is released and soaks into burning or exposed materials.

The deck gun was also available for CAFS application in defensive situations. It was particularly suited for exposure protection where the clinging ability of dry foam could be used to coat a surface. Unlike plain water, there is no need to provide a continuous coating of water film to protect the exposed surface. A layer of foam could be sprayed over the surface protecting the underlying material and need only be monitored as it slowly broke down. The deck gun was used only twice during the test period, once to protect an exposed exterior wall and once to project foam into a cockloft. It appeared to be effective in both instances.

Strategy and Tactics

There were two tactical approaches used by Engine 37 when dispatched to either reported or actual structure fires. The standard procedure used in the Boston Fire Department is that each of the three first due Engine Companies, arriving on a transmitted box alarm, will secure a water supply from three separate hydrants. This is accomplished by using either the four inch front intake hose or by laying a feeder line of four inch hose, up to 600 feet in length, from a hydrant. The remaining crew members advance a line, as ordered by the Company Officer, into the structure. The Engine Chauffeur, when ordered, then charges the line using available tank water of 500 or 750 gallons. Depending on the flow rate at the nozzle, the Chauffeur has several minutes to change over from the limited tank supply to the continuous supply provided by a hydrant. If all goes according to plan, the members attacking the fire are not even aware of the change from tank to hydrant.

When using CAFS, the 750 gallon water tank on Engine 37 allowed for 10 minutes of fire attack, which was ample for the great majority of situations. When arriving as one of the first alarm companies, a hydrant would be secured by Engine 37 to provide water to any additional engines should the incident escalate to greater alarm proportions. When dispatched to fires outside the first alarm assignment, the Chauffeur would position the Engine as close as possible, shortening the stretch required to reach the fire building. He would then obtain a source of water from another engine company. This caused some confusion for other units that did not understand the CAFS capabilities or the fact that Engine 37 could operate for more than 10 minutes before a supply line was needed.

Observations **—** The use of CAFS for initial attack significantly reduced the urgency of securing a supply line or hooking up to a hydrant. The great majority of incidents were controlled using tank water only and a supply line became a secondary consideration. Car fires were extinguished with as little as 100 gallons of water. Normal size dumpsters were controlled with 100 to 150 gallons. In one instance, a 30 cubic yard construction dumpster was completely extinguished with 350 gallons. Outside fires were extinguished with a sweep of the nozzle. At a majority of the structure fires where Engine 37 operated, the output of CAPS never used all of the 750 gallon tank, however, at every structure fire a precautionary supply line was stretched to a hydrant.

Where exposure protection is a critical concern, the superior exposure capability of CAPS could be used effectively by proceeding to a position from which the on-board tank capacity could be applied through the deck gun. Since CAPS has much more durable exposure protection qualities than plain water, it would be extremely effective in a pump-and-roll situation to quickly blanket several exposures. Pump-and-roll is often used in the wildland fire setting to protect threatened properties; however, most municipal fire engines are not equipped with this capability.

Operational Characteristics

During the test program Engine 37 used either the CAPS attack line or the deck gun on 218 reported occasions. The CAPS handline became the standard attack line for almost all fires, including structures, vehicles, and trash fires. The tables below summarize the CAPS fire experience. There were about a dozen situations where the CAPS line was used as the initial attack line on a significant working structure fire. In each of these cases, the opinions expressed by the firefighters using the system were positive. There were many structure fires where the line was used, but as a back-up line or one of several lines operating on the fire. The results of all these field test situations were recorded and comments were noted on field test evaluation forms. Results are summarized in the following tables:

CAFS Fire Response Experience	
Direct Offensive Attack	99
Overhaul	47
Total Fire Experience	**146**
Stood by, Returned by Chief, Did not operate, Used conventional extinguishment	72
TOTAL RUNS	**218**

CAFS as Extinguishing Agent	
More effective than water	119
As effective as water	26
Less effective than water	3
TOTAL	**146**

CAFS Hose Line Movement	
Easier than water	133
Same as water	10
More difficult than water	2
No response	1
TOTAL	**146**

CAFS Hose Kinking	
Not a problem	134
Some problem	2
No response	10
TOTAL	**146**

Problems with CAFS	
No problems	139
Slippery surfaces	1
Strong odor of foam	1
Skin irritations	5
TOTAL	**146**

The observations of the company officers and firefighters who operated with the CAFS unit are presented below. They have been consolidated, since in the great majority of cases they were very consistent. Despite the fact that the members of Engine 37 developed an understandable pride in the CAFS unit, their comments and observations were candid and thoughtful. There were only a few inconsistent comments and these generally related to a specific situation, as opposed to the majority of cases.

