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HOW KINKS AFFECT YOUR FIRE ATTACK SYSTEM

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AT THE START OF OUR FIREFIGHTING CAREER, we are taught the critical skills for executing our most important play: stretch the line and extinguish the fire. We were taught that when deploying the line, the engine company must “chase the kinks” or “kick the kinks” when pulling and flaking out the line to the fire to reduce the pressure in the line, avoid a burst length, and ensure adequate flow. Excessive kinks could result in the line’s reaching its maximum pressure. The idea is to remove the kinks when the line is charged to ensure that the line is flowing proper gallons per minute (gpm) and operating at the proper nozzle pressure. When a hoseline is kinked, the nozzle will not be operating at its proper pressure and, therefore, not at its maximum flow and reach.

Over the past few years, many companies have been moving back to 50 pounds per square inch (psi) smooth bore nozzles and the new low-pressure variable tip nozzles, which operate at 50 or 75 psi. The change results in increased flow with a reduction in nozzle reaction. As with any change within a system, there will be other effects. With the reduction in overall line pressure (between 25 and 50 psi), there is a greater chance that the hoseline will kink. Ask yourself, which line bends easier, the line operating at 120 psi or 150 psi?

We all know that when the flow on the attack line is reduced, the firefight takes longer, does not go smoothly, and places the firefighter and the public at greater risk. There have been many studies and articles on what the “target flow” should be and how to obtain it-more importantly, how to obtain it every time.

Lieutenant Jay Comella, Oakland (CA) Fire Department, published a ground-breaking study in 2003.[1] This study and subsequent articles caused many fire departments across the country to examine their target flow and make very successful corrections to their pump discharge pressures, hoselines, and nozzles. As a result, many firefighters have increased their safety by increasing their target flow. During the past several years, we have conducted engine company operations training for many departments and have found that many have made minor changes that resulted in major increases in flow and safety.

Articles by Comella and the late Andy Fredericks[2] examined target flow in detail and are excellent references. But as good as these articles are concerning choosing the correct line and nozzle combination for your department, they did not address the effects of kinks on actual flows.

WHAT IS A KINK?

We will define a kink as “a bend in the hose at a tight enough angle to cause a visible crease or fold in the outside jacket of the hose.” The assumption is that if there is a visible crease in the outside jacket, there is a large enough fold (kink) in the inside jacket to affect the hydraulics within the line.

To determine the effects of a variety of kinks on a hoseline, we tested three nozzles-a 15/16-inch smooth bore, which flows 180 gpm at 50 psi; a low-pressure variable, which flows 150 gpm at 50 psi; and an automatic constant pressure nozzle, which flows 150 gpm at 100 psi (50 to 300 gpm) (photo 1). The nozzles were placed at the end of 150 feet of 1¾-inch line. The nozzles tested have different volumes at the rated pressure; thus, our data will compare the difference in percent of flow lost for each nozzle, not just total volume lost. These numbers represent the difference in flow in an accurate and unbiased manner.

1. Photos by authors.

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To ensure that we had good baseline data, we first operated each nozzle at its designed operational tip pressure without any kinks and logged the pump discharge pressure (PDP). This became the PDP set for each nozzle to be used as the pressure for each line during the tests. To confirm that the pressure and flow were correct, we used an in-line flowmeter (on the intake side of the pump) and compared it (verified the flow reading) with the engine's discharge flowmeter. We installed an in-line pressure gauge at the nozzle to ensure the correct tip pressure. On the smooth bore only, we tested both gauges with a pitot as a redundant check for both gauges. From the baseline data, we determined that the nozzles were operating within their designed flow rates.

All kinks were imposed in the middle length of hose, leaving a 50-foot length of straight line between the kinks and the nozzle. To ensure that the tests with each of the nozzles were consistent, we laid out the kink angles on the ground using a simple carpenter's square and a lumber crayon. The ground layout (photo 2) was used to align the hose into the desired kinks and ensure consistency in kinks for all tests. We chose kinks that represented typical fireground situations: single 90° (photo 3), 135° (photo 4), and 180° (photo 5) kinks; and two 90° (photo 6), two 135° (photo 7), and two 180° kinks (photo 8).

2.

