9 Appendix

9.1 Public Safety Advisory Committee (PSAC)

9.1.1 Resolution to create PSAC

9.1.2 PSAC Charter

9.1.3 PSAC Meeting Minutes

9.1.4 PSAC Request for Proposal

9.1.4.1 CAFA Response Documents

9.1.4.2 DAFD Response Documents

9.2 Maps

9.2.1 Map - Dexter Township - Roads/Lakes/Sections

9.2.2 Map - Dexter Township Current Fire Service Area Boundaries

9.2.3 Map - WATS Estimated Travel Time - CAFA

9.2.4 Map - WATS Estimated Travel Time – DAFD

9.2.5 Map - WATS Estimated Travel Time - CAFA/DAFD

9.2.6 Map - WATS Estimated Travel Time – MLSA

9.2.7 Map - WATS Estimated Travel Time - CAFA/DAFD/MLSA

9.2.8 Map - WATS Estimated Travel Time - CAFA/DAFD/MLSA/Scio Twp

9.3 Cost Data

9.3.1 Scenario Cost Notes

9.3.2 Status Quo Scenarios - No MLSA

9.3.3 CAFA - 1 FTE at MLSA

9.3.4 CAFA - 2 FTE at MLSA

9.3.5 DAFD - 1 FTE at MLSA

9.3.6 DAFD - 2 FTE at MLSA

9.3.7 Status Quo & CAFA/DAFD 1 FTE Staffing at MLSA Comparison

9.3.8 Millage Revenue Comparison

9.4 Run Data

9.4.1 2005-2009 All Department's Run Data

9.4.2 2005-2009 HVA Run Data

9.5 Estimated Distance and Time - Raw Data

9.6 Financial Data

9.6.1 CAFA 12-31-2009 Audit

9.6.2 DAFD 12-31-2009 Audit

9.7 Regionalization Documents

9.7.1 2010 CAFA-DAFD Fire Chief Support Letter

9.7.2 8-16-2006 Wayne Berman-Benefits of Regional Collaboration

9.8 092007 Buying and Selling Fire Protection-Dr. Lynn Harvey

9.9 Compressed Air Foam (CAF) Study

9.10 Automatic External Defibrillator (AED)

9.11 ISO Questionnaire

9.12 100827 Flintoft Letter - How to dissolve CAFA

COMPRESSED AIR FOAM SYSTEMS IN LIMITED STAFFING CONDITIONS

EXECUTIVE DEVELOPMENT

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Morristown Fire Bureau

Morristown, New Jersey

An applied research project submitted to the National Fire Academy as part of the Executive Fire Officer Program

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ABSTRACT

This research project explored the feasibility of enhancing suppression crews of limited manpower by equipping them with Class-A foam and Compressed Air Foam Systems (CAFS) technology and training. The problem that was addressed was that, especially in the early stages of fire suppression operations, there were frequently insufficient personnel to employ traditional extinguishment methods safely and efficiently.

The purpose of this research project was to determine if CAFS technology and procedures could be used to increase effectiveness, efficiency, and safety under limited personnel resource conditions. Descriptive research, including the literature review, was used to explore the safety and operational results of under-staffing, and to clarify the present state of development of compressed air foam and class A foam. Evaluative research was used to measure hoseline handling for CAFS and traditional (plain water) handlines.

The research questions posed were:

1. What are the effects of reduced manpower upon suppression activities with regards to efficiency and safety?

2. What are the recognized advantages and disadvantages of CAFS when used in structural firefighting?

3. How do CAFS hoseline handling characteristics differ from those of plain water hose lines?

4. Can the use of CAFS by an understaffed crew reduce the number of stress and fatigue injuries at suppression incidents?

5. Can the use of CAFS increase the suppression ability of an understaffed firefighting force?

The procedure began with a literature review of staffing practices, including the effects of minimal staffing of suppression crews. Next, the description, history and extinguishment theory of CAFS; the claimed advantages and limitations of CAFS technology; and test data and anecdotal reports of fire experience with CAFS were examined for possible impact on minimum staffing safety and inefficiency problems. CAFS hose handling was field tested.

CAFS was found to provide increased suppression capability to crews of limited manpower and to reduce stress and fatigue of hose line operators. Recommendations included investigation and purchase of a CAFS for the Morristown Fire Bureau, and further research into the suppression abilities of CAFS.

TABLE OF CONTENTS

INTRODUCTION

The Morristown, New Jersey Fire Bureau is a combination department, consisting of 29 career suppression personnel and about 20 active volunteer firefighters, maintaining a minimum on-duty staffing of a Captain and four firefighters. The on-duty crew brings the apparatus to the scene, while the volunteers are alerted by pager and respond directly to the scene in their own vehicles. Usually the on-duty crew of 5 must begin suppression activities before the arrival of the volunteers. Since personnel are in short supply, often some necessary tasks must be delayed; some may be performed inefficiently or even unsafely.

In the early 1990's Compressed Air Foam Systems (CAFS) were being introduced to the structural fire service, with promises of greater fire knock-down power, less water used, lighter hoselines and less water damage (Almer, 1990; Davis, 1991; Fornell, 1991; Liebson, 1990; Rochna, 1990). After almost a decade, this technology has yet to find general acceptance in structural firefighting, at least in the northeastern United States.

The problem prompting this research project was that, especially in the early stages of fire suppression operations, there were frequently insufficient personnel to employ traditional extinguishment methods safely and efficiently.

This common problem is articulated by Larry H. Davis, editor of Fire-Rescue Magazine:

The three-step concept of opening the roof over the fire or letting it burn through, trenching each side far enough ahead of the fire to have some real effect and pulling ceilings in front of the fire to apply water is not working.…Why doesn't the three-step process work? We don't have 27 guys on initial attack! (1997a, p. 8) If CAFS technology were able to deliver on the claims made for it, this innovation could enhance safety and performance in the critical early stages of fire control.

The purpose of this research project was to determine if CAFS technology and procedures could be used to increase effectiveness, efficiency, and safety under limited personnel resource conditions.

Descriptive research, including the literature review, was used to explore the safety and operational results of under-manning, and to clarify the present state of development of compressed air foam and class A foam apparatus and usage. Several conflicting claims were examined. Evaluative research was used to measure and compare hoseline handling characteristics of weight, nozzle reaction, and ""bendability"" for CAFS and traditional (plain water) handlines.

The research questions examined were:

1. What are the effects of reduced manpower upon suppression activities with regards to efficiency and safety?

2. What are the recognized advantages and disadvantages of CAFS when used in structural firefighting?

3. How do CAFS hoseline handling characteristics differ from those of plain water hoselines?

4. Can the use of CAFS by an understaffed crew reduce the number of stress and fatigue injuries at suppression incidents?

5. Can the use of CAFS increase the suppression ability of an understaffed firefighting force?

BACKGROUND AND SIGNIFICANCE

Morristown, New Jersey is a small city/large town of 17,000 residents and 100,000 daily transients. The 1990 census reported 14,633 households with a 1989 median income of $59,413 and $2,448,515,000 aggregate worth of owner-occupied residences (U. S. Census Bureau, 1997). Commercial occupancies include five hi-rise office buildings and one hi-rise hotel. Morristown houses the county seat and jail complex. Morristown's Fire Bureau protects Morristown Memorial Hospital, the regional trauma center, and Morristown Airport, which is the third busiest airport in the state. Finally, there are several buildings of irreplaceable historic value, such as the Ford Mansion, which was Washington's headquarters for two years during the Revolutionary War.

Morristown has a history of strong volunteer fire service. Two hundred years ago, in 1797, a society was organized for the use of buckets, fire hooks, and cisterns. By 1837 the Morristown Fire Association was created by act of legislature and empowered to support two fire companies by special taxation. The six volunteer companies that are in service today were formed between 1867 and 1889. Full time career firefighters were first hired in 1929. As recently as the 1960's, there were waiting lists to serve as one of the town's 200 volunteers, in addition to 18 paid personnel, who functioned mainly as apparatus drivers and pump/aerial operators. Today Morristown is served by about 20 active volunteers qualified for interior structural firefighting, and an additional 30 in support capacity. The career firefighters, presently numbering 29 divided into four platoons, are no longer merely driver/operators, but generally function as one company at an alarm until volunteers arrive. In 1996 Morristown responded to 1288 alarms, which included 35 structure fires, 59 outside fires, 25 vehicle fires, 32 aircraft emergencies, 25 extrications, and 113 spills, leaks, and hazardous materials incidents.

It has become increasingly difficult to recruit and maintain qualified volunteers who are available to respond during daytime business hours. There is little local blue collar industry (the traditional rich source of volunteer firefighters), and many residents commute to work to surrounding towns and to New York City by rail. The trend toward two-career families has curtailed leisure time, and placed volunteer membership in competition with many other civic and family activities and duties. At the same time, the time commitment for initial and on-going firefighting training has increased, reflecting the progress in suppression understanding, safety and technology. Modern protective gear, SCBA, and communications has given today's firefighter the means to save lives and property which would have been lost a generation ago, but a substantial time commitment to training is required. Increased awareness and changing attitudes about safety (injuries and deaths are no longer considered acceptable costs of doing business) and environmental concerns mandate still more training and practice.

In addition to greater training demands, increased call volume has made it impossible for most volunteers to answer all (1300) calls. The general practice has been for volunteers to respond only after the on-duty crew is on the scene, discovered a serious fire, and called for a general alarm. This means that the five or six man initial crew will be carrying out fire suppression for several more minutes before the volunteers begin to arrive. Furthermore, while evening and weekend response has generally been adequate, although delayed, there have been fires during weekday hours where volunteer response has been at or close to zero.

Some efforts already taken to address this problem have been the formation of mutual aid agreements with the surrounding towns, recruitment efforts, and some conversation with Morristown's closest neighbor to institute limited joint responses. The government of Morristown considers it not feasible to fund more paid personnel. For the near future, the impact of this problem will be increased requests for mutual aid, some fire loss which could have been prevented with additional early manpower, and injuries suffered when too few firefighters try to do too many tasks as quickly as possible.

While not a panacea, and certainly not a replacement for manpower, the CAFS technology holds the promise of increased efficiency and safety for available personnel. If the claims for CAFS are validated, additional research is vital to implement and refine the technology, application and procedures for structural firefighting. If CAFS is found to be ineffective for structural firefighting use, research will be of great use to prevent fire department executives from committing thousands of dollars to purchase inappropriate CAFS systems.

This paper has been produced to satisfy the applied research project requirement for the Executive Development course at the National Fire Academy. The project relates to the course work on problem-solving, touching many of this unit's themes, including: problem recognition and definition, the barriers and constraints of inadequate and inaccurate information, the tendency to view problems and possible solutions too narrowly, inappropriate comparisons and analogies, and the effects of the organizational culture. Finally, this research will undoubtedly be a resource for Morristown's future apparatus purchase decisions.

LITERATURE REVIEW

Limited Personnel Operations

The current climate of fiscal restraints is prompting fire service leaders to examine the question of what constitutes adequate staffing at emergency incidents. The National Fire Protection Association (NFPA) recommends "An adequate number of personnel to safely conduct emergency scene operations" and that "Members operating in hazardous areas at emergency incidents shall operate in teams of two or more" and "In the initial stages of an incident where only one team is operating in the hazardous area, at least one additional member shall be assigned to stand outside of the hazardous area where the team is operating" (1992, p. 21). W. E. Clark (1991) notes that the important personnel consideration is the total number of firefighters responding early in the incident, on the first alarm. Ronny Coleman and John Granito (1988) agree:

Various controlled and statistically based experiments by some cities and universities reveal that if about sixteen trained firefighters are not operating at the scene of a working fire within the critical time period [before flashover], then dollar loss and injuries are significantly increased, as are the square feet of fire spread. (p. 119) Brunacini (1992) explains:

Another simple and related reality involves the direct and ongoing relationship between fire fighting capability, the number of fire fighters who respond, and their response times….We are effective to the extent that the system can produce workers quickly; too little and too late produce the same negative effect. (p. 28, 132)

In 1995 W. E. Clark noted, "Recommended minimums for initial response range from 12 to 16; but in actual practice vary from 4 to 35 (p. 623). The relative efficiency of understaffed companies was tested by former New York City Fire Chief John T. O'Hagan in the Dallas Fire Department staffing studies, involving 91 full-scale fire simulations and three full-scale fire tests (1984). He found that the result of understaffing was a forced choice between delaying some critical tasks and attempting to perform all of the original tasks less efficiently. O'Hagan further stated, "The consequences of these delays and omissions could include greater fire growth, delayed search and rescue, extension to the attic space, suspension of interior attack and rescue effort, and involvement of the exposure" (1985a, p. 21); and, "The consequences [of smaller crews] are overexertion to compensate for reduced manpower, early exhaustion, and a loss of effectiveness (1985, part 2, p. 27). Ronny Coleman and John Granito, of the International City Management Association (1988), note that it is the smaller communities which suffer disproportionately large fire losses because they lack the ability to produce sufficient initial attack suppression forces quickly (p. 119).

Bill Clark observes that reduced staffing is also inversely related to safety: Every fire requires a given amount of work for the needed results to be accomplished. This work, when divided by the number of firefighters assigned to do it, will show the amount of work each firefighter must perform. It is obvious that the fewer the firefighters, the greater will be the energy expended by each. This increase in physical stress could cause immediate or future heart problems and…other injuries as well. (B. Clark, 1994, p. 24)

Varone (1994) found that increasing the company staffing from three to four in Providence, Rhode Island resulted in a 23.8% reduction in all injuries, a 25% reduction the number of injuries serious enough to cause injury leave, and a 71% decrease in work time lost due to injury. The International Association of Fire Fighters (IAFF) found that fire fighters in companies of less than four were one third more likely to get killed or injured on the job. An injury rate of 13.5 injuries per 100 firefighters was

To whom it may concern:

During our life-long careers as firefighters and now Fire Chiefs in our respective communities, we have experienced much change. These changes have been big and small ones and include moving from volunteer departments to paid staff and many advances in technology. Today one of our biggest challenges is to continue to improve response times, and get emergency personnel onsite without delay. We know intimately that every second counts and that each second could be the difference between a life saved and one lost.

During our tenure as chiefs, we've communicated with other communities and parts of the country. We've seen and heard about all kinds of efforts to improve service and be more efficient and effective. As a result we both believe that the direction of best emergency response and firefighting capabilities includes a regionalized approach. A regionalized approach permits response districts, more even distribution/sharing of equipment and human resources, along with a great deal of flexibility in delivering superior service with reduced response times and travel distances.

We both support a proactive effort to explore regionalized firefighting and emergency response for our service districts and would be happy to be involved in a process to not only explore how we can proceed, but to implement a regional structure that best serves our primary as well as the surrounding communities.

Chief Jim Payeur (CAFA Fire Chief)

Jim Payeur ______________________ Date 10-18-10

Chief Loren Yates (DAFD Fire Chief)

Loren Yates ______________________ Date 11-19-10

THE BENEFITS OF REGIONAL COLLABORATION IN MANAGING NETWORK TRANSPORTATION OPERATIONS

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ABSTRACT

Regional collaboration has become an essential element in providing safe, reliable and efficient transportation systems. This paper illustrates the benefits of regional collaboration between agencies and jurisdictions with respect to transportation network operations by showcasing some of the best examples of regional collaboration and coordination in the U.S. today. The five case studies highlighted range from a simple collaboration between four road maintenance agencies between three counties to a multi-state wireless network that integrates transportation and criminal justice information for a multitude of agencies. Common benefits identified include: savings in procurement, expanded service area coverage, new funding opportunities, and formalized regional operations structures. Challenges to regional collaboration and performance measures used to evaluate these programs are also discussed.

BACKGROUND

The operation of transportation networks not only affects traffic on roadways, it also impacts economic growth, public safety, security and the environment. In light of this, it is important that the planning and operation of these networks involve regional coordination and collaboration from numerous jurisdictions, agencies and service providers. Common partners include departments of transportation, departments of public works, transit agencies, planning organizations, and public safety/security agencies.

Indeed, there has been a paradigm shift in transportation planning and operation from the traditional focus on single a single or jurisdiction to regions over the last decade. Some of the hurdles identified in advancing regional collaboration among stakeholders are the lack of common goals and visions, difficulty in sustaining collaborative efforts and realization of the benefits in collaboration among the participating agencies.

This paper focuses on the benefits of regional collaboration with respect to better management of road network operations. The following case studies showcase some of the best examples of regional collaboration and coordination in the U.S. today. Benefits that have been quantified are highlighted where available. Performance measures identified for future evaluation are also included.

The case studies highlighted in this paper range from a simple collaboration between four road maintenance agencies in three counties to a multi-state wireless network that integrates transportation and criminal justice information for a multitude of agencies. The first case study is SEMSIM, a regional collaboration among four road maintenance agencies in southeastern Michigan to coordinate snow removal technology and operations. The second case study is the Metropolitan Detroit Incident Management Coordinating Committee, an informal advisory group that makes recommendations for improving traffic incident management in the Detroit metropolitan area. The third case study is AZTech, a 40-member partnership of public and private agencies committed to improving travel by integrating intelligent transportation system technology throughout the Maricopa County region. The fourth case study is Kansas City SCOUT, a bi-state freeway management system that allows regionwide freeway monitoring and response from a centralized transportation operations center. The fifth case study is CapWIN, a multi-state, multi-agency wireless communications network connecting federal, state and local public safety and transportation agencies.

CASE STUDIES

SEMSIM

The Southeast Michigan Snow and Ice Management (SEMSIM) partnership is a regional collaboration formed among four road maintenance agencies in southeastern Michigan. The idea was conceived during a conversation between Managing Directors of the Road Commission for Oakland County (RCOC) and the Wayne County Department of Public Services who were both upgrading the AVL systems on their maintenance vehicles. They decided to invest in the same technology in order to save money on procurement and installation. This led to collaborating on operations, and bringing the City of Detroit Department of Public Works and the Road Commission of Macomb County on board as well. Together these four agencies formed SEMSIM in 1998 with the goal of outfitting 10 vehicles per agency with a common maintenance vehicle management system by Winter 2000.

RCOC is the lead agency in the SEMSIM partnership, and has individual contracts with each partner. As the lead agency, RCOC is responsible for securing Federal funding, paying contractors and buying parts. The project is financed with 80% Congestion Mitigation and Air Quality (CMAQ) funding and 20% matching contributions from the four agencies. No other staff or resources are explicitly shared. Each partner owns, manages and operates its own fleet, and retains control over road maintenance within its own jurisdiction. Operations and decisions are still localized; the SEMSIM collaboration simply facilitates information and resource sharing.

