Fire Engineering

FIRE STREAMS AND THE AGGRESSIVE INTERIOR ATTACK

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EFFICIENT FIRE STREAMS ARE SOMETIMES TAKEN FOR GRANTED; THE IMPORTANCE OF ADEQUATE FIRE FLOW WITH MANAGEABLE NOZZLE REACTION IS SOMETIMES OVERLOOKED.

The hallmark of a good fire department is the ability to make an aggressive interior attack. When occupants await rescue and are trapped by fire, it is the aggressive fire department that will save them.

Whenever the topic of interior structural fire attack arises, there is always debate as to which method of fire attack is best. Some departments rely on the direct attack method. Other departments attempt an aggressive interior attack using the indirect or combination method. Then there are the departments, primarily in Europe, that rely on a theory known as "3D water fog."

So much has been written about each method over the years, and some misconceptions have developed simply out of a lack of understanding. There are so many sources from which to draw conclusions; some of the sources contain contradictions, sometimes making it difficult to know what is actually meant. A compilation of these methods "under one roof" so to speak is probably the best way to figure out how each method is to be employed.

In addition, the need for effective fire flow goes hand in hand with any fire attack strategy. Efficient fire streams are sometimes taken for granted; the importance of adequate fire flow with manageable nozzle reaction is sometimes overlooked.

WHAT TECHNIQUES SHOULD BE USED?

What techniques should we employ when aggressively attacking a building fire from within? I compiled data on the various methods of fire attack from the most qualified and highly recognized sources. Certain conclusions can be drawn from these data. In drawing these conclusions, I hope to put to rest many misconceptions.

All of the fire attack theories have a single underlying foundation: Each is designed to effect extinguishment of a fire. From this point on, each method differs from the others. This is the point at which many debates rage.

This article is geared toward the aggressive interior attack for the typical building fires fire departments across the country face every day. It is not an all-inclusive strategy and tactics text but a look at a small element of this big picture. Obviously, safety is the overriding concern at all times, since firefighting is not the safest line of work.

DIRECT ATTACK

- "The direct method of attack is simply applying water to the base of the burning material, at the flame/fuel interface, where the flammable vapors being distilled by heat from solid material ignite and burn."[1]
- "The direct method of attack causes little disruption of the heated combustion products. Reducing heat production by extinguishing the fire at its base stops the burning process at its source, in turn stopping the upward liberation of more heat, smoke, and gases." (1)
- "If ellipse the officer feels the overhead needs to be cooled because it is preventing the crew from moving in, a quick 2- or 3-second dash with a straight stream will provide temperature reduction without generating a massive amount of steam." (1,363)
- "Sweeping the ceiling with the stream in a side-to-side or clockwise motion also helps eliminate the threat posed by the heated gases without excessive unwanted steam production and violent disruption of the thermal balance characteristic of the indirect and combination methods."[2]

DIRECT ATTACK ANALYSIS

The direct attack method is designed to extinguish the fire by applying water in a straight stream (or smooth bore stream) to the base of the fire. This type of stream offers the greatest penetration of the heat being produced. A fog nozzle on the straight stream setting, or a smooth bore stream, will allow a greater distance between the fire and the nozzle than a fog nozzle on a wider setting. The stream will then strike the combustibles and cool them below their ignition temperature, thereby effecting extinguishment. It is safer to attack the fire from a greater distance than from a closer distance. These straight or smooth bore streams will produce less steam, as the water is in a tighter pattern. A wider pattern allows for a greater surface-to-mass ratio of the individual droplets, which will turn to steam more quickly.

Another point emphasized from the data accumulated concerns the application of water to the ceiling. In environments of high heat, the stream should be directed into the overhead for a period of several seconds at a time, in an effort to lower the temperature. Since the danger of flashover is very real in an enclosed area, it is important to recognize this danger and a means of preventing it. A straight or smooth bore stream to the ceiling, worked side to side, will provide more safety when there is a potential for flashover. It is important to emphasize that all the sources cited here identified excess steam as a very real danger. Therefore, it is extremely dangerous to use a wide fog pattern within an enclosed space when making an interior attack.

