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CLASS A FOAM AND CAFS BRIEFING — STRUCTURAL FIREFIGHTING

By

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One of the most promising technological advances to occur within the Fire Service over the last 25 years was the technology associated with Class A foam and Compressed Air Foam Systems (CAFS). This technology, which primarily had its beginnings in wildland fire operations, represents a revolutionary breakthrough today for use in structural firefighting.

In the more than two decades that I have been involved in fire service training and education, I have seen a lot of innovations that held promise. Some worked and were adopted by the fire service -- some worked and were not adopted, while others just didn't work. But few innovations have come along that represent such a significant step forward in our capability to control structure fire.

The intent of this briefing is to share the basic concepts of Class A foams and CAFS and their benefits to the structural fire service, even though virtually all fire departments that need to fight fire in other types of ordinary combustible fuel could reap the same benefits. For those interested in obtaining a much more comprehensive text about Class A foam and CAFS technology, you should obtain a copy of *The Compressed Air Foam Systems Handbook* at *CAFSinstitute.org.*

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Debate on New Technology

In the past 25 years, Class A foam and CAFS has received a great deal of attention. Not since the start of the debate over which is the "best" nozzle — a smoothbore or a variable pattern — has there been such controversy over new technology in the fire service. It would seem that today there are numerous opinions on the use of Class A foam and CAFS from many in the Fire Service. Since an opinion is nothing more than a statement unsubstantiated by fact (if an opinion were a ‘fact,’ it would no longer be an opinion), let's examine the facts about Class A foam and CAFS, and see what they can do for your fire department involved in providing structural firefighting response and operations.

The concept of Class A foam and CAFS is simple: Add Class A foam concentrate to water, forming a foam solution which when applied to the surface of a Class A fuel will spread out, wetting the surface of the fuel, and penetrating below the surface to absorb heat and cool the fuel faster than plain water. In a nutshell, adding Class A foam concentrate to water doubles the water’s fire suppression effectiveness. Adding compressed air to Class A foam solution to make a foam bubble blanket makes the water up to 5 times more effective. How is this accomplished? Read on.

Surface Tension and Gravity Impede Firefighting Water

When 1 gallon of water at 60°F is heated to 212°F and vaporizes, it absorbs a maximum of 9,366 Btu of heat -— or 100% efficiency. If each gallon of water applied to a structure fire achieved 100% efficiency, fire suppression would be much easier and cause far less water damage. However, such is not the case.

Walter Haessler’s research in 1974 found that a solid stream of water achieved only 5-10% efficiency. [Haessler, Walter M. *The Extinguishment of Fire* (NFPA, 1974)]. This means that each gallon of water absorbed about 933 Btu, and that the majority of the water applied through a solid stream simply ended up on the floor and then ran out of the fire compartment. This was due to:

- The surface tension of water, and
- The force of gravity.

Surface tension affects the ability of a liquid to spread across a given surface. This is why water tends to bead on horizontal surfaces, and roll down vertical surfaces. Water's surface tension limits the surface area in contact with the fuel, as most of the water either beads or runs off, limiting its ability to absorb heat under actual fireground conditions.

What is Class A Foam?

While firefighting foams of various types have been around since the late 1800s, most of them have been designed for use on flammable liquid and other Class B fuels. The only foams which were intended for use on Class A fires were the high-expansion (200 to 1000:1 expansion rates) types originally developed for fighting fires in coal mines. These foams are best used as smothering agents where they are forced into compartments to displace air. With such high expansion rates, they have very little water within them to perform any significant cooling.

While some work was done in attempting to utilize high-expansion Class A foam for manual application in structural firefighting, the concept really was limited to basement fires and fires in other compartments which had very limited openings. Like any other foam, high-expansion foam is another specialized weapon in our fire fighting arsenal. It is, however, very effective in fixed building fire protection systems for some special hazards.

The Class A foam technology of today is totally different from that of the past and has come about because of work in the area of wildland fire control. The most important Class A Foam concepts are:

- How Class A foams enhance water's capability to control structural fires,
- How the technology, Including CAFS, used to produce and deliver these Class A foams work, and
- How the new Class A foam technology can enhance structural firefighting operations

Class A Foam Improves water

Class A foam is nothing more than a formulation of chemicals which is mixed with water and air to form an expanded extinguishing agent enhancing the ability of plain water to suppress burning Class A fuels. Unlike Class B foams which are intended to alter water's properties so it can float on a flammable liquid and thus extinguish the fire primarily by smothering, Class A foam alters water's properties to allow it to spread over and penetrate Class A fuels.

