

**THE USE OF COMPRESSED AIR FOAM TO ENHANCE FIRE FIGHTING
WATER SUPPLIES IN MONTGOMERY COUNTY, MD**

EXECUTIVE DEVELOPMENT

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ABSTRACT

The problem was the Montgomery County, MD fire rescue service is unable to deliver a stated fire flow goal equivalent to 500 gallons per minute (gpm) for 30 minutes (min) in many areas of the county.

The purpose of this applied research project was to explore the possibility of using compressed air foam systems, (CAFS) as a method to deliver an equivalent fire fighting capability to the 500 gpm for 30 min fire flow expectation with less water.

Historical research, including the literature review, was used to identify and summarize known information regarding CAFS. The review included experiences gained by others who have tested, or used, CAFS. Evaluative research was used to conduct a series of live test burns in a vacant high-rise building to verify the effectiveness of CAFS when pumped through a dry standpipe riser, while measuring agent usage, temperature drop rates, and time to extinguishment parameters.

The research questions examined were

1. What are the advantages and disadvantages of CAFS?
2. Can CAFS make a positive contribution to fire fighting capability on structure fires?
3. What experience do other fire departments and agencies have with CAFS in structural combat?
4. What critical elements are necessary to successfully deploy CAFS?

The procedure started with a literature review to provide a current analysis of CAFS usage by identifying the advantages, disadvantages, limitations and past

experiences using the technology. Live burn testing was initiated in a high rise building to validate the work of others and to provide new research regarding CAFS when pumped through a standpipe riser. Test data was evaluated carefully to classify water and foam use characteristics while monitoring the impact on fire fighting crews.

CAFS was found to extinguish similar fires in one-third the time, while using less than one-third the amount of water. The quality of finished foam was not degraded after pumping through the various hose and pipe diameters. Separation of air and water components did not occur resulting in extinguishing parameters that were consistent with previous testing.

Future recommendations were developed to pilot test a CAFS equipped pumper in Montgomery County, and to develop a research partnership with third party testing facilities in or near Montgomery County to validate the role of CAFS for interior fire fighting.

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INTRODUCTION

The Montgomery County, Maryland, Fire Rescue Service (MCFRS) is a combination department that employs 927 full time career personnel, 478 length of service awards program certified (LOSAP) volunteer personnel, and 63 civilians (D. Shaw, and K. Stewart, personal communication, May 28, 2002). Together, they provide fire, rescue, and emergency medical services to a population of approximately 875,000 persons. These services are deployed from 33 stations located in a combination of urban, suburban, and rural settings that span just less than 500 square miles of land area. Minimum staffing is such that with few exceptions, first due engine companies respond with three personnel.

In July of 2000, the Montgomery County Fire Rescue Service approved a fire suppression recommendation to “deploy resources to achieve a minimum stated fire flow goal of 500 gallons per minute (gpm) for 30 minutes in all areas of the county (MCFR, 2000, p. B-2).” Approximately 40 percent of the county land mass is without fire hydrants. The lack of fire hydrants in rural areas of the county is compounded by a continual build-out of very large, single family dwellings that have resulted in high challenge fires that stress available suppression forces.

The problem is that the Montgomery County, Maryland Fire-Rescue service is unable to deliver the stated fire flow goal equivalent to 500 gpm for 30 minutes in many areas of the county. This was identified in the Executive Summary of the Water Supply Study Implementation Workgroup (WSSIWG) in their April, 2000 report to the county Fire Rescue Commission:

“Without these improvements, the MCFRS suppression capability will not keep pace with the increasing level of fire risk associated with growth in the county, particularly in rural areas and rural-suburban fringe areas (MCFR, 2000, p. 1).”

Compressed Air Foam Systems (CAFS) technology has been available to the structural fire service for over two decades. With this technology came the promises of less water used, greater fire knock down capability, lighter hose lines, less stress on fire fighters, and increased fire fighting efficiency (Stern, Routely, 1996 p.3). Although successfully deployed in many departments throughout the United States, CAFS technology has failed to find acceptance in Montgomery County, MD.

If CAFS can deliver according to the accolades made by the many supporters of the technology, this added fire fighting capability could have a direct impact on the MCFRS ability to meet the stated fire flow goal.

The purpose of this applied research project is to evaluate the potential of using Compressed Air Class A Foam as a method to deliver an equivalent fire fighting capability to the 500 gpm for 30 minutes fire flow expectation using less water.

Historical research, including the literature review, was used to identify and summarize known information regarding CAFS. The review included evaluations by other organizations who have gained experience with CAFS. Information found was compared to circumstances unique to Montgomery County, Maryland. Evaluative research was used to conduct a series of live test

burns in a vacant high-rise building to verify the effectiveness of CAFS when pumped through a dry standpipe riser, while measuring agent usage, temperature drop rates, and time to extinguishment parameters.

The research questions examined were

1. What are the advantages and disadvantages of CAFS?
2. Can CAFS make a positive contribution to fire fighting capability on structure fires?
3. What experience do other fire departments and agencies have with CAFS in structural combat?
4. What critical elements are necessary to successfully deploy CAFS in Montgomery County, Maryland?

BACKGROUND AND SIGNIFICANCE

Montgomery County is Maryland's most populous and most affluent jurisdiction. The County is located adjacent to the nations capital, Washington, D.C., and includes 497 square miles of land area. Nearly 40 percent of this land area lacks municipal fire hydrants or other reliable fire fighting water resources that are available on a year round basis.

According to the 2000 U.S. Census, there were 334,632 housing units in Montgomery County, of which, 68.7 percent were owner occupied. The average new, single family detached dwelling in Montgomery County sold for \$364,195., while the average resale value for existing homes was \$243,000. Annual new housing completions during the 1990s averaged 3,500 per year. The 2000 median household income for Montgomery County was estimated at \$74,280. Sixty

percent of the resident population had earned a college degree, while an additional 16 percent have attended some college (MCPBO, 2002).

Single family detached dwellings are typically the least regulated in the model building and fire codes. Therefore, it is not insignificant that most of the fires attended in Montgomery County are residential in general, and single family residential in particular. This is especially true in the outlying areas of the county that lack municipal water for fire fighting.

During calendar year 2001, MCFRS units attended a total of 3,012 actual fires of all types, resulting in a \$30,491,948 reported fire loss. Of those reported fires, 700 occurred in structures, while 466 of the structure fires occurred in dwellings. There were 11 civilian fire fatalities during 2001. In the three years prior to 2001, total fires attended ranged from 2,324 to 2,613, with reported fire losses ranging from \$10,974,379. - \$18,817,361. Civilian fire fatalities ranged from a low of three to a high of six during that time period. Dwelling type structure fires ranged from 431 to 727, (Bingenho, 2002).

Presently, the number of fire-rescue stations located throughout the county is unbalanced, with a disproportionate number of stations located in the urban areas. The consequence of this station location problem is increased response times to areas of the county where fire fighting water is a precious commodity. Two additional factors have also been identified.