A stream to the ceiling can be viewed as an element of the direct attack. As the gases are potential sources of combustion, a stream directed above will keep the gases below their ignition temperature. But as with a stream directed onto other combustibles, you must limit its application to avoid the generation of excess steam. The direct attack does not advocate extinguishing the fire by generating massive amounts of steam, but by directly applying water to the seat of the flame/fuel interface. Maintaining the thermal balance is a must when making a direct attack. To do otherwise could create a dangerous imbalance in room temperature as a result of the high heat from the upper levels mixing with the lower temperatures at the floor.

Another point gathered from the data dealt with an overuse of water, even in the form of a straight or smooth bore stream. Too much water applied onto the combustibles after the initial knockdown will create excess steam that can hinder the attack.

One final point concerning the direct attack: Many of the sources stress that it is important to apply a stream of water to the ceiling. This flies in the face of some texts that say it is wasteful and that needless water damage occurs when shooting water into smoke. Remember that smoke is incomplete combustion; when present with enough heat and oxygen, smoke will ignite with catastrophic consequences. Water properly applied into the overhead provides a safety net and prevents flashover.

INDIRECT ATTACK

- "The indirect method of attack is not an interior fire attack operation."[3]
- "In addition to remote injection of the water fog, there are two other requirements for success when using the indirect method. First, the ceiling temperature within the fire compartment must be at least 1,0007F to ensure ready and efficient conversion of the fog spray to steam. When a fire is in the first or early second phase of development, the direct attack with timely and adequate ventilation is preferred. Second, the fire compartment (building) must be well sealed to prevent premature leakage of valuable steam to the outside. A well ventilated fire building on the fire department's arrival warrants a direct attack, since the indirect method is only effective if the fire building remains sealed with doors and windows intact." (3)
- "Nowhere in his writings did Chief Lloyd Layman present scientific arguments that advocated spraying water over the firefighters' heads in a fire situation in order to create steam bath conditions. On the contrary, he said firefighters would be burned if they were unfortunate enough to find themselves enveloped in a hurricane of water converting to steam." (1,84)

COMBINATION ATTACK

- "Like the indirect method of attack, the combination attack was originally designed primarily for exterior application of water." (3,68)
- "The objective of the combination attack is to 'roll' the stream around the perimeter of the room, cooling the walls, ceiling, and floor with the outer edge of the stream while the inner portion of the stream cools the hot gases being produced by the fire. Striking the heated ceiling, walls, and fuel materials produces the maximum amount of steam within the shortest period of time." (3, 70)
- "Insofar as the writings of Keith Royer and the late Floyd W. 'Bill' Nelson, of Iowa State University, are concerned, there is no mention of the impact of steam on trapped occupants. In Fire Stream Management Handbook, Fornell writes in reference to the articles and films of Royer and Nelson: 'In viewing the films and reading the results of their research, it must be noted that their tactics advocated application of water from outside the fire building. Though they did discuss interior application, the first priority in the Iowa method was to knock down visible fire before making entry. Royer says their testing did not address the problem of fire spread caused by applying streams from the outside of the building. The subject of life safety or the effects of steam on trapped victims was never addressed in the three films.' " (3,74)

INDIRECT AND COMBINATION ATTACK ANALYSIS

These theories of fire attack were never designed to be used as part of an offensive interior attack. Over the years, mainly through a lack of understanding on the part of many individuals and departments, these theories were misapplied. The data available from the original authors of these methods make it very clear that they were never designed to be used from within, what we have come to term "the aggressive interior attack."

Both the indirect and combination attack theories spell out the massive generation of steam that results from the use of these methods, and thus the danger of scalding injuries to firefighters operating within. In addition, there is the danger of spreading fire to uninvolved areas by pushing it throughout the structure with the power of a fog stream. This is not to be confused with the strategy advocated by the 3D water fog technique, which has no relation to the indirect or combination attack methods.

Layman clearly gave directions for using the indirect method. To paraphrase, Layman specifically stated that for his theory to work properly, the building must remain sealed so that steam can effect extinguishment. He went on to say that if ventilation was effected, specifically indicating that if doors and windows did not remain sealed, that a direct attack was warranted, as the steam created would exit from these same openings. Layman never stated that firefighters should make an attack from within using his theories and warned of the dangers associated with such tactics.