The physical features required for this project consist entirely of system-based technology upgrades that allow each agency to better monitor and communicate with its own fleet as well as its partners'. No physical facility was built, and no new vehicles were purchased for this project. Technology upgrades include in-vehicle status sensors that monitor the location, direction, speed, plow position, and salt application rate. New computerized salt spreaders automatically adjust the application rate based on the speed of the vehicle, improving the efficiency of salt application. GPS receivers improve communications by allowing two-way text messaging between vehicles and control centers.

The Suburban Mobility Authority for Regional Transportation (SMART), the regional transit agency, is an important stakeholder in the SEMSIM partnership. SMART provides the radio system that serves as the communications "backbone" for SEMSIM. Data are continuously fed from the in-vehicle units to computers at the control centers via the SMART radio system. SMART shares its radio system with SEMSIM free of charge, and receives real-time information about which roads have been salted and plowed in return. This benefits transit riders because SMART dispatchers can make informed route and scheduling decisions in adverse weather conditions.

Using a web-based map interface, partners can track snowplow locations and monitor treatment activities for all partner agencies, which facilitates sharing. For example, if RCOC sees that another county's snowplow is closer to an area that needs to be plowed in Oakland County, it can ask that county for permission to use its snowplow for the job. Agreeing to let snowplows cross-jurisdictional boundaries on an ad hoc basis allows for faster, more efficient plowing of roads. Before SEMSIM existed, there was no sharing of information or equipment between jurisdictions.

Regional collaboration has also opened up dialogue and improved relationships between partners. Periodic meetings keep communication lines open and ensure sustained collaboration. Before collaboration, agency counterparts may not have known each other, now they do not hesitate to pick up a phone to ask for advice or discuss an issue, and not only inter-jurisdictional issues. Informal sharing and exchanges also occur as a result of collaboration. For example, RCOC had a radio/computer expert who lent a lot of technical support to partner agencies during implementation of the first phase. Then when the City of Detroit changed from front-mounted plows to underbody scrapers, which RCOC had long been using, RCOC sent their operators to train Detroit workers. RCOC benefits from having well-trained operators on-hand in Detroit, and Detroit benefits from existing expertise by using the same technology as RCOC.

To date, SEMSIM has successfully integrated approximately 300 vehicles into the maintenance vehicle system, with a goal of all 500 vehicles by 2006. The main challenges they have encountered involve hardware and technology; collaboration itself has been fairly straightforward. Once they have equipped all of the existing partner vehicles, cities within Oakland and Macomb counties will be able to join SEMSIM. Some cities have already expressed interest in having their city roads included in the SEMSIM system.

SEMSIM is focusing on quantifying their savings using the large data set that now exists as a result of this project. The main performance measures being used to evaluate the program are reduction of salt use, which is expected to be 20%, and timesavings in clearing routes.

Future plans for the program include installing in-vehicle computers to better monitor vehicle maintenance needs. This is expected to reduce the cost of vehicle maintenance and prolong the useful life of the fleet. SEMSIM partners are also looking into real-time dynamic routing, which would identify the most efficient treatment routes given equipment availability at any time. There is also a desire to find more non-winter applications to make the program more cost effective. This would include pothole patching, street sweeping, lawn mowing, and road grading – all of which are responsibilities of these agencies.

Detroit Metro

The Metropolitan Detroit Incident Management Coordinating Committee is an ad hoc advisory group made up of public agencies and private interests with the purpose of improving response to traffic incidents. It was formed in 1992 as a result of an incident management workshop where participants from fire, police, and transportation agencies, and the metropolitan planning organization (SEMCOG) collaborated to develop a incident management program for the metropolitan Detroit area. This was formalized by the “Blueprint for Action”, which outlined twelve recommendations, and a lead agency, estimated cost and timeframe for completion for each recommendation.

Committee membership is open to any interested party from the public or private sector. Committee members meet every four to six weeks. Federal and state agencies include FHWA, Michigan Department of Transportation (MDOT), Michigan State Police (MSP), and Michigan State University (MSU). Other public agencies include SEMCOG, Road Commission for Oakland County (RCOC), Road Commission for Macomb County (RCMC), Wayne County Roads, and the cities of Detroit and Troy. Private partners include AAA Michigan, Emergency Road Response, and the media.

The Blueprint for Action has led to four major improvements to incident management response in the metropolitan Detroit area to date. First was the integration of the Michigan State Police (MSP) dispatch operations with the MDOT ITS Center (MITSC) in Detroit. This allows MSP dispatchers to view all of the CCTV cameras available on the metropolitan Detroit freeway system. This access improves emergency response by enabling dispatchers send fire and ambulance responders to the scene of an incident before state police officers arrive. Further integration has occurred with the microwave link connecting the MITSC in Detroit with the Road Commission for Oakland County (RCOC) traffic operations center (TOC). This allows for shared CCTV video, system integration and coordinated operations between the two TOCs.

The second improvement was the expansion of the freeway surveillance system from approximately 32 miles in downtown Detroit to over 200 miles of CCTV camera and VMS coverage in the metropolitan area. Third was the expansion of the Freeway

Courtesy Patrol from one van assisting motorists on I-75 in downtown Detroit to over 30 patrol vehicles operating on nearly all of the metropolitan Detroit freeways. The Committee is looking to further improve dispatching, extend service hours and expand service coverage. Lastly, the Committee played a major role in revising the abandoned vehicle time limit legislation from 48 hours to 18 hours. Removing these vehicles faster makes the freeways safer and reduces the risk of secondary crashes.

The Committee has developed a matrix to identify responder responsibilities for various levels of incident on metropolitan Detroit freeways. This matrix provides the basis for a joint operations strategy among incident response organizations. The matrix defines five incident levels – ranging from lane restrictions to full freeway closure – and the responsibility of each responder group – from police, fire, and emergency medical to road maintenance and hazardous material. The Committee will develop response roles, data and video requirements, and response and clearance performance measures as part of this matrix.

In early 2004, the Committee established six subcommittees to produce periodic reports on specific areas to the larger Committee. The traffic incident management planning subcommittee will update the Blueprint for Action, recommend incident management projects, provide support for the Great Lakes ITS funding program, and provide a national perspective on incident management activities. The arterial traffic management subcommittee will resolve boundary issues and integrate freeway and arterial operations. The courtesy patrol operations subcommittee will develop and update operating guidelines, review proposals for system expansion, and review data and technology needs relating to freeway courtesy patrol operations. The freeway operations committee will develop an outreach program to broaden representation of local fire and police, report on performance and benefits of freeway operations improvements, and develop incident management procedures. The abandoned vehicles subcommittee will suggest legislative action to further reduce abandoned vehicle time limit to four hours, coordinate with freeway courtesy patrol, review existing tag/removal procedures, and improve the system for removing abandoned vehicles from roadsides. The tow desk subcommittee will establish a tow desk at the MITSC that will have an exclusively assigned officer to handle tow operations.

The major challenge that many Committee members face is managing multiple regional collaboration efforts. Many of the same players are collaborating on different projects. These agencies are struggling with whether it is more effective to build on existing committees or establish new ones. There is concern that multiple committees overcomplicate things and cause redundancy, creating more roadblocks to collaboration than benefits.

AZTech

The concept for AZTech began in the early 1990s when traffic engineers in Maricopa County, Arizona wished to synchronize signal lights across multiple jurisdictions. Their objective was to implement inter-jurisdictional signal timing on their arterials. Since Arizona Department of Transportation (ADOT) owns and operates the signal intersections at freeway on-ramps, ADOT was included to synchronize lights from arterials to freeways.

The major physical components of AZTech are the AZTech server, eight Smart Corridors, a fiber optic network system, and center-to-center communication equipment. The AZTech server is a central database that fuses information from various sources and produces multimodal traveler information. The Smart Corridors are large-scale arterial street signal coordination and traffic detection systems that integrate seven jurisdictional traffic operation centers. Traffic detectors, closed-circuit television cameras, and changeable message signs were implemented along these Corridors. Traffic data from the participating jurisdictions are shared via the communication network administered by the AZTech server.

AZTech participants use inter-governmental agreements between ADOT and each city to address issues of responsibility for operation and maintenance of equipment. These agreements cover the transfer of funds, staffing, local funding, and operations and maintenance of AZTech equipment commitments, and leasing of some fiber optic lines. MMDI provided funds for the fiber optic connections between cities. The municipalities operate and maintain the equipment and communication links. Cities apply jointly to MAG for regular Federal funding in 80% of AZTech projects. The other 20% comes from County and Federal earmarks.

The operational arrangement of the Smart Corridors is a peer-to-peer permissive control traffic management scheme. Each jurisdiction retains control of its own signals, but coordinated signal timing plans for various pre-determined scenarios can be implemented with consensus from participating jurisdictions. Real-time traffic information is shared between the participating cities, MCDOT and ADOT, and traffic signal timing can be changed across jurisdictional boundaries via the communication network.

MCDOT was designated the official procurement agency for AZTech. MCDOT was determined to be more flexible in its procurement process and ability to work with local participants than ADOT. MCDOT is responsible for developing requests for proposal and contract negotiations. The County provided one procurement officer, as well as the AZTech Program Manager, to coordinate this work. The other agencies are also responsible for procuring selected technologies, but have the option to use MCDOT as the procuring agency or procure products and services themselves and be reimbursed by AZTech. The AZTech participants noted benefits from using one primary procurement agency to ensure that all products are compatible, no efforts were duplicated and costs were minimized through quantity discounts.

The sharing of costs and information through the AZTech server among multiple projects allowed for economies of scale, thereby making individual projects more affordable for participating agencies. The integration of ITS projects into an overall program under the AZTech umbrella provided a critical mass of multiple agencies. This heightened the awareness of ITS among local officials that individual ITS projects would not have been likely to accomplish.

The AZTech Evaluation Report also contained a partial signal re-timing evaluation study that quantified some of the benefits on a 5.7-mile section of the Scottsdale/Rural Road Smart Corridor, which contains 21 signals and passes through two jurisdictions. Three signals in Tempe were re-timed to match the Scottsdale cycle length. A GPS-equipped "floating car" field study was used to measure speeds and stops along the corridor. The re-timing was found to improve mainline travel speed by an average of 6.2% and reduce average stops by 4.2%. The impact was greatest in the southbound PM peak period, with average speed increasing 31% and average stops falling 19%. Fuel consumption and emissions estimates were made based on second-by-second speed and acceleration trajectories. The projected impacts were mixed: 1.6% reduction in fuel consumption, 1.2% increase in CO emissions, and no significant impact on HC or NOx emissions. Positive impacts were again amplified in the southbound PM peak period, where the largest increases in speed and reduction in stops were observed. Safety impacts were also estimated based on the speed profiles of the floating cars and data from the national crash database. The overall crash risk was predicted to drop by 6.7% overall, and by 20% in the southbound PM peak direction.

Computer simulation allowed assessment of these impacts for the entire corridor, including side streets. Simulation studies indicated that the improvements from partial signal re-timing in each of the above areas were not statistically significant when applied at the corridor level. Additional simulations were conducted for facility-wide optimized coordination plans. The results indicated that inter-jurisdictional optimization yielded the best performance, reducing delay by 20% and stops by 10% in the AM peak, over the baseline. This is compared to the 16% reduction in AM peak delay when signal optimization within each city was not coordinated between jurisdictions. Therefore, more benefits can be expected as AZTech expands its inter-jurisdictional signal timing coordination.

Overall, AZTech has shown clear benefits of both institutional collaboration and ITS integration, without any negative effects. The scope of AZTech was broadened as a result of workshops that were conducted following the completion of the MMDI project. An Executive Committee and Operations Committee were formed and meet regularly to guide future collaboration. Local fire and police departments and emergency services were added as AZTech partners. AZTech hopes to also include the medical community and the airport in the near future.

New collaborations led to work groups focused on emergency and evacuation management, expanded incident management programs, shared emergency traffic response teams, joint telecommunications projects, shared regional advanced signal system contracts, and integrated TMC systems. Regional forums were also established to identify priorities in traveler information deployment and expansion, and operations and ITS research. More recent collaboration between MAG and AZTech resulted in the MAG-led RCTO completed in 2003.

Kansas City SCOUT

The Kansas City SCOUT is a bi-state freeway management system formed by Kansas and Missouri State DOTs in 1997. The SCOUT system employs closed circuit television (CCTV) cameras, vehicle detection equipment, dynamic message signs, highway advisory radio (HAR), and ramp metering. Fiber optic cable, capable of carrying real-time data and video transmissions, will feed data from these field devices to SCOUT operators at the new regional Traffic Operations Center (TOC) located in the MoDOT District Office. KDOT and MoDOT have an MOU in place, and are currently working on a more formalized operations guide. They also have long-standing relationships with local departments of transportation, emergency services and police.

The primary advantage of SCOUT is to allow regionwide freeway monitoring and response from a centralized location. Prior to the formation of SCOUT, each state had motorist assist vehicles that patrolled freeways in their jurisdictions during peak commute periods. SCOUT allows both states to monitor freeways from the TOC using CCTV cameras mounted on freeways and dispatch patrollers when incidents arise. This will eliminate the need for continuous patrolling, and reduce the time to detect and clear incidents. While each State continues to run its own patrol program independently, there is more informal coordination and information sharing between the two groups as a result of collocation. The new TOC has been operational since January 2004, and operates 24/7.

The collaboration of SCOUT will also improve traveler information in this region. While both states will continue to own and operate variable message signs on freeways, SCOUT is helping them communicate more effectively. Permanent dynamic message signs and moveable changeable message signs in both sates will be coordinated with respect to placement and messages displayed to eliminate confusion and create a seamless information network for motorists. Performance measures will include incident response time, incident clearance time, and travel time reliability.

CapWIN

The Capital Wireless Network (CapWIN) project was conceived to create a seamless communication bridge between various incident management responders in the National Capital region (Washington D.C.). Before CapWIN, in order to transmit a message from one agency’s response unit to another, responders had to communicate with their respective communication centers to request that they phone their counterpart agency communication center to relay a message to their responding mobile unit. Fragmented and indirect communication added unnecessary delay in situations in which every second counts. The concept for CapWIN was to have multiple mobile data platforms communicating seamlessly across the network regardless of their jurisdiction or geographical location. The result was a web-based application that can operate on any IP network, allowing vehicle-to-vehicle text communication and remote, in-vehicle database access for law enforcement, transportation and safety agencies, fire departments and emergency response teams. CapWIN's end-users include federal, state and local police, fire, and EMS vehicles, as well as state DOT service patrols.

To avoid potential "turf issues" and overcome any perceived fear, participating agencies decided to have day-to-day operations managed by a third party. It was determined that the Center for Advanced Transportation Technologies at the University of Maryland would serve as the operations center for CapWIN, contributing management and staff support to the project. The university was considered an unbiased participant who was less threatening to agencies working together and sharing high-security information for the first time. There are thirteen university employees dedicated to the CapWIN project, whose salaries are paid by the project. The university is responsible for all system integration and procurement, as well as day-to-day operation and management.

Given the scale and nature of the CapWIN project, its potential benefits are significant and far-reaching. One valuable benefit already realized by the agencies is avoiding investment in costly technology that is incompatible with other agency systems. The improved systems are seen as a return on investment of time and resources. On-scene access to local and national databases provides better information when critical and timely decisions must be made. Additionally, more effective and efficient multi-agency operations help with major events such as terrorist attacks, fires, large scale Haz-Mat incidents, presidential inaugurations, state visits, and major sporting events. Table 1 provides a summary of some of the pertinent benefits to regional collaboration in network transportation operations.

Table 1. Potential Benefits of CapWIN

Benefits	**Performance Measures**
Reduced Dispatch Efforts	Reduced dispatch time per case
Quicker Communication	Reduced staff time per case
Inter-jurisdiction Information Flow	Detailed messages between participants
Improved Highway Management	Improved traffic flow
Maintains a Log	Number of messages

Once the full system is deployed, it is expected that a robust, data-oriented evaluation will be performed. Table 2 lists the performance measures that relate to transportation operations. One inherent problem in evaluating these performance measures is that many are aggregate measures that may not directly attributable to CapWIN or any single specific source.

Table 2. Potential Performance Measures of CapWIN

Safety
- Reduction in secondary crash rates

Congestion Improvement
- Reduction in travel time delay
- Reduction in travel time variability
- Improved incident clearance times
- Improved incident queue return-to-normal flow times
- Reduced average queue length at incident sites
- Increase in customer satisfaction levels
- Better traveler information disseminated

Productivity Measures
- Reduced costs for other communication systems
- Improved vehicle utilization and better fleet performance
- Cross-training and inter-agency cooperation increases

TANGIBLE BENEFITS OF REGIONAL COLLABORATION

Each example of regional collaboration has its own unique set of motivations, objectives and benefits. However, there are several common benefits that were found in the case studies above. Most of these benefits reflect an increase in productivity or cost effectiveness for the agencies involved. The tangible benefits of regional collaboration include:

- **Facilitation of information and data sharing –** Sharing data and information is often the first step in collaboration. It allows agencies to communicate better and develop strategies to work together more effectively. *SEMSIM's first task was to share vehicle location and treatment activity information across agencies. Future plans involve using data to plan treatment strategies, and conduct post-event analysis that can help reduce the costs of future winter maintenance operations. Sharing environmental data with the SMART transit agency allows their dispatchers to make scheduling and routing adjustments during winter storms.*

- **Technology upgrades and compatibility –** Technology upgrades often initiate collaboration, which leads to integrated, compatible systems across multi-modal and/or multi-jurisdictional boundaries. *This was the case with SEMSIM, in which system upgrades to road maintenance vehicles were the original motivation for collaboration between Oakland County and Wayne County. This led to involvement by the City of Detroit and Macomb County to integrate the technology of all four agencies into a common system.*

- **Savings in procurement –** Collaboration produces economies of scale, which reduces equipment costs through quantity discounts. *Both SEMSIM and AZTech report saving in procurement by having one agency purchase equipment for the group.*
- **Faster response time –** Collaboration coordinates operations of related agencies to provide better, faster service and response time. *Detroit Metro's Incident Management Committee successfully revised state legislation for abandoned vehicles from a 48-hour time limit to 18 hours. Removing these vehicles prevents secondary accidents, and frees up lane blockage from causing congestion or preventing emergency vehicle access. SCOUT's freeway management system allows constant monitoring on freeways from CCTV cameras, which can detect an incident much faster than the old method of patrolling the freeways by car.*
- **Extended hours of service/operation –** Collaboration and collocation combines funding, equipment and staff resources to allow for longer hours of service and often 24/7 operations. *The new SCOUT regional TOC collocates KDOT and Missouri DOT operations and plans to have 24-hour operation by Fall/Winter 2004.*
- **Expanded service area coverage –** Collaboration moves agencies away from jurisdiction-specific operation toward a regionwide, multi-jurisdictional approach that provides the public with a seamless transportation system over a larger area. *Detroit's Incident Management Committee has expanded the freeway surveillance system from 32 miles in downtown Detroit to over 200 miles of CCTV camera and VMS coverage across the metropolitan area. They have also expanded the Freeway Courtesy Patrol from one van assisting motorists on one freeway in downtown Detroit to over 30 vehicles operating on nearly all of the metropolitan Detroit freeways.*
- **New funding opportunities –** Collaboration enables agencies to finance much larger projects, or those that they may not be able to afford on their own, through pooled resources, joint applications and access to new Federal funds. *Many regional collaborations begin as pilot programs and demonstration projects, and Federal funding is often available to initiate them. All of the case studies mentioned in this report were mostly or fully funded using Federal dollars.*
- **Centralized operations –** Many collaborative efforts combine separately functioning TOCs or systems into one centralized operations center or single interface. *Both SEMSIM and CapWIN created web-based architecture to enable their agencies to access information remotely. This allows previously disconnected networks to communicate seamlessly with real-time information, and allows new agencies to be easily added in the future.*
- **Formalized regional operations structures –** Collaboration can lead to a formal Regional Concept for Operations document, or a new regional organization. *AZTech and MAG's on-going collaboration led to the recently completed Regional Concept for Transportation Operations.*

CHALLENGES TO REGIONAL COLLABORATION

While there are clear benefits to regional collaboration, there are also frequent challenges that many agencies face in their collaborative efforts. The following are some of the common challenges agencies reported and some of the ways they are dealing with them.