First, the increase in response time to fires in the outlying areas has repeatedly allowed for fire growth beyond the compartment of origin prior to the arrival of suppression forces. As a result, first arriving suppression units are

confronted with high challenge fires that are occasionally beyond their capability to control with existing resources. Second, modern, lightweight construction of single family dwellings in these growing areas produce fires that burn with unusually high heat release rates. These fast, high intensity fires result in auto-extension to other areas of the structure very rapidly. Consequently, initial suppression forces can be easily overwhelmed. The average size of most of these new homes is frequently in excess of 2,500 sq. ft. It is not unusual to encounter single family dwellings in Montgomery County that are in excess of 4,000 sq. ft., nor is it unusual to find estate homes that are two to five times that size.

Efforts already underway to minimize the impacts of these developing problems include the passage of residential sprinkler legislation for new construction, revision of rural water delivery standard operating procedures, computerized mapping and pre-planning of static water assets, and standardization of large diameter hose (LDH) and appliance inventories throughout the county. Apparatus purchases have been initiated to provide for three additional large capacity water tankers, and one additional engine-tanker. The standard MCFRS pumper specification has been enhanced to increase pump capacity, provide additional discharges, and equipped to take full advantage of four-inch large diameter supply hose.

Four additional fire rescue stations have been recommended to improve service delivery in the growing areas of the county by FY08. The addition of these four stations will provide pumper service in 35 of the 37 proposed fire rescue stations. When completed, the ability to provide faster response times to

many of the areas of the county will be improved, as will the ability to assemble both equipment and personnel at a given incident. Nonetheless, it is unlikely that future staffing levels will be increased in the foreseeable future. Therefore, new technologies like CAFS offer the opportunity for improved fire fighting performance and increased efficiency while maximizing fire fighter safety.

If the advantages of CAFS for use on structure fires can be validated, additional work will be required to implement the technology as a component of the safe structural fire fighting strategy for Montgomery County. If CAFS fail to be effective for structural fire fighting use, then this research effort will provide necessary information for others to make informed decisions regarding the future use of this technology.

This Applied Research Project (ARP) is important for several reasons. First, the project offers the promise to increase the fire fighting effectiveness in Montgomery County by applying non-traditional technology to well known problems. Second, this effort relates to the course work found in the Executive Development program at the National Fire Academy (NFA). This ARP relates to the course material in unit ten, service quality, unit one, monitoring team performance, and several other broad based themes identified throughout the course. They include: problem solving, data analysis, creativity and leadership, and improving performance. Finally, this effort supports the United States Fire Administrations (USFA), operational objective “to promote within communities a comprehensive, multi-hazard risk reduction plan led by the fire service

organization”, and to a lesser degree the opportunity to “reduce the loss of life from fire to firefighters (NFA, 2001, p.II-2).”

LITERATURE REVIEW

The purpose of this literature review is to provide a comprehensive overview of existing data and information regarding compressed air foam. To accomplish this task, several questions need to be addressed. First, what is CAFS and how does the addition of compressed air foam solution affect the extinguishment of most structure fires? Second, what experience do others have with CAFS that can assist Montgomery County in their efforts to improve fire suppression capabilities? Dominic Colletti of Hale Products defines a CAFS as:

A CAFS consists of a water source, a fire pump, a foam proportioning system, an air compressor, and ancillary controls that tie all the components together for effective pump operation (1998, p.97).

Ron Rochna of the Boise, Idaho, Interagency Fire Center further develops the role of the compressed air in CAFS:

“The air compressor provides energy, which, gallon for gallon, propels compressed air foam farther than aspirated or standard water nozzles” (1991, p.14).

The tactical advantages of using CAFS are well documented and can be summarized as follows:

The reach of the fire stream is considerably longer than conventional fire streams. A CAFS produces uniform sized, small air bubbles that are very durable. CAFS generated foam adheres to the fuel surface longer and resists heat longer

than low energy foams. Hoselines containing CAFS are significantly lighter than low energy foam or plain water. CAFS allows effective fire attack on fires from a greater distance which improves fire fighter safety (IFSTA, 1996, p.77).

Additional advantages of CAFS as a structural fire fighting tool were identified by several authors (Brackin, et al., 1992, p.60-61). CAFS provides faster knockdown time do to greater heat transfer through the foam blanket. CAFS simultaneously attacks all three sides of the fire triangle while improving the wetting and penetrating capabilities of plain water. This is possible because it reduces the surface tension of plain water and has an affinity for carbon-based materials. The use of CAFS results in less foam concentrate and water usage which results in less water damage and reduced insurance losses. Additionally, fire fighter fatigue is reduced because the hose line is fifty to sixty percent air which reduces the weight by approximately one-half to two-thirds. Overhaul operations are enhanced, dropping the in service times for operating companies while simultaneously reducing the opportunity for rekindles. Finally, the shelf life of Class A foam concentrate is typically listed as twenty to twenty-five years (1992).

The versatility of CAFS cannot be overstated:

CAFS produce foam types ranging from wet to very dry. Therefore, the ideal foam type can be applied to each fire to maximize the effectiveness of water and personnel for each tactical fire control purpose (Colletti, 1998, p.103).

Foam consistencies for finished Class A Foam are divided into 5 types (IFSTA, 1996, p.123):

Type 1 foam (Very Dry). The air to foam solution ratio is 44:1. Proportioning rates are between 0.6 and 1.0 percent. Finished foam proportioned at this rate will produce a very dry, fluffy texture blanket that easily clings to vertical surfaces, will be slow to drain, and can be adversely affected by winds.

Type 2 foam (Dry). The air to foam solution ratio is 22:1. The foam is proportioned at rates between 0.5 to 0.6 percent. The finished foam will have a consistency close to shaving cream. This foam will not immediately run on vertical surfaces, but will drain quicker than Type 1 foam.

Type 3 foam (Medium). The air to foam solution ratio is 15:1. Foam is proportioned at rates between 0.3 and 0.5 percent. This foam will have the consistency of watery shaving cream and will not readily cling to vertical surfaces. Type 3 foam is considered the best compromise for all around use.

Type 4 foam (Medium-Wet). The air to foam solution ratio is 11:1. Proportioning rates are between 0.2 and 0.3 percent. This finished foam will have little if any body or shape. The very fluid consistency has an excellent ability to penetrate porous materials.

Type 5 foam (Wet). The air to foam solution ratio is 8:1. Foam is proportioned at rates of 0.1 to 0.2 percent. This is very watery, and will readily run off of vertical surfaces. This type finished foam is generally considered best for overhaul operations.

Since CAFS is primarily water based, a discussion of the extinguishing characteristics of water is appropriate.

According to the 18th edition of the National Fire Protection Associations (NFPA) Fire Protection Handbook, fires can be extinguished by physically separating the substance from the flame, diluting or removing the oxygen supply, reducing the temperature of the fuel(s) below the ignition temperature, or, by introduction of chemicals that modify the combustion chemistry. More often than not, several of these extinguishing mechanisms work together simultaneously (NFPA, 1997, p. 1-92).

The principle mechanism at work when water is applied to a fire is the cooling of a gasifying combustible fuel. Water has the ability to absorb more heat than any known element except mercury. The high latent heat of vaporization of water, (970.3 Btu/lb; 2260 kJ/kg) is four times that of any other non-flammable liquid. This means that water will expand at ratios up to 1700:1 when converted from liquid to steam. The specific heat of water is higher than most substances, (1 Btu/lb °F; 4.186 kJ / kg K) and is the physical property that makes water such an effective extinguishing agent. Water remains consistent over a wide range of temperatures and therefore is easily transported and pumped. Water is also a relatively heavy, stable liquid with a high density that allows it to be projected from nozzles. Finally, water has a high surface tension that permits it to be applied in a range of forms from small droplets to solid streams (NFPA, 1997, p.1-94). However, water is not a perfect extinguishing agent.