Anyone who has ever fought an interior structural fire knows that water tends to run off fuel surfaces. This runoff is essentially wasted water, and occurs even when fog streams are utilized to maximize steam conversion. For many years, wetting agent additives have been used to create *wet water*. Wet water is simply a solution of water and a wetting agent which has a reduced surface tension to allow the solution to spread and penetrate much the same as the detergent added to water in the laundering process allows water to penetrate fabrics to remove dirt.

Class A foams not only provide water with the properties of wetting agents but also provide it with the ability to form bubbles which tend to cling to Class A fuels. This clinging ability holds the water in the

Figure 1. A CAFS Institute instructor supervises a crew using a CAFS handline prior to making entry into a burn building during live-fire training in New Jersey. Training and education are a significant part of the overall program when adopting new technology. This cannot be overemphasized.

form of bubbles on the fuel surface. Rather than running off, the water applied in the form of foam remains on the fuel surface and continues to absorb heat until it is all gone. Thus the water is held in position so that more of it is effectively utilized for cooling the fuel.

Class A foams were originally developed for use in wildland fires, and had their origins in the "Texas Snow Job" first used in 1977 by wildland firefighters in Texas. The Texas Snow Job made use of pine soap as the foaming agent. Since that time, work has been done to develop the optimum Class A foam, with the first being developed in the early 1980s.

While these agents were originally intended to make the water available to wildland firefighters more effective and to essentially stretch it a little further, they demonstrated great value in the exterior protection of structures in wildland fire situations. This was vividly demonstrated in the fires in Yellowstone National Park in 1988.

Class A Foam Concentrate and Water

Class A foam concentrate is a synthetic detergent hydrocarbon surfactant which when mixed with water, reduces the water's surface tension. A solution of 99.7% water and 0.3% Class A foam concentrate will reduce the surface tension of the solution by about 2/3. Unlike plain water, a drop of this foam solution will flow across a horizontal Class A fuel surface and penetrate it. Because of this,

Figure 2. An attack team assembles and initiates fire attack with compressed air foam. The knockdown power of compressed air foam provides more bang for the buck from fire attack resources—personnel, equipment and water supply. Simply, using CAFS, initial attack teams can handle a much greater volume of fire than ever before.

more of the solution's surface area contacts the fuel, thus increasing the altered water's rate of heat absorption.

In addition, Class A foams have an affinity for carbons and form a cooling foam blanket that is "oil-loving." The foam solution has a physical attraction to the charred carbon layer on most burning Class A fuels, which allows water to first cling to and cool the surface, and then drain out of the bubble blanket, to spread, wet, and penetrate the fuel.

Foam Solution

A mixture of water and foam concentrate is called a *foam solution*. Class A foam solutions generally consist of from 0.1% to 1.0% foam concentrate. They have excellent spreading and penetrating properties because of their low surface tension. However, they do not reduce runoff due to gravity. Thus, while foam solution as an extinguishing agent is suited to some tactical applications such as deep-seated wildland fuels or garbage dump fires, foam solution, itself, is not in the optimum form for structure fire attack situations because it doesn't cling to vertical surfaces.

Finished Foam.

Finished foam is foam solution that has been "aspirated" to make the solution bubble. Children blowing bubbles dip a ring in a form of foam solution and then aspirate the bubble when they blow on the film of solution suspended on the plastic ring. In making firefighting foam, aspiration is achieved by mechanically agitating the foam solution to add air which creates a bubbly mass of finished-foam. It is the bubbles in the aspirated or finished foam that allow the agent to cling to the vertical surfaces of fuels and hold the water-based liquid in place until it has absorbed enough heat to evaporate.

You can perform a simple demonstration of the difference between foam solution and finished foam. Take a soda bottle and fill it about halfway with water. Then add a couple of teaspoons of liquid detergent to the water. The water and detergent is essentially a foam solution. Cover the top of the bottle and shake it vigorously. You will see that the solution is bubbly -- the solution has expanded into "finished-foam." If you really want to see a high quality foam bubble structure, pour the solution into a blender. Since the blender creates much more agitation than shaking the soda bottle, the bubble mass will be much denser.

