BUILDING A CASE FOR IMPLEMENTING SMOOTH BORE NOZZLES

BY TODD CONNORS

Clearwater Fire and Rescue recently changed all of its preconnected hose loads. Originally, we had four 1¾-inch lines with fog nozzles. We removed a 1¾-inch preconnect and replaced it with a 2½-inch preconnect with a smooth bore. In addition, we replaced the fog nozzle on another 1¾-inch preconnect with a 15⁄16-inch smooth bore.

This configuration now allows the officer to choose among a 1¾-inch line with foam capabilities, a 1¾-inch fog nozzle, a 1¾-inch smooth bore nozzle, or a 2½-inch smooth bore nozzle. In addition to these preconnect changes, we removed our 1¾-inch fog high-rise packs and replaced them with ultra-light 2½-inch hose with a smooth bore. The biggest change was adding the smooth bores to the 1¾-inch lines. We had never used them before.

The main reason we added the smooth bore was so that we would have a choice between automatic fog nozzles and smooth bore nozzles. A fellow firefighter and I began the process for instituting the change. It took us about a year and a half. Although we experienced some rough times, the end result was worth it. An outline of the process follows.

THE STEP-BY-STEP PROCESS

All in our department do not agree with adding a smooth bore nozzle to the 1¾-inch hose. Some members say they will never use it, whereas others say they will use it exclusively. I believe that it comes down to the ability to accept change. Some will resist change just to resist; others are always willing to try something new. Also, some may be afraid that they might not know all there is to know about the new approach and fear that they might look "ignorant" or incompetent.

What is amazing overall is that after some 200 years-plus of firefighting in America, there still is no "standard" relative to the type of nozzle used for interior attack.

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(1) The 13⁄4-inch automatic fog nozzle in use in Clearwater (FL) Fire and Rescue. (Photos by author.)

The process used to present the case for implementing smooth bore nozzles was comprised of field tests by line personnel and live fire training to evaluate different smooth bore nozzles. Methods used included a research document; a Power Point® presentation; and assessment of funding options, training issues, and operational procedures. It seems like a lot of extra work, but when our department looked at smooth bore nozzles a few years ago, it decided not to adopt them. Therefore, we had to overcome this issue.

Field Testing

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(2) The new 15⁄16-inch smooth bore nozzle, which has a stream shaper.

I was fortunate to work with a lieutenant who is willing to look at new options and a crew that doesn't mind doing extra work. After evaluating four or five smooth bore nozzles with our existing automatic fog nozzles, some firefighters were opening up to the idea of adopting a smooth bore. We evaluated ⅞-, 15⁄16-, and one-inch tips with various setup and bail configurations. We looked at stream reach, nozzle reaction, kinking tendencies, stream characteristics, and ease of use.

Research Document

We prepared a research document that cited the differences among various methods of attack, flow rates, and nozzle reactions; safety issues; water damage concerns; and field test data. The paper was presented through the chain of command. When it reached the training chief, it was approved for live fire testing.

Live Fire Training Evaluation

It took some extra work to get the department to perform a live fire training evaluation of the nozzles. We had to coordinate the schedule at the Training Center with the schedules of the department and area departments, our shift work, and the administrative schedule.

We were surprised with the end results of the live tests. Three crews evaluated two nozzles and flow rates. Each test involved comparing our automatic fog nozzle and a smooth bore nozzle to experience the difference. We held a debriefing at which the pros and cons of each nozzle were discussed and members offered their opinions. Many firefighters who didn't believe in the smooth bore nozzle changed their minds after these evaluations and were impressed with the difference in knockdown ability and steam conversion of the smooth bore over the fog nozzle. This information was passed up the chain of command again.

Administrative Evaluation

I did not participate in the administrative evaluation. The administration approved the change based on the data presented.