This notion is not new as Chief William E. Clark writes in the first edition of his textbook, fire fighting/principles & practices:

If one analyzes the facts, it becomes apparent that the process of extinguishing fire by water is cumbersome and generally costly...Such analysis would show that the cost of installing water mains large enough for required fire flow, the installation and maintenance of hydrants, and the acquisition and maintenance of fire department pumpers, hose and nozzles, make water a fairly expensive extinguishing agent...Thousands of buildings are destroyed annually in the presence of a fire fighting force with sufficient water and equipment...It can be seen that water is hardly the ideal way to extinguish fire. It is just the way we have adopted, concentrated on over the centuries, and learned to accept as the most practical. There must be a better way waiting to be discovered, but until then, our major effort should be to obtain the maximum benefit from the use of water as an extinguishing medium (Clark, 1974, p.16).

Water has long been the principle means of extinguishing fires. Most would argue that water is abundant, cheap, and easy to obtain. These assumptions have been accepted by custom and past practice in the fire service. "Barriers lie within both the people and the policies of the institution, the fire department (Liebson, 1995, p.25)."

Water can be a precious commodity in areas not serviced by municipal water supplies. The traditional response to this problem has been the purchase of suppression vehicles capable of transporting water to the fireground. There are inherent problems with this strategy.

Success is determined by factors that include: the distance the water must be moved, the quantities of water that can be delivered uninterrupted, and pumping the water with sufficient pressure and flow to provide an adequate delivery rate on the fire. With larger fires, these problems are further exasperated by getting water on all of the fire. Many times this is impossible due to available water, access problems, the high heat release rates of lightweight construction, structural integrity of the fire building, the accumulation of products of combustion in concealed spaces, limited staffing, and other impediments to practical fire fighting (1974).

The primary limitation of water as an extinguishing agent is its high surface tension, the same property that allows water to be applied in different forms. This property causes water molecules to attract to other water molecules. Practically speaking, this causes water to form individual droplets, bead up, and roll off of fuel surfaces. The problem created by this physical property is best described by Raymond Friedman in the NFPA handbook:

In practical fire fighting, water must be applied at ten to one-hundred times the rates used in research because of the difficulty of delivering water directly to the burning surface (NFPA, 1997, p.1-95).

IFSTA emphasizes this point in their training manual on fire fighting foams:

Research indicates that 5 percent to 10 percent of the water applied during a fire attack is actually involved with extinguishing the fire...The high surface tension of plain water prevents formation of a protective, vapor

sealing coating, and interferes with the ability to penetrate most fuel surfaces unless applied in copious quantities (1996, p.122).

Class A foam concentrate added to water reduces the surface tension of the water allowing more surface area of water droplets to contact the ordinary combustible surface. This provides increased heat transfer through conduction.

Colletti writes:

Class A foam concentrate is a synthetic detergent hydrocarbon surfactant, and when mixed with water at the recommended ratios, is biodegradable.

Because it is a hydrocarbon surfactant, it also has an affinity for carbons and causes the water to penetrate into wood fuels (1993, p.54).

Colletti estimates that the surface tension of plain water is reduced by two-thirds in a 0.3 percent Class A foam solution. This permits the water droplet to spread out and contact more of the burning fuel surface which therefore results in more rapid heat absorption. In addition, the same surfactants help emulsify paints, chemicals, grease and other water barriers (Grady, 2002).

Carbon particles are a major by-product of the combustion process. The high affinity for carbon particles facilitates rapid water absorption and fuel wetting. Finally, Class A foam solution adheres to burning Class A materials, acting as a vapor seal by insulating the burning fuels. Lowering the water content of the foam through additional air aspiration can epitomize this characteristic (IFSTA, 1996, p.122).

A complete evaluation of CAFS technology reveals that noteworthy disadvantages exist. Reasonable caution should be exercised by departments

evaluating this technology for everyday use to assure that the desired benefits outweigh the possible costs. With this in mind, the literature revealed that several limitations and disadvantages exist and are reported here.

Class A foam concentrate is a strong corrosive detergent that can corrode metal tanks and pump parts. Careless handling of the concentrate will damage paint and finish on modern fire apparatus. For this reason, most CAFS inject foam concentrate on the discharge side of the pump. This has the additional advantage of keeping air out of the centrifugal fire pump.

Regular exposure to the concentrate can cause drying and chapping of exposed skin. CAFS can be irritating to the eyes, and respiratory tract. Colletti compares Class A foam to “triple strength dish soap” (1992). It is imperative that personnel follow safe handling techniques recommended by the manufacturer which typically includes wearing eye protection, as well as the use of rubber boots and gloves.

Depending upon the proportioned ratio, CAFS solution is likely to cause slip hazards on certain surfaces. Personnel using CAFS must be trained to be aware of this hazard. In the United States Fire Administration (USFA) Technical Report Series, Class A Foam for Structural Firefighting, Stern and Routley write: “surveyed departments felt the foam created somewhat of a slip hazard beyond plain water, and others did not note any additional hazard (USFA, 1996, p.27-28).”

Even though Class A foams are considered more environmentally friendly than Class B foams, Class A foam concentrate is a hazardous material by

definition and should be treated as such. The long term environmental effects of Class A foams have not been completely determined. Recognizing the need for greater awareness to this issue, the NFPA established a task group to study the problem. Although their focus was on Class B foams which are typically deployed at significantly higher concentrations and far greater quantities, their recommendations are applicable to this report. They found that synthetic foams are less biodegradable than other foams and that protein-based foams may be more apt to contribute to nutrient loading. The task group distinguished between controlled and uncontrolled foam releases while proposing methods to minimize risks from foam discharges. One of the risk management solutions was dilution (Darwin, Ottman,, Norman, Gott, Hanauska, 1995, p.68). Since Class A foams are proportioned at less than 1.0 percent, this issue seems mute. Stern and Routley report that Class A foams approved for U. S. Forest Service use are fifty percent biodegradable within twenty-eight days of application (1996, p.27). Others list the product as “Biodegradable-Foam does not harm the environment” (Robwen, 2002).

The additional mechanical components and human procedures necessary to produce CAFS provide the opportunity for more failures, either by man or machine. This is particularly a concern with CAFS deployed in structural combat since failure of any of the CAFS components could compromise the attack stream for interior crews. Restrictions built into the plumbing of some systems to agitate the foam can reduce plain water flow from the same discharge. It should be noted

that some present generation CAFS have successfully overcome this problem (Grady, 2002).

Frequent and serious problems with apparatus that was retrofitted with CAFS have been noted. Arrangement of pump panel controls, reliability of bladder style tanks, access to essential CAFS components, air compressor capacity, ventilation, and power take-off reliability created problems in a field evaluation of Boston's Engine Company 37 (Routley, 1994, p.21). Fairfax County, VA had a similar experience with a retrofit unit (Stern, Routley, 1996, p.20).

Firefighters in other departments have confused Class A and Class B foam concentrates unintentionally mixing the two in the same tank. This causes the products to gel which can severely damage foam proportioning equipment. In response to this problem, foam concentrate manufacturers typically ship Class A foam in rectangular five gallon containers, and Class B foam concentrate in round five gallon containers to minimize this problem (3M, 2002).

