NOZZLE TESTS PROVE FIREGROUND REALITIES, PART 2

BY JERRY KNAPP, TIM PILLSWORTH, AND CHRISTOPHER FLATLEY

This is a report on Phase 2 of the nozzle testing program at the Rockland County Fire Training Center in Pomona, New York. These test results provide insights that can help make your next aggressive interior fire attack more successful. With these data in hand and the visual display of our findings, you will be better prepared to design, redesign, or at least evaluate your current method of aggressive interior fire attack. Additionally, we developed a repeatable and safe method for demonstrating the dangerous event we call "fog nozzle ricochet." Part 1 was published in the February 2003 issue.

DURING AN AGGRESSIVE INTERIOR FIRE ATTACK, THE attack team's application of water is the most important factor in a successful attack. The volume of water and the stream pattern are the critical factors in determining the effect the fire attack will have on the interior fire environment and, consequently, the outcome of your operation.

The nozzleman does not have time to study and obtain first-hand knowledge about the effect his stream is having on the fire environment. Smoke and steam mask all visual clues, and the urgency of the fire attack operation further inhibits opportunities to observe what the stream is doing to the interior conditions. There remains, however, a desperate need for engine company firefighters to understand exactly the positive and negative effects of their stream on the interior fire environment.

When designing the fire attack method, target flow rate and nozzle and pattern selection are critical factors for engine company leaders. It is critical that all engine company members understand what happens inside the fire room when the attack team opens the nozzle. The ability to demonstrate the effect of these streams to incoming trainees will help make us safer and more effective in the future.

The fire attack methods discussed here are based on several critical factors and our total fire attack doctrine strategy and tactics. Never try to apply one segment of a total fire attack strategy to another set of fire conditions in different types of structures; in different geographical areas; and, most importantly, where other parts of the attack strategy, tactics, tools, and methods are different or not included. One size does not fit all: It is a system.

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FIRE ATTACK DOCTRINE AND CONDITIONS

It is our doctrine in the northeastern United States to ventilate in a robust manner before we commit members to an aggressive interior attack. There are several reasons for this tactic:

- Without adequate ventilation, heat will bank to the floor, creating untenable conditions that will prevent the engine company from aggressively advancing. If the engine can't get in, the fire will continue to grow and endanger occupants and firefighters. To put it simply: If the engine can't get in, the fire can't go out.
- There may be more than one room of fire. Therefore, it is necessary to control or knock down the first room, move through it, and then extinguish other rooms of fire.

If the fire is not controlled quickly, it will continue to grow, leading to flashover conditions. A rapidly developing fire will trap and kill truck company members searching near or above the fire. Fires are either getting bigger or smaller. If the fire is not getting smaller (being extinguished) at a significant rate, it is growing and building up energy (in the form of flammable gases) that will lead to rapid-fire development (flashover or backdraft) and injure or kill firefighters.

- In the 1990 report "Firefighter Deaths as a Result of Rapid Fire Progress in Structures 1980-1989," the National Fire Protection Association recommends adequate and timely ventilation to prevent flashover and backdraft.[1]

FIRE ATTACK CONDITIONS

For the purpose of this article, we will assume the incident commander (IC) has determined the building is safe to enter and there is salvageable human life (worth risking firefighter lives for) or there is a reasonable expectation that firefighters can save property within acceptable risk levels. The fire attack will be from the inside.

Additionally, we know from the National Institute of Standards and Technology (NIST) testing with live burns that ceiling temperatures for a typical residential living room fire will exceed 2,000°F.[2] Therefore, whatever fire attack method we choose, extreme heat levels will be a significant factor. Recall that our skin burns at 124°F; steam is produced at 212°F. Steam penetrates firefighters' protective clothing and carries large amounts of heat with it. In other words, we must keep conditions tenable so we can continue the advance and kill the fire, not just wound it. Wounded and still burning, flammable gases are being produced, setting the conditions for possible flashover.

It is also important to remember that we should not base all our firefighting strategy and tactics on how well we extinguish a one-room fire. You can do almost anything—booster lines, low flows, fog streams, or a garden hose on a good day—and extinguish a one-room fire. The real test of a successful aggressive fire attack method is how well it works on several rooms of fire when you have to move through the room you just knocked down to get to the others.

FIRST PHASE OF TESTING

As reported in Part 1 of this article, we developed a test apparatus to capture and measure the airflow caused by straight-stream, smooth-bore, and fog-nozzle patterns. In summary, all the nozzles were operated in a clockwise motion 10 feet from a window opening. Air-volume measuring devices measured the airflow caused by the streams. A solid-bore nozzle ($\frac{15}{16}$-inch) flowing 180 gallons per minute (gpm) moved 725 cubic feet per minute (cfm). The straight stream from a combination nozzle moved 650 cfm at 150 gpm; the 30° fog nozzle moved well over 2,000 cfm. The fog-pattern airflow exceeded the measuring capability of the instrument, but we estimate total air movement to be between 6,000 and 10,000 cfm. Phase 3 of our testing will measure total airflow under various additional situations.