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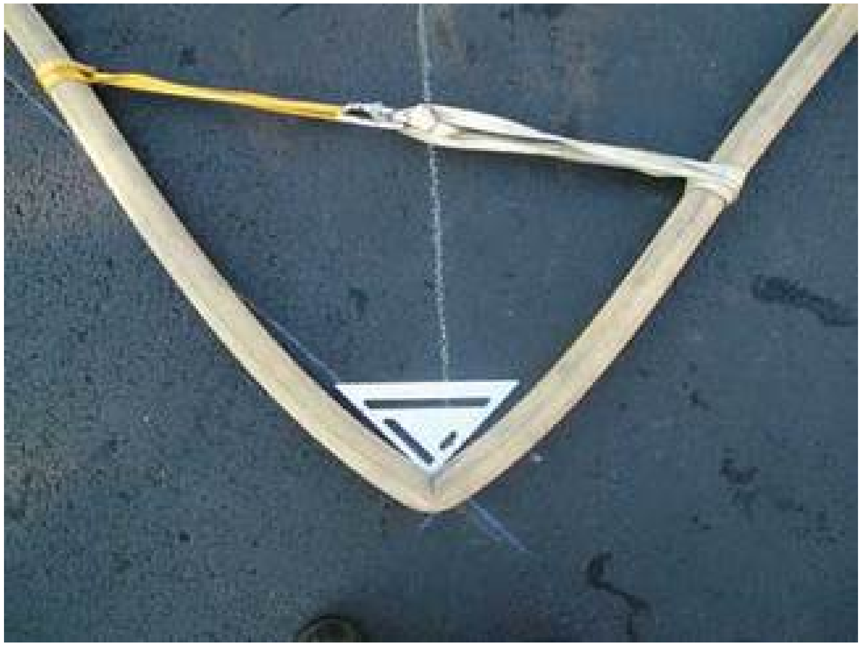

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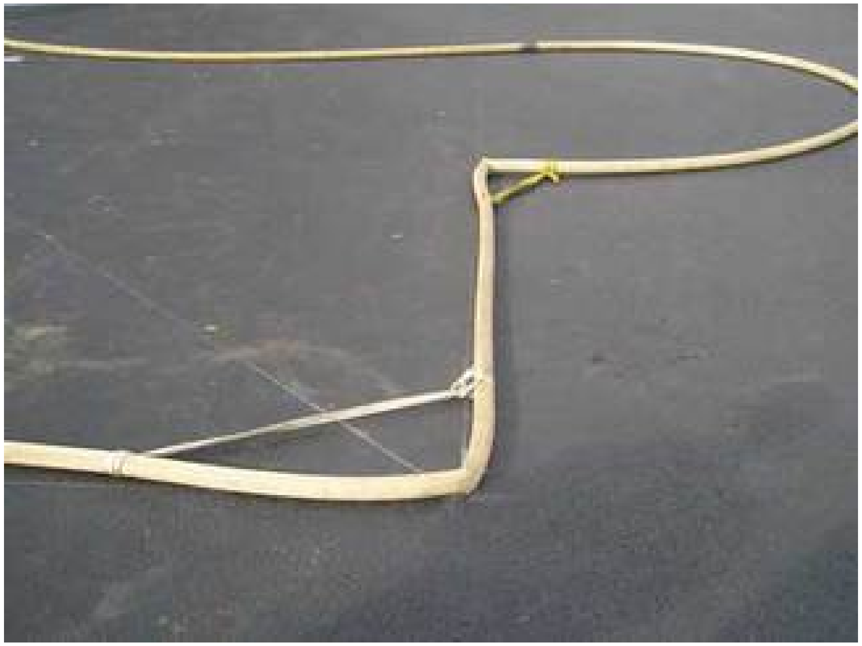

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To hold each kink at the same angle for each test, we locked in the kink with webbing. To ensure the uniformity of the kinks for each nozzle, an additional ball shutoff from a break-apart nozzle was placed at the end of the line, and each nozzle tested was attached to the shutoff. This shutoff was closed when changing the nozzle, to keep the pressure in the hoseline and maintain the kink. Although the additional ball valve would have a minor reduction in pressure at the nozzle, it was used throughout each test so that the results were evenly affected. The ball valve allowed the line to remain charged throughout the test at each kink simulation. With each kink scenario, the PDP, gpm flowing, and nozzle pressure (NP) were captured and logged.