Finished-foam bubbles also provide a temporary “vapor-seal” for Class A fuels that assists in fire extinguishment by affecting both the fuel and oxygen components of the fire tetrahedron. Foam bubbles create dead air spaces that “insulate” the fuel from heat and flames thereby slowing heat transfer to the insulated fuel and flame spread.

The most important fact to remember about Class A foam is that regardless of the type of foam-generating system used, it is the *water* within the finished foam that actually extinguishes the fire. *All the foam concentrate does is make the water work better.*

Under ideal conditions, 100% of the finished foam will cool the fuel or penetrate the fuel to which it’s applied with no runoff. However, achieving 100% efficiency on the fireground is very unlikely. This is because the efficiency of a foam application is affected by variables such as foam production methods, application methods, application rates, as well as the fire situation itself.

Foam Proportioning

While there are a number of foam proportioning devices available, we will look at three basic methods. These are:

- Tank (batch) mixing
- Eduction
- Direct Injection

Tank or Batch Mixing

One of the easiest ways to mix a Class A foam solution is to pour foam concentrate directly into the water tank of a pumper. This is known as "tank-" or "batch- mixing". Many departments who want to experiment with Class A foam use this method, since all that is needed is a container of foam concentrate. Mixing 2.5 gallons of foam concentrate with 497.5 gallons of water in a 500-gallon booster tank produces 500 gallons of foam solution with a 0.5% concentration.

While tank-mixing works, it can have some disadvantages:

- Since the foam solution is in the water tank and must pass through the pump and discharge piping, the foam concentrate's "degreasing" action can attack lubricants and packings over time.
- The discharge of Class A foam ends when the apparatus water tank is empty.
- Class A foam cannot be produced when the pumper with the batch-mixed tank is drafting or fed by a pressurized supply.
- Once the foam solution is tank-mixed, the ratio of foam concentrate to water cannot be easily changed for specific fire conditions.
- When refilling the water tank, foam solution residue can become agitated and expand in the water tank and overflow before the tank is full of water. The expanded foam inside the tank can also become lodged in the fire pump causing extensive pump priming times.

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Eduction

Another method of mixing foam solutions is to use some form of foam eductor. An eductor is a mechanical device which makes use of a venturi and atmospheric pressure to force foam concentrate from a container into a stream of water.

Most foam eductors are generally designed for flows from 60 to 95 gpm, and have adjustment settings of 0.5, 1, 3, and 6% to regulate or proportion the proper quantity of foam concentrate to the amount of water passing through the eductor. In general, however, Class A foams are usually proportioned at 0.5%.

Of critical importance in using foam eductors are the following:

- The rated flow of the nozzle used must match that of the eductor. If the eductor to be used is rated at 95 gpm, then the nozzle used with it must have a 95-gpm rating.
- The eductor manufacturers' recommendations for pump discharge pressure and maximum hoseline length must be closely followed.
- The nozzle must be fully opened position during use, maintaining the rated flow, or a loss of foam concentrate in the fire stream will result.

Direct-injection Discharge-Side Proportioning Systems

Today, this method of foam proportioning is king -- that's because it eliminates the logistics and inherent limitations associated with the tank-mix and foam eduction methods. The direct-injection method utilizes a foam pump supplied by a foam concentrate tank to deliver the foam concentrate into the water stream on the discharge side of the fire pump to create foam solution. These systems make the mixing of foam solution very easy and accurate. Direct-injection devices provide the capability to adjust the percentage of foam concentrate injected to compensate for changing fire conditions. These direct-injection or discharge-side proportioning systems work throughout a wide variety of flows and pressures and keep foam concentrate out of the fire pump and water tank.

Foam injection systems provide a precise method of proportioning the foam concentrate to water, so foam concentrate is not wasted and cost-effectiveness is enhanced. When Class A foam concentrate is proportioned at 0.5%, the cost per gallon of foam solution created is typically from 7- to 9-cents.

Generating Class A Foam

As we mentioned earlier, the final product of the foam generation process is *finished foam* which is created when air has been added to foam solution. The Class B foams which we have historically used in the Fire Service are known as *low expansion* foams. Low expansion foams generally expand at a ratio up to 20:1 when aspirated. This means that, at a 10:1 expansion ratio, 100 gallons of Class B foam solution would expand 10 times, to 1000 gallons of finished foam.

Finished foams are classified as: 1) low-expansion, 2) medium-expansion, and 3) hi-expansion. Low-expansion foams have expansion rations less than 20:1. Medium-expansion foams have ratios of 20:1 to 200:1. High-expansion foams on the other hand, have expansion ratios above 200:1 and as high as 1000:1.