The next step was for the administrators to select the tip size and the hose loads that would have the smooth bore nozzles and to determine how many of the nozzles would be placed on each engine. Of course, none of this was included in the budget, and funding would be a big factor when implementing this change on all of our engines and conducting the dedicated training.

The department opted for a single 15⁄16-inch tip on a 200-foot pre-plumbed 1¾-inch hose load. The Training Division dedicated a month of training to the various methods of attack. Videos, Power Point® presentations, and lectures were presented. In addition to the smooth bore training, there was also training on the new hose load configurations.

All of these changes occurred within a year and have had a positive impact on our operations.

Present Status

The department overall is accepting the smooth bore in small steps. I believe that it will be more widely accepted as it is used. The automatic fog nozzles will stay on the engine companies, since we have preplumbed foam capabilities at the pump panel and some operations are better suited to a fog nozzle than a smooth bore nozzle.

The process was developed to allow engine companies to have a choice. That objective was accomplished. If you plan on implementing this type of change in your department, be prepared for responses such as "No," "Maybe," "We'll see," and, hopefully, "Let's try it." I was fortunate to receive the response, "Let's try it."

The Resources

Below are the resources we used to present our position to the administration. If you decide to take on this task, you will need dedication and resolve.

Administration Survey-Options

To implement the use of smooth bore nozzles, we must decide the following:

1. What size tip?
a. 7⁄8-inch.
b. 15⁄16-inch.
c. One-inch.

2. What type of smooth bore nozzle?
a. Simple smooth bore.
b. A break-apart nozzle with a fog and built-in smooth bore.
c. A combination fog and smooth bore with selection by bail movement.

3. Where will these nozzles be placed?
a. On the rear Mattydale, 200 feet only.
b. On a Minuteman, 150 feet only.
c. Both the Mattydale and Minuteman.

Of the options above, it was the consensus of the firefighters who participated in the research for this proposal that a 15⁄16-inch tip with a simple smooth bore nozzle on both the Mattydale and the Minuteman would be best.

Implementation Guide

These are the steps taken to obtain smooth bore nozzles for our department. An implementation plan must also be considered to be effective. We formulated the following suggestions to aid Clearwater Fire and Rescue.

1. Submit for approval from Operations.

2. Funding for purchase.
a. Capital improvement purchases.
b. End-of-year unspent funds.
c. Grants.

3. Training on use of smooth bores.
a. Power Point® presentation.
b. Videos.
c. Live fire.

4. Placement of smooth bores.

Research Document

An aggressive interior fire attack is the trademark of a good fire department. When occupants await rescue and are trapped by fire, it is the aggressive fire department that will save them. But it must be done efficiently and safely at the same time. If not, firefighters and occupants can be injured.

Do you use a smooth bore nozzle or a fog combination nozzle for the aggressive interior attack? This is a debate that will raise the emotions of fire chiefs at a convention to firefighters at the dinner table. What is the best weapon for efficiently and safely doing our most critical function, saving life and property? Much has been debated on this topic for years and probably will continue to be debated for years to come.

Discussed here are the advantages and disadvantages of smooth bore and fog nozzles, the techniques of nozzle control and how they pertain to the nozzle selected, safety concerns, flow rates and nozzle reactions to accomplish quick knockdowns, and the history of smooth bore and fog nozzles.

The purpose of this discussion is to provide information on which to base decisions on allowing smooth bore nozzles on the 1¾-inch attack lines for our bread-and-butter operations, the aggressive interior fire attack. We will discuss class “A” fire in a structure.

HISTORY

To better understand the background of the contrasting views, we must look at how the fire service has developed around these two nozzles. The original nozzle was the smooth bore, partly because of its simple design-no moving parts or springs, just a piece of metal that allows water to take shape when it leaves.

When Dr. Charles Oyston obtained a patent on a spray nozzle in 1863, the debate slowly emerged. The U.S. Navy introduced the fog nozzle to thousand of men during World War II. Lloyd Layman, commander of the Coast Guard Fire School, discovered the indirect application of fog technique. It was taught at great length, since shipboard fires are very easily compartmentalized and a flammable liquid was the combustible. This fire condition was efficiently and safely extinguished with ease with the indirect fog attack method.