The combination attack, a concept experimented with heavily by Royer and Nelson in the early 1950s, brought to the forefront many new concepts. Like many other theories, departments may have used the combination attack incorrectly simply because they did not thoroughly understand the concepts.

The combination attack, like its indirect attack counterpart, is based on the belief that generating massive amounts of steam within the shortest time frame will extinguish the fire. Again, the hazard of steam and its negative effects on firefighters and victims are apparent when used within an enclosed compartment or space. Also, the danger of spreading fire is evident if the stream pattern is set to inadvertently push the fire into uninvolved areas.

The use of a fog pattern will generate excess steam and cause a disruption in the thermal layering, creating a dangerous environment within. This is not to be confused with the concepts or methods advocated by the 3D water fog theories discussed later.

These methods are used in settings where life safety is not an issue and the compartment remains relatively sealed so as to maintain the integrity and allow the steam to do its job. As stated, these methods were never designed to be used for the aggressive interior attack because of the hazard posed by dangerous levels of scalding steam.

GAS PHASE COOLING/NEW WAVE 3D WATER FOG/OFFENSIVE WATER FOG

- "The use of three dimensional (3D) (also termed 'offensive') water-fog techniques during gaseous-phase suppression of structural fires is a most recent and innovative approach, and the reader should be clear that such applications are used not (solely) to extinguish fires but mainly to make 'safe' the approach route to the fire and reduce the likelihood of fire gas ignitions-flashovers, backdrafts, and so on."[4]
- "Neither are these techniques designed to replace the direct style of fire attack utilizing water in a straight-stream setting but, moreover, to complement existing forms of fire attack in an effort to increase the safety and effectiveness of firefighting teams." (4)
- "The 'pulsing' of water fog into the overhead on the approach route using short rapid bursts at the nozzle serves to 'inert' the fire gas layers and will prevent or mitigate the potential for any gas ignition of the fire gases that may lead to such a major event." (4)
- "The 'pulsing' action is created through rapid 'on-off' motions of the flow control lever or trigger. This is achieved with some practice, and some nozzles are more suited to the action than others. Ideally, individual 'pulses' should last from 0.1 to 0.5 of a second and will place a fine range of water droplets into the overhead for a brief few seconds .... Any sweeping motion of the nozzle is most likely to upset the thermal balance within the compartment and force heat down to the lower parts of the room occupied by the firefighting crew, and continuous bursts of more than a second may cause a 'piston' effect to push fire into uninvolved areas, roof spaces, etc."[5]

GAS PHASE COOLING/NEW WAVE 3D WATER FOG/OFFENSIVE WATER FOG ANALYSIS

Gas phase cooling, or 3D water fog, is designed to protect firefighters most notably from the dangers of flashover. It advocates spraying water in a fog pattern of specific dimensions into the overhead for very brief periods of less than one second at a time (referred to as "pulsing" the nozzle). This method's theorists acknowledge that water will expand to steam rapidly. Yet, if used sparingly, the technique will make the atmosphere safer by cooling the overhead combustible fire gases, which will allow the attack team to continue its approach to the seat of the fire.

This method does not advocate the massive application of water fog with the intention of creating steam for fire extinguishment. It recognizes the dangers associated with steam and pushing fire into uninvolved areas. The technique stresses that it is in no way similar to the strategy of the indirect attack founded in the 1940s and 1950s.

The 3D water fog strategy relies on the direct attack method with a straight stream from a fog nozzle once the fire is located. It seeks to apply water directly to the flame/fuel interface to effect final extinguishment.

FIRE FLOWS AND NOZZLE REACTIONS

1 3/4-Inch Handlines

For the purpose of this article, we will use the 1 3/4-inch medium-diameter handline, since it is popular and can deliver flows of up to 185 gallons per minute efficiently in stretches of about 200 feet. Other benefits of the 1 3/4-inch handline are that it takes less time to deploy than the 2 1/2-inch handline and fewer firefighters are needed to staff it efficiently. One and a half-inch handlines, while not as popular as 1 3/4-inch lines, can flow about 125 gpm efficiently in stretches up to 200 feet. A larger-diameter line must be used to fill out stretches longer than 200 feet-for example, 2 1/2-inch hose to a reducer or a wye followed up by the 1 1/2-inch or 1 3/4-inch handline tasked with extinguishment. Simply put, friction loss becomes a major factor in the longer stretches, and pump efficiency and capability then become factors. This is a topic unto itself and will not be fully discussed here.