The key to expanding foams is to produce the type of foam bubble which benefits the specific fire suppression application the most. Low expansion foams have a greater amount of water contained in each bubble and thus tend to cool fuels more effectively than high-expansion foams. High-expansion foams have very little moisture in them and as a result resemble soap suds which are very light. However, when we remember that the purpose of using high-expansion foams is to displace the air within a compartment with foam to effectively smother a fire, not much moisture is needed.

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The Process

After the foam solution and plain water are properly proportioned to create foam solution, the foam solution is ready to be applied through a discharge device onto the burning fuel. The amount of aspiration and the type of discharge device are contingent on the fire problem at hand. This is where experience, training, and available resources come into play.

The finished foam that provides the best knockdown and extinguishment characteristics for structure fire attack is a low-expansion, quick-draining foam comprised of small, uniform bubbles. A finished-foam with an expansion ratio of 7:1 of finished-foam to foam solution, produces a wet frothing foam, which increases the water's surface area for efficient heat absorption, yet still holds a sufficient amount of water on the fuel to wet the surface and extinguish the fire.

Does the fire problem dictate a dense finished-foam? A quick-draining finished-foam? A very lightly aspirated foam? A deep-seated fire in a bale of paper, for example, may require using a foam solution in its raw form without aspiration. Protecting exposures will require an air-aspirating nozzle that forms a slower-draining finished-foam blanket that adheres to, insulates, and wets the exposure for a considerable length of time.

Different low-expansion foam-generating devices—fog nozzles, air aspirating nozzles, or compressed air foam systems—produce different qualities of finished-foam bubble structures — bubble sizes, bubble durability, and bubble drain time. These variables have a direct correlation to the efficiency and effectiveness of the foam for different tactical challenges.

Conventional Foam Generation

Foam solutions can be applied through conventional nozzles. Smoothbore nozzles produce finished-foam with little or no bubbles and are excellent for deep-seated fires in compacted fuels. Fixed gallonage, adjustable gallonage, and automatic nozzles, depending on design and stream pattern, produce a finished foam with from little or no bubbles to a 2:1 to 4:1 low-expansion, quick-draining foam. These nozzles are excellent for producing foam for deep-seated fires in compacted fuels and for structure attack. The only aspiration with these conventional nozzles is that which occurs through natural air entrainment created by the fire stream and turbulence inside the nozzle itself. Applying foam solutions through conventional (smoothbore or variable pattern nozzles) is an ideal way to institute a Class A foam program since the flow and firefighting techniques remain basically the same.

Nozzle Aspirating Foam Systems — NAFS

In a nozzle aspirated foam generating system, the fire apparatus pump provides the energy to move foam solution from the apparatus to an aspirating nozzle at the end of an attack hose or fixed or portable monitor. This energy is not only used to propel the fire stream, but also is used to draw atmospheric air into an aspirating foam nozzle or foam tube. As foam solution passes through the specially-designed nozzle, the nozzle design draws atmospheric air into the nozzle and mixes it with the foam solution to create the finished-foam.

Nozzle aspirated foam generating methods produce low-expansion foams (20:1 or less) or medium-expansion foams (from 20:1 to 200:1).

Low-expansion finished-foams produced by air-aspirating nozzles, particularly on the lower end (below 10:1) of the low-expansion range, are excellent for direct structure fire attack. Choose a nozzle with a high gpm flow to maximize volume and reach. Medium-expansion foam generally is not a suitable choice for direct fire attack, since medium-expansion, air-aspirating nozzles use most of the fire stream energy to create the finished-foam and leave little energy to propel the fire stream.

Medium-expansion nozzles produce a drier finished-foam bubble that will fill most structural wall cavities, fill inaccessible/poorly ventilated fire compartments such as basements, and envelope burning tire or rubbish piles, cutting off oxygen while wetting and cooling fuels. Medium-expansion foams are also excellent for mop-up and overhaul.

Compressed Air Foam Systems — CAFS

Compressed Air Foam Systems produce finished-foam by injecting "compressed air" into the foam solution stream. The term “high energy” is sometimes used when discussing CAFS because the energy of the air compressor which forces air into the foam-solution stream is added to the energy already provided by the fire pump to create the foam-solution stream.

While CAFS technology represents a radical departure from the more traditional methods of foam generation, it provides significant tactical advantages in structure fire suppression.

