BACK-TO-BASICS PUMP OPERATIONS

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Operating the pump at a working fire can be a high-pressure job, if you will excuse the pun. Pump operators are obliged to supply water on demand to a wide variety of appliances ranging from booster reels to cellar pipes to sprinkler systems, including every kind of handline and master stream in between. Each appliance has its own exigencies and requirements. For the study of hydraulics, friction loss formulas, pump specifications, and so on, to lead to precision in pumping operations, it is necessary to understand the underlying concepts and terminology on which they are based. Some of the basic concepts of fire service hydraulics for the "hands-on" pump operator in the field are discussed below.

FLOW
Flow is the volume of water delivered through hoselines to the burning material by means of the mechanical force of the fire pump. Measured in gallons per minute (gpm), flow is the definitive factor in whether the fire will be controlled or not. The minimum flow recommended for a handline operating inside a burning building is 150 gpm, except during overhaul. Flow rates to master streams range from 350 gpm for deluge sets up to 1,000 gpm for elevated platforms.

Most standard fire pumps are designed and rated to flow a capacity of either 1,000; 1,500; or 2,000 gpm. Hence, a 1,000-gallon pumper would be capable of supplying one tower ladder or up to three deluge sets, provided that conditions are right, meaning that the water source was capable of yielding 1,000 gpm to the intake side of the pump.

Of course, the larger the flow requirement, the larger the diameter hoseline needed. In general, it is not advisable to supply master streams and handlines from the same pump at the same time. However, fireground conditions often necessitate that exposure lines be used along with master streams from the same pump.

The manufacturer's specifications plate is mounted on the pump panel. Flow capacities are given in relation to pressure and revolutions per minute and are verified at annual pump tests. (Photo by author.)
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The pump's flow capacity is listed on the manufacturer's specifications plate, mounted on the pump panel (see photo 2). The flow is listed in relation to pressure and is verified by annual pump tests. A typical multistage pump is rated to flow its full capacity at 150 psi in the volume setting. It will flow 75 percent of its capacity at 200 psi and 50 percent at 250 psi. A pump's capacity depends on the size of its impellers and waterways.

The quantity of water supplied to the pump determines whether the pump will achieve its rated capacity. In general, the closer the pump is to the hydrant, the more water will be supplied. However, a 1,000-gpm pump will never pump its rated capacity if it is connected to a hydrant that flows only 600 gallons per minute. If you use in-line pumping or forward stretches, you must use large-diameter or parallel siamesed lines between the hydrant and pump to get the most water available from water sources.

PRESSURE
Pressure, measured in pounds per square inch (psi), is the force with which the water moves through the hoselines. As the pressure increases, the flow increases, as long as the water source has the necessary capacity. The horizontal and vertical reach of the fire stream expands as the pressure is increased, within the range of the nozzle in use. There are several types of pressure; they are discussed below.

REACH

Reach is an important consideration when delivering water to the fire. Heat, wind, building partitions, as well as the angle of the stream all have an impact on the stream's reach. The greater the reach of a fire stream, the safer the nozzle team will be. In general, a properly charged 13/4-inch handline can be expected to reach 100 to 130 feet prior to the effects of wind and heat's breaking up the stream or turning it to steam. Knowing the fire building's dimensions can thus indicate whether the stream can reach the seat of the fire.

NOZZLE PRESSURE

Nozzle pressure (NP) is the optimum pressure needed at the end of the hoseline for the nozzle to produce an effective fire stream. The nozzle pressure is the starting point for determining proper pumping procedures-it is the determining factor. Nozzles must be supplied at their proper operating pressure. Different nozzles are designed to operate at different pressures-for example, handline smooth-bore nozzles operate best when pressurized at between 40 and 50 psi. Master stream smooth-bore nozzles operate best at 80 psi. Most fog nozzles for handlines and master streams are designed to operate at 100 psi, although a new generation of low-pressure fog nozzles is set to operate at 75 psi (see Table 1).

The proper stream shape and maximum reach can be achieved at these pressures. If the nozzle does not have sufficient pressure, obviously its reach will be reduced. If it has too much pressure, turbulence can occur at the nozzle; this also will reduce the reach. The maximum horizontal reach can be achieved at an elevation angle of between 307 and 357.

FRICTION LOSS (FL)

Friction loss (FL) refers to the resistance the water meets as it travels through the hoseline, whether the hose is between the pump and the nozzle or the water source and the pump. It is the primary impediment the pump operator must overcome and is measured in psi. The narrower the hose, the greater the friction loss for a given flow-for example, 150 gallons of water per minute flowing through 100 feet of a 11/2-inch-diameter line will create 55 psi of friction loss. The same gallonage flowing through 100 feet of 13/4-inch-diameter line will produce only 35 psi of friction loss. In turn, if 150 gallons were flowing through a 21/2-inch line, it would produce only five psi of friction loss. Therefore, the more water needed, the larger the hoseline. This is especially true for supply lines between the water source and the pumper.