- Crews felt CAFS was equal to or superior to plain water, with all other conditions the same. The crews felt that in almost every case the fire suppression effectiveness of the CAFS line was at least equal or equivalent to the water stream that they would have used in the same situation. (Their normal interior attack line is a l-3/4 inch hose with a 150 gpm combination nozzle.)

- They felt that the CAFS line was clearly superior in terms of weight and maneuverability. It was much less fatiguing to advance, operate, and extend than a water stream, particularly when going up or down stairs.

- The ability to attack with tank water meant that they did not have to take the time to lay supply lines or pick up wet supply hose. This gave them a time advantage attacking the fire. Also, one of the benefits from the air compressor was the ability to blow all liquid from the hose before repacking it back on board.

- They did not notice an appreciable difference in knockdown capability for most fires. *(Note, however, that the knockdown was achieved with about half the flow rate of a conventional water stream.)*

- The CAFS application greatly reduced the need to overhaul contents after an interior fire. It soaked into and through materials to fully extinguish all fire, much more effectively than water.

- The foam stream did not have the “punch” of a water stream, so a different tactical approach was needed when fighting interior fires. This was not reported to be a problem in any of the fires.

- Where fire was burning in a concealed space, such as a wall cavity or above a ceiling, it was necessary to have someone open a hole to apply the stream. However, when the CAFS stream was applied through the hole it was much more effective than water at reaching and extinguishing pockets of fire. When applied into a cockloft, it soaked into all of the insulation and extinguished the fire.

- The firefighters did not feel an appreciable difference in heat absorption with the CAFS line and they did not have a problem on the few occasions that the compressor quit working during the attack. The built-in fail safe of the CAFS was, if all else failed, plain water could be pumped through the line already stretched. By backing out to a safe refuge and regrouping, another attack on the fire was still possible.

- Kinking of the hose was not a problem, as long as they paid attention to where they were going. It was a benefit when they wanted to extend the line because they could completely stop the flow to add hose by manually kinking the line.

- The most obvious advantages of CAFS were seen with vehicle and dumpster fires, where the CAFS virtually eliminated the need for overhaul. A brief application of CAFS completely controlled and extinguished the fires. There was no need for lengthy overhaul. Large dumpsters, which normally require extensive overhaul and a supply line from a hydrant were extinguished with less than 200 gallons of foam solution.

- There are several hospitals in Engine 37's area that use large containers for contaminated waste and sharps. Fires in these containers were handled without having to climb in or dump the contents for overhaul. This was considered to be a <u>major</u> advance.

- Footing on a fire ground is never completely without obstacles, whether it be several inches of water or piles of lathes, plaster or other fire debris. The slippery conditions caused by the foam were not a problem to the crews that were used to working with it. To other members it was something strange and foreign.

A few other observations were made by other companies and officers. These were:

- The foam obscures the floor, hiding hazards that firefighters could slip on or trip over. It also makes the footing slippery.

- Although members' facepieces, at times, would be covered by foam, once this was understood, a simple wipe with a gloved hand removed it. A side benefit was a cleaning effect from the detergent base of the foam solution.

- A fire investigator complained that the foam covered up the fire area, making it impossible to find a point of origin. The investigator did not have time to wait for the foam blanket to break down to proceed with the investigation. The other view is that foam aids investigation. It doesn't dislodge and disorder room contents, fixtures, etc. the way hose streams do. It doesn't wash away paper trailers, etc., and in fact safeguards some physical evidence.