According to Layman, the rules for this success depended on the following:

1. The water must be in spray (fog) form.

2. The ceiling temperature must be 1,000°F at the site the water is applied.

3. Confinement of the steam within the building is essential.[1]

As peacetime occurred, the fog nozzle was introduced heavily into the fire service as a result of the experience aboard ships. The fire industry began to shift from smooth bore to fog nozzles. The combination nozzle reached its height as the weapon of choice in the late 1980s. We recommend going back to the smooth bore for numerous reasons that will be discussed.

METHODS OF ATTACK

How the first attack line is used will determine the outcome of the fire. The nozzle has the greatest impact on success or failure. The nozzle dictates the technique the nozzleman uses; if used improperly, it can be dangerous. The method will determine many factors of the fire condition and safety of the firefighters and occupants.

The three methods are the direct, indirect, and combination attack. We will discuss each of these. Of course, this is not an all-inclusive strategy and tactics text but only a small look at a small element of this big picture, the aggressive interior fire attack.

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.” [2]

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. (2)

If the officer feels the overhead needs to be cooled because it is preventing the crew from moving in, a quick two-to-three-second dash with a straight stream will reduce the temperature without generating a massive amount of steam.[3]

The direct attack method is designed to extinguish the fire by applying water in a straight or solid stream to the base of the fire. This allows the greatest amount of penetration of the heat being produced. In our tests, the solid stream had a greater reach than a fog straight stream, allowing an attack from a distance that is safer. The stream will then strike the combustible material and reduce the temperature below the ignition level, thereby extinguishing the fire. With a solid stream of water passing through the heated gases, less steam is produced because of a larger mass of water. A wide fog pattern of water passing through the same gases will produce an enormous amount of steam because of the greater surface-to-mass ratio. This excessive steam could be pushed back on the attack crews and occupants, resulting in steam burns.

Since danger of a flashover is becoming more commonplace because of building construction methods and an increased use of plastics that have higher rates of heat release, it is imperative to recognize this potential. In environments of high heat, the solid stream can be directed into the ceiling area for a short period to lower the temperature. Since droplets of water produced by the solid stream’s hitting the ceiling are larger, they will absorb more heat without interrupting the thermal balance. If a wide fog pattern were to be introduced into this atmosphere, excess steam would be produced and possibly cause injury. Therefore, using a wide fog pattern could produce an extremely hazardous situation.

Although applying a solid stream to the ceiling is not attacking the burning material itself, it is viewed as a direct attack. Remember, smoke and gases are unburned combustibles that can ignite. But, as with a stream directed into other burning materials, you must limit the length of application to prevent excess steam. By directly applying water to the seat of the flame/fuel interface through the direct attack method, you don’t generate massive amounts of steam. In a direct attack, maintaining the thermal balance is imperative. Mixing the high heat from the upper level with the lower temperatures at the floor creates an imbalance in the room that is very dangerous. One final point about cooling the ceiling in high-heat conditions: Safety is paramount. Smoke is incomplete combustion. When present with enough heat and oxygen, smoke will ignite with terrible results.

Indirect Attack

“The indirect method of attack is not an interior fire attack operation.”[4] “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 1,000° F, to ensure readily and efficient conversion of the fog spray to steam. When a fire is in the first or 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.” (4)

“Nowhere in his writings did Chief Layman present scientific arguments that advocate spraying water over the firefighters’ heads in a fire situation 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.” (2, 84)

Combination Attack

“Like the indirect method of attack, the combination attack was originally designed primarily for exterior application of water.” (4, 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 material produces the maximum amount of steam within the shortest period of time." (4, 70)

"Insofar as the writings of Keith Royer and the late Floyd 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 outside the building. The subject of life safety or the effects of steam on trapped victims was never addressed in three films.'" (4, 74)

The indirect and combination attacks are not designed for an interior aggressive attack. These techniques have been misused because of a lack of understanding on the part of individuals, departments, and training centers. The original developers of these two attack methods never intended them to be used as interior operations, contrary to what we have been taught regarding the aggressive interior attack. The massive amounts of steam produced from the indirect and combination methods of attack pose a danger for the firefighters and trapped occupants. Also, there is potential for fire spread: The power of the fog stream can push the fire throughout the structure.