The addition of CAFS to a pumper specification requires a considerable initial investment with ongoing costs associated with maintenance, foam concentrate replenishment, and training. These areas are a concern for all departments considering adoption of CAFS technology. It is estimated that the cost to add a present generation CAFS to a pumper is approximately \$40,000. per unit (Grady, 2002).

A review of the available literature produced two notable reports that thoroughly identified and summarized previous CAFS experience and testing up

to 1997. The first is an Executive Fire Officer Applied Research Project entitled: “Compressed Air Foam Systems in Limited Staffing Conditions” completed by Robert G. Taylor of the Morristown, New Jersey Fire Bureau.

In a review of twelve different studies conducted over a seven year period, Taylor identified several common test results. First, as compared to both plain water, and non air-aspirated Class A foam solution, application of CAFS required the lowest quantity of needed extinguishing agent, resulting in the quickest fire suppression time in all cases. Second, the rate of temperature drop at the four ft level was dramatically enhanced using CAFS. This is particularly important since the survivability of trapped occupants and the tenability of responding fire fighters would be most affected at this level. Third, large high-challenge fires with calculated needed fire flows ranging from 250 gpm to 1,600 gpm could be quickly extinguished with CAFS at flows of 7 gpm to 120 gpm rates. Finally, application of CAFS as an ignition retardation agent on exposures yielded test results that were up to twenty times as effective as plain water (Taylor, 1997, p.90).

The second major report reviewed was completed by Jeff Stern and J. Gordon Routley entitled “Class A Foam for Structural Firefighting.” Completed in December of 1996, this report was one of the Federal Emergency Management Agency, U.S. Fire Administrations, Major Fires Investigation Projects completed that year. The report focused upon hands-on evaluations by several fire departments that were using Class A foam systems in structural combat or, wildland/urban interface situations.

Departments included in the study were: Nashville, TN, Phoenix, AZ, Fairfax County, VA, and Westlake, TX. All departments surveyed concluded that Class A Foam and CAFS were additional tools which increased the efficiency and effectiveness of their fire suppression operations. Collectively, the departments reported quicker fire extinguishment, faster overhaul time, less damage to buildings, and reduced fatigue on fire fire-fighting personnel due to quicker mop-up after the fire is out. The 1996 report was an extension of a previous effort in 1993 that highlighted the experimental use of a retrofit CAFS by the Boston, MA Fire Department's Engine Company 37 in 1992-93. That test concluded that more information needed to be gathered to determine the extinguishing capabilities and conservation of water supply when using CAFS in an urban environment. The report further identified some shortcomings in retrofitting existing apparatus (Stern, 1993).

Current CAFS data and field experiences found during the literature review include a wide variety of end users. The Travis County Emergency District 2 in Pflugerville, TX, just outside of Austin has experienced such success with CAFS that they have equipped all of their pumpers with the technology. Department representatives successfully lobbied the Texas Legislature which resulted in a bill requiring insurance companies provide homeowners with a reduced rate on premiums in cities and areas protected by CAFS (Moellenberg, 2000, p.36). This effort led to Insurance Service Office, (ISO) credits in Texas for fire departments that have a CAFS engine responding to all structure fires. This change has been recognized for increasing the City of Plano, TX to a Class 1 ISO

rating and is being considered by larger departments like Houston, and Dallas. Plano has successfully marketed their Class 1 ISO rating as a key component of their Economic Development Program (Bland, 2002,).

The Oatman, AZ Fire District conducted a series of tests on both wood cribs and tires. The results revealed that using CAFS as compared to plain water, the wood cribs were extinguished in one-fourth the time using less than one-fourth the amount of water. When extinguishing burning tires, the fire was extinguished 4.5 times faster using less than one-fourth the amount of water (Naiker, 2002).

Researchers at the National Institute of Science and Technology, (NIST) Fire Safety Division demonstrated that protein-based compressed air foam can protect building exteriors from ignition. Using identical L-shaped wood-frame walls covered with exterior vinyl siding, one test wall was coated with the protective foam one hour prior to ignition. Both test samples were exposed to a fifty kilowatt fire for ten minutes. Within three minutes of ignition, the untreated corner was burning into the eaves and roof area. After ten minutes of fire exposure, the treated corner had received only minor damage. No fire spread was recorded on the treated corner. The results as presented in the abstract of the study conclude:

The agents, both as solution and as CAF, were more effective than plain water at remaining on or in the plywood but less effective than plain water on the vinyl. The penetrating/wetting ability of the agents may be the

characteristic which most affects the increase time to ignition (Josler, 1997).

In studies at the University of Canterbury, Christchurch New Zealand the fire fighting effectiveness of CAFS has been compared with plain water using high pressure delivery (HPD). The HPD method uses a flow rate of 16-63 gpm at 400-500 psi. The high pressure produces a fine mist that has proven to be very effective and efficient method to extinguish a single post flashover compartment fire. These experiments concluded that the CAFS attack was as effective as the HPD attack. An additional advantage was noted with the CAFS attack method. Fire fighters could operate from a much greater distance, protecting themselves from the high temperatures and smoke exiting the compartment (Fleischmann, 2002).

The most compelling recent research identified during the literature review was conducted by the Los Angeles County Fire Department in 2001.

Three 1,105 square ft, one-story frame, single-family dwellings were furnished with identical new furniture to simulate a real world fuel package. Windows were replaced with plywood and composition shingle roofing was left in place. The interior of the structures were equipped with thermocouples to record temperatures at various locations.

All fire attacks used the same LACFD structure pumper equipped with a CAFS unit. The tests were designed to compare plain water, Class A foam solution, and CAFS. A combination nozzle was used in the water and Class A solution tests, and a 1-inch smooth-bore nozzle was used in the CAFS tests. The

attack line was a standard 200 ft long 1-3/4 inch hoseline. Attack flow rates were based upon the Iowa formula which calculated at 90 gpm. The CAFS attack was 90 gpm with 30 cubic ft per minute (cfm) of air. Foam concentrations were set at 0.5 percent for the Class A solution and 0.2 percent for CAFS. The results are summarized in the following table:

LACFD Foam Test Results (2001)			
	Water	Class A	CAFS
Foam Setting (percent)	n/a	0.5	0.2
Water Flow (gpm)	90	90	90
Air Flow (cfm)	n/a	n/a	30
Knockdown (sec)	50	25	11
Water Used (gal)	75	44	16
Temperature Drop to 200 °F (min:sec)	6:03	1:45	1:28

The test results were conclusive. CAFS knocked down the fire in approximately one-fifth the time as plain water. Do to the extended reach of the CAFS fire stream, the fire could be attacked earlier; in this case from the curb some thirty-five ft away from the dwelling. When compared to CAFS, it took 4.7 times the amount of plain water to extinguish the fire. Most important, CAFS cooled the interior from 600°F to 200°F four times faster and with a significantly larger initial temperature drop.

In addition, the test team noted several other benefits of the foam that were not quantitatively measured. First, faster knockdown resulted in less

products of combustion both inside and outside the dwelling. Second, less water used resulted in less damage to the building, contents, and contaminated water runoff. Third, the increased standoff distance because of stream reach enhanced fire fighter safety (Cavette, 2001, p.28-33).