Also, for this article, water is the extinguishing agent; a discussion of Class A foam is outside the scope of the article.

NOZZLE REACTION AND FIRE FLOWS

Are your medium-diameter handlines being used to their maximum capability? Although they can deliver flows of up to 185 gallons per minute, most departments are not flowing anywhere near this simply because of the very high nozzle reactions they are encountering.

Probably, the most important point to keep in mind is that in the interest of safety and efficiency, a sufficient volume of water must be available through medium-diameter attack handlines. Small-diameter lines of less than 11/2 inch are not suitable for interior fire attack operations. Although there is no doubt that many fires can be handled with the limited flows of a one-inch booster line (about 40 gpm), no additional flow will be available should it be needed.

As important as adequate flow is to fire suppression operations, you must remember that nozzle reaction is the ultimate decider of effective fire flows for handlines. In other words, if the nozzle reaction is significant, the nozzle operator will do one of two things: If he cannot control the nozzle reaction exhibited by the stream, he will gate down to deliver a lesser flow with more manageable nozzle reaction, or the nozzle operator will simply lose control of the handline and suffer the corresponding deadly consequences. Nozzle reaction is directly attributed to nozzle pressure and flow (measured in gallons per minute). The end result is nozzle reaction measured in pounds force.

Realistically, a two- person nozzle team (consisting of a firefighter assigned to the nozzle and a second member in a backup position) can safely and effectively control somewhere between 65 to 70 pounds force of nozzle reaction. The higher the nozzle pressures at a given flow, the greater the nozzle reaction. The table below lists flows and reactions from a variety of nozzle types.

Note that the lower the nozzle pressure, the less nozzle reaction at a given flow. A lower reaction with a higher flowing handline means greater safety and more water delivered in a shorter time. Several formulas are available for computing flow and reaction, which may cause the figures to vary slightly when compared with various charts of major nozzle manufacturers.

Remember that to extinguish any given Class A fire requires that you deliver the flow rate needed to absorb the given Btus. If the volume of water needed is not delivered, the fire will continue to grow until it consumes all the given combustibles within its reach. As the fire eventually burns itself out, the Btus given off will be absorbed by the flow rate being delivered, and the fire will be extinguished. As an example, if a fire requires a flow rate of 200 gallons per minute for extinguishment and only 40 gpm are delivered, the fire will not go out. It will continue to burn until the Btus given off are low enough to be absorbed by the 40-gpm flow rate. This is simply a matter of physics and cannot be changed.

How then can we deliver a flow sufficient to accomplish rapid extinguishment without endangering ourselves? Ultimately, we want to deliver as great a flow as possible in the shortest period of time and in the safest and most effective manner. To do this, we must strive for high flows with limited nozzle reactions and consistent application of the fire stream in a safe manner.

What flows are considered best for our medium-diameter handlines? As a rule, the more water a suppression team has available, the more fire it can extinguish and the safer the incident will be. How much water to flow should be based on the consideration of how much nozzle reaction you can safely handle. If your nozzle team can control the line safely up to 65 to 70 pounds of force reaction, base the flow volume on that value.

Note that in the chart, 185 gpm through a 50-psi smooth bore exhibits a reaction of 69 pounds of reaction. A 100-psi fog nozzle flowing 125 gpm has a reaction of 63 pounds force, whereas the 75-psi low-pressure fog nozzle can flow about 150 gpm with a reaction of 66 pounds force. Note: A major nozzle manufacturer offers an emergency low-pressure feature for its line of automatic nozzles. When the feature is activated, a nozzle pressure of about 50 psi, instead of 100 psi, will be provided; nozzle reactions will be comparable to the smooth bore counterpart. Flow is the key to fire extinguishment, but without pressure to project this flow, the water available is irrelevant.

Even if nozzle reaction is held to a manageable level, it is still imperative that a firefighter be assigned to the backup position. Although not the most glamorous position, it is a most critical one. The backup person is responsible for absorbing the great majority of the reaction, which allows an adequate amount of water to be delivered. Without the backup person, the attack becomes less efficient and safety is compromised. Obviously, the more members assigned to the stretch, the more efficient and safer the fire attack.