- **Multiple, overlapping committees involving the same key players –** Agencies report participating in several different committees with many of the same players in the region. The challenge is to find ways to minimize redundancy and complication without sacrificing the effectiveness of collaboration. *Agencies in the Detroit Metro area feel that too many committees overcomplicate working relationships. They are taking a closer look at where they can build on existing committees rather than create additional ones.*
- **Finding a champion –** Many of the successful collaborations report one or more champions who were committed to seeing the project through. Many say that the collaborations would not have had the same success without the vision and investment of these individuals or organizations. *The ITS Directors at Virginia DOT and the Maryland State Highway Association became the champions of a multi-jurisdictional communications bridge among agencies in the Capitol area and are credited as being the catalysts for the formation of CapWIN.*
- **Voluntary participation –** Some agencies do not participate because they lack staff or funds to commit to a regional project or they do not see the direct benefit to their agency. *In the case of SEMSIM, it was easier to bring the Detroit Public Works and Macomb County Road Commission on board once the plans for technology procurement and installation had already been laid out.*
- **Lack of stable/secure funding –** Many of these projects have high start-up costs because they are oriented toward technology improvements. Collaboration often opens up new Federal funding opportunities, particularly for pilot programs and demonstration projects. Once the projects are underway, however, agencies must allocate their own funds to keep projects going. *Many projects, including SEMSIM, report linking the benefits of collaboration to air quality improvements in order to secure Federal funding.*
- **Technology integration –** Because regional collaboration is often technology-focused, many projects report hardware and system integration as their biggest challenge. This can be particularly difficult, and often costly, when trying to integrate older technology with newer technology into a common system. *Although upfront costs of integration may be high, the long-term benefits can be significant and far-reaching once systems are fully integrated. CapWIN considers their improved system a return on investment of time and resources by preventing investment in incompatible technology by member agencies.*

- **Quantifying Benefits –** Data collection and analysis required to quantify benefits consume valuable time and resources that these projects simply cannot spare. Because funding is often limited and needed to carry a project to the next phase, funds for evaluation reports are not always available right away. *Many of these projects, including SEMSIM and CapWIN, are introducing technology that allows agencies to track and store data more easily. This will make it less time consuming and costly for them to quantify benefits. Other projects, particularly federally funded ones, need to have money set aside for evaluation at the time funding is awarded to ensure that evaluations are completed.*

MEASURING THE PERFORMANCE OF REGIONAL COLLABORATION

Most agencies participating in regional collaboration recognize the importance of measuring performance. On-going or periodic evaluation not only helps justify the need for additional funding, it also helps guide future collaborative activities. Unfortunately, evaluation of these programs is often put off, especially when funding is limited. While only a few of the projects highlighted here had completed evaluation reports, all had identified performance measures that would be used to evaluate their programs in the future. The following are performance measures identified by agencies for evaluating regional collaboration.

Congestion Improvement

- Reduction in travel time/delay (AZTech, CapWIN)
- Increased in travel time reliability (CapWIN, SCOUT)
- Improved incident clearance time (CapWIN, Detroit Metro, SCOUT)
- Improved incident queue return-to-normal flow times (CapWIN)
- Reduced average queue length at incident sites (CapWIN)
- Increase in customer satisfaction levels (CapWIN)
- Better traveler information disseminated (CapWIN)

Productivity

- Increased hours of service/operation (SCOUT)
- Expanded area of coverage (SCOUT)
- Reduction in dispatch time/Streamlined communication channels (CapWIN, Detroit Metro, SCOUT)
- Reduction in time to clear travel routes (SCOUT, SEMSIM)
- Improved vehicle utilization and better fleet performance (CapWIN, SEMSIM)
- Cross-training and inter-agency cooperation increases (All)

Cost Effectiveness

- Savings in procurement (AZTech, SEMSIM)
- Savings in labor costs (SCOUT)
- Reduced costs for other communication systems (CapWIN)

Safety

- Reduction in number of traffic accidents (AZTech)
- Reduction in secondary crash rates (AZTech, Detroit Metro)
- Improved incident response time (CapWIN)

Environment

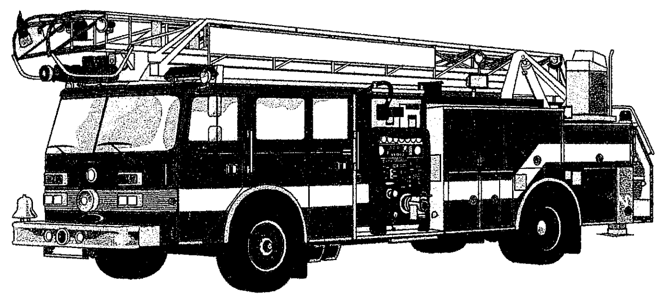
- Reduction in fuel consumption (AZTech)
- Reduction in vehicle emissions (AZTech)
- Reduction in salt use (SEMSIM)

CLOSING

The case studies presented in this report demonstrate the range of collaborative activities that various agencies in multiple jurisdictions can engage in. These case studies also provide an initial look at the tangible benefits that have been reaped by agencies involved in regional collaboration. In addition, they support advancing better management of network operations from a regional perspective. The benefits illustrated in these case studies highlight the importance of regional operations collaboration coordination in allowing advanced ITS technology to be utilized to its fullest extent.

BUYING AND SELLING

FIRE PROTECTION



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BUYING AND SELLING FIRE PROTECTION

Introduction

The provision of fire protection represents one of the basic services of townships and municipalities. While not all local governments *produce* fire protection services, most units arrange for the *provision* of fire protection services for their citizens. Units which do not engage in the direct production and provision of fire protection, generally purchase fire protection through intergovernmental agreements. Some rural townships, in order to provide adequate fire protection services for the entire township, may contract with several neighboring units to secure adequate geographic coverage.

The buying and selling of fire services has the potential to create conflict over the quantity, quality and price of fire protection. The current financial stress that many local governments are experiencing has prompted sellers of fire protection to reconsider pricing methods in order to ascertain whether the unit is covering the costs incurred in selling services to a neighboring unit. Changes in pricing strategies result in buyers of fire protection becoming resistant to accepting higher prices. Buyers of fire services often threaten to exit the agreement and establish their own department if prices are raised. Negotiating a new contract becomes much more difficult when either or both parties are experiencing financial stress. If the seller is the only "game in town," such negotiations take place in a monopolist environment. The entire negotiations process becomes politicized and threats of court action emanate from township, village and city halls. The politicization of the intergovernmental agreement process leads to open bitterness between the parties and frustrates the attempts of reaching a collaborative agreement. The inability to reach consensus on a fire service agreement increases public uncertainty as to whether quality fire protection will be available to residents.

Selling Fire Protection

Why do local units sell fire protection? In general, when municipalities or townships assemble the necessary resources, equipment, personnel and capital to produce fire protection services for their own unit, they may generate excess capacity. Units with excess fire protection capacity choose to sell protection to a neighboring unit in order to recapture a portion of the fixed costs of producing fire protection. A seller faces two key issues: (1) how much fire protection to sell (quantity) while still maintaining a given level of protection for the producing unit; and (2) what price to charge for the service being offered for sale. Establishing the price to charge is generally the source of disagreement between buyers and sellers. A city manager of a medium size city once remarked "that the appropriate price to charge is one upon which the two parties agree." While accepting his statement as true, there are other economic, social and political principles that should be considered.

Research[1] in 1976-78 of 94 communities engaging in the provision of fire protection services found, that the lowest cost per unit of the provision of fire protection occurred in units engaging in joint production. Intergovernmental contracting ranked second, while self-production and provision was the most costly. Therefore it is not difficult to understand why units attempt to sell fire protection to neighboring unit. On the other hand, the large capital investment required by a unit desiring to produce their own fire protection service often serves as a barrier to self-production, thus, provides an incentive to purchase fire services from a neighboring unit of government. When a unit buys fire protection, they not only purchase the services of fire suppression equipment and personnel, but also purchase a portion of the management services of the seller and the security of knowing that fire services will be available.

Pricing Fire Protection Services

A producer and seller of fire protection faces two types of costs, fixed and variable. Fixed costs include the costs of vehicles (tankers, grass rigs, pumpers, ladder trucks), buildings, and communications equipment. Since units do not purchase new fire vehicles each year, depreciation serves as a proxy for fixed costs. Variable costs include such items as wages and benefits of fire suppression personnel, operating costs of equipment, fire fighting gear, insurance, utilities, gasoline and repairs to equipment, accounting or bookkeeping services, and other items. The question for the seller is on what basis is fire protection sold?

Units throughout Michigan sell fire protection in a variety of ways; (a) *fire run*; (b) *annual subscription fee*; (c) *subscription fee plus run charge*; (d) *percentage share based on usage*; (e) *state equalized value share*; and (f) *weighted formula*. Each selling method has strengths and weaknesses that need to be recognized by decision-makers. No one single method appears to be a dominant means of selling protection in Michigan, however, some methods are perhaps more appropriate, depending on one's objectives. A brief outline of each will help clarify the differences between the pricing strategies.

A. Fire Run

Selling protection by the *fire run* is essentially average cost pricing. The seller determines the total costs of fire protection (budget costs) and divides the total costs by the total number of runs for the previous year. Or alternatively, using historical production costs, the seller establishes a cost per run to be charged for future runs. An assumption is made that the established fire run charge includes fixed costs. This method is appealing from the standpoint of its simplicity but masks the problem of

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1 "The Organizational and Provision of Fire Protection Services by Municipal Governments in Hillsdale, Jackson, and Lenawee Counties (Michigan)," Department of Agricultural Economics, Michigan State University, May 1978.

treating every fire run as being relatively equal in terms of costs. One cannot logically argue that a fire run to put out a car fire consumes the same level of resources as a fire fun to extinguish a barn fire. Year to year fluctuations occur in the number of fire runs thus the cost per run can change from year-to-year. If few fire runs are encountered in any given year, the producer of the service ends up bearing a larger share of the costs associated with the provision of fire protection. On the other hand, a buyer may find that the costs are high due to a large number of runs due for automobile or trash fires, but in terms of actual hours of service consumed, the governmental unit utilized relatively few fire suppression resources. An additional weakness of the pricing by "fire run" strategy is that sellers seldom take into account fixed costs. While the seller may recapture variable costs, the seller bears fixed cost. Fire run pricing introduces uncertainty to both the seller and buyer and may result in an inequitable sharing of costs of production and provision or what is referred to as cross-subsidization.

B. Annual Subscription Fee

Some municipalities sell fire protection based on an annual subscription fee (lump sum) basis for the year. The buyer makes a predetermined payment to the seller and receives fire protection for the entire year with no specified number of runs or consumption levels. The seller is assured of a given revenue contribution from buyers therefore reduces budget uncertainty. Depending on the basis for determining the annual fee, this method of selling could leave either the buyer or seller saddled with costs not accounted by the pricing scheme. Generally, historical usage data is utilized to determine consumption levels thus leading to the establishment of the annual fee. While revenues from selling the service are stable, a seller may go broke providing the service with this pricing method. Fire suppression resources utilized in two major fires may consume the entire annual fee, leaving residents in the producing unit paying for any additional fire protection calls for the buyer. On the other hand, if the subscribing unit experiences few fire calls, the buying unit may have over-contributed to the financing of the services for the year.

C. Subscription Fee + Run Charge

Establishing a *run charge* in addition to the *subscription fee*, in part eliminates the weakness of the previous discussed method. The subscription fee is essentially an access fee for the right of the buyer to purchase service from the seller. The seller then attempts to cover the variable costs of fire protection via the fire run charge. Another interpretation of the subscription fee, is that the fee partially offsets the capital costs incurred by the buyer in the production of fire protection services. Uncertainty again is introduced by assuming that all fire runs consume the same amount of fire suppression resources. Whether the subscription fee actually covers a portion of the capital costs incurred by the buyer is subject to the buyers ability to properly account for the total costs of producing fire services and the accurate apportionment the costs based on consumption of fire services.

D. Percentage Share Based on Usage

Under this pricing strategy, the seller of fire protection determines that total costs of fire protection and apportions the costs to buyers based on historical usage. Historical usage is determined by calculating the total number of fire personnel hours consumed by the buyer as a percent of total fire personnel hours of the department for the previous year. In order to avoid large year to year swings, a three or four year rolling average of fire personnel hours are utilized to determine percentage shares. The success of this pricing strategy is dependent upon the seller's ability to accurately reflect costs and requires accurate records with respect to personnel hours used in responding to each fire call. This method if implemented properly introduces the principle of equity. Units who historically consume more fire protection services pay more, those who consume less pay less. Utilizing this pricing method, buyers pay for both fixed and variable costs assuming the seller has included both in the budget development process. If the accounting is properly executed, no subsidization on either the buyer or seller occurs since the seller is able to realize not only the variable costs of producing fire protection, but recognizes the incurred capital costs and apportions those costs to the buyer including the sellers own unit. This strategy also insures that the seller (producer) can count on a pre-determined revenue payments from the buyer(s), thus reduces budget uncertainty.

E. State Equalized Value

A pricing method frequently utilized by sellers of fire services, especially those producing units levying special millage for fire protection, is providing fire services to buyers based on the equivalent yield of millage levy or a fraction of a mill levied on the taxable value (TV) of the tax base of the buyer. Prior to March 1994 and Proposal A, State Equalizes Value was utilized as the tax base measure. Utilizing TV introduces another variable in the pricing equation that was not present with SEV. Since TV represents an artificially capped value and not 50 percent of the marker value of a unit, some distortion may occur in equating the tax base of participating units. While the use of taxable value reduces budget uncertainty for both the buyer and seller, cross-subsidization of fire protection costs frequently occurs with this method. Since the selling price of fire services is not related to actual production and provision costs, a seller may end up paying for a portion of the fire costs for the buyer or vice-versa. An argument is often made by sellers that since residents in the producing unit fund the fire department through a millage levy, it is only fair that residents in a buying unit pay the same millage levy for fire services.

Sellers of fire protection services have the responsibility of determining fire protection and production costs. How a buyer chooses to pay for the purchased service is a separate issue from pricing. A buyer may elect to pay for fire services through the unit's general fund, service fees, user charges, create a special assessment district or unit may ask voters to approve an extra-voted fire millage. The issue of pricing on the part of the seller of fire services is separate from the issue of how a buyer pays for services

F. Weighted Formula

A *weighted formula* pricing method takes into account factors which have the potential to impact the demand for fire protection. The factors of *population, state equalized value and historical usage* are discrete and measurable and when combined together in a formula give transparency to the allocated share of fire protection costs, both for the buyer and the seller.

As the population of a unit increases, the incidence of fires generally increases. Therefore, including population accounts for added risk of exposure and the potential for the demand for fire services. State equalized value (SEV) of a governmental unit is included to represent the value of property to be protected. Similar to insurance, the more valuable the property to be protected, the more willing the owner should be to pay for fire protection. Recognition is made in the formula that open space is less costly to protect as opposed to residential, businesses, and commercial structures. Readers will note that SEV and not TV are used in the formula in part to more accurately reflect the value of land and property to be protected. The use of TV would not accurately reflect 50 percent of market value. Historical usage is included in the weighted formula in order to capture historical consumption patterns. How to determine usage? The simplest measure is fire runs however, a discussed previously, the use of fire runs in pricing schemes leads to cross-subsidization due to the application of average cost pricing. Usage could also be determined by tracking the total number of fire personnel hours utilized in suppressing fires and responding to fire calls. The use of a three-year rolling average would smooth out the peaks and valleys associated with usage. Perhaps a more accurate measure for both buyers and sellers is actual use data. For example, each emergency response consume "x" amount of resources with resources being measured by number of personnel at the scene, the hours at the scene and the equipment used. In today's computing world, vehicles dispatched, personnel at the scene and the hours spent at each incident can readily be determined. If over a twelve month period, such records are maintained, it can be easily determined what percent of usage is allocated between the seller and the buyers of fire service. [Hours at scene X personnel at scene x number of vehicles at scene = total consumption. Sum all consumption for one year and allocate by incident to all users (buyers and seller) and the resulting percentage can be used in the weighted formula. If possible use a three-year rollign average.]

Each of the three factors is assigned a weight - for example, SEV may be given a weight of 30 percent, population 30 percent, and usage 40 percent - the actual weights is a political negotiated decision. In rural areas where a significant percent of the SEV is attributed to open agricultural land, only fifty percent of the open space SEV is added to the SEV of residences and other structures. Ideally, if property record cards are computerized, an actual determination of the SEV of building structures could be determined and an agreed upon percentage of open space value added to determine the SEV of the area to be serviced. A percentage of the open space SEV should be included due to reflect the potential occurrence of grass and timber fires.

To calculate a formula share for each buyer of fire protection including the seller, the total population for the units or coverage area (if coverage area is different than the political boundaries) is determined and a percentage population share calculated for each unit (buyer). The total adjusted SEV is determined for the service area and a percentage share assigned to each buyer including the seller. A similar calculation is made with regards to historical usage.