As of July, 2001, Los Angeles County was operating with 224 front-line engines, 10 reserve engines, and 15 front-line quints equipped with Class A foam proportioners. An additional 19 front line engines were equipped with CAFS. The collective experience gained in Los Angeles County while using CAFS resulted in the publication of the following six lessons learned (2001):

1. CAFS used for interior attack should be applied at the same rate as plain water. CAFS saves water by knocking down the fire faster, not by using a lower flow rate.
2. The initial nozzle reaction of a charged CAFS line is substantial.
3. An interior CAFS attack can often be made through a door or window. Best results are achieved when the stream is directed towards the ceiling.
4. Large amounts of steam are generated when CAFS hits a fire.
5. Even though CAFS reduces interior temperatures faster than water, the upper portions of the rooms will remain quite hot.
6. Always overhaul. LACFD prefers a wet CAFS that maximizes surface penetration.

PROCEDURES

The initial literature review for this project began at the Learning Resource Center (LRC) at the National Emergency Training Center in November of 2001. Additional information was gathered from the Washington County, MD Free Library, the World Wide Web, personal interviews, and the author's personal library.

Numerous telephone interviews and personal meetings with Dominic Colletti, Senior Fire Protection Systems Engineer, and Mike Laskaris, Engineering Director for Hale Products of Conshohocken, PA resulted in a single day of live fire testing on March 29, 2002 in Silver Spring, MD. Additional personal interviews were conducted with Clarence Grady, Foam Applications Specialist, Pierce Manufacturing, Appleton, WI, and Maintenance Chief John W. Kovatch, Jr. of the El Paso, TX, Fire Department on April 17, 2002. A follow up interview was conducted with Mr. Grady on May 16, 2002 in Appleton.

The focus of the literature review was limited to two general areas: a current evaluation of compressed air foam capability including previous testing, and the experience obtained by others who have used compressed air foam systems.

Historical research was used to provide a current analysis of CAFS usage for structural firefighting by identifying the advantages, disadvantages, limitations and past experiences of the technology. Based upon this review, the contribution of CAFS use on structure fires could be predicted. Second, using evaluative research, the study attempts to provide new test data using CAFS in a high rise

application. Finally, the study combines the results of these research efforts and challenges traditional suppression strategies in Montgomery County, MD in the pursuit of their stated fire flow goal.

As part of an ongoing training project underway in Montgomery County, a vacant high-rise office building was used to conduct test burns using CAFS on March 29, 2002. In preparation for these burns, members of the MCFRS had outfitted each of the top three floors of the building with burn rooms, safe rooms, ventilation openings, etc. to bring the site into compliance with NFPA 1403, the Standard on Live Training Evolutions. The building is described as follows.

The office building at 818 Roeder Road is a Type I fire resistive structure with concrete slabs and reinforced concrete columns. There is a basement with seven floors measuring 100 ft by 59 ft per floor. Each floor measures 9.5 ft slab to slab. There is one internal stairwell located on side C between quadrants B and C with a standpipe riser. The core is equipped with an elevator lobby with two elevator cars, which were inoperable.

Unique to this research effort, a large burn room was constructed on the fifth floor of the structure to accommodate a series of controlled burns. This room was 29 ft x 9 ft x 9.5 ft (2480 cubic ft) and constructed of a double layer of one-half inch gypsum wallboard over two by four wood studs. The ceiling was lined with one-half inch plywood under one-half inch gypsum board held in place by ceiling anchors to allow repeat burns without affecting the buildings structural integrity.

The goals of the tests were to conduct a series of 12-16 burns using plain water, Class A solution, and CAFS. The results could be used to compare the extinguishing characteristics of the three agents and determine if CAFS would degrade during transit through the above ground hose layout, standpipe riser, and attack line layout in a high rise application. Review of the available literature had failed to identify the use of CAFS in this manner. Therefore, these tests would contribute to the overall body of knowledge regarding CAFS.

The eight burns were recorded using thermal imaging technology provided by Bullard Industries and later transferred to video tape. In addition, the MCFRS photo team was able to capture some video of initial burning on VHS equipment.

Needed fire flow requirements for the room geometry were calculated prior to the tests and established at 50 gpm. A combination fog nozzle was used for the plain water and class A solution burns. A solid bore 1-3/8 inch nozzle was used to deliver CAFS.

Agent usage for water and foam concentrate was calculated and recorded using the FoamPro microprocessor on a CAFS equipped pumper provided by the Conshohocken Fire Company #2 of Conshohocken, PA.

Temperature changes were recorded using a strip chart recorder fed by eight thermocouples placed throughout the burn room. Two were placed on the ceiling (9.5 ft), positioned 5.5 ft from each end, and 4.5 ft from the opposite walls. Two were placed on the interior wall mounted 3 ft and 4 ft from the floor, one adjacent to the doorway at the 2 ft level, one at the one ft level located 7 ft from the end of the room. Finally, two additional thermocouples were positioned at

the 1.5 ft and 3 ft levels 7 ft from the end walls of the room. Time to extinguishment parameters were recorded by the operator of the strip chart recorder in a safe room. Information was provided via portable radio from an observer adjacent to the attack team to record: nozzle open, nozzle closed, and fire extinguished benchmarks.

Water supply and delivery to the burn room was accomplished as follows: A CAFS equipped pumper was connected to a hydrant adjacent to the building. Two 100 ft long sections of three-inch hose with 2-one-half inch couplings fed a standard fire department connection on the front of the building. A gated wye and 150 ft of 1-3/4 inch attack line was connected to the single, dry, six-inch standpipe riser located in the stairwell of the fifth floor. All fires were extinguished using either plain water, or 0.3 percent CAFS through this line.

The nozzle technique was identical for all burns. It was agreed that to protect the ceiling for the maximum number of burns, a Z followed by an inverted T pattern would be used to attack the fires. This was accomplished from a position on the floor just outside of the room through a standard three ft wide doorway.

The fuel package consisted of three identical sets of six wood pallets and three bales of straw arranged in a pyramid fashion to achieve flashover conditions. These fuel packages were equally spaced left to right and front to back throughout the room.

Each fire was ignited using a flare near the base of the three fuel packages. Burning rates and ceiling temperatures were monitored until a peak was reached.

As soon as the fire began to decay, the attack team was directed to open the nozzle and extinguish the fire. On plain water burns, the nozzle had to be opened and closed several times. The attack team stopped flowing when the fire was successfully extinguished. Data was recorded and preparation for the next burn began that included ventilation of the burn floor, total removal of the fuel package, and re-stocking of three completely fresh fuel packages.

When extinguishing agents were changed, the riser and attack line were flushed to remove any residual foam from the riser and lines.

A full NFPA command, accountability, and safety team was in place throughout the day long test burns.

The testing of the three agents was intended to validate the effectiveness of CAFS on the upper floors of a high rise, and to demonstrate the extinguishing efficiency of CAFS. This was not fully achieved for a number of reasons.

Primarily, the author underestimated the time required to complete the series of burns and the logistics necessary to completely restock the burn room, flush and calibrate the agents between burns, and ventilate the structure after each burn. Second, the personnel and equipment on loan from Pennsylvania were only available for a single day, not nearly sufficient to gather the desired data. Third, the building had to be available the next day for scheduled high rise training, the primary mission of the project. Finally, coordinators responsible for the building could not allow any synthetic fuels to be used in the structure.