From data collected during Phase 1 testing, it is reasonable to conclude that the air moved by smooth-bore and straight-stream patterns from fog nozzles is very similar. Mathematically, there is a 10 percent difference based on our measurements. Assuming an additional 10-percent margin for error, one can reasonably assume the air introduced to the fire environment is for all practical purposes very similar and will have similar effects on a real-fire environment and attack.

SUCCESSFUL MIX

Solid-bore and straight-stream nozzle patterns have been the patterns of choice for interior fire attack for a number of years. Our testing shows that is because they provide the critical but correct combination of air movement, water volume into the fire area balanced with an adequately sized ventilation opening to let steam and hot gases out of the fire area. We will come back to this critical principle when we discuss the air movement caused by fog lines.

In the case of the straight-bore or straight-stream nozzle, we have proved that it moves 600 to 700 cfm into the fire area. This amount of air can easily be moved through the vent-size opening, assuming it is at least 3 feet × 4 feet in size. Especially in the case of the smooth-bore nozzle, water flow volume, 180 gpm for a $\frac{15}{16}$-inch tip at 50 psi, provides a fire-killing volume in short order. Additionally, it provides this volume in large drops produced when the nozzleman bounces the stream off the ceiling to any great extent. This does not disturb the hot air at the ceiling. Also, it penetrates the superheated air and falls on the fuel, extinguishing that section of the burning fuel. This large drop of water permanently extinguishes that bit of fire. In our engine company class, we say it this way, "If you want to put the fire out, leave the bad air up and the good air down, and put water on what's burning."

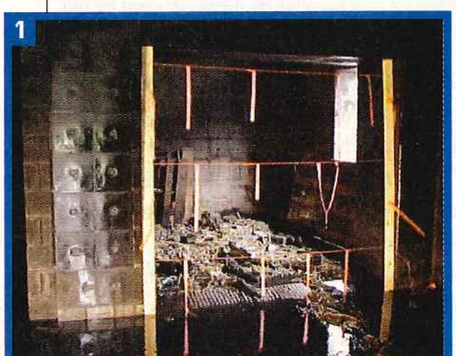
FOG PATTERNS

We tested fog patterns from combination nozzles under three ventilation conditions and found that even in a very well-vented fire room, the air currents caused by the stream would have stopped the fire attack.

Supporters of fog patterns for interior fire attack often cite the value of the fog nozzle's massive movement of air in the fire area. In theory, the massive air movement caused by the fog stream drives *all* the heat and products of combustion away from the attack team and out the vented window, door, or roof. Part of this misunderstanding is caused by the fact that if we operate a fog nozzle outside in a parking lot, the air movement is 100 percent away from the nozzleman. The error comes in when we apply "parking lot" experience and try to transpose it into an interior fire attack situation.

To test and demonstrate the air movement caused by a fog nozzle during an interior fire attack, we developed the following test apparatus.

1



(1) The Rockland County Fire Training Center concrete burn building. Debris from previous fires is on the floor. A full-size door is on the right-hand wall. The room we discharged water into was 12 feet wide, 10 feet deep, and 8 feet high. The doorway is 96 inches × 31 inches. (Photos by Jerry Knapp.)

TEST CONDITIONS

An unlimited air supply—an open door and two open windows—was behind the nozzle. Mason twine was strung across the opening, and vinyl survey tape was attached, as shown in photo 1.

The water flow volume was monitored with engine-mounted flowmeters and maintained at 180 gpm for each type of nozzle.

2

(2) View of the exterior door used as a vent opening.

Three ventilation conditions were provided ahead of the nozzle. The first was without ventilation (the door shown above was closed). In the second scenario, the door was open, but a section of plywood was placed across the lower half of the door, resulting in a 3-foot-wide by 3-foot-high (9-square-foot) vent opening. In the third situation, the door was fully open (3 feet × 7 feet), resulting in a 21-square-foot vent opening.

(3) Arrow shows the direction of the hose streams into the simulated fire area.

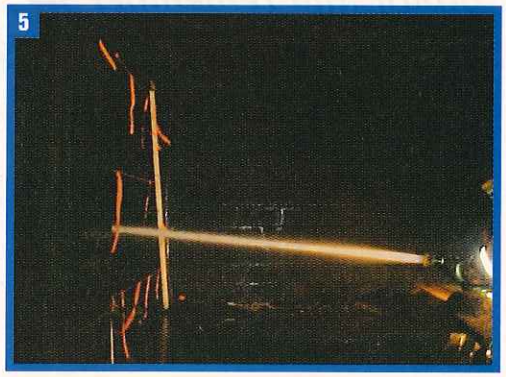
The water was directed toward the vent opening and/or into the room from hose streams as shown in photo 3, indicated by the blue arrow. The nozzle position varied from six to 10 feet back from the airflow indicators.

TEST RESULTS

A summary of the results of directing a solid-bore nozzle, a combination nozzle on straight stream and then on a 30° degree fog pattern, toward the vent opening and/or into the simulated fire room follows.