WATER DAMAGE

Water damage is not caused by flow rate but by prolonged application of water by an untrained nozzle team that does not know when to shut off the line. A stream flowing 60 gpm for 25 minutes will cause more water damage than a stream flowing 200 gpm for one minute. An effective nozzle team knows when to open and shut down a line and what stream patterns and techniques to use.

CONCLUSIONS

With regard to fire suppression strategies for interior firefighting, the biggest conclusion that can be drawn is that the generation of steam within a confined area can prove detrimental and dangerous to all inside the structure. The original theories of the indirect and combination methods made it very clear that massive amounts of steam had to be generated. In addition, the techniques used in the 3D water fog approach also make it very clear that too much steam will have negative consequences. Water dispersed in a fog (spray) pattern will turn to steam more quickly than water confined within a straight stream. This rapid expansion in a very high heat environment can cause injuries.

Flows and Reactions

Nozzle Pressure	Nozzle Type	Flow in gpm	Nozzle Reaction
100 psi	100-psi Fog	125	63 lbs. force
75 psi	75-psi Low-Pressure Fog	125	55 lbs. force
50 psi	3/4-inch Smooth Bore	118	44 lbs. force
100 psi	100-psi Fog	150	76 lbs. force
75 psi	75-psi Low-Pressure Fog	150	66 lbs. force
50 psi	7/8-inch Smooth Bore	161	60 lbs. force
100 psi	100-psi Fog	185	93 lbs. force
75 psi	75-psi Low-Pressure Fog	185	81 lbs. force
50 psi	15/16-inch Smooth Bore	185	69 lbs. force

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Another conclusion drawn from the various forms of attack is that the wide fog pattern used in all but the short "pulses" advocated in the 3D water fog technique can push fire and heat into uninvolved areas.

Ultimately, the data available show that the direct method, which relies on the straight (or solid) stream, is the most effective pattern for fire extinguishment. The 3D water fog strategy also relies on the direct attack method, but, as stated, using a fog pattern in short applications renders the approach safe. Overuse of water, regardless of the pattern used, can inhibit the attack by creating excess steam and disrupting the thermal balance.

Another clear fact that emerged is that more water can be safely delivered at a lower nozzle pressure simply because you will have to contend with less nozzle reaction. The fog nozzle vs. smooth bore nozzle debate has been covered extensively in other articles.

VENTILATION

Ventilation is paramount to any interior attack. Even though it is not the theme of this article, it must be included. Combustible gases are inherently dangerous and await only a sufficient amount of heat and oxygen to ignite. It is imperative that the products of combustion be allowed to exit. For the members inside making their attack, these combustible gases are better off outside the building than inside with them.

Sometimes, ventilation is not easy to accomplish. When this happens, the threat of flashover is very real, and getting water into the hot gases will delay or eliminate this threat. Direct attack advocates say that it is important to get a stream into the overhead area when there is intense heat even though no fire has been encountered. A stream into the overhead for a period of several seconds will delay flashover while the advance to the seat of the fire continues.

Flashover mitigation and fire extinguishment can take place with the indirect and combination attack, but these methods were never designed for inside application when victims or firefighters are present. Again, the massive generation of steam would cause extreme problems for those inside.

Preventing flashover was a primary goal of the 3D water fog advocates, who specify that water be applied into the overhead for a very, very brief time and then be followed up with a direct attack from a straight stream onto the seat of the fire.

Personnel using the 3D water fog technique must be properly trained in this application. Sustained use of the wide fog pattern within an enclosed area could adversely affect the firefighters making the interior attack. Massive quantities of scalding steam could be generated, and the fire could be pushed into uninvolved spaces.

References

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2. "Little Drops of Water: 50 Years Later, Part 2," Andrew A. Fredericks, Fire Engineering, March 2000, 132.
3. "Little Drops of Water: 50 Years Later, Part 1," Andrew A. Fredericks, Fire Engineering, February 2000, 66.
4. www.firetactics.com, a British Web site with in-depth information on the 3D Water-Fog Technique.
5. Grimwood, Paul. Flashover and Nozzle Techniques. May 25, 2000. Available through www.firetactics.com.

The above authors have made significant contributions to the field. Fire service professionals should read their works.

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