There were two reasons for this mandate.

NFPA 1403 prohibits the use of synthetic fuels. Approximately sixty personnel were involved with the tests. Safety of the participating personnel could not be compromised.

The coordinators of the high rise training project had an agreement with the local business community that promised the exterior glass wall panels would remain intact throughout the ninety day training effort. In addition, they had agreed that excessive release of the products of combustion into the environment would be limited. Therefore, the test burns stopped short of the high challenge fires that would normally be associated with a similar scenario. As a result of these limitations, tests were limited to eight burns that failed to produce statistically significant data.

To compound these problems, construction of a tightly sealed, large burn room with a single doorway restricted fresh air entrainment to the burning fuel. It was the authors assessment that all of the test burns were under ventilated, failing to maximize the fuel potential of the designed fuel packages. Because the fires remained largely fuel controlled, the flow rates for the tests may have been higher than necessary.

Through the series of eight burns, the test team consistently struggled to bring the fires to the full ventilation controlled burning rate. There were two adverse impacts as a result. First, although peak ceiling temperatures reached 1150-1420°F, they did not stay there long. Second, because the room was under ventilated, the fuel package for the various burns failed to completely ignite, flashover, and burn as planned. Considerable amounts of partially burned fuel had

to be removed after each burn. This in turn, slowed the efforts down considerably. Nonetheless, the effort to stay on schedule by all personnel participating in the testing was exemplary.

In an attempt to deal with these issues, additional forced ventilation was provided by positive pressure ventilation blowers. Although the burning rate increased along with the maximum ceiling temperatures achieved, complete room flashover was not achieved. In hind sight, additional ventilation openings were required, preferably to the atmosphere. Review of the video tapes of the burns provided by Bullard Industries verified this conclusion.

Definition of Terms

Aeration—The introduction of air into a foam solution to create bubbles that result in finished foam.

Biodegradable—Capable of being broken down into innocuous products by the action of living things, such as microorganisms.

British Thermal Unit (btu)—The amount of heat needed to raise the temperature of one pound of water one degree Fahrenheit.

CAFS—A abbreviation for compressed air foam system(s).

Class A Fire—Fires involving cellulose type ordinary combustibles such as wood, paper, and cloth.

Class A Foam—Foam specially designed for use on Class A combustibles, made from hydrocarbon based surfactants that lack the strong filming properties of B foam, but exhibit excellent wetting properties.

Class B Foam—Foam especially designed for flammable/combustible liquid fuels.

Cubic Ft per Minute (cfm)—A standard measure of the flow of compressed air.

Defensive Attack—An exterior fire attack with an emphasis on exposure protection.

Eductor—A proportioning device that injects a liquid, like foam concentrate, into the water flowing through a hoseline.

Engine Tanker—A term assigned to a combination pumper/tanker that carries a minimum of 1,500 gallons of water.

Fire Flow—The quantity of water needed, or available for fire fighting in a given structure.

Fire Triangle—A geometric figure in which the three sides of an equilateral triangle represent: oxygen, heat, and fuel; the elements necessary to sustain combustion.

Foam—A extinguishing agent formed by mixing a foam concentrate with water and air.

Foam Concentrate—The raw foam as delivered in its storage container prior to the introduction of water and air.

Foam Solution—The mixture of foam concentrate and water before it is aerated.

Gallons Per Minute (gpm)—The standard measure of flow for a liquid.

Handline—A hoseline intended to be managed by up to three fire fighters, typically flowing less than 350 gpm.

Indirect Fire Attack—Directing the fire stream at the ceiling level of a room or ceiling in order to generate a large volume of steam.

Large Diameter Hose—Supply hose four-inch or larger in diameter.

Nozzle Reaction—The backward force caused by the mass and velocity of water discharging from a nozzle orifice.

Pressure—Force per unit area. Measured in pounds per square inch (psi).

Quint—A combination apparatus that is equipped with a pump, water tank, aerial device, and hose.

Surfactant—A chemical that lowers the surface tension of a liquid.

Vaporization—The passage from a liquid to a gaseous state.

RESULTS

Results of the high rise testing were disappointing. Considerable time, effort and expense failed to produce scientifically verifiable data. Nonetheless, direct comparison of the best plain water burn and the best CAFS burn verified previous experience with CAFS. More importantly, new and important questions were developed that should provide a basis for additional research.

Burn number five was the hottest plain water burn that was extinguished with 60 gallons of water after the ceiling thermocouple reached a peak temperature of 1420°F. This fire was allowed to free burn for approximately 300 seconds before extinguishment began. The nozzle had to be opened and closed three times to achieve complete suppression. Total nozzle flow time was approximately 80 seconds. The strip chart recorder was prematurely stopped during this test prior to the temperatures in the room dropping to 212°F. However,

the ceiling temperature dropped to approximately 300°F at the end of 150 seconds. The temperature at four ft from the floor where fire fighters live dropped to 212°F in approximately 95 seconds.

In comparison, burn seven was the hottest CAFS burn. This fire was extinguished with 18 gallons of water and 0.1 gallon of Class A foam proportioned at 0.3 percent. The peak ceiling temperature was 1390°F. This fire free burned for approximately 340 seconds before suppression. The nozzle was opened and closed once with a total nozzle open time of approximately 25 seconds. The temperature drop for all eight thermocouples was similar. However, the rate of temperature drop was significantly faster than the plain water burn. The ceiling temperature was reduced to 212°F in approximately 65 seconds, while the temperature drop to that level at four ft occurred in just less than 40 seconds.

Burn eight was a CAFS burn and the last one of the day. The peak ceiling temperature only reached 1160°F. This fire was extinguished using 22 gals of water and 0.3 percent CAFS. Significant deterioration of the ceiling board and walls were observed at this point. A decision was made to suspend testing after an exhausting effort.

Burn six was noteworthy in that it was the only burn where non air-aspirated Class A solution was successfully tested. Using the same 50 gpm application rate, at 0.4 percent solution, 43 gallons of water was required for extinguishment. For undetermined reasons, this fire began to decay quickly when the peak ceiling temperature reached 1200°F. Extinguishment was quickly

initiated, resulting in nearly identical temperature drops as recorded with the hottest CAFS burn.

The total water used in the three reported burns were 60 gals of plain water, 43 gals of water when enhanced with Class A Foam, and 18 gals of water when enhanced with CAFS. The comparison between plain water and CAFS is 3:1, consistent with previous testing by others in a non-high rise application.

For the purpose of this ARP, the author reluctantly excluded the results of burns one through four. These tests can be viewed as failures do to the problems encountered with ventilation, fuel loading, and heat stress on the building. In all cases, low temperatures, consistent with lack of free burning fuel packages resulted in high total agent flows to extinguish smoldering fuels prior to removal from the burn room.

These test results combined with the historical literature review answered the following research questions specific to this ARP.

1. What are the advantages and disadvantages of CAFS?

The literature review found CAFS to be more effective than either plain water or non air aspirated Class A foam solution. This was confirmed in the high rise testing. CAFS was found to absorb heat more rapidly to reduce the chance of flashover, penetrate fuels more effectively, form a vapor barrier on the fuel surface, coat exposure fuels, and provide faster fire extinguishment using less water. The potential for rekindle is less. Smoke production and water damage is significantly reduced which directly relates to better property conservation. Hose line weight is reduced by up to 60 percent which has a positive affect on fire

fighter fatigue, safety, and welfare. This has the additional potential benefit of reducing the load on aerial devices when supplying master streams. Stream throw (effective reach) is increased up to three times allowing greater standoff distances for suppression forces (Cavette, 1999).