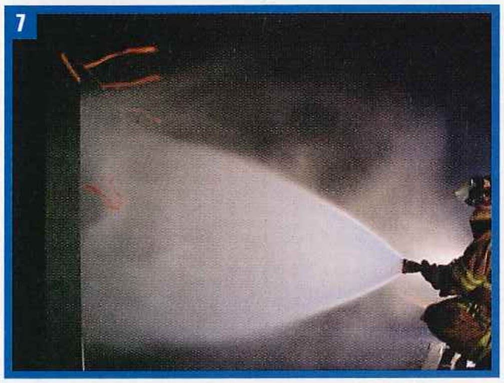
The solid-bore nozzle, $^{15}/_{16}$-inch, 50-psi, flowing 180 gpm did not move the airflow indicators under all three test conditions (see photo 4). Even without any ventilation in front of this test scenario, the airflow indicators remained virtually still. The reason for this was that even with the injection of 700 cfm into the unvented fire room, it did not overpressurize the room and cause a rapid air movement back toward the nozzleman. This is critical during a fire attack because the effect of this stream is that a large volume of water is going on the fire, there is little disturbance of the hot air at the ceiling, and the

(4) Solid-bore nozzle did not move the airflow indicators in all three test conditions.



(5) The combination nozzle, using a full straight-stream pattern and flowing 180 gpm, showed minimal airflow in all three test scenarios.

(6) Airflow was extreme in all three ventilation conditions when the combination nozzle was opened to a 30° fog pattern.



(7) The airflow indicators clearly show the direction, velocity, and volume of air movement in this interior fire attack scenario. The movement of air we experience with fog lines outside a building are not the same as the air movement inside a fire building. If you were the nozzleman in this scenario, do you think you would be able to continue an aggressive interior attack? Would you be burned by scalding steam, water, and products of combustion?

vent opening is large enough to let out the air injected and the steam and other hot and flammable gases with it.

The combination nozzle (photo 5), flowing 180 gpm, did not move the airflow indicators under all the three test conditions. The pattern used was a full straight stream and caused minimal airflow. As with the solid bore, even without any ventilation in front of this test scenario, the airflow indicators remained virtually still.

When the combination nozzle was opened to a 30° fog pattern (photo 6), airflow was extreme under all three ventilation conditions. This airflow condition drove water and air back at the nozzle team, even when the full vent doorway was open.

Although we could not measure the airflow or volume of water coming back toward the nozzle team, it was clearly visible during the demonstration. We could feel the air movement and water droplets coming back at us and could only imagine what it would feel like after some of that stream has been converted to steam and began to burn the nozzle team and stall the fire attack.

It was clear that this nozzle pattern, even when a huge vent opening is in front of it, introduces so much air into the fire environment that it creates a dangerous condition for the attack team and causes the engine company's advance to come to a screeching halt. When the attack team stops, the fire continues to grow unchecked and becomes well camouflaged by smoke and steam. Ultimately, the operation becomes defensive, ladder pipes go up, and the building dies a slow death.

Keep in mind that this nozzle tactic and pattern will work very well for a one-room fire. It will fail miserably if fire is beyond that room.

In addition, the overpressurization of the fire room caused by the fire stream raises the following questions:

Nozzle Tests, Part 2

• What effect did the inrush of air have on areas near the fire area? Did they light up?

• Did that air push fire into several other areas?

• Did that air cause the air-starved fire to ignite?

• Did that inrush of air drive the fire up walls in balloon-frame buildings or into voids of modern construction?

• Did it push steam up into these areas and put out the fire?

• Most importantly, did it have a negative effect—did the steam produced by the line scald the occupants? Did the steam delay or completely stop the search and rescue operation?

The answers to these questions depend on the situation.

TEST CONCLUSIONS

The tests confirmed and demonstrated the following:

• Airflow volumes introduced into the fire area by solid-bore and straight streams from combination nozzles are very similar.

• Air moved by solid-bore nozzles and straight streams from combination nozzles do not disturb the fire environment and did not create untenable conditions for firefighters under the three ventilation conditions tested here.

• Fog nozzles move so much air volume into the fire area that even a large ventilation opening cannot relieve the overpressure created, thus resulting in a ricochet of air from the fire area back to the attack team.

Much has been written regarding the use of fog and solid-bore nozzles. The tests described here for the first time provide firefighters with an easy, repeatable, and safe method for comparing the effects of solid and fog streams on an interior fire attack. ■

References

1. "Firefighter Deaths as a Result of Rapid Fire Progress in Structures—1980-89," National Fire Protection Association, Federal Emergency Management Agency/U.S. Fire Administration funded research, August 1990.

2. "Fire Development in Residential Basement Rooms," National Institute of Standards and Technology (NIST), 1980.

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This article is dedicated to Lieutenant Andrew A. Fredericks, Fire Department of New York, Squad 18, who was killed during the World Trade Center attacks on September 11, 2001. He lives in our hearts as a friend, a firefighter, and an ever-present enthusiastic supporter of solid-bore nozzles.