- The Boston Fire Department Chemist noted that the foam residue could mask or complicate the detection of hydrocarbon accelerants in the rubble of a fire. A more sophisticated analysis would be needed to isolate the foam from any evidence of accelerants taken from the scene of a fire.

- Some of the District Chiefs, particularly in surrounding areas, were concerned when Engine 37 came in to their fires with the l-3/4 inch line as a back-up and used tank water instead of a supply line from a hydrant. They were not convinced that the CAFS was an equivalent to a 2-l/2 inch back-up line supplied from a hydrant.

No problems were reported with hot or cold ambient temperature operations. The CAFS was used in temperatures ranging from around 15 OF to almost 110 °F, with no significant changes in performance reported.

Controlled Fire Experiments

In addition to the field test of CAFS by Engine 37, a series of controlled fires was conducted at the Massachusetts State Fire Academy. The experiment was an effort to conduct a more objective comparison of the effectiveness of a CAFS with a conventional fire stream in interior structural fire fighting by using the same fuel load and fuel load configuration in each fire. The tests measured the number of gallons of agent (CAFS or water) used and the time required to extinguish each fire. The tests were not intended to be rigorous, rather they were meant to permit an objective, measurable comparison of the effectiveness of CAFS in interior structural fire fighting and to validate the field experience.

Three experiments of two fires each were conducted. In each experiment, one fire was extinguished using a conventional fire stream from a l-3/4 inch hose with an adjustable nozzle on the straight stream setting; the other fire was extinguished by the CAFS discharged from a l-3/4 inch hose with a smooth bore nozzle. Slightly different test scenarios were devised for each experiment to determine what influence, if any, the effect of head pressure, ventilation and unrestricted air movement, and heat containment and oxygen deprivation had on the performance of CAFS versus water.

Every attempt was made to keep the variables for each set of fires identical and to control for mitigating factors. The fires were fought within the organizational structure of the Incident Command System and the crews were rotated between the water and CAFS to control for experience and familiarity. As a "control," the fire fighting crews were from Engine 37. The officers, pump operators, and hosemen were trained to a level of proficiency that was already demonstrated during the field test.

Engine pressure, nozzle pressure, flow rate, and foam/air/water mixture were predetermined and remained constant throughout each test burn. Nozzle spray patterns were the same for both water and CAFS, and the crews were instructed as to the amount of distance they could penetrate each burning room for initial extinguishment. In each experiment of two fires, fire fighting began when the temperature recorded reached a predetermined level. The crew was not instructed to fight the fire in any specific manner, but was encouraged to fight the fires as they would in actual practice. The captain radioed when the fire was extinguished. The start time, stop time, and gallons of agent used were recorded.

Several factors should be noted:

- No attempt was made to evaluate specific manufactures of foam, air compressors, foam proportioning devices, hoses, or nozzles.

- The effects of hose line crew size, ease of hose line advancement, and hose line kinking were not evaluated.

- Specific fire fighting strategies or tactics with respect. to the use of CAFS were not considered or evaluated.

- For purposes of comparison, CAFS and conventional water streams were considered as equivalent.

- No attempt was made to determine the limitations or specific applications of either agent.

- No attempt was made to determine the effect of either agent on post-fire investigations.

Observations **-** Of the two criteria selected, gallons of agent used and time to extinguish, the CAFS performance was better than water in every experiment in terms of either time to extinguish, gallons of agent, or both. These criteria are shown in the table below.

Controlled Fire Experiments: Water versus CAFS			
Experiment #	Measure	Water	CAFS
Experiment # 1	Time (minutes)	1:48	0:59
	Gallons of agent	69	30
	Apparent gpm	38.3	30.6
Experiment # 2	Time (minutes)	1:06	1:06
	Gallons of agent	100	36
	Apparent gpm	90.9	32.7
Experiment #3	Time (minutes)	2:48	1:39
	Gallons of agent	90	90
	Apparent gpm	32.1	54.5

Further Observations

***Controls* —** The CAFS operating controls were complicated and were not arranged in a convenient manner on the pump panel, making it difficult to follow the steps in the required sequence and to set all the discharge pressures. The sequence is much more complicated than simply delivering water and requires more skill and attentiveness from the pump operator while the system is in operation. These problems are at least partly attributable to the fact that the installation was a retrofit on an existing vehicle. The policy in the Boston Fire Department is to rotate the driver/operator position among all the firefighters in the company; all members of Engine 37 had to be trained to operate the system.