SMOOTH BORE NOZZLE

We gathered the data in Table 1 from kinks imposed on a line using a 15/16-inch smooth bore nozzle.

Table 1. 15/16-Inch Smooth Bore Nozzle

KINK(S)	PDP	GPM	NP	GPM REDUCTION	REACH
No kink	120	180	54	—	—
1-90°	120	175	50	3%	NSC*
1-135°	125	150	40	17%	NSC
1-180°	125	135	25	25%	POOR
2-90°	120	155	40	14%	NSC
2-135°	135	105	20	42%	POOR
2-180°	130	115	20	36%	POOR

* no significant change

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As the angle or number of kinks increased, the total "GPM" and "NP" were reduced as expected. Interestingly, a single 90° kink reduced the flow only by 3 percent, or 5 gpm, which would not be noticed during a firefight. Even with two 90° kinks, the flow was reduced by 17 percent but was still a usable 150 gpm. Although it is not the recommended target of between 160 and 180 gpm, it is still superior to the 125-gpm nozzles operated at the end of a 1 1/2-inch line used not so long ago as the main attack line. Here again, we see the value of beginning with a target flow of 180 gpm: The fire attack is still safe and successful even with less-than-perfect engine company operations.

As expected, as the angle or number of kinks increased, the total flow and nozzle pressure were reduced. To take the worst-case scenario, with two 135° kinks, which could happen if the entire hose load is not pulled from the crosslay or not flaked out in a narrow stairwell or hallway, the flow was reduced by 42 percent, or 76 gpm. The double kink reduced the nozzle pressure to a very low 20 psi and created a very soft line with little to no nozzle reaction. If this scenario happened, even the most inexperienced nozzle team would feel the results. Although we did not measure or quantify the stream quality or reach, both were greatly reduced. The stream velocity was limited and had no punch.

LOW-PRESSURE COMBINATION NOZZLE

Next, we were eager to move to the newest type of nozzle on the market today, the low-pressure variable nozzle. Many departments have been purchasing these nozzles as a replacement for the 100-psi variable nozzles to reduce the nozzle reaction while flowing greater gpm to meet the needs of today's fireground.

We tested a 150 gpm at 50 psi. The data are representative of this nozzle and make for an even comparison to the smooth bore and the automatic nozzle. This may not be representative of all the others available on the market today. To keep the tests equal, the same kink scenarios were followed in the same order; the results are noted in Table 2.

Table 2. Low-Pressure Variable Nozzle

KINK(S)	PDP	GPM	NP	GPM REDUCTION	REACH
No kink	90	150	55	—	—
1-90°	110	150	65	0%	NSC*
1-135°	115	140	60	7%	NSC
1-180°	120	120	45	20%	NSC
2-90°	110	140	60	7%	NSC
2-135°	130	95	25	37%	POOR
2-180°	125	105	35	30%	POOR

* no significant change

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As with the smooth bore, the single 90° kink did little to affect the total gpm flowed. With the gauges and flowmeters we were using, we saw no overall change in flow. There was, however, an increase in pump discharge pressure, which proves an addition in back pressure caused by the kink.

As with the smooth bore, there was an even reduction in flow as we increased the angle and number of kinks. The greatest reduction in flow was created by two 135° kinks, not two 180° kinks. From these numbers, we assume that the 135° kink produced the greatest obstruction in the waterway, as illustrated in photo 7.

The increase in the pump discharge pressure is an expected result from the kink in the line. The kink reduces the flow area within the hose, which causes additional backpressure in the line. This is the same principle as when a line is operating at a pump discharge pressure of 90 psi while flowing water (active or kinetic pressure) and when the line is shut down (static pressure). The reading on the discharge gauge will increase greatly.