Reports on the greater knockdown power of CAFS ranged from a low of two to a high of 20 times the effectiveness of plain water. Real world fire fighting experience has demonstrated a benefit factor of three to five times (Colletti, 2002). Testing for this ARP determined a 3:1 advantage comparing the two hottest burns. Enhanced exposure protection, and reduced fire fighter stress have also been identified.

Noted disadvantages of CAFS included the high expense to acquire and maintain, a large nozzle reaction when the nozzle is first opened (Rochna, 1991), the tendency of hose lines to kink, and in some cases CAFS was found to create slip hazards on certain floor surfaces (Stern, Routley, 1996, p.27).

Increased training for personnel operating CAFS is considered fundamental as is increased and regular maintenance on the equipment producing CAFS do to the complex plumbing (Grady, 2002).

2. Can CAFS make a positive contribution to fire fighting capability on structure fires?

The advantages of CAFS were verified by proving that it can be successfully supplied through complex length and diameter changes in a high rise application. The extinguishment advantage over plain water was determined to be 3:1 in a limited number of tests. Foam concentrate usage was almost too small to

quantify. Rate of temperature drop in the burn compartment was improved over plain water.

Improvements and experience gleaned in over two-decades of using CAFS has yielded consistent and impressive results for the use of CAFS in municipal fire fighting operations. Like many new technologies, CAFS has been greeted with a lukewarm reception by many fire fighters and departments. This lack of acceptance stems from a reluctance to use CAFS until confidence is obtained that it will work as promised (Roche, 2001). Nonetheless, those who use CAFS are passionate about the level of success achieved. The benefits of CAFS to the small line fire fighter continue to be quantified.

In original research conducted by Kevin Taylor of the Morristown, N. J. Fire Bureau using a recommended air mixture ratio of 1 cfm of air to 1 gpm of foam solution under 110 psi,: “The CAFS attack line weighs 60 to 61 percent of the water line of equal size, and flows half the amount of liquid.” He goes on to conclude that: “a 2-inch CAFS line’s weight is 79 percent of the 1.75-inch water hose’s weight, and flows 65 percent of the liquid of a 1.75-inch water hoseline”(Taylor, 1997, p.102). Larger nozzle diameters produce less nozzle reaction at equal flows. Best practice is to use a straight stream nozzle with a large enough tip to expel the volume of air, typically a 1-3/8 inch bore (Laskaris, 2002).

CAFS increases the extinguishing efficiency of a firefighting crew by three to five times, possibly more on high challenge fires and master stream applications. If you accept the most conservative value, what department or fire chief would not want to increase the effectiveness of their fire fighting force by a

factor of three? CAFS can extinguish fires in less time, using less water, while expending less energy by fire fighters. The benefits to these powerful conclusions are obvious.

Results of this research conclude that fires are extinguished with less total water. CAFS has found application in all structure fire scenarios including exposure protection, and deployment from elevated streams.

3. What experience do other fire departments have with CAFS in structural combat?

CAFS technology offers great advantages to the structural fire service. It seems that you are either a disciple of the technology, or not. Negative reviews on CAFS were virtually non-existent in the literature. If departments have had negative experience with CAFS, they have failed to share those experiences.

Many departments throughout the United States large and small have identified increased success with CAFS in nearly every case researched.

In addition, CAFS has gained popularity internationally as is evidenced by comments on the Leicestershire, U.K. Fire Brigades website. They write: “Much better, quicker to get to work, easier to manoeuvre, hoselines are lighter, finished foam produced means less water is used and extremely versatile in that you can use the foam on just about any incident (2002).”

Troy Thornton, Fire Project Officer Country Fire Authority (Victoria)
Australia says of CAFS:

There are applications for both the firefighter who may have to drive to a distant water source, and the rural homeowner who may have a finite

water supply. High agent concentrations and low mix ratios (3 litres per 1000 litres) permit adequate on-board storage without reducing appliance capacity. Hoses filled with foam are also lighter and more manoeuvrable, perhaps its most effective application. Compressed air provides the distance to reach, and the agitation to cling to walls, eaves, roofs, and trees (Thornton, 2002).

4. What critical elements are necessary to successfully deploy CAFS in Montgomery County, MD?

The results of this ARP have verified that CAFS can improve knockdown capability while reducing temperatures to fire fighters at a greater rate anywhere in Montgomery County, including the urban areas.

The impact upon future deployment of stations, apparatus, and personnel should be evaluated given the potential benefits of increased suppression capabilities offered by CAFS. Total deployment time should be tested consistent with the limited staffing available throughout Montgomery County.

The additional extinguishment capability offered by CAFS should be compared to the available fire fighting water supply, particularly in rural areas.

Training requirements must be planned for, developed, and practiced.

Required maintenance of critical mechanical elements must be provided.

DISCUSSION

Throughout the literature, claims of greater extinguishing capability have been made for CAFS. The testing conducted in this ARP concluded that this capability could likely be extended to high rise fire fighting applications in urban

areas. Fears that air would leak out of the standpipe leaving wetter foam appear unfounded. If there is a reduction in foam quality while pumping through a standpipe riser, it is re-generated by the scrubbing action of the attack hose, resulting in no discernable performance of the finished foam product (Laskaris, 2002).

During debriefing of the tests, the following additional items were considered.

Any attempt to use CAFS in standpipe operations must be done with assurance that adequate back flow protection is in place. Contamination of the municipal water supply would be a primary concern. Back flow preventers are normally required to prevent the fire department pumper from pressurizing water mains, providing little if any benefit to the standpipe riser. In high rises greater than fifteen stories, CAFS could move through additional pump(s) on upper floors. In addition to the possible effects of degraded foam quality, there are legitimate concerns about the life of the fire pump if air bubbles are introduced into the pump suction. Cavitation could occur, permanently damaging essential pump parts (Laskaris, Colletti, et al., 2002). This led the author to conclude that ideally, CAFS should be stored and introduced after the riser valve on each floor. Finally, the transit time of the CAFS must be considered in high rise applications, as well as dilution of the agent in wet standpipes.

During tests for this ARP, fires were attacked with equal flow rates calculated for standard fuel packages. Results confirmed a 3:1 knockdown efficiency using CAFS over plain water. Just as important, once the fires were

extinguished, they remained extinguished. The impressive knockdown capability of CAFS makes believers out of those who can observe its effectiveness. This is one of the reasons that CAFS has successfully “moved out of the forests and into the cities (Cavette, 1999, p.)” This increase in extinguishment efficiency may encourage the use of smaller diameter hose lines with lower flow rates. The literature is divided on this issue. Taylor writes in 1997:

Several authorities, with strong evidence, hold that less gallonage is needed with CAFS for a given amount of fire. The literature reports many test fires promptly extinguished with less than 1/10 of the minimum gallonage required by the Iowa State Formula, or even the more demanding National Fire Academy required flow formula. This reduced flow can indeed be delivered by smaller, more maneuverable lines. However, other sources hold that when using CAFS, the foam solution must equal the minimum required flow of plain water. This school of thought advocates exploiting the extinguishment “premium” of CAFS in the form of quicker knockdown, rather than smaller, lighter, and less fatiguing hoselines (Taylor, 1997, p.105).

