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TESTING YOUR TARGET FLOW

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BY CHRISTOPHER FLATLEY, JERRY KNAPP, AND TIM PILLSWORTH

Extinguishing the fire is the most basic and most critical operation for all fire departments. It is our most important task, our mission. We can be successful without many other operations on the fireground, but we cannot succeed without extinguishing the fire. Additionally, our doctrine for structure fires sends truck company members into the building for search and rescue before the fire attack begins. Rapid, aggressive, and effective fire attack will prevent these members from being injured or killed by rapid fire development, flashover, or backdraft and will help ensure success for our overall fireground operation. The purpose of this article is to provide a method for establishing and testing your target flow.

Providing the attack line with the proper nozzle pressure and flow is critical to a successful structural fire attack. The combination of correct flow and pressure is the target flow. This is the flow in gallons per minute (gpm) needed to extinguish a fire-the gpm that will overcome the heat release rate of the fire and win the firefight. Achieving the desired target flow depends on the amount and size of the hose and the type of nozzle used.

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HISTORY

In the 1970s and 1980s, the variable gallonage combination nozzle was the mainstay of the fire service. Its selectable flow varied from 30 to 125 gpm at 100 psi; newer models ranged from 95 to 200 gpm. This nozzle could be adjusted for situations when water conservation was an issue. It could be used at 30 gpm for outside fires or car fires to effectively use limited water supplies. The concept was to change the flow setting to 125 gpm for fighting structural fires. The 125-gpm requirement was based on the fire flow formula developed by Keith Royer, director, and Bill Nelson, chief instructor, at the Fire Service Institute of Iowa State University at Ames in 1954. Frequently, in the rush to attack the fire, the nozzleman would not change the setting, and many firefighters were injured and buildings lost attempting to attack the fire on the 30-gpm setting. More on fire flow later.

Using this type of nozzle required accurate communication between the pump operator and the nozzleman or officer. Simply dialing the nozzle to the 125-gpm setting does not magically increase the flow at the nozzle. The nozzle could not supply that flow without an increase in pump pressure. If the pump pressure is set for 100 psi at the 30-gpm setting and the selector is turned to the 125-gpm setting, the nozzle pressure will drop to about 10 psi, and the actual flow from the nozzle at the 125-gpm setting would be almost 40 gpm. The effective reach of the stream would also be reduced.

We have found in many departments we have trained that there was a lack of awareness of the effects of gallonage selection and pressure adjustments on flow maintenance. Some pump operators would say, "I give them what I think they need; if they need more, they can call me, and I'll give it to them." The question is, Why can't we figure it out ahead of time?

TARGET FLOW

Today the generally accepted target flow for a structure fire is 150 to 180 gpm. This is based on many factors, including the amount of combustible contents and the rate of heat release from the vast amount of synthetics used in our society. We recommend 180 gpm as the goal. On the fireground, many factors will work to reduce the flow-kinks, bends, and elevation, to name a few. If the goal is set too low and if any of these factors come into play, the actual flow may become critical.

Some would say that 180 gpm will cause too much water damage. I ask those people, "How do I make a nozzle capable of delivering 180 gpm deliver only 95 gallons?" The answer is to operate the line for only 32 seconds. Properly applying water on the fire is the responsibility of the member with the nozzle under the supervision of the officer. Providing the water is the job of the pump operator. Setting the flow rate is the responsibility of the department leadership.

This is not just a moot point. As already noted, many factors will reduce the flow: kinks, bends, and elevation, to name a few. If the fire flow goal is set too low and any of these factors come into play, the actual flow may become critically low.

Tables 1 and 2 illustrate the effect of reduced nozzle pressure on flow.

Table 1. Solid Stream Nozzles

| Tip Size | Nozzle Pressure | | |
|-----------|-----------------|---------|---------|
| | 40 psi | 45 psi | 50 psi |
| 7/8 in | 144 gpm | 153 gpm | 161 gpm |
| 1 5/16 in | 165 gpm | 175 gpm | 185 gpm |

Table 2. Combination Nozzles

| | Nozzle Pressure | | | | | |
|-------------|-----------------|--------|--------|--------|--------|---------|
| GPM Setting | 50 psi | 60 psi | 70 psi | 80 psi | 90 psi | 100 psi |
| 95 | 67 | 74 | 79 | 85 | 90 | 95 |
| 125 | 88 | 97 | 105 | 112 | 119 | 125 |
| 150 | 106 | 116 | 125 | 134 | 142 | 150 |
| 200 | 141 | 155 | 167 | 179 | 190 | 200 |

Many automatic nozzles have a dramatic reduction in flow, some up to 50 percent with as little as a 20-psi nozzle pressure reduction. Additionally, it is important to remember that these are theoretical numbers; actual flows may vary considerably. Also, the loss in flow may not be apparent to the nozzleman because the stream may appear unchanged.