Once the percentage share for each factor, population, SEV and historical usage is determined, the assigned weights are multiplied times the percentage share for each factor. The numerical result represents the weighted share to be used to determine each units financial share for fire protection services. The factor is used to determine both the operating cost share and fixed cost share for participating units.
Example: Applying the Weighted Formula Pricing Method

Assume that city is produces excess fire protection capacity and sells fire services to two townships. The negotiated weights for each of the factors are: population 30 percent; SEV 30 percent and usage 40 percent. The following tables demonstrate the determination of financial shares for fire services using the *weighted formula.*

Table 1: Population

Unit	2000 Popl'n	% Total Popl'n
City	4,575	53.5
Township A	2,225	26.0
Township B	1,750	20.5
Total	8,550	100.0

Table 2: State Equalized Value

Unit	2007 SEV Adjusted	% SEV
City	65,000,000	57.0
Township A	27,000,000	23.7
Township B	22,000,000	19.3
Total	114,000,000	100.0

Table 3: Usage
Three Year Average - Total Hours

Unit	Usage (3 Year Avg.)	% Usage
City	640	41.8
Township A	480	31.4
Township B	410	26.8
Total	1,530	100.0

Table 4: Factor Share
(Factor Weight X Percent Factor)
(Cross-Multiplication)

Unit	Popl'n 30% (1)	SEV 30% (2)	Usage 40% (3)	Sum Weights (1+2+3)
City	0.161	0.171	0.167	0.499
Township A	0.078	0.071	0.126	0.275
Township B	0.061	0.058	0.107	0.226
Total	0.300	0.300	0.400	1.000

The "sum weights" in Table 4 represent the formula share for each of the three units and are used to determine cost shares for each unit. For example, Township B's weighted factor share is 22.6 percent and would be used to determine their cost share for fire protection services.

Assume the total costs of budgeted fire services (variable cost + fixed cost) for the city in producing fire services is $86,000 - Township B's share equals $19,436.

While the weighted formula appears to be a bit more complex as opposed to other pricing strategies discussed, the weighted formula more accurately reflects the benefits and costs of fire protection services. The factors (population, SEV and usage) can be adjusted annually to reflect changes. Normally, population figures are only available every ten years unless a special census is taken, however, local officials may wish to adjust the population figure every five years if information is available. Since SEV and usage changes annually, the new data can be inserted into the formula for updating the weighted factor share for each unit.

Resistance to the adoption of such a pricing formula is usually the result of cost shifts that occur in the adoption of the new pricing strategy, especially if fire services have been historically sold on a subscription fee or fire run basis. The key to the formula is the recognition of the principle that incidence, value to be protected, and usage are captured in one formula. If properly applied, the formula reduces uncertainty in the pricing of services while insuring that costs of the producer are covered. Buyers on the other hand, have a clear understanding of the basis for the determination of their share of the costs to secure fire protection.

Determining the Costs of Fire Protection Provision

The main stumbling block to establishing intergovernmental fire protection revolve around determining what costs the producer includes in production costs. Buyers are often suspicious of producers, fearing that the unit is attempting to cover non-fire protection costs in the fire budget. Buyers are often unwilling to accept the concept that fixed capital costs need to be included in the costs to be passed along to buyers of fire protection. If capital costs are not recognized then the producer of fire services is likely to go out of business or residents living in the producing entity end up paying for a portion of the costs of provision of fire services to contracting units. The *weighted formula method* of selling fire protection minimizes cross-subsidization for fire services among the participating units.

An appropriate method for capturing capital costs is through the use of depreciation schedules. Buildings and equipment have a certain life of usefulness before they have to be upgraded or replaced. Establishing a depreciation schedule and including the

annual costs of depreciation as a fixed costs in determining total annual costs of fire protection production is a way to solve the fixed costs allocation problem.

Sellers must be cognizant of the costs of managing the fire department and the incurred costs of bookkeeping, training of personnel, maintaining inventory and ordering supplies. These costs are legitimate fire production expenses, and need to be included in the total costs of production of fire services. Buyers need to recognize that they are indeed contracting and purchasing a service, a service for which actual production costs can be determined. Buyers need to insist on a clear and detailed accounting for the basis of determining costs, especially capital and management costs.

Related Issues in Buying and Selling

Frequently one hears from buyers of fire protection that the seller needs to discount the cost of providing fire protection services to areas located some distance from the fire station. The argument is put forth that since the citizens in the outlying areas suffer higher personal costs when fires occur due to the time and distance from the fire station, the value of the fire protection service is less. Personal loss due to fire may indeed be greater as the distance from the fire station increases, but this does not mean that fire protection has less value to the residents. While it is true that personal loss increases as one increases the distance from the closest fire station, one must assume that the property owner was well aware of the risks involved in locating residence some distance from fire stations. The costs of providing fire protection to outlying areas of a buyer increase for the seller due to wear and tear on the equipment as well as increased personnel costs, therefore, the expectation that sellers should discount their service to outlying rural areas lacks economic principles.

Negotiating intergovernmental agreements is a frustrating and time consuming process. The transaction costs of arriving at consensus are high. The establishment of a fire service committee comprised of representatives of the various buying units along with representatives of the seller can serve as a problem solving board for both parties. While lacking statutory authority, a fire service committee can serve to deal with problems that arise during the life of the agreement. [Michigan law does permit the creation of a "statutory fire service or administrative board" (P.A. 365, 1982). The act covers the establishment of a joint administrative fire board to oversee fire department operations when a department is jointly owned by two or more units.] In the case of buy-sell relationships through intergovernmental contracting, units can use P.A. 7, 1967 (Extra Session) for the enabling authority. The act is very permissive and permits contracting parties to include in the agreement items such as advisory boards, pricing methods, and other terms/conditions for the buy-sell arrangement.

Waiting to begin the negotiation of a new contract until the old one expires is a poor path to follow. Bad contracts are developed during the heat of the battle and deep political scars that damage intergovernmental relations are usually the end result.

Questions are frequently raised by the buyers of fire protection, who have been contributing to the capital fund of the seller, related to the ownership of equipment acquired through expenditures from the capital fund. Whether a buyer is actually buying into ownership of capital purchases such as fire trucks is dependent upon the language in the intergovernmental fire agreement. Contract language should be clear and concise as to whether buyers are buying just the service rendered by the capital purchases or whether the buyer is indeed purchasing a portion of ownership of the equipment. If the seller is including depreciation costs into the costs of operation, then the buyer is clearly not buying ownership of the equipment. A seller who provides a specialized piece of equipment to service the fire protection needs of a buyer, may request that the buyer pay a major portion of the cost of acquisition and have the title of the equipment be held by the buyer or in joint ownership. Generally, buyers are not buying into ownership of equipment and buildings unless specified in the contract. It is highly unlikely in the case of a city selling fire protection to a township for example, that the city is selling a portion of the ownership. Municipalities and townships can avoid legal questions by developing a detailed intergovernmental agreement with clear contract language over the type and levels of service being sold and purchased.

The acquisition of fire protection through intergovernmental arrangements has the potential to provide political, social and economic benefits to both the buyer and seller. The key to successful intergovernmental relationships is the development of clearly articulated written agreements. For further reading on intergovernmental contracting readers are encouraged to review the following:

(1) ***On-Call Fire Departments: The Townships Board's Responsibilities*, G. Lawrence Merrill, Michigan Township Association, 512 Westshire, Lansing, MI 48917, 1993.**

reported for companies staffed at less than four, compared to 10.0 for companies staffed at four or more (1992, p. 21).

William Peterson, writing for the NFPA (1997), reports a nineteen year average of well over 100 firefighter deaths and 100,000 injuries per year. In 1995 heart attack from stress was the cause of half (50.5%) of all fatalities. Of the 1,070 on-duty firefighter fatalities over the last10 years, at least 498 were heart related (p. 10-61).

Of non-fatal injuries, Ladford (1996) reports: The NFPA statistics also say that each year, strains and sprains are the most common form of injury among firefighters, with slips and falls being the second most common form of injury. These specific injuries can be directly related to firefighter fatigue. As our firefighters become more tired during an incident, their potential for injuries increases. (1997a, p. 15) This sobering data, combined with the knowledge that it is unlikely that the Morristown Fire Bureau will be able to rapidly increase its personnel strength, motivated the author to investigate other resources, such as CAFS, to maximize the abilities of present personnel.

Description of CAFS

Ron Rochna of the Boise, Idaho Interagency Fire Center defines a compressed air foam system (CAFS) as: A standard water pumping system that has an entry point where compressed air can be added to a foam solution to generate foam….The air compressor also provides energy, which, gallon for gallon, propels compressed air foam farther than aspirated or standard water nozzles. (1991, p. 14)

Typical components include a centrifugal water pump, a water source, foam concentrate tanks, a rotary air compressor, a direct-injection foam proportioning system on the discharge side of the pump, a mixing chamber or device, and control systems to ensure the correct mixes of concentrate, water, and air (Colletti, 1993a; Colletti, 1996; Grady, 1994; Murdock, 1997).

One of the advantages of CAFS is versatility: A major advantage of using CAFS is having the unique ability to produce a wide range of foam qualities or foam types to provide the most appropriate foam response to individual fire situations….This gives the fire officer the advantage of custom tailoring the best foam type for the tactical use and fire problem at hand. (Colletti, 1994b, p. 39)

CAFS is able to deliver a range of useful foam consistencies, labeled from Type 1 (very dry) to type 5 (wet), which are controlled by the air-to-solution ratio, and, to a lesser extent, by the concentrate-to-water percentage. Type 1 and 2 foams have long drain times (i.e., the bubbles do not burst and give up their water quickly) and long duration. Wet foams, Type 4 and 5 drain more quickly in the presence of heat (IFSTA, 1996).

After testing a dry Type 2 foam in several situations Johnny Murdock notes: The emerging consensus is that the dryer foams (Type II; maybe Type I) should be used to suppress vapors, protect unburned structures, build wildland fire lines involving unburned fuels;…and that structural fire suppression requires a wetter foam (Type IV or Type V); and that both structural and wildland overhaul require Type V foam. (1997, p. 9)

For structural firefighting with CAFS, Dominic Colletti recommends, "A 1-3/4-inch hoseline flowing 80 gpm and 80 scfm [standard cubic feet per minute] with Class A foam proportioning at 0.3% will produce a wet, quick draining finished-foam that has excellent flame knockdown" (1994b, p. 39).

History of CAFS

The idea that water is not a perfect tool for extinguishment has been long noted, as by W. E. Clark (1991): The process of extinguishing fire by water is cumbersome and generally costly…[including] the cost of installing water mains large enough for required 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….the use of water is hardly the ideal way to extinguish fire….there must be a better method waiting to be discovered. (p.75) Liebson (1996) adds, "Water is an inefficient extinguishing agent. It requires the use of large quantities at costs both financial and physical. These costs are imposed on the firefighter and the community" (p. 5).

The use of foam additives to water for extinguishment dates back to an English patent in 1877 for a method to produce chemical foam (Liebson, 1991, p. xi). The British Navy experimented with agents foamed by means of compressed air in the 1930's (Darley, 1995) and the United States Navy was using compressed air foam systems (CAFS) in the 1940's for flammable liquid fires. By the 1960's do-it-yourself car washes were using CAFS with low pressure, small diameter hoses and nozzles, which flowed about four gallons per minute (gpm) solution and four cubic feet per minute (cfm) of compressed air, with a nozzle reach of about 40 feet (Rochna and Schlobohm, 1992).

In the mid 1970's the Texas Forest Service developed a water expansion system known as the Texas Snow Job. This pioneering Class A CAFS used a pine soap derivative, which was readily available as waste from local paper manufacturing industries, as a foaming agent mixed as eight to nine parts agent to 91 to 92 parts water, flowing up to 30 gpm. The duration limited by the use of compressed air cylinders rather than compressors. By the mid 1980's research by the US Bureau of Land Management led to modern design features of rotary air compressors, centrifugal pumps, and direct-injection foam-proportioning systems (Fornell, 1991; IFSTA, 1966).

CAFS received national attention in 1988 during the Yellowstone Park wildfires when the four story Old Faithful lodge was successfully protected by blanketing it with compressed air foam (Darley, 1995).

The overview and historical data propelled the research on to a closer look at the claims made for CAFS and the reasons behind them.

Extinguishing mechanism of CAFS

Water has several properties which make it a good extinguishment agent. Water excels at cooling because it has a high thermal inertia and high latent heat of vaporization, which means it can absorb more heat for its mass than most other substances. It can be transported readily by pumping and is generally available anywhere humans are (W. E. Clark, 1991).

The chief limitation of water’s ability to extinguish fire is its high surface tension caused by water molecules being attracted only to other water molecules. This is the force that causes water to bead up, form droplets, and roll off surfaces. According to IFSTA (1996, p. 122) and U.S. Department of Agriculture (Darley, 1995, p. 17), only five to ten percent of the water used in structural firefighting actually becomes involved in extinguishment. In addition, this surface tension makes it difficult for water to penetrate many substances, such as fibers, cloth, and upholstery. Water also does not form a protective coating on most substances, and cannot suppress vapor production unless there is enough water to submerse the vapor source.

Class A foam addresses these limitations. It is a synthetic detergent hydrocarbon surfactant (surface active agent). A 0.3% solution reduces surface tension by about two-thirds (Colletti, 1992), which allows the bulk of the droplet to spread out, enabling more of its surface area to contact the fuel, resulting in more rapid heat absorption. These same surfactants emulsify grease, petrochemicals, paints and other barriers to water penetration (Fornell, 1991). As a hydrocarbon surfactant, the foam has an affinity to carbon particles, which facilitates wetting of carbon fuels (Darley, 1995). IFSTA (1996) adds: "Many of the home furnishings and structural finishes in use today are made of synthetic materials that do not absorb water…the nature of finished foam also permits it to coat materials, such as plastics, that will not allow penetration" (p. 44).

The bubble structure in the foam is important to the increased extinguishing abilities. Plain water cools most effectively when the droplet size is very small. "Calculations show that the optimum diameter of a water droplet is in the range of 0.01 to 0.04 in. (0.3 to 1.0 mm), and that the best results are obtained when the droplets are fairly uniform in size" (Wahl, 1997, p. 6-6). The problem is that with conventional application, droplets this size are evaporated in the fire plume and never reach the seat of the fire. Testing by the Osaka, Japan Fire Department concluded that even smaller droplets, in the 250-350 micron range, are even more efficient (Fornell, 1991).

When Class A foam is directed into the fire, the air within the bubbles becomes heated and pops, fracturing the water solution into extremely small particles, which are immediately vaporized near the heat source (Colletti, 1994b). "Researchers believe that Class A agents provide the vehicle to deliver a more efficient droplet size into the flame/fuel interface area, without having the droplet evaporate en route" (Fornell, 1991, p. 308).

With CAFS, seven bubbles can be made the size of the original droplet. These durable bubbles stay in place releasing moisture as they diminish (Darley, 1995). They are also able to cling to vertical surfaces, which water cannot. "During the breakdown of the foam blanket, the bubbles tend to break down uniformly, with the water migrating towards the source of heat, rather than away from it" (Liebson, 1990, p. 25). As the solution drains out of the bubble mass, it penetrates the fuel. "The net effect is…that the available water supply is efficiently used to cling to and cool the fuel" (Colletti, 1993a, p. 56).

In addition to cooling, CAFS foam has been reported to extinguish or prevent fire in several other ways: by smothering (preventing air and flammable vapors from combining); by separating (intervening between the fuel and the fire); by suppressing (preventing the release of flammable vapors)(IFSTA, 1991); by providing insulation from radiant and convected heat by means of the dead air spaces within the bubbles (Colletti, 1994b); by reflecting radiant heat with the opaque surface of the foam (Liebson, 1996); and by interrupting the chemical chain reaction (Darley, 1995).

CAFS Experience and Testing

The literature contains numerous reports of evaluating CAFS and Class A foam under a variety of fire situations. In 1992, an acquired structure was burned while instrumented with a thermocouple-strip chart recorder in Salem, Connecticut "to measure the time/temperature-reduction relationships with the application of [plain] water, Class A foam solution, and Class A foam aspirated through a compressed-air foam system (CAFS)" (Colletti, 1993b, p. 41).

Identically fire-loaded 11-foot by 10-foot by eight feet-high rooms were allowed to burn to flashover. In each of the rooms, a 2-minute attack was then initiated, consisting of ceiling cooling for 60 seconds, followed by room and contents application for 60 seconds. The flow rate was 20 gpm of water or solution. At the four-foot high level, where "Heat…would directly affect the stress/survivability of trapped occupants...and also that of firefighting personnel involved in rescue/suppression operations" (Colletti, 1993b, p. 42),.

CAFS was found to be 480 percent more effective than plain water in lowering the temperature. Unaspirated Class A solution was found to be 110 percent more effective than plain water. If the test had been stopped at the temperature of 212 degrees Fahrenheit, water used would have amounted to 74 gallons of plain water, compared to 34 gallons of Class A solution, compared to 13 gallons of solution as compressed air foam (Colletti, 1993b; 1994b).

At the U.S. Army's Fort Indiantown Gap, in Annville, Pennsylvania, a 150-foot by 25-foot by 12-foot wood frame barracks building was allowed to burn to total building flashover and extinguished with CAFS. "The objective was to prove to the students that CAFS have the capacity to extinguish a large structure fire using only marginal personnel and water-supply resources" (Colletti, 1996, p. 55). Ninety-eight percent extinguishment was achieved with a single 2.5 inch exterior handline flowing 180 gallons per minute (gpm) of 0.04% Class A foam solution and 180 standard cubic feet per minute (cfm) of compressed air within six minutes. An estimated 1,080 gallons of solution was used. Using plain water only, the Iowa Rate-of-Flow formula would require a 450 gpm delivery rate; the more conservative National Fire Academy formula would require 1,041 gpm (Colletti, 1996).

The National Fire Protection Research Foundation, in a 1994 project named "Structural Fire Fighting - Room Burn Tests, Phase II," conducted several test burns in an 8 ft x 12 ft x 8 ft enclosure (National Fire Academy formula required fire flow of 32 gpm) with a calorimeter hood to measure heat release. Upon flashover, plain water or Class A aspirated foam or CAFS was applied until suppression was achieved. It was found that the use of Class A foam solutions was more effective in reducing the amount of heat release and the damage to the combustibles present, as compared to plain water. Additionally, when agents were tested at the low rate of 7 gpm, direct application of Class A foam as CAFS resulted in the shortest time and lowest quantity of agent needed to reduce the rate of heat release to 500 kilowatts. However, when using the indirect method at 10 gpm, aspirated Class A foam was more effective than plain water or CAFS (Carey, 1994).

In a live-fire drill conducted by the Chemeketa Community College Fire Protection School and the St. Paul (Oregon) Rural Fire Protection District, a 60 ft x 80 ft x 30 ft barn (NFA formula required fire flow of 1,600 gpm) was ignited and allowed to progress to full involvement. Knockdown was achieved in 50 seconds with a single 1.5-inch CAFS line flowing about 85 gpm, using less than 100 gallons of water (Liebson, 1991, p. 45).