In addition to the hose's diameter, the longer the hose stretch, the greater the friction loss, because it is cumulative. Taking the above example, if 35 psi of friction loss is produced in 100 feet of 13/4-inch hose, a 250-foot preconnect flowing 150 gpm would have approximately 87 psi of friction loss because it must travel farther.

Obviously, the more water you wish to flow, the larger the diameter hose you will need. It takes a larger hose to supply a 1,000-gallon pumper than it does to supply a handline nozzle. Common hose dimensions range from 3/4-inch booster lines up to five-inch-diameter supply hose. Hose diameters refer to the waterway's inside diameter. To enable the fire pump to produce its full capacity, large-diameter supply lines are used to reduce friction loss. A five-inch line can supply 1,000 gpm at a friction loss of only eight psi per hundred feet. By contrast, a 31/2-inch line supplying 1,000 gpm will have a friction loss of 34 psi per hundred feet. However, if supply lines are siamesed or laid parallel, the friction loss is greatly diminished. Taking the above example, two siamesed 31/2-inch lines flowing 1,000 gpm will produce only nine psi of friction loss, because the flow for each is only 500 gpm. In addition to reducing friction loss, siamesed lines have the added benefit of ensuring a continuous flow of water if one line fails. However, if very long stretches are the norm, one supply bed of large-diameter hose is preferable to parallel beds of smaller-diameter hose.

HEAD LOSS

Head loss (HL), the loss in pressure caused by gravity, is the second encumbrance that hinders pumping operations. It is generally measured at 0.5 psi per foot of rise or five psi per story. Head loss increases with the height, regardless of the hose's diameter or the number of gallons being raised. At five pounds of head loss per story, how much head loss would occur when supplying water to the top floor of a three-story building?

The answer is 10 pounds-five pounds to get the water from the ground floor to the second floor and five pounds to get the water from the second floor to the third floor. These numbers are rather small, but head loss is an important consideration when operating at high-rise fires. Note: When operating at a high-rise, consider also system loss (SL)-the pressure loss in the siamese and piping. It is usually considered to be 15 psi.

Of course, if pressure is lost when going uphill, it is gained when flowing downhill. Thus, pumping from grade level to a basement fire would increase the pressure by five psi. Notwithstanding pumping operations, head also impacts municipal water systems. A hydrant at the bottom of a hill would be expected to have better pressure than one at the top of the hill unless a pump station is nearby.

PUMP DISCHARGE PRESSURE

Having discussed flow, nozzle pressure, and friction loss, we can now talk about the primary factor for the pump operator-pump discharge pressure, also known as pump pressure or engine pressure. It can be summarized in the following general formula:

Pump Discharge Pressure = nozzle pressure + friction loss; head loss + system loss = NP + FL + HL + SL

The pump discharge pressure is the flowing pressure at the pump (considering the friction loss, head loss, and system, where applicable) needed to supply the nozzle at its rated pressure. It is read on the discharge gauge when the nozzle is open and the water is flowing.

While it is necessary to consider all the factors discussed above in determining the pump discharge pressure, it is not necessary to use formulas on the fireground if your company uses preconnected hoselines. With a preconnected hoseline, the length of the stretch, the diameter of the hoseline, the type of nozzle, and even the handle on the pump panel all remain constant. It is therefore possible to precalculate the pump discharge pressure before leaving quarters and mark it on the pump panel to eliminate the guesswork on the fireground. The only variable left is head loss, which is simple to compensate for once you arrive at the scene.

When initially supplying water to the nozzle crew, the pump operator first takes a static pressure reading on the discharge gauge. This reading will be equal to the hydrant pressure (if hooked up) plus the pressure increase caused by the rotation of the pump's impellers at idle. It will, therefore, be several psi higher than the static pressure reading on the pump intake gauge. The pump discharge pressure cannot be adjusted until the nozzle is opened.

Once the nozzle is opened, the discharge pressure reading will drop because the water is flowing. When the drop occurs, the pump operator needs to bring the pressure up to the proper pump discharge pressure. Not supplying the correct flow and pressure to the nozzle is one of the primary reasons crews are driven out and buildings are lost. As explained above, the reach and quantity of water delivered on the fire generally increase and decrease with nozzle pressure. There are two primary reasons for undersupplied nozzles:

•The pump discharge pressures are too low.
•There are kinks in the hoseline.

The reach and flow of a hose stream determine its effectiveness in extinguishing the fire. The pump discharge pressure is increased to overcome the friction loss (and head loss, and so on) to provide adequate water flow and reach at the nozzle. When it comes to an aggressive interior attack, more is better. As mentioned, the readings on the discharge gauge indicate the flowing pressure of the stream when the nozzle is open and the static pressure when the nozzle is closed. If the pump operator takes the static pressure to be the pump discharge pressure, the nozzle will be substantially underpressurized. The nozzle team may appreciate the ease of handling the nozzle, but the stream will be less effective. The correct pump discharge pressure is read on the discharge pressure gauge when the water is flowing and adjusted accordingly.

The discharge pressure reading, however, does not take into account or compensate for the impact of kinks which, in many cases, are beyond the sight of the pump operator. At a recent training class, a 90 degree kink was imposed on a hose line flowing 140 gpm. It caused the flow to drop to 55 gpm.