Layman clearly states that the indirect method of attack should not be used for interior operations and boldly advocates the adverse potential of misuse of his method. The rules for the indirect method must be in place prior to applying water. There is a need for this type of extinguishment, just not in our most typical fire conditions.

The combination method of attack uses the principle of creating a massive amount of steam to push out the oxygen, thereby breaking the fire chain reaction. The use of steam and the negative effects are clear when used in an enclosed compartment or space. A dangerous situation will occur in interior operations when using a fog pattern, which generates excess steam and disrupts the thermal balance with interior operations. As the steam dissipates and fresh oxygen is introduced into the area, the chance of reignition is high, since the fuel hasn't been cooled and is still emitting gases.

FLOW RATES AND NOZZLE REACTION

Today's fireground is a much more dangerous environment than in the past. Better protective gear lets firefighters penetrate deeper into the fire than ever before. This is both good and bad. It is good because we can perform a more aggressive search for victims. It is bad because we are getting caught in more flashovers. Another contributing factor is the building itself. Buildings are better sealed; thus heat and smoke stay inside. Also, more plastics are used than ever before. "Plastics generate 16,000 Btus per pound of fuel while cellulose material generates 8,000 Btus per pound. Not only is there the Btu difference, but also plastics have higher rate of release than traditional fuels." (4)

How does the flow rate affect nozzle selection? The most important point to keep in mind is that in the interest of safety and efficiency, a sufficient amount of water must be used. The minimum flow required to extinguish a fire is called the "critical flow rate," a term sometimes wrongly defined as "the flow needed to absorb the heat as fast as it is generated." The most accurate definition is "the water flow needed to reduce the temperature of the burning material to where it no longer emits the flammable gases that are the fuel."[5] The standard in the fire service for a 1¾-inch attack line is 150 gallons per minute (gpm) minimum for residential fires; 180 gpm is desirable-it provides a margin of safety.

Another assessment tool on the fireground is the following: "If a fire continues to burn in the presence of the fire department, the rate of flow is not sufficient or the water is not coming in contact with the burning material."[6]

With smooth bore nozzles, two tip sizes will meet the demands of the critical flow rate. The ⅞-inch tip produces 162 gpm by the mathematical formula (gpm = 29.7 × diameter squared × square root of the nozzle pressure),[7] achieving the minimum standard. The 15⁄16-inch tip flows 184 gpm by the formula, attaining the higher standard.

The horizontal reach with an effective stream is also an important factor: The greater the distance between the fire and attack crews, the better. The ⅞-inch tip reach is 56 feet; the 15⁄16-inch tip reach is 59 feet, according to the formula (hr = ½ nozzle pressure + 26 for ¾-inch tip; add 5 for each ⅛-inch tip larger than ¾ inch). (7) Although the first choice may be the 15⁄16-inch tip with the higher flow rate, you must consider additional factors involving the tip sizes.

The Oakland (CA) Fire Department lost a member, Tracy Toomey, in 1999 during an aggressive interior attack. A Board of Inquiry was convened to investigate his death. The fire was in a two-story residential structure; heavy fire was showing on the first floor on arrival. The fire was not extinguished in time to prevent the loss of structural integrity, even though several attack lines were in place. All were fog nozzles. The Board of Inquiry report cited as one of the three direct causes of the line-of-duty death "the inability to flow sufficient water to extinguish the heavy fire encountered."(5) The report contained 10 recommendations, ranging from do nothing to have ⅞-inch tips on the 1¾-inch preconnects and 1⅛-inch tips on 2½-inch attack lines. The Board strongly urged that smooth bore nozzles be used on their preconnects. Obviously, the critical flow rate with effective knockdown capabilities must be considered in choosing the proper nozzle for an aggressive interior attack.