In 1994, a series of Class B (jet fuel and fuel oil) burns were conducted at Liverpool, England's Speke Airport. One hundred eighty gpm aqueous film forming foam (AFFF) solution discharged through a CAFS was compared with the same AFFF solution flow applied with a conventional variable-gallonage/constant flow nozzle. The CAFS demonstrated superior fire-killing power, extinguishing amounts of fire that conventional application methods could not (Colletti, 1994c).

In Limerick, Pennsylvania, a 25-foot by 30-foot (calling for a 250 gpm Required Fire Flow by National Fire Academy formula) wood frame building with a heavy fire load was attacked with CAFS flowing 120 gpm Class A solution and 120 cfm compressed air, using a 2.5-inch exterior handline. The fire was knocked down in 25 seconds (Colletti, 1994c).

A series of eight standard Underwriters Laboratories "100-AB" 711 crib (each containing 3,300 pounds of lumber) fires were burned from October 2 to 17, 1992 at Vernon Military Camp, Canada. The test fires were extinguished with plain water, Class A solution, and Class A aspirated foam. The objective was to compare the flow rates needed for each agent to achieve fire knockdown. Class A foam was found to have superior extinguishing power: "On a preliminary basis, it appears that 80 gpm of ALEF [Aspirated Low Expansion Foam] is as effective as 160 gpm of plain water, both being applied in a straight stream" (Edwards, 1994, p. 68).

In November, 1993, the Fairfax County, Virginia, Fire and Rescue Department, the U.S. Naval research Laboratory, Washington, DC, and the Fort Belvoir (U.S. Army) Fire Department collaborated on a series of full scale structure fire tests, using single-story balloon frame barracks, 32 ft x 19 ft x 10 ft in size. At identical flows of 53 gallons per minute, CAFS extinguished the fire in less than half the time and with less than half the agent, even though the structure extinguished by CAFS had been significantly more heavily fire-loaded, had a longer pre-burn, and was burning at a higher temperature when extinguished (Jones, 1995; Colletti, 1994b).

Also at Fort Belvoir, Underwriters Laboratory conducted a series of burns of Class 20-A wood cribs, designed to be extinguished by a 33 gpm straight stream hoseline in one minute. Fifteen gpm of Class A solution as nozzle aspirated foam was found adequate to extinguish; fifteen gpm of water could not extinguish these fires. UL concluded:

The limited tests did demonstrate the ability of hand hoselines supplied with Class A foam solutions to provide enhanced fire fighting performance compared to hand hoselines supplied with water. The results of the wood crib fire tests demonstrated the ability of the Class A foam solutions to reduce the time required to control the fire as compared to water only. (Underwriters Laboratories Inc., 1994, p. 2)

A training exercise conducted in Montgomery County, Maryland involved burning a 10 ft x 40 ft

(National Fire Academy required fire flow of 133 gpm) room loaded with 25 wooden pallets and 15 bales of straw. The fire was knocked down with a one inch smooth bore nozzle on 1.5 inch hose flowing only 40 gpm Class A solution as CAFS, with 40 cubic feet per minute compressed air. Knockdown time was five seconds (Colletti, 1992).

In Sikeston, Missouri, four identical rooms of a single story motel were instrumented and burned to flashover and attacked with plain water and with Class A solution. The attack was terminated when temperatures were reduced to 150 degrees Fahrenheit, and the rekindle time was measured. The Class A agent provided knockdown in 29% to 52% less time than plain water. Class A also used 77 gallons of treated water, compared to 242 gallons in the plain water attack (Almer, 1990; Fornell,1991).

In 1995, Johnny I. Murdock tested a dry (20 to 1 expansion) CAFS on two identical test fires, each an 11 ft x 13 ft x 8 ft (NFA formula required fire flow of 48 gpm) bedroom. The 0.8% solution CAF flowing less than 10 gpm solution produced knockdown in 22 seconds, and complete extinguishment in 106 seconds, compared with knockdown in 7 seconds and extinguishment in 42 seconds for 150 gpm plain water (1997).

Concerning defensive fire fighting operations, Daniel Madrzykowski (1988), conducted ignition retardation (exposure protection) tests for the U.S. Department of Commerce, National Institute of Standards and Technology. Employing the Lateral Ignition and Flame Spread Test (LIFT) apparatus, he exposed samples of T1-11 textural exterior wooden siding material to heat radiation. The samples were either sprayed with plain water, Class A solution, or dry (14 to 1 expansion) Class A CAF. The foam exhibited a mass retention efficiency (ability to remain on the vertical surface) approximately 20 times that of water. Although the foam layer used was thin (6 mm), the foam treatment delayed ignition twice as long as plain water. There was no significant difference in the delay times of plain water and unaspirated Class A solution.

Advantages of CAFS

Many claims have been made for the increased firefighting performance of CAFS and Class A foam. Jeff Stern and J. Gordon Routley, in Report 083 of the US Fire Administration’s Major Fires Investigation Project (1996), surveyed several fire departments using CAFS. The reported advantages of include:

1. Class A foams allow faster fire suppression and extinguishment than plain water.

2. Class A foam increases efficiency and conservation of water supply.

3. Class A foam can be produced at a relatively low cost. One department estimated that the cost of Class A concentrate was probably offset by the savings in their use of diesel fuel resulting from reduced operating time on the fireground.

4. Class A foam forms a protective blanket.

5. Foam is visible during and after application.

6. Foam clings to most surfaces and protects exposures much longer than plain water.

7. CAFS attack lines are lighter than plain water hose lines.

8. Foam use may help to preserve evidence of fire cause.

9. Class A foam can be used on flammable liquid fires.

10. Class A foam aids wildland/urban interface attack.

11. Class A foam may provide long term cost savings and reduced property damage.

12. Firefighter stress and fatigue may be reduced. (p. 13-15)

The literature contains many opinions and estimates of the relative extinguishing power of CAFS compared to water. John Liebson (1991, p. xii) summarizes comparisons between CAFS, Class A foam without compressed air (also known as nozzle aspirated foam) and water in this chart:

Extinguishing Agent Used	**Time to Knockdown**	**Gallons of Water used**	**Amount of Foam Agent used**
Plain Water	**X**	**Y**	**N/A**
Class A Foam .	**.7 X**	**.5 Y**	**Z**
Compressed Air Foam	**.25 X**	**.3 Y**	**.35 Z**

This chart indicates that CAFS will knock down a fire in one quarter of the time with and thirty percent of the water needed when plain water only is used for extinguishment.

A selection of other estimates, quoted directly because terminology and units of measure are not standardized, include:

• "The addition of Class A foam and compressed air to a plain water fire stream multiplies the fire-killing power of the stream and the meatware [personnel] using it from 5 to 10 times (Davis, 1997b, p. 77);

• "Class A foam systems and CAFS may knock down up to 10 times more fire with a tenth of the water traditionally used" (Edwards, 1994, p. 66);

• "Effectiveness per gallon of water is estimated in the literature as high as 5 to 10 times over plain water for some applications" (Stern & Routley, 1996, p. 13);

• "Advanced Class A fire suppression technology allows a nozzleman to darken between three and 20 times as much fire as the conventional plain water system (Edwards, 1992, p. 97);

• "Anecdotal/empirical evidence and limited comparative testing have yielded a ‘three to five times more effective than plain water guideline’" (Colletti, 1993b, p. 1);

• "CAFS has a firefighting capability eight to ten times that of plain water" (Liebson, 1991, p. 23);

• "It has been estimated that when combined as solution with water, Class "A" foams are up to twenty times more effective than plain water alone" (Darley, 1995, p. 16);

• "The foam industry is saying it’s ‘three to five times more effective than plain water’…in my experience with using CAFS and contrasting flows on structures with Iowa Supply methods, the general range has been a fivefold increase in efficiency—but not scientifically quantified" (Colletti, 1992, p. 7-8);

• "It has been estimated that the use of Class A foam allows interior structural fires to be suppressed three to five times faster" (Davis, 1991, p. 50);

• "When Class-A agents are added to water, the resulting solution increases knockdown and holding potential anywhere from 3 to 15 times over plain water alone….If a fully involved room could be knocked down in 45 seconds using plain water, the use of Class-A solution will black out the fire in about a third of the time" (Fornell, 1991, p. 301,309);

• "They [Fairfax County Fire and Rescue Department] estimate that the CAFS unit will prove to be 60-100 percent more effective than a plain water engine, effectively giving them a fire suppression capability equivalent to two fire engines" (Stern & Routley, 1996, p. 11).

There are currently no test methods or requirements specified by NFPA in 298, Standard for Foam Chemicals For Wildland Fire Control, or elsewhere, to evaluate Class A foams and CAFS for effectiveness. Perhaps one assessment with which all writers would agree is provided by Samuel Duncan after evaluating CAFS for the US Army Tank-Automotive Command in 1994: "Based on the results and conclusions of this evaluation, it is the unanimous recommendation of the project members of the CRADA [Cooperative Research and Development Agreement] that CAFS technology would significantly improve the performance of most fire trucks….The technology is…effective enough in extinguishing fires to be of great value" (p. 19).

Although still new to the structural fire service, CAFS experience, in both test burns and in actual hostile fires, has been favorable. "With proper training, Class A foam can be utilized very effectively for both interior and exterior structure attack" (Colletti, 1993a).

IFSTA (1996) finds:

Early indications show that many of the same advantages realized in wildland fire fighting are duplicated when applying Class A foam to structure fires….The following are four main areas of tactical application:

• Interior (offensive) attacks

• Exterior (defensive) attacks

• Protection of exposures

• Overhaul operations (p. 140).

Duncan (1994) reports, "CAFS generated foam in structural firefighting proved to be capable of knocking the fire down faster, using less water, reducing the weight of the hose and increasing discharge distance over standard equipment" (p. 17). Carothers (1996) found that as much as 90 percent of water used to extinguish structure fires did not reduce any of the heat necessary for extinguishment. Darley (1995) agrees:

According to U.S. Department of Agriculture studies, when fighting an unconfined fire, less than 10 percent of the water applied to the fire actually goes toward extinguishment….The use of compressed air foam can reduce the amount of wasted water to about 20 percent. This means that 80 percent of the water is used to extinguish the fire. (p. 17)

The reason for this great increase in extinguishing agent efficiency is that the foam holds its water on the fuel, where it penetrates or is evaporated cooling the fire (Colletti, 1994b). Colletti (1993b) also estimated that this efficiency of CAFS increased suppression effectiveness of booster tank water by 300 to 500 percent. This in turn leads to less need for tanker support (Darley, 1995). Since less water is needed when using Class A foam, the risk of building collapse from runoff water is reduced (Brackin et al., 1992; Colletti, 1992).

This quicker knockdown translates into shorter exposure to fire hazards by firefighters, less damage to property, and less insurance losses (Brackin et al., 1992; Jones, 1990).

Other claimed benefits include less firefighter exposure to higher heat environment, increased firefighter safety, increased operational efficiency, and increased chances for victim survivability (Colletti, 1992; Fornell, 1991). Quicker knockdown also extends the useful life of available water: "Water conservation appears to be a significant advantage of CAFS. The reduced flow rate effectively doubles the capability of tank water" (Stern & Routley, 1996, p. 3).

Overhaul is also quicker and more water-efficient: " Because firefighters can see where and how much foam has been applied, the tendency to apply more than necessary is reduced" (IFSTA, 1996. p.143).

CAFS may reduce the hazards of firefighting in several ways. As previously noted, a large percentage of firefighter injuries and deaths are related to stress and fatigue. Stern & Routley (1996, p. 11) report reduced firefighter fatigue through diminished suppression and overhaul times, causing less exposure to heat and products of combustion. Colletti (1994a) claims: " [CAFS] can reduce flame knockdown times, increase fire stream reach, and provide lighter-weight hoselines, all of which increase firefighter safety through stress reduction" (p. 66).

A Federal Emergency Management Agency (FEMA) study concluded:

Attack lines that are used to deliver compressed air foam are significantly lighter and easier to handle than plain water hand lines, because the product inside the hose is mostly air. The line weighs approximately half the weight of a regular hose line of the same diameter. The reduced weight and increased maneuverability can reduce firefighter fatigue and stress. (Stern & Routley,1966, p. 15)

A report from the U.S. Army Tank-Automotive Command Research, Development and Engineering Center concurs: "Hose line weight is significantly reduced thus mitigating one of the primary physical stressors of fire fighting" (Duncan, 1994, p. 18). Darley (1995) claims that CAFS can reduce hoseline weight up to one quarter that of plain water, producing less firefighter strain. Colletti (1994b) notes that a CAFS 1.75 inch hoseline weighs about the same as a one-inch booster line filled with plain water, and that "On an interior structural attack the lightweight hoseline can reduce physical exertion and stress of attack team personnel advancing it" (p. 39).

The International Society of Fire Service Instructors (1997) reported that "CAFS diminishes the amount of work required to handle hose lines" (1997, p. 2). Westlake, Texas and Fairfax County, Virginia also reported light weight and easy hose management characteristics of CAFS lines (Stern and Routley, 1996). IFSTA (1996) notes that CAFS hoselines have the advantage of being lighter than both plain water hoselines and also nozzle aspirated Class A solution hoselines.

CAFS increases the probability of success of a "blitz" attack with fewer personnel, in many cases avoiding the alternative of subjecting personnel to large defensive tactical operations (Davis, 1991).

As observed in the Sikeston tests (Almer, 1990), covering uninvolved portions of a structure as advance is made reduces the risk of being trapped by re-ignition. Although "It takes repeated applications of [plain] water in order to keep a well involved structure from re-igniting" (Jones, 1990, p. 7), fire areas extinguished by foam have a greater tendency to stay extinguished, since the foam insulates the fuel from the remaining heat sources.

This property of resistance to re-ignition also makes possible an extinguishment technique known as panel soaking, here described by Fornell (1991): The idea is to tackle one panel at a time….The ceiling should be taken care of first….One wall panel at a time can then be soaked…reduce[ing] not only the fuel load but also its radiation ability. A panel penetrated by Class-A agent radiates almost no heat and can no longer contribute to the total heat load, helping reduce the chances of flashover….Removing the fire’s fuel by panel soaking does have a cumulative heat-reducing effect. By eliminating heat and fuel piece by piece, large fires can sometimes be successfully extinguished piece by piece. (p. 324,325)

Furthermore, when overhauling with foam, "Once the fire has been knocked down, a maintenance blanket of foam can be applied….This protective cover allows water to seep out as needed….Blow-holes will form in the blanket as steam is released, indicating hot spots below" (Fornell, 1991, p. 326). The threat of re-kindle is reduced (Darley, 1995; ISFSI, 1997).

The use of Class A foam and CAFS can create improved conditions for structural fire attack crews, including increased visibility, decreased steam generation, decreased combustion by-products, and quicker temperature reduction (Colletti, 1992;Colletti, 1994b; Darley, 1995; Fornell, 1991; IFSTA, 1996).

However, there have also been reports of an increase in residual heat after structural extinguishment (Brackin et al., 1992); a retention of residual heat (Liebson, 1990); and "Reports of hotter steam conditions as the fire is knocked down (by 25 or 30 degrees). It has not been determined if this increased temperature is real or a perception; it may relate to firefighters going more deeply and aggressively into hot areas" (Stern & Routley, 1996, p. 10).

One of the effects of energizing Class A foam with compressed air is greatly increased stream reach (Rochna, 1991). "Tests indicate that the reach of the CAFS fire stream can be greater than twice the reach of a low-energy [e.g., plain water or nozzle-aspirated foam] fire stream" (IFSTA, 1996, p. 72). Colletti (1992) states: "Forty gpm of water produces four brake-horsepower; an additional 20 cfm of air adds 10 brake-horsepower and will propel the stream approximately three times farther" (p.53). Darley (1995) reports a reach of 100 feet for 25 to 50 gpm streams. At the Idaho State Fire School, Davis achieved a reach of over 200 feet for 180 gpm through a deck gun’s 1.5 inch smooth bore nozzle (1991).

When an interior attack is not feasible (e.g., too few personnel, lightweight building construction, advanced fire conditions), this increased reach provides for enhanced fire fighter safety during an exterior attack. "CAFS can allow fires to be knocked down quickly from a relatively safe distance outside the burning structure" (International Society of Fire Service Instructors, 1997, p. 2). IFSTA (1996) notes:

"The extended reach of the CAFS stream assures that the foam is delivered deep into the structure and to the seat of the fire" (p. 142). Stern and Routley add:

Fires that occur in unstable or unsafe buildings could be fought from a greater distance by using the long reach of CAFS foam streams. Crews could remain at a safe distance outside of the collapse zone….The rapid and enhanced fire suppression capability of nozzle-aspirated foam systems and CAFS could improve fire suppression when fighting fires in modern, lightweight construction or trussed-roof structures. (1996, p. 8-9)

An additional safety benefit is provided by the stored energy of the compressed air in the hoseline, which in emergency conditions, can function similar to a pressurized water extinguisher: "When you run out of water, or lose prime, or run out of fuel, or any reason the truck or pump quits—the firefighter is still safe for a while because of the stored energy in the hose. The more hose installed means more time available" (Darley,1995, p. 21).

Relatively dry, slow-draining CAF has excellent protection and fire-confining ability when used to blanket uninvolved structures exposed to fire. CAF can hold its moisture for 20 minutes to 10 hours depending on the application, wind and temperature (Carothers, 1996; Fornell, 1991). It adheres to fuel and resists heat longer than low energy foams (IFSTA, 1996). It also has the advantage of being able to cling to non-water accepting building materials such as vinyl siding, glass, and painted surfaces (Clark, W. E., 1991).

This durability of CAF yields important manpower savings. Similar in concept to panel soaking described above, exterior exposures may be protected sequentially, rather than simultaneously. "Once the structure is coated, firefighters may move on to the next structure. When plain water is used, firefighters must remain with each structure and continue to apply water" (IFSTA, 1996, p. 139).

In addition to safety concerns, the use of CAFS has been found to reduce damage of all kinds. This reduced damage and firefighter injury is claimed to save taxpayers substantial money (Darley, 1995). The Boise (Idaho) Interagency Fire Center found that 75 cents out of each dollar paid out by Oregon insurance companies was spent on water damage and not direct fire damage (Jones, 1990). Water damage to structures is reduced by using CAFS (Liebson, 1990). An analysis of several fires in Idaho and Wyoming, confirmed by insurance adjusters, indicated that operations conducted with CAFS resulted in only 10 to 20 percent of water damage considered normal (Grady, 1994).

Darley (1995) Claimed that the use of CAFS also produced reduced smoke emissions and smoke damage.