These problems could be partially alleviated in a vehicle that was initially designed for the installation of the CAFS system. The controls could be simplified by automating the sequential functions and installing digital pressure and flow balancing controls as part of the standard CAFS package.

***Maintenance & Reliability* —** The limited space that was available behind the pump panel made the installation fairly difficult and resulted in a crowded work space for maintenance and repairs. This consumed extra hours for both installation and the frequent repairs that were necessary to keep the system operational.

There were several problems encountered with the reliability of the major system components, particularly the air compressor and the bladder-type foam tanks. The system requires a large, heavy duty air compressor which is driven by the vehicle motor through a power take-off. The compressor overheated several times and had to be repaired; at the end of the test period it was inoperative due to overheating and needed servicing or repairs. The compressor problems appeared to be related more to the limitations of the retrofit installation rather than to the equipment itself.

The air compressor was powered by a PTO hydraulic pump. The hydraulic fluid was circulated through a closed-loop system and cooled by water through a heat exchanger. Water for the heat exchanger was taken directly from the fire pump, passed through the exchanger where it absorbed heat from the oil, and returned to the 750 gallon on-board tank. During the early stages of the test, a small rock entered the water cooling line, blocking the flow completely, eventually causing the compressor to overheat. This was not detected until a burning odor was noticed and a check of the system revealed the problem. (The temperature gauge was small and difficult to read.) There were continuing problems with the overheating of the compressor for the duration of the test program, which caused down time and diverted attention from the performance of the Class A foam to the problems with the equipment. These problems could have been avoided if there had been a better filter in the water line and a high temperature alarm had been installed.

The major operational deficiency with the foam proportioning system relates to the bladder tanks that are used to store and proportion the foam concentrate. The bladders developed leaks and required several bladder replacements during the test period. On many occasions one of the two tanks was out of service awaiting parts for repair. However, the loss of one tank was only a problem for long duration incidents, as either tank has enough capacity for most incidents. The bladder system does constitute a reliability and maintenance problem that needs attention. A different type of proportioning system, which does not rely on bladder tanks, would be preferable.

The leaking tanks and spillage of the foam concentrate when refilling the tanks created hazardous conditions on the steps and running boards of the apparatus, as the concentrate is very slippery. These problems could also be reduced on a vehicle designed for CAPS, as opposed to a retrofit installation.

LESSONS LEARNED

1. Extinguishing: Agent.

The results of both the field test and experiments cannot be called conclusive for several reasons. The evaluation was limited by the extent and duration of the program and the relatively few occasions in which the CAPS technology was tested against challenging fire situations. The CAPS provided an effective extinguishing capability with less manual effort than water. It also reduced the labor that would be required for overhaul, particularly in the case of vehicle and trash fires, especially those involving medical wastes.

2. Exposure Protection.

The exposure protection properties of CAPS were verified, which could be an extremely valuable asset in a few very critical situations. The adhesion to vertical surfaces is very effective for exposure protection.

3 . Water Usage.

The CAFS technology provided a very capable unit using only the 750 gallons of water carried on the attack vehicle; however the value of this capacity is difficult to measure in an urban environment where there is a hydrant on every comer. The ability to operate more effectively with a limited water supply would be more valuable in an area without hydrants or during a water shortage. Insurance companies may be interested in the ability of CAFS to extinguish fires, while reducing water damage. Interested insurance groups could possibly be convinced to support the adoption of this technology.

4. Equipment.

The field installation suffered from the shortcomings and compromises of a retrofit installation on an existing vehicle that was not designed to accommodate the equipment. Clearly, the hardware and installation would have to be improved upon to make CAFS a viable candidate for installation in a busy urban fire company.

FURTHER READING

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