NOZZLE REACTION

Today, many nozzles are similar in appearance to the older 100-psi combination nozzles, but they operate at 50 or 75 psi. This lower nozzle pressure results in lower nozzle reaction (the force created as the water leaves the nozzle) with the same flow. This reaction is similar to pounds of thrust. The force of the thrust is what the nozzle team has to absorb as it pushes forward in an aggressive interior fire attack. The force is based on the nozzle pressure (psi rating of the nozzle) and the flow (gpm). A typical 100-psi combination nozzle flowing 150 gpm will have a reaction force of 76 pounds. The 75-psi or a 50-psi combination nozzle at the same flow will have a reaction force of 66 pounds and 54 pounds, respectively.

Generally, if one firefighter can handle the line, you probably do not have the flow required. Even at 54 pounds of reaction force, it requires some effort on the part of the nozzle team to control the line. When you are developing your system, have the members of your department flow the lines to determine what force they can handle. Refer to Tables 3 and 4 for reaction force data. If the limit is 60 or 65 pounds of force, develop your attack lines to get the maximum flow with that reaction force.

Table 3. Solid Stream Nozzles in Pounds

| | Reaction Force | | |
|------------|----------------|--------|--------|
| Tip Size | 40 psi | 45 psi | 50 psi |
| 7/8 inch | 48 | 54 | 60 |
| 15/16 inch | 55 | 62 | 69 |

Table 4. 100-psi Combination Nozzles in Pounds

| | Nozzle Pressure | | | | | |
|-------------|-----------------|--------|--------|--------|--------|---------|
| GPM Setting | 50 psi | 60 psi | 70 psi | 80 psi | 90 psi | 100 psi |
| 95 | 24 | 29 | 34 | 38 | 43 | 48 |
| 125 | 32 | 35 | 38 | 51 | 57 | 63 |

| | | | | | | |
|-----|----|----|----|----|----|-----|
| 150 | 38 | 45 | 53 | 61 | 68 | 76 |
| 200 | 51 | 61 | 71 | 81 | 91 | 101 |

FIELD DEMONSTRATION

With an understanding of target flow and reaction force, you can begin to select an attack system (water supply, engine, hoseline, nozzle, and attack crew) to meet your department's needs. When testing and choosing components in your system, you can balance flow with acceptable reaction force. A simple field demonstration we have developed uses a fish scale. A loop of webbing secures the scale to a substantial object, and a loop secures the hose (photo 1). The values on the scale will be close to the theoretical values from the flow charts. This will also allow you to experiment with hose and nozzle combinations that may not appear on the chart.



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(1) Photos by Christopher Flatley.

NOZZLES

Clearly, nozzle reaction is much lower for nozzles operating at 50 and 75 psi. So, why are we still using the combination nozzles designed to operate at 100 psi? Why not have a nozzle that gives you that same flow at reduced reaction?

Until recently, no such nozzle was available. In the past, if a combination nozzle was to be National Fire Protection Association compliant, it had to operate at 100 psi. Not until 1998 when the standard (NFPA 1410) changed to allow the "authority having jurisdiction" (the fire department) the option of determining the nozzle pressure did the industry develop lower-pressure nozzles that would be NFPA-compliant. The more pervasive use of 1 3/4-inch hose in the fire service prompted the change. Departments could achieve the 200-gpm required flow for two attack lines at much lower pressure.

Many volunteer and short-staffed career departments are making use of preconnected attack lines. This further illustrates the point: If the line is the same length, has the same nozzle, and requires the same nozzle pressure, how do you get the pump pressure right every time? The answer: You have to test your hose loads.

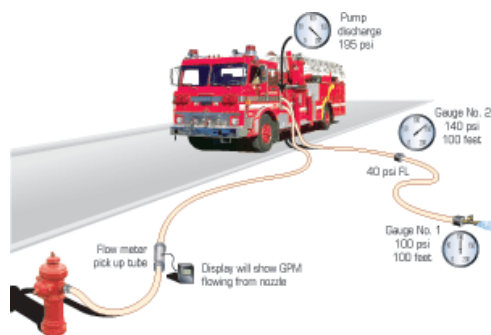
THE NEED FOR TESTING

Friction loss charts, nozzle reaction formulas, and nozzle discharge specifications are all theoretical numbers. To ensure you are achieving your target flow, you have to conduct a real-world test.

Do not wait for an actual fire to test your apparatus. The "Hose and Flows" station at Hands-On Training Engine Company Operations at FDIC has been demonstrating this method with positive results. It is a reliable test for determining if the pump operator is supplying the right water flow. Your trainees understand friction loss; your nozzle teams understand a correct target flow and nozzle reaction. This test will bring theoretical pump operations into practical reality.

The Hose and Flows Test Method

This is the test method used to test your attack lines that can help you to establish proper flows and pressure for all the attack lines on your rig. To properly test your apparatus, you will need a properly calibrated in-line flowmeter and one or two in-line pressure gauges (Figure 1).



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Figure 1. Diagram of Test Method

To test the attack lines, place the flowmeter in the supply line to the pumper. This will allow you to test all the attack lines with one supply line setup. The flowmeter pickup tube can be at the pump panel, but we recommend that the tube not be at the hydrant or the water source, to avoid turbulence that may affect the readings (photo 2). Since water is incompressible, the water going in will equal the water going out. Pressure will be lost, but the volume will be the same.