Claims have been made that the use of CAFS may reduce wear and tear on other standard equipment by:

a. Lower truck operating rpm

b. Less pressure needed, due to lack of friction

c. CAFS does not allow water hammer

d. Reduced fire ground times, less spare air bottles needed

e. More efficient mop up, less tools needed" (Darley, 1995, p. 22).

Extinguishment with CAFS instead of plain water has been claimed to reduce environmental damage (Colletti, 1993a; Darley, 1995). When using plain water as the extinguishing agent, "You also carry with the wasted water all the carbon deposits and unburned particles that pollute lakes and streams, and also can get into our city water systems (Carothers, 1996, p.24). The use of CAFS reduces the amount of toxic gases, smoke and particulates put into the air by the fire, reduces the loss of natural resources, and reduces pollutants through reduced apparatus use (Colletti, 1992; International Society of Fire Service Instructors, 1997).

CAFS Limitations and Disadvantages

The literature contains references to several problems, concerns, and questions about the use of Class-A foam and CAFS. Health and safety topics include corrosiveness, slipping and falling hazards, and effects of equipment malfunctions.

Class-A foam concentrate is a hazardous material and should be treated as such, with the manufacturer's Material Safety Data Sheet available. The corrosiveness of modern Class-A foam concentrate is described as comparable to triple strength dish soap (Colletti, 1992). It can be irritating to the skin, eyes, and upper respiratory tract; can cause contact dermatitis and sensitization dermatitis; it can be corrosive to some metals and may reduce the life expectancy of leather products (Brackin et al., 1992;Darley, 1995).

Foam concentrate could corrode apparatus paint and finish, as well as metal tanks and pump parts (Stern & Routley, 1996), which is why CAFS are designed to inject foam concentrate on the discharge side of the pump. Studies by the U.S. Department of Agriculture Forest Service specify protective equipment, including eye goggles, or shields, water proof gloves, and rubber boots (Brackinet et al., 1992).

When Class-A foam is used, full turnout gear and SCBA should be worn. Gear should be thoroughly cleaned after contact with concentrate or solution, but not necessarily after contact with finished foam (Colletti, 1992). Class-A foam concentrate has been reported as a falling or slipping hazard (Brackinet al., 1992), but in the FEMA study (Stern & Routley, 1996), "Some departments felt the foam created somewhat of a slip hazard beyond plain water, and others did not note any additional hazard" (p. 16).

In the event of a malfunction preventing the flow of foam solution, a dangerous condition can occur. Known as slug flow, the compressed air and plain water separate inside the hose resulting in a violent serpentine hose movement and a completely ineffective fire stream (Colletti, 1996; Liebson, 1991). Fornell (1991) warns: "If a hose line bursts or a coupling blows off, the increased pressure of the moving force will cause the broken ends to whip about in a much more dangerous manner than a split [plain] water line" (p. 320). Newer systems, such as the one used by this author in this project, have automatic shutdown of compressed air when foam solution is not flowing.

In concentrate form, spills need to be kept out of ground water. Although modern Class-A finished foam produced from concentrates that meet NFPA 298, and have been approved by the USDA Forrest Service, is considered biodegradable (Darley, 1995; IFSTA 1996), long term environmental impacts are still uncertain (Stern & Routley, 1996).

A CAFS increases complexity of pumping operations, doubling the amount of operator calculations necessary to produce effective fire streams (Fornell, 1991). Much of this complexity has been removed in 2nd and 3rd generation systems.

A costly error is possible when Class-A and Class-B concentrate tanks are available on an apparatus. The Nashville, Tennessee Fire Department and others reported:

Severe damage to foam system components occurred in instances when firefighters, by mistake, added class B foam concentrate to a class A foam concentrate tank. The mixing of the different concentrates caused the concentrated AFFF to congeal, gel, and clog the foam tank and system, requiring the entire system to be removed and cleaned. (Stern & Routley, 1966, p. 9)

There is some evidence that hose wear may be accelerated from chatter and slug flow, possibly leading to earlier coupling failure and separation of interior hose liners; only hose approved for CAFS by the manufacturer should be used (Colletti, 1996).

The use of CAFS requires considerable initial expense for equipment, foam and training. The full sized unit may cost $35,000 or more; foam concentrate may cost $10 per gallon (Stern & Routley, 1996). Duncan (1994) reported that CAFS can be specified in a new pumper for about an additional 15% of the base price.

The descriptions, experiences, and claimed attributes of CAFS led to a consideration of how the advantages identified could counteract the operational and safety disadvantages of minimal staffing. The absence of any published data, or even theoretical formulas, for CAFS hoseline handling characteristics led to consideration of hands-on measurements.

PROCEDURES

The research procedure used in this study began with a literature review initially conducted at the Learning Resource Center (LRC) at the National Emergency Training Center in June and October of 1997. Additional information was gathered from the Lloyd George Sealy Library, John Jay College of Criminal Justice, City University of New York; from the Morristown Fire Bureau library; and from the author’s personal library.

Personal and telephone interviews were conducted in November and December, 1997 with Mr. Jack Alderton of the Brookside Engine Company of Morris County, New Jersey; with Mr. Keith Danis of the Rochelle Park, New Jersey Fire Department; and with Mr. Dominic Colletti, fire protection systems engineer at Hale Fire Pump Company, Conshohocken, Pennsylvania.

The literature review focused on two areas: an overview of the development and current state of Class-A foam systems and especially compressed air foam systems (CAFS); and staffing levels and the safety and operational shortcomings of limited staffing.

This study attempts to explore the interrelationship between the special needs/problems of limited staffing and the advantages of CAFS. No measured data about the hose handling characteristics of weight, nozzle reaction and resistance to bending applied to CAFS were found in the literature. These characteristics are important contributors to stress and fatigue of firefighters. Therefore it was decided to attempt to take measurements under simulated conditions.

Definition of Terms

Compressed Air Foam System (CAFS) - A pumping and delivery system that mixes water, foam solution and compressed air.

Class-A foam - "Foam intended for use on Class A or woody fuels; made from hydrocarbon-based surfactants—therefore lacking the strong filming properties of Class B foams, but possessing excellent wetting properties" (Liebson, 1991, p. xii).

Cfm or scfm - Cubic feet per minute, or standard (@ 0 degrees Celsius, 14.7 psi pressure) cubic feet per minute - a measure of the flow of compressed air, similar to gpm of a liquid.

Gpm - Gallons per minute, the standard measure of flow of a liquid.

Handline - A hoseline intended to be hand held by one to three firefighters, rather than supported by a mechanical tool or appliance; usually limited to 350 gpm flow.

Nozzle reaction - The backward thrusting force caused by the mass and velocity of the water discharged from the nozzle.

Pressure (psi) - A force per unit area, commonly expressed in pounds per square inch.

Research Methodology

This research was historical in that data from the literature review was used to understand the current state of development of Class-A extinguishment systems, and how their attributes can be used to enhance suppression efforts with today's limited staffing.

The evaluative methodology was used to test three CAFS hose line handling characteristics, and to compare with plain water hose lines. The characteristics were weight, nozzle reaction, and resistance to bending.

Weight was calculated by first weighing dry hose, and then calculating and adding the weight of foam. This was compared to similar calculations for plain water.

Nozzle reaction was measured under actual flow by means of two dial spring scales attached by nylon webbing to the hose immediately behind the nozzle, and anchored to a utility pole by chain at waist height. Fifty feet of Ponn Conquest hose of 1.75 and 2.0 inch diameter was laid out straight behind the nozzle in a slightly serpentine pattern. 3-M Class-A foam concentrate was used, injected at 0.3 and 0.5 percent. Nozzles and pressures were chosen to reflect the needs of a limited manpower attack.

Resistance to bending was measured by a reading from the spring scale of the force required to pull 10 feet of pressurized hose into a 90 and a 180 degree bend. Force was measured at waist height. Plain water hose lines were tested on December 4, 1997 at the Morristown Fire Bureau's parking lot. CAFS hose lines were tested with the same measuring apparatus on December 5 and 8, 1997 at Rochelle Park Fire Department’s parking lot/training ground.

Assumptions and Limitations

The testing and comparing of the handling characteristics of CAFS and plain water hoselines was intended, as far as possible, to approximate actual firefighting conditions of "working" a hoseline in a structure fire. Nozzle reaction, hose weight and resistance to bending are forces that stress and fatigue firefighters and impede progress and efficiency at real fires.

All force and weight measurements were rounded off to the nearest pound. The spring scales were not certified for commercial use, but in measuring loads with known weights they were found to be accurate within plus or minus four percent. Each dial recorded zero to 50 pounds in one-half pound increments.

A limitation of the accuracy of the nozzle reaction measurements relates to the friction between the hose and the ground surface. This friction tends to take some of the nozzle reaction force, and the interior floor surface of a fire building could be much more slippery than the asphalt at the sites of these tests. The test set-up was pre-tested by comparing plain water hoseline readings to values predicted by formula and were found to be within plus or minus six percent of the predicted values. Similar formulas relating nozzle diameter, pressure and gallons per minute flow do not yet exist for CAFS.

Other limitations include the author’s lack of experience with CAFS and limited knowledge of pneumo-hydraulics; the accuracy of the pumping engines’ flow meters and pressure gages; the variability of friction loss of individual lengths of hose; human error in reading gages; and the limited number of runs for each set up, caused by time and cost constraints.

RESULTS

1. What are the effects of reduced manpower upon suppression activities with regards to efficiency and safety?

The effects of reduced manpower upon suppression activities were found to be well-documented in the literature and consistently observed, both in actual fireground situations and in simulated exercises, extending back to Clark’s Wisconsin tests in 1960 (Clark, 1995). As the number of firefighters available at an incident decreases, significant increases have been noted in fire spread, dollar loss and injuries. Critical tasks, including search and rescue, were delayed or performed inefficiently. Physical stress was increased, which contributed to exhaustion of work crews. Greater number of injuries, greater rate of serious injuries and death, and longer injury leave have been found to occur when manpower is scarce.

2. What are the recognized advantages and disadvantages of CAFS when used in structural firefighting?

In the literature CAFS was found to provide more efficient fuel wetting and more rapid fire knockdown than plain water. After knockdown, foam was able to cling to fuel, even fuel arranged as vertical surfaces, preventing re-ignition for extended periods. While plain water extinguishes fire almost exclusively by cooling, CAFS was found also to smother, separate fuel from oxygen and heat, reflect heat, insulate fuel from heat, and suppress burning by interrupting chemical chain reactions. All sources found in the literature review agreed that CAFS had exhibited greater fire knockdown power with less agent than had plain water. Attempts to quantify this advantage ranged from a factor of two to a factor of fifteen. This enhanced extinguishment ability was found to result in less exposure time to heat and combustion byproducts, less stress and fatigue, and fewer injuries. The greater stream reach of the high energy system allowed extinguishment from greater distance to danger areas.

Losses due to fire, water and smoke damage were found to be reduced by the use of CAFS. Other benefits included less environmental damage from runoff water, greater operational efficiency, and reduced wear and tear of equipment.

Disadvantages of CAFS were also noted. Class-A foam concentrate has been found to be corrosive to some substances and an irritant to unprotected skin and eyes. The concentrate was found in some cases to present a slip and fall hazard. CAFS technology was found to complicate pumping operations, requiring additional training and extending possibilities of operator error and mechanical malfunction. Certain malfunctions were noted to have presented hazards to firefighters. Although biodegradable, Class-A concentrate has raised some long term environmental concerns.

3. How do CAFS hoseline handling characteristics differ from those of plain water hoselines?

Three hoseline handling characteristics were examined: weight, nozzle reaction force, and resistance to bending.

Table 1 - Weight of Hoseline

Per 50 feet length

Diameter	Hose	Couplings	Agent	
Total			(inches)	(pounds)
(pounds)	(pounds)	(pounds)		
1.75 inch:	13	2	52 (water)	67
1.75 inch:	13	2	26 (CAFS)	41
2.0 inch:	17	2	68 (water)	87
2.0 inch:	17	2	34 (CAFS)	53

As can be seen in **Table 1**, attack lines of equal size are considerably lighter when charged with CAF than with plain water. The above weights are calculated on a recommended air mixture ratio of one cfm to one gpm of foam solution under 110 psi.

The pumping pressure of 110 psi equals 7.48 atmospheres and compresses the air by that factor. A cubic foot of water also contains 7.48 gallons. This means that the hose contains a pressurized foam mixture of very nearly half liquid and half air by volume. Upon expulsion from the nozzle, the air in the foam expands to seven times the volume it had occupied under pressure in the hose. The CAFS line weighs 60 to 61 percent of the water line of equal size, and flows half the amount of liquid.

A 2.0-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.

Table 2 - Nozzle Reaction

Hose	Agent	Nozzle	GPM	Nozzle
Reaction		Diameter		Diameter
Flow	(pounds)			
1.75 inch	water	15/16	185	66
1.75 inch	CAFS	15/16	130	70
1.75 inch	CAFS	1 3/8	130	66
1.75 inch	CAFS	1 ½	shut off 130	44
1.75 inch	CAFS	1 3/8	150	70
2.0 inch	water	1 1/8	250	94
2.0 inch	water	100 psi fog	150	79
2.0 inch	CAFS	1 1/8	130	50
2.0 inch	CAFS	1 1/8	170	70
2.0 inch	CAFS	1 1/8	250	100+

Table 2 shows a number of combinations of flows and nozzle sizes which were selected to approximate conditions that would be appropriate for hoselines handled by only one or two firefighters. All nozzles were smooth bore except as noted. Plain water lines were charged with 50 psi at the nozzle (smooth bore) and 100 psi (combination fog). CAFS lines were charged with varying pressures to achieve the flows shown.

To achieve the same gpm of solution as plain water hose lines, CAFS lines were found to produce greater nozzle reactions. Larger nozzles produced less nozzle reaction at equivalent flows. At a flow of

130 gpm of foam solution, the 1.5 inch shut off valve without a nozzle produced an acceptable stream with only 67 percent of the nozzle reaction of a 1 3/8-inch nozzle, and only 63 percent of nozzle reaction of the 15/16-inch nozzle.

Table 3 - Resistance to Bending

Hose Diameter	Agent	PSI	Force at 90 degrees (pounds)	Force at 180 degrees (pounds)
1.75 inch	water	50	6	10
1.75 inch	CAFS	110	10	14
2.0 inch	water	50	5	6
2.0 inch	CAFS	110	14	18

Table 3 presents the results of the bending tests. The pressures (static) were chosen to reflect those actually used for CAFS and water. At the 50 psi pressure used with water, required bending forces are lower than those at 110 psi used with CAFS. This is true for both hose sizes. Unexpectedly, at the 50 psi pressure, the larger hose required less force to make both the 90 and 180 degree bend than did the smaller hose.

4. Can the use of CAFS by an understaffed crew reduce the number of stress and fatigue injuries at suppression incidents?

Understaffed crews were found to be under increased physical stress resulting from overexertion and early exhaustion. Unavailability of relief personnel further increased fatigue. Smaller firefighting forces, especially during initial attack, were shown to be at more risk of death and injury, both serious and moderate, than were a more adequate force of 16 firefighters, comprised of four-person companies The National Fire Protection Association reported that just over half of the on duty firefighter deaths that occurred in 1995 (and 47 percent over the previous 10 years) were caused by stress-related heart attack.

The most common fireground form of injury was found to be strains and sprains; the second most common form was slips and falls. The NFPA related these injuries directly to firefighter fatigue. The use of CAFS was found to reduce stress and fatigue by shortening suppression and overhaul times, thereby reducing firefighter exposure to heat, exertion, and products of combustion. CAFS lines were found to be lighter in weight and easier to handle than water lines of the same size. The durability of foam was shown to eliminate the need for constant soaking of fuels to prevent both fire extension and reignition.

Better visibility, a key to reducing slipping and falling injuries, was noted when using CAFS for interior operations.

5. Can the use of CAFS increase the suppression ability of an understaffed firefighting force?

Smaller suppression crews were found to be less efficient than crews of adequate staffing. Critical tasks were delayed or performed inefficiently. CAFS was found to have a greater extinguishing ability than plain water by a factor estimated between two and fifteen. Even accepting the lowest of these estimates, a one- or two-person hoseline crew equipped with CAFS has fire extinguishing power considerably superior to that of a plain water hoseline of equal weight and nozzle reaction. In situations where interior operations were not possible for a small crew, CAFS was found to significantly out-perform plain water exterior fire streams in the amount of fire extinguished.

DISCUSSION

In several accounts in the literature, one of the advantages claimed for CAFS is lighter, more maneuverable hose lines. The measurements resulting from this study's empirical testing indicate that, at equal gallonage flows (plain water compared to foam solution, not finished foam), the CAFS lines need to be larger and heavier (to carry an equivalent flow of liquid, **plus** compressed air), and exhibit greater nozzle reaction and bending resistance forces caused by higher pumping pressures. This discrepancy points to a controversy surrounding the enhanced extinguishment power of CAFS.

Several authorities, with strong evidence, hold that less gallonage is needed with CAFS for a given amount of fire (Edwards, 1994; Stern and Routley, 1996). 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, lighter, more maneuverable lines. However, other sources (Colletti, 1992; Fornell, 1991; International Fire Service Training Association, 1996; Liebson, 1992, 1996) 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 fire knockdown, rather than smaller, lighter and less fatiguing hoselines.

The reason that this is such an important question is that fire suppression is a threshold event—either a suppression crew has enough knockdown power to stop combustion and damage, or the crew does not, in which case the fire and damage continues until the fire has burned itself down to the threshold of available extinguishing power. A relatively small increase of extinguishing power from just below to just above this threshold can make all the difference between stopping a fire and total loss with extension to other properties. This threshold of extinguishing power has been quantified for water by several required flow formulas relating minimum gpm water flow to area or volume of fire. At this time, there is not a consensus on how these minimum flow formulas may, or may not, be adjusted for flows delivered as Class-A foam by CAFS.

As Liebson wrote in 1991:

The greatest lack at the time of the writing of this book is quantitative data…for specific fire scenarios. Given a specific type of building, with a known fire load, what quantifiable improvement in fire suppression might be expected when using Class A or CAFS, contrasted to the traditional use of plain water? (p. xi) Seven years later, in spite of a large body of research, this question remains unresolved.

The first line of **Table 2** represents a benchmark. Fornell (1991) considers 185 gpm at 50 psi nozzle pressure on 1.75-inch hose with a 15/16-inch smooth bore nozzle to be the most efficient one-person plain water fire stream. It has a computed nozzle reaction of 69 pounds, and a measured nozzle reaction of 66 pounds in this study.