A typical CAFS apparatus includes:

- A water tank,
- A foam concentrate tank,
- A fire pump,
- A foam proportioner,
- and an air compressor.

Figure 3. When confronted with a large volume of fire, applying compressed air foam through portable master stream devices has become the norm. The light-weight foam filled hose makes easy movement of the monitor to positions where the foam stream can be most effective at extinguishment.

Compressed air is injected into the foam-solution stream in the fire apparatus, where it mixes with foam solution in a mixing chamber and the discharge hoseline. CAFS rely on the "scrubbing action" or turbulence within the mixing chamber and hoseline to create finished-foam. Foam bubbles produced in this way are very small and consistent through this highly efficient method of generating foam bubbles.

In a CAFS, approximately 90% of the foam solution is converted into foam bubbles. All that is needed for a discharge device is a ball valve or smoothbore nozzle. The finished-foam is ready for application as it leaves the last section of hoseline. Adjusting the amounts of water, air, and foam concentrate entering the discharge alters the characteristics of the finished-foam produced. Foam can range from wet (milky consistency) to dry (shaving cream consistency) by varying the amount of air that is injected into the discharge. Wet foam is ideal for structural fire attack while dry foam is ideal for wildland structure protection applications.

In addition, the discharge distances of CAFS attack lines and monitors are dramatically increased with the addition of energy from the air compressor. In general, CAFS discharge is usually much farther and holds a much tighter pattern than plain water and conventional systems. The most noticeable difference between CAFS and nozzle aspirated foam is in direct fire attack. CAFS attack lines dramatically reduce knockdown times, generate much less steam, and create virtually no runoff or water damage.

In operation, the apparatus pump pumps water from the water storage tank through a pipeline where

Figure 4. Compressed air foam first clings to and then wets fuels. This makes for a much more effective and less time consuming overhaul process.

foam concentrate is injected. From this point on, foam solution continues through the pipe to a point where air from the air compressor enters the pipeline to form the finished foam. From this point to the actual discharge device, finished foam is propelled.

The key difference in a CAFS is an air compressor that has the capability of delivering air in the order of 200 cfm. The introduction of this air on the discharge side of the fire pump not only aerates the foam solution but ads energy to propel the foam through hoselines to discharge devices and then onto the fire.

Class A Foam and the Structure Fire Attack

The advantages of using CAFS generated Class A foam in structural firefighting are:

- As the finished-foam stream contacts the burning fuel, it immediately begins penetrating the material to slow and then halt the combustion process.
- Since combustion is stopped more quickly than it is when using plain water, the development of heat and toxic by-products are reduced.
- Water applied in the form of a finished-foam absorbs heat more efficiently, causing temperatures to drop more quickly to reduce the likelihood of flashover.
- Keeps the water where it's needed — on the vertical surfaces of the fuel and compartment/structure — so all of the water applied can absorb heat.
- Since the penetrating ability of water is enhanced by the finished-foam, less water is required to knockdown the fire.
- Since the penetrating ability of water is enhanced by the finished-foam, less time is required for overhaul.

Using CAFS, we can handle a much greater volume of fire than ever before. This know-how has redefined our perceptions of what we can do with initial arriving resources—our personnel and water supply. CAFS use can impact firefighter decision making in regard to fire control strategies at potential large-loss structure fires. Without CAFS, in some severe fire cases, we would ordinarily choose a defensive water application strategy—stand back, let the main body of fire burn and protect exposures. When deploying CAFS, we are highly effective with an aggressive offensive fire attack with initial arriving firefighting resources.

As an end-user of CAFS generated Class A foam for over two decades, I've come to expect quick knockdowns and reduced total water supply need, sometimes by as much as two-thirds, as compared to using water alone. Time after time, fire after fire, CAFS show significant benefits over straight water.

These benefits include:

- Fire extinguished in less time;
- Fire extinguished with less total water supply;
- Reduced personnel stress from advancing lightweight compressed air foam-filled hoselines;
- Reduced personnel stress due to quick extinguishment;
- Firefighters have to spend less time performing overhaul operations;
- Reduced personnel exposure to heat and the toxic products of combustion;
- Greater fire volume extinguishment from the initial exterior foam application point (when conducting an offensive attack on a fully involved dwelling) prior to the crew making aggressive entry;
- Reduced fire and water damage to structures;
- More effective exposure protection applications;
- Increased likelihood of victim survivability; and

- Increased efficiency of personnel and available resources.

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