This test illustrates the importance of removing kinks from the stretch. On the fire scene, there are often numerous kinks in a hose line. Generally speaking, a higher nozzle pressure reduces the tendency of the line to kink, but all hose lines are subject to kinking. As a rule of thumb, it is the pump operator's responsibility to remove the kinks from the hose stretch on the outside of the building and the nozzle team's responsibility to remove them on the inside. With reduced staffing levels, this important job is often overlooked. The hydrant man should take the time to flake out the kinks in the stretch as he enters the building en route to the point of operation.

Newer pumps are outfitted with dual gauges that display both discharge pressure and flow. When calibrated properly, the flow gauges can indicate the presence of kinks or obstructions in the stretch. As an example, if the pump discharge pressure reading is 150 psi but the flow is only 80 gpm, either the nozzle is only partially open or kinks are obstructing the flow. An astute pump operator who keeps a close eye on the discharge gauge readings can advise the nozzle team of kinking. Often, the nozzle team's calling for more pressure when removing a kink or two would be the better solution to the problem.

PROCEDURAL CONSIDERATIONS

Perhaps the pump operator is the most important member of the engine crew. The crew's safety and job's success often depend on the pump operator's skill. Officers should, therefore, be mindful of this when assigning this job. The firefighter assigned should be a member who understands the pump thoroughly and is capable of operating without supervision. Ideally, a senior member should be assigned, but this is not always possible. When a newer member is assigned to the pump, the hydrant man should assist him on his way into the building. The first few minutes of a working fire can be harrowing, and the novice pump operator may need some assistance.

At most fires, hand lines are initially supplied from the onboard booster tank and later switched over to a hydrant or static water source. The pump operator's initial concern should be supplying the nozzle team from the tank. He should be able to locate the "tank-to-pump handle" and proper discharge gate in his sleep. Once the tank is "dropped" and the hand line is supplied, the pump operator has three to five minutes to get the supply lines attached and the hydrant open. The most common complaint of nozzle teams is that it takes too long for the line to be charged after they call for water. There are several potential reasons for this. The best way to supply the nozzle in a timely manner is to follow a standard procedure until it becomes habit. Here are some suggestions:

•Be sure to wear your portable radio and have it turned on before leaving quarters. This may seem obvious, but it is easy to forget the radio in the confusion if it is not being worn; without the radio, you will not hear the crew calling for water.
•When approaching the scene, enter the block at a reduced speed to allow for an opportunity to size up the fire situation and locate a hydrant. If stretching into the fire, stop at the hydrant and let the hydrant man off; then approach the fire building. Depending on the responding ladder's direction, either stop the apparatus before the building or stretch past it. If there is room to get the apparatus off the street, all the better. Try to leave the front of the building open for the first-due ladder, and avoid parking in the collapse zone.

When the engine comes to a stop, find out which line the officer wants to stretch before he exits the cab. When you exit the cab, pull the tank-to-pump valve so that the tank water will prime the pump. Next, chock the wheels. There are many documented cases in which rigs have slipped out of pump while revved up and the nozzle crew had been "reverse" stretched out of the building before it intended to leave.

Next, walk to the back of the apparatus (or side if mattydale hose loads are used), and double check which line is being taken into the building. Make sure all the hose is pulled from the basket. Remove any kinks in the street or piles of hose at the back step. Begin connecting the supply line(s) from the hydrant, and carefully monitor the radio for the officer's request for water. There will assuredly be a lot of chatter, but this is the pivotal transmission.

When called, be sure to acknowledge that you received the officer's transmission. Then immediately open the correct discharge valve, and adjust the throttle to the proper discharge pressure. Now you have several additional minutes to complete the switchover to hydrant pressure.

When you are ready to switch over, advise the officer you are switching to hydrant pressure. Throttle down as you open the intake port so there won't be a surge in nozzle pressure. Then readjust the pump discharge pressure. Once you have switched over to hydrant pressure, crack open the tank fill valve. This will refill the onboard water tank so that if there is some failure in the water supply (a burst hose line or water main failure, for example) the inside crew will be able to fall back on the tank.

Procedural Checklist

- Enter the block at a reduced speed.
- Stop at the hydrant and let the hydrant man off.
- Locate the apparatus out of the collapse zone, and leave.
- Before exiting the cab, find out which line the officer wants.
- Be sure you have your handheld radio on.
- Once you exit, drop the tank.
- Chock the wheels.
- Check which line is being stretched.
- Be sure all the hose is removed from the basket.
- Begin connecting the supply lines into the pump.
- When the officer calls, acknowledge that you received the message.
- Pull the proper discharge gate, and adjust the throttle to the proper pump pressure when the nozzle is opened.
- When switching from tank to hydrant, throttle down accordingly.
- Crack open the tank fill valve and refill the tank.

The pump operator's job is not glamorous, but it is essential and challenging. Once the basic principles are understood, experience becomes the best teacher. Following a standard procedure helps it become second nature. When the job is done correctly, there is a well-deserved sense of satisfaction when the fire goes out.

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