Fornell (1991) considers this amount nozzle reaction force the upper limit for the average firefighter to successfully overcome for approximately 10 minutes of continuous firefighting. For a larger firefighter, the rule of thumb is that the nozzle reaction can range up to one half the firefighter's body weight. This flow of 185 gpm (of foam solution) could not be achieved within this nozzle reaction limit with the 1.75 inch CAFS lines under the conditions and nozzles tested. CAFS options within the nozzle reaction limit for the single firefighter include 150 gpm via the 1.75 inch handline or 170 gpm via the 2.0 inch line. Indications (e.g., the low 44 pound nozzle reaction with the nozzle removed) are that a 185 gpm CAFS flow with the 1.75 inch handline might be approached with larger diameter nozzles. If so, the CAFS 1.75 inch line would still be under much more pressure than the 50 psi water line, and so would be much more resistant to bending.

CAFS appears to be well suited to the initially limited manpower response of the Morristown Fire Bureau. Noted CAFS expert Dominic Colletti recommended (in telephone interview, January 7, 1998) using an initial attack line of 1.75 diameter hose, 95 gpm foam solution, 80 cfm air at about 110 psi pumping pressure for a typical one or two room-and-contents house fire. This is a fairly easily handled stream, satisfies the traditional 95 gpm minimum interior attack flow, has an actual extinguishment power probably beyond the 185 gpm of plain water, and can be increased up to 150 gpm as necessary.

Larger diameter nozzles specifically designed for CAFS can provide options to optimize a balance between nozzle reaction and fire stream requirements. There is a response time component to the required flow threshold discussed above. The typical fire is continuously growing, and the later the suppression activities are begun, the higher the needed flow. O'Hagan found (1985b) that a single 150 gpm hose line, on the average, has reached the limit of its extinguishment ability when the average fire has been burning 10 minutes after flaming ignition.

The use of CAFS in Morristown would help alleviate the problem of delayed response by volunteer forces. Fairfax County Fire and Rescue Department, after an evaluation phase, employed CAFS in areas characterized by long second-in company response times (Stern and Routley, 1996). Davis (1997a) reports that the Brookside Engine Company of Morris County, N.J. uses CAFS to "maximize its fire suppression capability with minimal personnel—especially during daytime hours when manpower is short" (p. 29).

Numerous authors (Colletti, 1994b; Duncan, 1994; IFSTA, 1996) warn that CAFS is not a panacea and is not a replacement for personnel. Liebson (1996) describes this approach as "a great danger as far as injuring or killing firefighters" (p. 6).

In 1998 Morristown's Engine Two is scheduled for refurbishment. Initial inquiries indicate that retrofitting with CAFS is feasible. This engine is assigned to protect Morristown Airport and is now equipped with a roof turret and Class-B foam tank. The CAFS would also enhance the Class-B foam delivery and reach at aircraft fuel and other flammable liquid incidents.

RECOMMENDATIONS

It is the recommendation of this author that Morristown proceed with plans to incorporate CAFS technology into the Engine Two refurbishing project. Additional research into the most appropriate brand, model and features will be necessary. Time and funds must be allotted for training both the career and volunteer divisions in CAFS operations. Pump operators in particular will need time and practice foam to develop additional skills. Tactical considerations and standard operating procedures will need to be developed. There will soon be at least five CAFS units in operation in northern New Jersey. An attempt should be made to network and share information and experience in this new technology.

The problem of limited manpower on the initial response will need to be monitored and addressed. Unless present trends are changed, increased reliance on mutual aid and additional career firefighters will become necessary. Longer-range recommendations include more research into CAFS extinguishment ability. Whatever further testing is necessary for various authorities to achieve consensus on evaluating the CAFS extinguishment "premium" should be identified and performed. Modified critical flow formulas should be developed and incorporated into texts and courses explaining pneumo-hydraulics.

As the fire suppression community gains experience with CAFS, fireground and training evolutions should be developed and refined. An aggressive interior attack at a structure fire is presently the hallmark of a competent suppression force. With current technology, this is how victims are saved and damage is minimized. The Morristown Fire Bureau prides itself on this ability, even when minimum manpower is present. However, several anecdotal accounts in the literature relate very rapid extinguishment of structural fires by means of exterior attack with small CAFS handlines.

For several decades, it has been the dream of the fire service to discover an effective method of extinguishment (fog injection, high pressure guns) which does not require interior operations before fire control is achieved. Delaying entry into this dangerous and uncontrolled environment until the fire is knocked down would prevent firefighter injury and death. Although there will probably always be some need for interior operations, this phenomenon must be thoroughly studied.

In investigating such controversial material, the fire community should maintain the healthy skepticism expressed by David Fornell (1991):

Some claim that a 39 GPM water flow rate when used with CAFS can be as effective as 200 GPM of plain water applied by conventional means. Similar claims were made forty years ago for high-pressure fog. Experience later proved that flow rate, not pressure, is what extinguished the fire. High-pressure delivery may have increased distribution effectiveness but put out little more fire than the same gallonage delivered at normal pressures. While Class-A agents increase knockdown times and help seal burning surfaces more efficiently than plain water, exaggerated claims for the foam’s efficiency should be investigated closely. (p. 320)

REFERENCES

Almer, S. (Producer); Emge, C. & Wilson, C. (Editors). (1990, October). American Heat: Class A foam tests: Sikeston, MO [Video magazine]. Volume 5, program 4. (Available from American Heat Video Productions, Inc., 240 Sovereign Ct., Ste. C, St. Louis, MO 63011)

Brackin, M., Bublitz, D., Crosley, S., Farmer, K., Wallace, L., & Wiggins, T. (1992, July). The pros and cons of class a foam. Fire Engineering, 145, 59-66.

Brunacini, A. (1992, May/June). Shrinking resources vs. staffing realities. NFPA Journal, 84, pp. 28, 132.

Carey, W. M. (1994). National class a foam research project technical report: Structural fire fighting - room burn tests phase II. Quincy, MA: National Fire Protection Research Foundation.

Carothers, T. (1995, December/1996, January). Firefighter’s foam-u-la for change. Firefighter’s News, 13, 24-26.

Clark, B. (1994, February). Is there safety in numbers? Fire Engineering, 147, pp. 24, 27.

Clark, W. E. (1991). Firefighting principles and practices (2nd ed.). Saddle Brook, NJ:Fire Engineering.

Clark, W. E. (1995). Fire company operations. In J. R. Bachtler & T. F. Brennan (Eds.), The fire chief’s handbook (pp. 611-641). Saddle Brook, NJ: Fire Engineering .

Coleman, R. J. & Granito, J. A. (Eds.). (1988). Managing fire services (2nd ed.). Washington, DC: International City Management Association.

Colletti, D. J. (1992, July). Class a foam for structure firefighting. Fire Engineering 145, 47-56.

Colletti, D. J. (1993a, March). Class a foam: Q & A. Firehouse, 18, pp. 54, 56, 57.

Colletti, D. J. (1993b, February). Quantifying the effects of class a foam in structure firefighting: The Salem tests. Fire Engineering, 146, pp. 41, 42, 44.

Colletti, D. J. (1994a, March). Compressed-air foam mechanics. Fire Engineering, 147, 61-65.

Colletti, D. J. (1994b, December). Compressed air foam systems: Your questions answered. The Voice, 23, 38-43.

Colletti, D. J. (1994c, March). Testing cafs in live burns. Fire Engineering, 147, pp. 74, 76.

Colletti, D. J. (1996, July). Compressed air foam systems and fire hose. Fire Engineering 149, 50-52.

Darley, P. C. (1995, September). The use of class "a" foam and compressed air foam systems (CAFS) in firefighting. Foam Applications for Wildland & Urban Fire Management, 7, 15-22.

Davis, L. (1991, April). Class a foams. Firehouse, 16, pp. 49, 50, 75.

Davis, L. (1997a, November). The Brookside solution. Fire-Rescue Magazine, 15, 29-32.

Davis, L. (1997b, December). The great equalizer: Compressed air foam systems (CAFS). Fire-Rescue Magazine, 15, 77-80.

Duncan, S. (1994). Technical report no. 13606: Evaluation of NDI compressed air foam system (CAFS) applied as a retrofit [on line]. U.S. Army Tank-Automotive Command Research, Development and Engineering Center, Warren, MI 48397-5000. Available at http://www.usfa.fema.gov/usfa/nfp/tedhreps/tr083.htm.

Edwards, C. B. (1992, September). Critical flow rate. Fire Engineering, 145, 97-99.

Edwards, C. B. (1994, March). The Camp Vernon burns. Fire Engineering, 148, pp. 66, 67, 68, 70, 73.

Fornell, D. P. (1991). Fire stream management handbook. Saddle Brook, NJ: Fire Engineering.

Grady, C. (1994, January). Compressed air foam: An idea whose time has come. American Fire Journal, 46, 12-16. IAFF study shows inadequate staffing leads to injury. (1992, March/April).

International Firefighter, 21.

International Fire Service Training Association. (1996). Principles of foam fire fighting (Wieder, M., Smith, C., & Brakhage, C., Eds.). Stillwater, OK: Fire Protection Publications, Oklahoma State University.

International Society of Fire Service Instructors. (1997). Class a foam: Moving structural fire suppression into the technology of tomorrow [on line]. Available at http://afem.org/afem/foambroc.html.

Jones, K. (1995, March). Put the white stuff on the red stuff. Fire Chief, 39, 52-54. Jones, K. L. (1990). Urban application of the compressed air foam system. (Executive Development Research Paper). Emmitsburg, MD: National Fire Academy.

Ladford, R. F. (1996, December). Safety officer’s corner: Replacements and recovery. The Voice, 25, 15.

Liebson, J. (1990). Is water really the answer? New foams may be better, part II. The Voice, 19, pp. 14, 25, 27.

Liebson, J. (1991). Introduction to class a foams and compressed air foam systems for the structural fire service. Ashland, MA: International Society of Fire Service Instructors.

Liebson, J. (1992). Recent developments in class a foam. The Voice, 21, 12-13.

Liebson, J. (1996, March). Change your policies—then adopt class a foam. American Fire Journal, 48, 6-8.

Madrzykowski, D. (1988). Study of the ignition inhibiting properties of compressed air foam. Gaithersburg, MD: Center for Fire Research.

Murdock, J. I. (1997). Compressed air foam systems: A project pertaining to an adoption decision. (Executive Development Research Paper). Emmitsburg, MD: National Fire Academy.

National Fire Protection Association. (1992). NFPA 1500 standard on fire department occupational safety and health program. Quincy, MA: Author.

O’Hagan, J. T. (1984). Staffing levels: A major new study. Fire Command, 51, 16-19.

O’Hagan, J. T. (1985a). Staffing levels: The private residential fire problem. Fire Command, 52, 18-21.

O’Hagan, J. T. (1985b). Staffing levels: Conclusions. Fire Command, 52, 20-23.

Peterson, W. (1997a). Fire department occupational safety and health. In A. E. Cote (Ed.), Fire Protection handbook (10:59-62). Quincy, MA: NFPA.

Rochna, R. (1991). Compressed air foam: What is it? The Voice, 20, 14-17.

Rochna, R. & Schlobohm, P. (1992). Foam Applications for Wildland & Urban Fire Management 4, 5-9.

Stern J. & Routley, G. (1996). Class a foam for structural firefighting [on line]. Available at http://www.usfa.fema.gov/usfa/nfp/techreps/tr083.htm.

Underwriters Laboratories Inc. (1994). Report of class a foam tests. Northbrook, IL: Author. U. S. Census Bureau. (1997). Selected 1990 census data [on line]. Available at http://www.census.gov/population/www/censusdata/censusdata.html.

Varone, J. C. (1994). Providence fire department staffing study. (Executive Development Research Paper). Emmitsburg, MD: National Fire Academy.

Wahl, A. M. (1997a). Water and water additives for firefighting. . In A. E. Cote (Ed.), Fire Protection handbook (6:6-7). Quincy, MA: NFPA.

RETURN TO HOME PAGE

DETAILED INFORMATION ABOUT CAFS

EMAIL NEAL BROOKS FOR MORE INFORMATION

Automated External Defibrillators (AEDs)...

Music At Madison Helps Local Police Departments Fight Sudden Cardiac Arrest
Click above to read the article.

It happens quickly. Without warning. It can affect anyone - healthy adults, even teenagers. It cannot be prevented. There is no vaccine. Most do not survive.

It's called Sudden Cardiac Arrest (SCA) and there's only one way to treat it. ***Defibrillation.***

Unfortunately, 90 - 95 percent of SCA victims die because they didn't have quick access to this easy-to-administer lifesaving treatment. By making more people aware of sudden cardiac arrest and by improving access to Automated External Defibrillators (AEDs), we can increase the survival rate for these people.

Survival rates of over 50% have been achieved where easily organized AED programs have been established. These rates are ***twice*** those reported for the most effective EMS systems, and ***ten times better than the national EMS system average of 5%!***

Every responsible household has an easily accessible fire extinguisher. In many ways, it is appropriate to think of an AED as a ***medical fire extinguisher!***

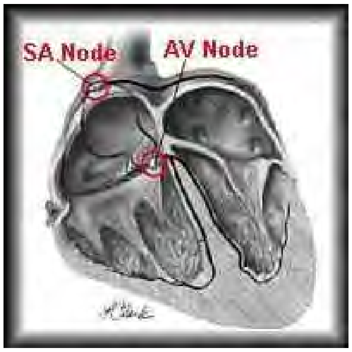
Sudden cardiac arrest, or SCA, is a frequently misunderstood worldwide killer. It can affect anyone, anywhere, anytime. SCA occurs more than 600 times every day in the U.S. alone, killing at least 250,000 people each year. That's more people than the entire population of cities like Derby, England or Raleigh, North Carolina. SCA kills more people than house fires, AIDS, firearms, prostate and breast cancer, and automobile accidents, ***combined***. It is one of the leading causes of death among American adults.

Yet few people are familiar with sudden cardiac arrest.

* How many times have you seen or heard about Emergency Medical Technicians flying across the lobby of your building into a waiting elevator. Our Fort Lauderdale Fire-Rescue E.M.T.s tell us that a

substantial number of calls that they respond to on the Barrier Island are for Sudden Cardiac Arrest. Unfortunately, ***they often arrive too late!*** Fire-Rescue Techs have been visiting Condos to alert our residents about the lifesaving benefits of on-site Automatic External Defibrillators. ***Some of us are starting to listen!***

- What is sudden cardiac arrest?



Sudden cardiac arrest (SCA) is a condition in which the heart stops beating suddenly and unexpectedly due to a malfunction in the heart's electrical system. When this happens, the heart's lower (pumping) chambers contract in a rapid, unsynchronized way. The malfunction that causes SCA is a life-threatening abnormal rhythm, or arrhythmia. The most common arrhythmia is ventricular fibrillation (VF).

When in VF, the heart's rhythm is so chaotic (called "fibrillating") that the heart merely quivers, and is unable to pump blood to the body and brain. Once a heart has entered VF, sudden cardiac arrest occurs.

A victim in SCA first loses his or her pulse, then consciousness, and finally the ability to breathe. But all of this happens quickly - in a matter of seconds. Without immediate treatment from a defibrillator, 90-95 percent of SCA victims will die.

The only effective treatment for SCA is to deliver an electrical shock using a device called a defibrillator (to de-fibrillate the heart), which stops the chaotic rhythm of a heart in VF or in ventricular tachycardia (extremely rapid heartbeat), giving it the chance to restart beating with a normal rhythm.

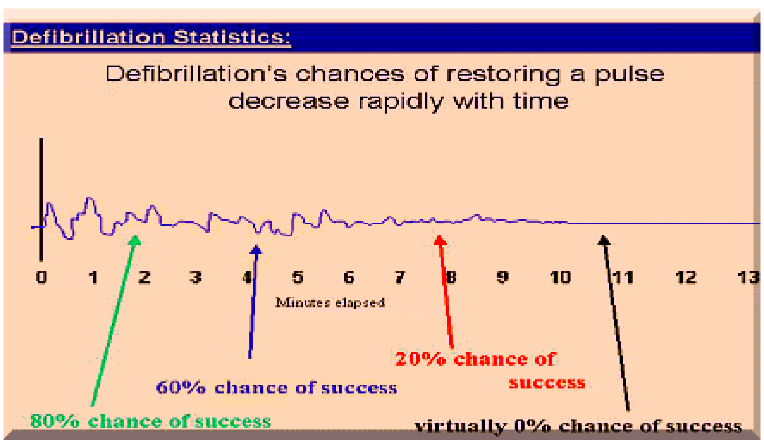
Cardiopulmonary resuscitation (CPR) will ***not restart a heart in sudden cardiac arrest.*** CPR is just a temporary measure used to continue a minimal supply of oxygen to the brain and other organs. When someone is in sudden cardiac arrest, ***defibrillation is the only way to re-establish a regular heartbeat.***

- Who can be affected by SCA?

Unfortunately, anyone can suffer sudden cardiac arrest. SCA is unpredictable and can happen, without warning or symptoms, to anyone, anytime, anywhere...even teenagers. Although pre-existing heart disease is a common cause of cardiac arrest, many victims have never had a heart problem. Risk does increase with age.

Without immediate treatment, only 5-10 percent of people survive SCA. But survival rates above 50 percent have been achieved in places that have successfully implemented AED programs. Survival rates can climb even higher when the person is treated within three minutes of cardiac arrest.

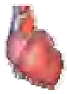
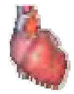
These statistics are impressive, but they're still just numbers. It's not until you save a life, or meet someone whose life has been saved by an AED, that the awesome power of an AED program becomes evident.



- Is sudden cardiac arrest the same as a heart attack?

  Sudden cardiac arrest (SCA) is not the same thing as a heart attack (myocardial infarction), although a person suffering a heart attack has an increased risk of SCA.

  Here's how they differ:

	Heart Attack	**Sudden Cardiac Arrest**
Cause	 Caused by an occlusion (blockage) in an artery that supplies blood to the heart (coronary artery). The affected heart muscle then begins to die due to lack of oxygen.	 Caused by an abnormal heart rhythm, usually ventricular fibrillation.
Warning Signs	Often preceded by chest, arm, upper abdomen, or jaw pain; weakness, dizziness, nausea, vomiting and sweating are common.	Rarely a warning; victim collapses suddenly and has no detectable pulse
Victim's Response	Usually remains conscious and alert	Always loses consciousness; unresponsive
Risk of Death	With proper treatment, many people survive.	90 - 95% will die, unless a defibrillation shock is delivered within 10 minutes of collapse.

It's not always easy to tell if someone is suffering from SCA, but the victim will typically:

- Be unconscious
- Have no signs of circulation (e.g. no pulse)
- Not be breathing

Why is it important to know the difference between SCA and a heart attack? Because the treatment for each is very different:

- For a heart attack, medical professionals must administer medications, other life-saving procedures, and sometimes surgery, to unblock blood flow to the heart muscle. Time is important, with the best results occurring if treatment is received in the first hour of symptoms.