AUTOMATIC NOZZLE

The 100-psi automatic constant pressure nozzle automatic rated at 150 gpm has been the multipurpose mainstay of the fire service for the past 25 years or more. The automatic nozzle is designed to adjust its orifice, through the use of springs, to ensure that the tip pressure stays at 100 psi and to keep a long reaching uniform stream. Once again, the angle and number of kinks were used in the same order. It was more difficult to bend the hose into the noted kinks because of the higher operating pressure. The resistance to kinking is greater in lines with higher nozzle pressures.

The stream quality was found to be different with the automatic nozzle (Table 3). The PDP remained the same throughout the test scenarios. There was only a minor reduction in appearance and reach. However, the kinks greatly affected the overall flow. The reduction in flow from one 90° kink was 20 percent in this nozzle-more than that in the other nozzles tested. As the angle and number of kinks increased, the flow was reduced even further; however, the reach remained the same. The last test-which would be considered the worst-case scenario, was that involving two 180° kinks. The flow was reduced by 80 percent, for a flow of 30 gpm. This would be the flow expected from a one-inch booster line.

Table 3. Automatic Nozzle

KINK(S)	PDP	GPM	NP	GPM REDUCTION	REACH
No kink	150	150	110	—	—
1-90°	150	120	115	20%	NSC*
1-135°	150	105	105	30%	NSC
1-180°	150	75	100	50%	POOR
2-90°	150	115	115	23%	NSC
2-135°	150	100	110	33%	NSC
2-180°	150	30	90	80%	POOR

* no significant change

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We believe these data represent realistic reductions in flow and pressure caused by kinks in the specific hose system. Using similar methods, you can test your fire attack system to show the effects of kinks on fire flow. We determined that it was much easier to kink the hose operating a 50-psi nozzle, but the reduction in flow attributed to a kink was much greater in the automatic nozzle. This proves one thing and one thing only: It is critical to ensure that all deployed lines do not have any kinks, especially in the fire attack line. An attack line is not static as is a supply line. Because the attack line is in constant motion, a kink can develop at anytime during the suppression efforts.

PLACING RESPONSIBILITY

Regardless of the nozzle selected, not only must the line be properly charged at the pump panel, but it is equally as important to make sure that the stretch is kink free. Who is responsible for making sure there are no kinks in the line? As a rule, the pump operator is responsible for all hose in the street between the discharge port and the front door. The nozzle team is responsible for all hose inside the building extending from the front door to the point of operation. In cases where staffing permits, the hydrant man should straighten any leftover kinks in the stretch when entering the building.

The pump operator should not charge any hoseline before making a visual check to see (1) that all the hose has been pulled out of the hosebed if using preconnected lines and (2) that it is not lying in a pile near the back step of the engine. The nozzle team is focused on getting the line in operation inside the building and will disregard any excess line left in the street. The pump operator should ensure that all the hose is out of the bed and all the kinks have been removed in the street.

The nozzle crew is responsible for "flaking out" the working length of hose brought to the point of operation. The nozzle crew is not ready for water until the excess hose has been flaked. The choices for placing this extra hose include downstairs, upstairs, out the window, or into an adjoining room or apartment. Depositing the excess line upstairs is often preferred so that line advancement is aided by gravity. However, if you are going up with it, be sure the forcible entry team has control of the door so that you don't find yourself inadvertently above the fire.

It is also important for the company officer to call for the right amount of hose. Having 100 feet of extra hose in the hallway is too much to distribute without kinking. Although it is generally thought to be better to err on the side of stretching too much hose than not enough (stretching short), the overestimation should not be more than one 50-foot length. The officer must estimate how much hose will be needed from the engine to the front door and from the front door to the fire floor, plus one working length. Consider the overall dimensions of the structure and the location of the fire floor above the street.

The purpose of our testing was to examine the effect of kinks on three fire attack systems in a practical and realistic manner. Our test methodology can be replicated by any fire department in its station or on its drill ground. The flow instruments and pressure gauges used are common in the fire service and provide reliable data.

Clearly, the data presented in this article show the importance of understanding your fire attack system-pump, hose, nozzle team, and the effects of kinks and other negative factors.

References

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

2. “Little Drops of Water, 50 Years Later, Part 2,” Andrew Fredericks, *Fire Engineering*, March 2000.

Additional Resource

“Nozzles and Handlines for Interior Operations,” David Wood, *Fire Engineering*, April 1999.

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