Taylor identified a divergence of opinions that has not been resolved.

The study did not attempt to measure the stress on fire fighters, although the relationship is obvious and should be considered for future work. The positive contribution to structural fire fighting has been substantiated many times in the literature. Enhanced fire fighter safety is frequently trumpeted as a primary benefit of CAFS. However, skepticism remains.

Paul Grimwood of the United Kingdom hosts a large website dedicated to structural firefighting. Concerning CAFS, Grimwood writes: “It is apparent that CAFS offers rapid knockdown when applied in straight stream form and enables the fire attack to be mounted from a safer distance and sometimes from an exterior position.” However, he cautions: “The use of CAFS from an interior position has yet to be proven more effective than pulsing water-fog patterns in gas cooling applications (Grimwood, 2002).”

Grimwood develops a critical question regarding the use of CAFS in interior fire fighting applications that have not reached flashover conditions. Essentially, he believes that straight stream CAFS is less effective at cooling pre-ignited gas layers than pulsing water fog enhanced with non air-aspirated Class A foam. Ignition of these gas layers has been attributed to the loss of many fire fighters lives during structural fire attack. Grimwood develops his argument further by challenging convention: “How can a CAFS stream in smooth-bore form take control of such an event that isn’t yet on fire? You cannot coat the gases with foam from a straight stream (2002).” His argument is not without merit. It should however, be evaluated with the complete understanding that high pressure pulsating fog application is the delivery choice advocated by Grimwood, et al., for shielded (pre-flashover) fires. The use of CAFS for interior structural fire attack is a complete turn-around for European firefighters and will undoubtedly receive complete review before it is accepted (2002). Unfortunately, the testing conducted in this ARP could not substantiate or disprove these concerns.

In contrast to the European theory, it is important to note that many large municipal fire departments in the U.S. have routinely used solid bore, plain water delivery for interior fires, large and small. The long standing success of this attack method conflicts with the European experience and needs to be validated. It has been the observation of this author that departments who rave of success with smooth bores also have the benefit of optimally staffed engine companies who can deploy heavy, large diameter hoselines efficiently. In most cases, they are leading off with, and attacking fires with larger flow rates. An apples, to apples comparison would be useful.

Routinely, fire departments are not reluctant to equip their apparatus with Class B foam. The reason for this is clear. Class B fires cannot be extinguished with water, therefore by default; foam becomes the agent of choice. In spite of documented increased efficiency, Class A foam has failed to gain the widespread acceptance many had hoped for. Roger Ruth of National Foam says: “fire departments have recognized the effectiveness of foam and are buying the most cost-efficient system for their particular application (1999).” Perhaps this should be a challenge to the industry to develop a more cost efficient method to produce and deliver the product. It seems that few are willing to argue against the technology based upon extinguishing mechanisms, but most would argue that the costs are excessive in day to day operations. There are certainly exceptions to this belief as evidenced by the widespread use in department after department such as Phoenix, AZ, Los Angeles County, CA, Travis County, TX, et al.

Like most large municipal departments, Montgomery County has competing needs and priorities that drive day to day operations. To be successful, CAFS must provide value to the customers, increased efficiency for the managers, performance for the employees, and reliability for maintenance personnel.

Kenneth L. Jones of the Fairfax County, VA Fire Rescue Department predicted in 1994: “The insertion of CAFS into the suppression officers trick bag will enable the Chief Fire Officer to meet current and future service demands even with a possible reduction in total suppression assets brought about due to budgetary downsizing (Jones, 1994, p.2).” His high expectation for CAFS points to the monetary restraints placed upon municipal fire departments. The technology simply has to be worth the risk of investment. The impact of Jones statement implies a reduction in force and staffing that would not be well received by existing suppression forces charged with the responsibility to make CAFS work. Support of the workforce is fundamental to the successful implementation of CAFS in any department that follows minimum staffing standards, like Montgomery County.

The positive affects on personnel using CAFS has been reported in many instances. There were no reports in the literature where fire fighters were replaced after implementing CAFS. The fear of downsizing should be addressed. Foam should not replace fire fighters. Rather, CAFS would simply allow fire fighters to perform their jobs better and more safely.

The additional training requirements for personnel at all operational levels must be planned for. Small line firefighters, unit officers, pump operators, and

command staff must be proficient in the deployment of CAFS. Selective use of the technology in certain areas would have to be considered with regards to volunteer personnel, details, and transfers. More importantly, departments planning to use CAFS for structure fire attack should conduct an in-depth strategic review concerning their approach to fire fighting (Grimwood, 2002).

The ability to properly maintain the equipment is fundamental. Nothing is more frustrating than to purchase technology that is unreliable. Even worse is to have equipment available that is constantly out of service. The extra costs associated with additional maintenance should be included in any plan to implement CAFS. Very little information is available in the literature regarding the long term costs associated with the maintenance and reliability of CAFS. This is of particular concern to managers charged with balancing budgets, while striving to improve services.

Clearly, CAFS affords the opportunity to extinguish larger fires with less water, using fewer resources. This is the primary conclusion of interest to Montgomery County, MD, where high challenge fire potential exists in areas without fire fighting water available in sufficient quantities to meet their stated fire flow mandate. In areas where resources cannot be assembled quick enough to produce consistent success, CAFS could be deployed to provide that additional value. This is evidenced in the law change that has occurred in Texas, a large state in terms of size, diversity, population, and economics (Moellenberg, 2000, p.34).

RECOMMENDATIONS

A careful analysis of the fire fighting capability of the available water supply with and without CAFS should be done on a station by station basis in Montgomery County. In areas where fire fighting water, and or, other resources cannot be assembled to meet the fire flow mandate, CAFS should be considered.

Additional field tests should be conducted that are consistent with the high challenge fires overwhelming suppression resources in rural areas.

The author recommends that MCFRS proceed with the lease of a latest generation CAFS equipped pumper for field evaluation. By leasing a pumper, the service is not “stuck” with the technology if the field evaluation is not successful. Additional research will be needed to acquire the most appropriate unit for the anticipated use. The CAFS pumper should be deployed in a station where the fire workload is sufficient to properly evaluate the experience. Stations 31, 29, and 8 would be likely candidates.

To accomplish this, time and monies must be reserved to train the personnel on the proper use of CAFS. The impacts on current policy and procedures will need to be considered. Tactical considerations and standard operating procedures unique to the CAFS station will need to be developed.

Future efforts regarding CAFS should be aimed at the scientific community, where statistically significant, comparative analysis by third party agencies can validate its use in day to day, real world fire fighting applications. The MCFRS should network with a third party agency with the resources necessary to conduct full scale fire testing. The National Institute of Science and

Technologies Building Fire Research Laboratories are located in Montgomery County. In addition, the newly constructed fire research lab for the Bureau of Alcohol, Tobacco, and Firearms is located in adjacent Beltsville, MD.

Perhaps the most compelling argument for a CAFS pilot program for Montgomery County rests in the humorous words of Phoenix Fire Chief, Alan Brunacini: “In Phoenix, troops on the apparatus committee can’t cut CAFS...the policy comes down from God, and She says, ‘Fire trucks are red, and they shall have CAFS (Stevens, 1999).’”

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