- For SCA, an electrical shock from a defibrillator must be delivered, the sooner the better, otherwise the victim will likely die. Laypersons can be easily trained to use an AED, thus dramatically increasing the odds of saving someone's life.

Waiting for emergency professionals (e.g. EMS) when someone is in SCA could delay treatment and could cost the person his or her life.

How is sudden cardiac arrest treated?

The only way to effectively treat sudden cardiac arrest (SCA) is with an electrical shock delivered by a defibrillator. Voltage stored by the defibrillator pushes electrical current through the heart by means of the electrodes or paddles placed on the chest. This brief pulse of current halts the chaotic activity of the heart, giving it a chance to start beating again with a normal rhythm. Delivering a shock that returns the heart to a normal rhythm is called defibrillation.

Early defibrillation is the key to surviving SCA.

Survival rates for SCA are highest when defibrillation occurs within the first few minutes. The person has the best chance of survival if the defibrillation shock is given within the first three minutes of collapsing.

But if a defibrillator is not immediately available, the outlook is grim. For each minute defibrillation is delayed, survival rates drop by about 7-10 percent-even if CPR is started immediately.

- The rate of survival for SCA victims averages less than two percent when defibrillation is delayed ten minutes or more.
- The average time it takes emergency crews to arrive is between 6-12 minutes.
- If the heart isn't restarted within the first four to six minutes after the arrest, the victim may sustain irreversible brain damage.

For Your Information!

- The International Guidelines 2000 from the **American Heart Association** reports that "extraordinary survival rates-as high as 49%-have been reported in PAD (Public Access Defibrillation) programs. These rates are twice those previously reported for the most effective EMS systems.
- In one study, when a Las Vegas casino implemented an AED program, survival rates for VF-related SCA reached 70 percent when the SCA was witnessed and the AED was used within three minutes.

Automated External Defibrillators (AEDs)

An Overview

An AED is a small, portable device that analyzes the heart's rhythm and prompts the user to deliver a defibrillation shock if it determines one is needed. Once turned on, the AED guides the user through each step of the defibrillation process by providing voice and/or visual prompts.

AEDs are specially designed for easy use by a “first responder”, who would be the first person to typically arrive on the scene of a medical emergency. A first responder can be an emergency medical services worker, a firefighter or police officer, or it can be a layperson with minimal AED training.

Time to defibrillation, the most critical factor in sudden cardiac arrest (SCA) survival, can be reduced if an AED is “on-site” and can be brought to the victim quickly. This is one of the reasons that survival rates improve in communities with active AED programs. Remember, every minute that passes before defibrillation reduces survival rates by 7-10 percent.

The goal is to improve SCA survival rates…..on-site AEDs can make the difference.

- How does an AED work?

  Once an AED is turned on, it provides prompts to guide the user through the process. One of the first prompts instructs the user to connect the AED to the victim via the adhesive electrodes (pads) placed on the chest.

  The AED's microprocessor then analyzes the victim's heart rhythm through the electrodes using a built-in computer program. It then determines if a shock is "needed" or "necessary." More specifically:

  - The electrodes placed on the victim's body send the heart rhythm information (ECGs) to the AED.
  - The AED "reads" short segments of the heart's rhythm. It checks characteristics such as frequency, shape, slope, amplitude and heart rate.
  - Based on these characteristics, the AED determines whether or not a shock is needed and activates the appropriate user prompts or (in fully automatic versions) administers the shock.

In the above graphic series, the particular AED requires either 2 or 3 steps to save a life. Three steps if it is the semi-automatic unit and only the first two steps if it is the fully automatic version. Once you determine the person isn't breathing or conscious, you just:

1. ***Push the button to release the lid and turn on the defibrillator.***
2. ***Pull the handle to get the electrode pads and adhere them to the person's chest as shown.***
3. ***Press the flashing button if told to do so. (Not necessary in fully automatic versions!)***

If a shock is needed, the AED will prompt the user to press the button that delivers the shock. It will then re-analyze the heart rhythm to determine if more shocks are needed. If the unit is fully automatic, it will automatically administer shocks as needed. If a shockable rhythm is not detected, the AED will prompt the user to check the victim for a pulse, and to perform CPR if needed.

- How does the shock “fix” SCA?

The delivery of an electrical shock to a heart experiencing SCA briefly stops all electrical activity in the heart. This brief "break" from the previous electrical chaos can be enough for the heart to restart beating with a normal rhythm.

Not everyone can be saved from SCA, even with defibrillation. But early defibrillation, especially when delivered within three minutes of a person's collapse from SCA, does provide the best chance.

- Is an AED safe to use?

An AED is safe to use by anyone who's been trained to operate it. Studies have shown the devices to be 90% sensitive (able 90% of the time to detect a rhythm that should be defibrillated) and 99% specific (able 99% of the time to recommend not shocking when defibrillation is not indicated). This level of accuracy is greater than the accuracy of emergency professionals. Because of the wide variety of situations in which it will typically be used, the AED is designed with multiple safeguards and warnings before any energy is released. The AED is programmed to deliver a shock only when it has detected VF. However, because recognizing the signs of sudden cardiac arrest should trigger an AED intervention, the AED should always be functional and available. That's why training including safety and maintenance is important.

The **AHA** (American Heart Association) recommends that persons who live or work where an AED is available for use by lay rescuers participate in an AED Course. AEDs are so user-friendly that untrained rescuers can generally succeed in attaching the pads, pressing **ANALYZE** (if required), and delivering shocks. However, untrained rescuers probably would not know how to respond to the victim if the AED prompts ***"no shock indicated."*** An operator needs only to follow the illustrations on the electrode pads and the control panel and listen and follow the voice prompts (for example, ***"Do not touch the patient"***). While the fully automated version delivers shocks as needed, the partially automated AED will deliver a shock only when a shock is advised and the operator pushes the **SHOCK** button. This prevents a shock from being delivered accidentally.

An AED should not be used on a child younger than 8 years old or weighing less than about 55 pounds.

COMMUNITY OUTREACH QUESTIONNAIRE

FROM THE

ISO COMMUNITY MITIGATION WEBSITE

Please mail the questionnaire and a map that shows your current fire protection boundaries and fire station locations to the appropriate ISO office listed below. The map is very important to insurers as it defines your fire protection area and the properties deserving of the insurance premium recognition reflecting your classification number.

If this questionnaire is for a community or fire district in the following states:

Alabama	Maryland	Pennsylvania
Connecticut	Massachusetts	Rhode Island
Delaware	New Hampshire	South Carolina
Florida	New Jersey	Tennessee
Georgia	New York	Vermont
Kentucky	North Carolina	Virginia
Maine	Ohio	West Virginia

please use the following address:

Pam Messina
Insurance Services Office
4 B Eves Drive
Suite 200
Marlton, NJ 08053-3112
877-892-5622

If this questionnaire is for a community or fire district in the following states:

Alaska	Kansas	New Mexico
Arizona	Michigan	Oklahoma Oregon
Arkansas	Minnesota	South Dakota
California	Missouri Montana	Utah
Colorado	North Dakota	Wisconsin
Illinois	Nebraska	Wyoming
Indiana	Nevada	
Iowa		

please use the following address:

Community Outreach Department
Insurance Services Office
111 North Canal Street
Suite 950
Chicago, IL. 60606-7270
312-930-0070, ext. 6214

If this questionnaire is for a community or fire district in the following state:

Texas

please use the following address:

Sharon Whitehurst
Insurance Services Office
4030 West Braker Lane
Suite #350
Austin, TX 78759
800-444-4554, option 2

FIRE PROTECTION SURVEY

Date Survey Completed: ______________________

Community or Fire Protection Area: ______________________

County:		State:			
Fire Department name:		Telephone no:		Ext:	
Hdqtrs street address:		City:		Zip:	
Chief of Department:		Telephone no:		Ext:	
Admin Officer of City:		Telephone no:		Ext:	
Admin Officer address:		City:		Zip:	
Person completing survey:		Telephone no:		Ext:	

Fire Department or Chief Officer's E-mail address: ______________________

Telephone number the Fire Chief can be reached during the day: ______________________

GENERAL INFORMATION

1. Population served: ___________ Year of "Population served" statistics: _____________
   Source of "Population served" statistics: ☐ US Census Bureau ☐ Other : ______________________
2. Have there been any changes to the boundaries of your fire protection area as shown on the enclosed map?
   ☐ Yes ☐ No

If there have been changes please show the new boundaries by drawing a red line at the appropriate location on the enclosed map. If you provide service to both sides of a street, please offset the boundary accordingly.

FIRE ALARM/COMMUNICATION

1. Emergency phone number: ________________
2. Total number of Emergency lines at dispatch facility: ___________
3. Is there a recording device at dispatch facility that records all incoming emergency calls? ☐ Yes ☐ No
4. Where are phone calls to report a fire received and dispatched? Briefly describe: ________________________
   ____
5. How many fire alarm dispatch personnel are normally on duty to receive fire calls? _______
6. How are the fire department members notified of a fire alarm? Check all that apply:
   ☐ Fire station CAD/printers ☐ Fire station direct phone ☐ Fire station facsimile
   ☐ Fire station radio ☐ Fire station telegraph system ☐ Fire station voice alarm
   ☐ Home radio/scanners ☐ Outside air horn ☐ Outside siren
   ☐ Pager – alerting only ☐ Pager – alpha numeric ☐ Pager -- voice
   ☐ Other, describe: ____

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FIRE PROTECTION SURVEY

FIRE DEPARTMENT

1. Type of Fire Department:
   ☐ Career ☐ Volunteer ☐ Combination ☐ Public Safety ☐ Other:________________

2. Total number of calls (past calendar or fiscal year): _______________
   Structural fires: _______ Non structure fires: _______ EMS: _______ Other: _______
   Of the above, how many were: False/faulty alarms? _______ Multiple alarms? _______

3. Number of fire stations the Fire Department has within the fire protection area: ________

4. Total number of personnel (past calendar or fiscal year)
   Paid: _____ Volunteer: _____ Uniformed: _____ Civilian/Support: _____ Paid on call: _____

5. Minimum staffing per shift: _______

6. Minimum number of apparatus and personnel responding to initial alarm of fire from your department:

Number of units responding

	Engines	Ladder/Trucks	Chiefs	Other	Total Personnel Responding
Dwelling					
Commercial					
High-rise structure (over 35 feet)					

7. Does your community receive any first alarm automatic aid from any fire departments that are located outside of your area? ☐ Yes ☐ No

   If yes, please provide the following information:
   Fire department(s)/station providing the coverage: ____
   Is the assistance received on a 24-hour basis: ☐Yes ☐ No
   Is there a contractual agreement for the assistance? ☐ Yes ☐ No
   Please outline on the enclosed map the areas covered by this assisting fire station or describe: __________
   ____

8. Do you have any, or use any of the following training facilities:
   Structural burn building ☐ Yes ☐ No
   Drill tower ☐ Yes ☐ No
   How often are these facilities used each year? ____
   Who operates the training facility? ____

9. What is the average number of structural fire fighting drill and company training hours per year that EACH active firefighting member of your fire department receives? _______ hours

Please verify the location of all of your fire stations on the enclosed map and provide street addresses. Mark new or relocated stations with a red "X". Cross out any closed fire stations and write "Closed" over the existing "X". If a fire station operates only during parts of the year, write "Seasonal" over the existing "X"

FIRE PROTECTION SURVEY

WATER SUPPLY

1. Please indicate who owns the hydrants and water system: ____

   ____

2. How often are fire hydrants flushed and inspected? ☐ Semi-annually ☐ Annually
   ☐Other: ____

3. Major changes to the water system(s) in the past 5 years:

   ☐ Significant addition/deletion of water lines ☐ Significant addition/deletion of water storage capability
   ☐ Significant increase/decrease in water flow rates ☐ Other ____

4. Amount of storage added or removed? _____________

5. Total number of fire hydrants on the system: ________

6. Please provide a current community Hydrant Map.
   Hydrant Map enclosed? ☐ Yes ☐ No

7. If you cannot provide a Hydrant Map, please provide the contact information of someone who can.
   Hydrant Map can be obtained from: ________________________________ Telephone number: ____________

8. If hydrant flow test information is available from your jurisdiction in an electronic format, please provide a contact name and phone number: ____

9. Does your fire protection area have certified dry hydrants or suction points capable of providing 250gpm or more? ☐ Yes ☐ No

   If yes, please provide an address list of those locations or plot them on the enclosed map.

10. Is your fire department capable of providing 250 gpm or more, uninterrupted, for a period of 2 hours using tender/tanker shuttle operations or large diameter hose relays? ☐ Yes ☐ No

11. Is your fire department capable of delivering an uninterrupted fire flow of 200 gpm for 20 minutes beginning within 5 minutes of the first arriving engine company? ☐ Yes ☐ No

Fire Station Information Sheet

(*Please provide a separate sheet for each fire station*)

Fire station name: ______________________________ Fire station number: ________________

Fire station street address (please be specific and include the nearest cross street):

____

Does this station operate all year long: ☐ Yes ☐ No

Fire Apparatus – Pumpers (use additional sheets for additional apparatus)

A. Unit number: ____________

Pump size: __________ gpm Water tank size _________ gal.

List amount of hose carried: 1 ½” ______ ft 1 ¾” ______ ft 2” ______ ft 2 ½” ______ ft

3” ______ ft 3 ½” ______ ft 4” ______ ft 5” ______ ft

Dates (year) of last 3 dates that the hose was tested: _____ _____ _____

What pressure is the hose tested to? ______ psi

Is the deck pipe, deluge set or monitor carried rated to flow at least 1000 gpm? ☐ Yes ☐ No

Dates (year) of last 3 service tests from draft: ______ ______ ______

How many minutes is the test? ______

B. Unit number: ____________

Pump size: __________ gpm Water tank size _________ gal.

List amount of hose carried: 1 ½” ______ ft 1 ¾” ______ ft 2” ______ ft 2 ½” ______ ft

3” ______ ft 3 ½” ______ ft 4” ______ ft 5” ______ ft

Dates (year) of last 3 dates that the hose was tested: _____ _____ _____

What pressure is the hose tested to? ______ psi

Is the deck pipe, deluge set or monitor carried rated to flow at least 1000 gpm? ☐ Yes ☐ No

Dates (year) of last 3 service tests from draft: ______ ______ ______

How many minutes is the test? ______

What is the average staffing level of the above apparatus for structural fires?

Paid: ______ Volunteer: ______

Fire apparatus – Aerial Ladders/Platforms (use additional sheets for additional apparatus)

Unit number: ____________

Type of unit: ____________ Length of aerial device: ________ feet

Pump size: __________ gpm Water tank size _________ gal.

How many self-contained breathing apparatus (masks) are carried? ______

Dates (year) of last 3 operational load tests: ______ ______ ______

Date (year) of the last non-destructive aerial device test: _______

What is the average staffing level of the above apparatus for structural fires?

Paid: ______ Volunteer: ______

Fire apparatus – Tankers (Water Tenders) (use additional sheets for additional apparatus)

Unit number: ____________

Pump size: __________ gpm Water tank size _________ gal.

List amount of hose carried: 1 ½” ______ ft 1 ¾” ______ ft 2” ______ ft 2 ½” ______ ft

3” ______ ft 3 ½” ______ ft 4” ______ ft 5” ______ ft

Other Structure Fire apparatus (including rescue or other service apparatus) (use additional sheets for additional apparatus)

Unit number: ____________ Type of unit: ____________

Special structural fire fighting equipment carried: ____

____

____

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August 27, 2010

Township of Dexter
Emergency Services Committee
c/o Pat Kelly, Supervisor
6880 Dexter-Pinckney Road
Dexter, MI 48130

Dear Ms. Kelly:

You have asked for an opinion as to the following questions:

1. Under what circumstances can the Chelsea Area Fire Authority be dissolved?

2. What is the effect of dissolution upon the current taxes levied?

I was the original drafter of the Articles of Incorporation of the Chelsea Area Fire Authority (CAFA). However I have not at all times been the attorney for CAFA and therefore make my opinion based upon the version of the Articles of Incorporation of CAFA which were adopted originally.

The Articles of Incorporation provide that CAFA continues "perpetually or until dissolved by act of the parties or by law, provided, however, that such Authority shall not be dissolved if such dissolution would operate as an impairment of any of its contracts" Article V. CAFA is formed under the provisions of Public Act 57 of 1988! The Act and the above language comes from the Act, has no provision for dissolution

Dexter Township, as you know, was not an incorporator with CAFA, but it has had several contracts with CAFA.

With respect to the subject of dissolution, obviously the incorporating municipalities could "by act of the parties" dissolve the corporation. This would be done by action of each legislative body of the incorporating townships, and the filing of a Certificate of Dissolution with the Office of the Great Seal, under the Michigan Secretary of State and the publication of the Act of Dissolution.

To our knowledge there is no other provision for dissolution of CAFA "by law", in the absence of any subsequent enabling legislation by the Michigan Legislature.

As you know, incorporating municipalities may withdraw but the municipality remains subject to the "tax levied in its jurisdiction under §12 for the duration of the period of that tax as determined pursuant to §12(3)." [MCL 124.611.]

With respect to the levy of the tax, §12 of Public Act 57 of 1988, MCL 124.612 authorizes the levy of a tax by vote of the electors residing within CAFA's service area. A tax has been authorized by the electorate for a period of time. As such that tax rate "shall be levied and collected as are all ad valorem property taxes in the state" . . . . . . and . . . . . "each tax assessing and collecting officer and each county treasurer shall levy and collect the taxes certified by the authority and shall pay those taxes to the authority by the time provided in [MCL 211.43]".

Should CAFA be dissolved before the term of the current authorized tax expires, the immediate problem would be that there would be no "authority" to certify to the local officers the amount of the taxes to be collected.

There does not appear to be any legislation that the undersigned can find which speaks to such a situation. There are provisions in other sections of the Public Acts of Michigan dealing with the dissolution of other municipal authorities, but there is none with respect to an authority created under Act 40 of 1988.

Examination of the cases under MCL 211.43 shows that there has been occasional times when the courts will entertain an action for declaratory relief where the purpose of a tax can no longer be determined and where the assessing officers seek the guidance of the court. We would think that should that unlikely event occur that CAFA were dissolved by action of its incorporating bodies, that it would be appropriate to file a declaratory action in the court to suspend the levy of the tax.

This opinion does not purport to advise as to the distribution of the other assets of CAFA in the event of its dissolution. There were several pre-incorporation agreements. Those agreements provide for a levy of tax, such as that currently authorized, and for the building of substations. The assets of CAFA are substantial, and this opinion should not be construed as to any planned manner of distribution of assets upon dissolution.

Yours very truly,

KEUSCH, FLINTOFT & CONLIN, P.C.

Peter C. Flintoft

Pb