[Click here to enlarge image](#)

2.

Place the in-line pressure gauge behind the nozzle to be tested. This will read the nozzle pressure. A pitot gauge may be used to determine the pressure of water discharged from a solid stream nozzle, but it can be used only on a solid stream. If the goal is to test a combination nozzle, the stream-no matter how tight the pattern-cannot be accurately measured with a pitot gauge.

Flow the line until you reach the correct nozzle pressure. Record that pressure reading on the pump discharge. If you have two in-line pressure gauges, you obtain both readings in one step. Place the in-line pressure gauge one or two lengths from the nozzle in the hoseline you are testing. Return the pump to the pressure you just recorded. Take a reading on the pressure gauge in-line. The difference between the reading on the gauge and the nozzle pressure is the friction loss for that hose. Subtract the total hose friction loss and the nozzle pressure from the pump discharge pressure to determine the friction loss of that pump discharge.

Example (see Figure 1): When 100 psi is reached at the nozzle, the pump discharge pressure is 195 psi and the gauge placed in the middle of the 200-foot preconnect reads 140 psi. From this, we can calculate the friction loss of 40 psi per 100 feet of hose. What, then, is our friction loss in the apparatus? Our example would look like this: From the total engine pressure, subtract the nozzle pressure, then the total friction loss for the hose; what you are left with is the friction loss in the piping of the apparatus.

Engine pressure 195

– Nozzle pressure and 100

Friction loss (hose) 200 feet 80

Lost in the pump and plumbing 15 psi

It is important that you stretch and operate a line from every discharge to determine pressure losses in each discharge. Differences in the amount, size, and type of pipe will have a dramatic effect on pump pressure, especially in crosslays. Older apparatus with 1 1/2-inch metal piping will have a greater friction loss than newer equipment that has a two-inch high-pressure hose to supply the crosslays.

It is important to note that this is the friction loss for that particular age, condition, and manufacturer of hose. Age, condition, and the type of hose lining will have a dramatic impact on friction loss numbers. Another significant factor that will determine the friction loss in the hose is how much it will stretch when charged. Some brands will swell to their designed diameter; others a bit beyond, which may significantly reduce the theoretical friction loss.

Fireground Application

For those who say, "Our rig has flowmeters. We just run the throttle up until we reach 180 gpm," by knowing the ideal pump pressure associated with a particular flow, you will be able to tell if a line is kinked or if the flow is restricted. By understanding the relationship between engine pressure and flow, the pump operator can quickly resolve water problems. This will ensure that a line is not overpressurized, which could result in a burst length and produce disastrous results. The Fire Department of New York rewrote its "Fire Tactics and Procedure" Engine Company Operations to address this critical issue. Table 5 is adapted from the bulletin.

Table 5. Engine Pressure and Flow Relationship

| Nozzle Flow | Reading | Discharge Pressure Reading | Flowmeter Problem |
|------------------------------------|--------------------|-------------------------------------|-----------------------|
| Call for more water or pressure | Normal or Higher | Flow reduced | Kinks |
| Almost no water Flow inadequate | Normal or Higher | No reading Flow severely reduced | Multiple/severe kinks |
| Almost no water Flow inadequate | Pressure decreases | Flow dramatically increases | Burst length |

TEST ATTACK LINES FROM BOOSTER TANK

Don't stop here. Once the proper pressure and flow have been determined, you need to take the process one step further: You need to test your attack lines from the booster tank.

A story told to us by a salesman from a major nozzle manufacturer illustrates the point. A city in upstate New York wanted to procure new nozzles. Following a substantial amount of flow testing, similar to the method above, the fire department generated new pump charts and implemented a training program. Shortly after the equipment was put into service, the department responded to a fire. The first-arriving engine company officer had the pump operator supply water from the booster tank until he hooked up to the nearby hydrant. The engine company had difficulty extinguishing the fire until it went on the hydrant. An investigation of the event revealed that the piping from the booster tank was too small and could not supply the new target flow the city had adopted. This may be a common situation with older apparatus. NFPA 1901, *Standard for Automotive Fire Apparatus*, requires that a flow of 250 gpm be supplied for apparatus with a water tank with a capacity of less than 500 gallons and 500 gpm for tanks with capacities of 500 gallons and more.

KEEP THE INFORMATION READILY AVAILABLE

Now that you have determined the flow and pressure of your attack lines, don't forget that information. What has worked for many departments is to place a label on the gauge. If you are using preconnected handlines of the same length with the same nozzle, why aren't you able to supply the same pressure? You just figured it out: Put a label on the gauge. Make the pump charts simple. You now know what the friction loss is for your hose. Write it down. Write down the formula to figure out the pump pressure if you extend a hoseline or operate from a gated wye.

This is hydraulics, not rocket science. Remember, the firefighter with his face in the fire is counting on you to get it right. If you are one of those who "will give them more water if they call for it," consider that maybe the firefighters inside may be a little too busy getting burnt to ask for it.

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