The nozzle reaction ultimately decides effective fire flows for hand-lines. With high nozzle reaction, the nozzleman will probably do one of two things: gate down to deliver a lesser flow with more manageable reaction or lose control of the handline. Nozzle reaction is directly correlated to nozzle pressure and flow. The end result is nozzle reaction measured in pounds per force. A major benefit of a solid stream nozzle vs. a fog nozzle is that at equal flows, a solid stream nozzle typically produces one-third less nozzle reaction. This decrease in nozzle reaction has many advantages for the attack crew: ease of maneuverability of the nozzle; less fatigue, which reduces air consumption, enabling firefighters to aggressively attack the fire longer; and less chance that the nozzleman will gate down, thus achieving the critical flow rate to put out the fire. A fog nozzle at 100 psi produces 76 pounds in nozzle reaction while flowing 150 gpm, but at 180 gpm, the nozzle reaction is 91 pounds (nozzle reaction + .0505 × gpm × square root of nozzle pressure). (7)

On the other hand, a ⅞-inch tip that flows 160 gpm produces 57 pounds in nozzle reaction, and a 15⁄16-inch tip that flows 180 gpm creates 66 pounds in nozzle reaction (nozzle reaction = 1.5 × diameter squared × nozzle pressure). (7). Which type of nozzle is safer and more efficient with regard to nozzle reaction and flow rates is clearly evident.

SAFETY CONCERNS

There are many issues that accompany each nozzle. For instance, if debris should enter the nozzle, a smooth bore would be the choice nozzle because of its open design; the fog nozzle would have an ineffective stream. Another issue is hose kinks. There are two beliefs on this. One is that with the fog nozzle at 100 psi, the hose won't kink, but yet it would be more difficult to move in smaller spaces. The opposite is true for a smooth bore nozzle; it kinks, but it is easier to maneuver in confined areas.

The St. Petersburg (FL) Fire Department evaluated two tips sizes-⅞ inch and 15⁄16 inch. It found that kink and line-control problems are less severe when a ⅞-inch tip is used.[8] All firefighters at the scene should be aware of kinks and remove them as they are found; otherwise, an ineffective stream will be produced, endangering everyone on the fire scene. Another option is for all firefighters at the scene to be aware of kinks and remove them as they are found.

Another concern is the airflow caused by a water stream. A recent study performed at the Rockland County (NY) Fire Training Center revealed that with a fog nozzle the air flow in the fire room was 6,000 to 10,000 cubic feet per minute (cfm) using a 1¾-inch attack line at 150 gpm to 180 gpm. The solid bore nozzle used had a 15⁄16-inch tip and produced 510 cfm at 180 gpm."[9] This air movement plays a critical role in safety. Since the fog nozzle has the potential to produce massive amounts of air movement, the thermal balance will be disrupted and create a dangerous situation.

As much as firefighters love to battle the fire, it must be extinguished quickly for the safety of the attack crews but, more importantly, for the trapped occupants. In other words, the nozzle must have a quick knockdown punch. New construction methods also necessitate quick knockdown capability. To perform this fast knockdown, the aggressive attack crew must strive for high attack flows to reach the seat of the fire with limited nozzle reaction and consistent application of the fire stream in a safe manner. To obtain this, a straight or solid stream, along with proper training, is a must.

Ventilation, whether vertical or horizontal, is vital in any interior attack. Although ventilation is not the main topic in this discussion, it greatly improves safety in a direct attack. Removing the unburned gases, smoke, and heat will help prevent the spread of the fire and reduce the chance for rollover and flashover. Water may be used to ventilate, although it is not the preferred method of ventilation.

Since you may have no other option but to water ventilate, it is discussed here briefly. In a study at the Rockland County Fire Training Center involving fog and smooth bore ventilation, test data analysis showed that a 15⁄16-inch tip with a broken stream had 650 cfm four feet from a window, whereas a 30-degree fog nozzle setting four feet from a window had a 1,500 to 2,000-plus cfm. Obviously, the 30-degree fog moves more air, thereby ventilating more efficiently than a smooth bore. "Although we don't understand why you would choose a nozzle based on its ventilation abilities and performance, we repeatedly hear this argument. It's akin to choosing a ventilation saw for its suitability to flow water or a hook to beat out the fire."[10]

WATER DAMAGE

Flow rate does not cause water damage. Prolonged application of water by an untrained nozzle team that does not know when to shut off the line causes the damage.[11] An effective nozzle team knows when to open and close the nozzle, regardless of whether it is a smooth bore or fog nozzle. Proper training is essential. The proper technique for using the direct method of attack is-after hitting the area above the fire to cool the heated smoke and gases-to sweep the base of the fire and close the nozzle when the fire is knocked down. If the fire should reignite, apply a short burst of water in a solid stream to extinguish. To keep the nozzle open will cause water damage and the steam and heat to roll back toward the attack crew.

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Generating steam within a confined area can prove detrimental and dangerous to all inside the structure. The most effective method for quick extinguishment and safety is a direct attack using the straight stream or solid stream. Water applied in a fog pattern will turn to steam more quickly than water confined within a straight or solid stream. To use the indirect and combination attack developed in the original theory is to produce massive amounts of steam that will have a negative impact on an aggressive interior attack. Overuse of water on any of the three methods can prove ineffective and create a hostile environment.

What is proposed is to have a smooth bore nozzle on one of the rear 150-foot preconnects and on the rear 200-foot Mattydale. Important factors relative to a ⅞-inch tip and the 15⁄16-tip for smooth bore nozzles should be considered when choosing a tip size.

Of course, there will be a need for fog nozzles, such as for exposures, Class "B" fires, and gas leaks. They should remain on some of the preplumbed attack lines. Having a smooth bore nozzle as an additional weapon will provide a choice (fog or smooth bore nozzle) for the fire attack members. When reviewing the above option, consider several factors, including how each option affects durability, effectiveness, efficiency, member safety, and victim safety.

Hopefully, the information in this discussion will assist this organization to remain a leader in aggressive interior attacks, thus improving not only our safety but also the community we serve. ■

References

1. Clark, William E, “Fighting Fire with Water.” Fire Engineering, September 1995.

2. Fornell, David. Fire Stream Management Handbook. Fire Engineering,1991.

3. Fredericks, Andrew, “Little Drops of Water: 50 years Later, Part 2,” Fire Engineering, March 2000.

4. Fredericks, Andrew, “Little Drops of Water: 50 year Later, Part 1,“ Fire Engineering, February 2000.

5. Comella, Jay, “Planning a Hose and Nozzle System for Effective Operations,” Fire Engineering, April 2003.

6. Clark, William E. Firefighting Principles. Fire Engineering, 1991.

7. Fire Service Hydraulics student resource manual, Florida State Fire College, 2002.

8. Regan, Jim and Andrew Fredericks, “Improving the Quality of Your Solid Streams,” Fire Engineering, April 2000.

9. Knapp, Jerry; Tim Pillsworth; Christopher Flatley, “Nozzle Tests Prove Fireground Realities, Part 3,” Fire Engineering, February 2004.

10. Knapp, Jerry; Tim Pillsworth; and Sean White, “Nozzle Tests Prove Fireground Realities, Fire Engineering, February 2003.

11. Guzzi, Armand F., “Fire Streams and the Aggressive Interior Attack,” Fire Engineering, February 2002.

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Fire Engineering February, 2006
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