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by

Larry Davis

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Fluid Motion, Part 1

Maximize Pump Output From Drafting Operations

A Message the Author, Larry Davis

In October 2002, I started writing the monthly "Rural Fire Command" column for *FireRescue Magazine*. Since that time, the RFC column has been carried in just about every subsequent issue of the magazine.

As time has passed, several readers have contacted me about obtaining back issues of the column. Some expressed an interest in acquiring the articles in Powerpoint format for use in training programs.

This led to, my adaptation of the RFC columns to the PowerPoint format. These PowerPoint programs are being made available through the combined efforts of *FireRescue Magazine* and the Rural Firefighting Institute.

Fluid Motion — Part 1
Maximize Pump Output From Drafting Operations

If we don’t pay attention to the little things, we could easily commit a lot of time & energy to setting up a drafting operation that delivers less water than it should.

Figure 1. Drafting operations are the mainstay of the rural fire service. However, if we don't do some homework to get an idea of our pump's capabilities and what we can do to increase flow, we may in fact waste a lot of time and energy moving less water than we can with our minimum resources.

Key Points

- Fire Pump Limitations
- Maximum Usable Pressure (MUP)
- Key MUP Factors
- MUP in Action

The major difference between rural and urban firefighting centers around the fact that rural firefighters depend on drafting operations far more than our urban brothers and sisters, but from my perspective, drafting is one of the most neglected training topics in the firehouse (probably because it isn't very popular with the troops). While most drivers/operators want to know how to get a prime and move water from draft, they aren't interested in really understanding drafting or how to maximize output, in terms of gpm, from a drafting operation.

In most cases, however, we perform a drafting operation because the initial fire attack didn't or isn't knocking down the fire and we need a sustained attack. This means that both the fireground commander and the water-supply officer will need the maximum flow possible from a drafting operation.

While every firefighter may not need to understand drafting operations, certainly a department's water-supply specialists and water-supply officer must fully understand how various factors—over which we usually have very little control—impact a drafting operation's output.

Unfortunately, few training programs get into what I like to call the "nuts and bolts" of drafting, which is probably one of the most, if not *the* most, labor-intensive operations rural firefighters perform. And yet, if we don't pay attention to the little things, we could easily commit a lot of time and energy to setting up a drafting operation that delivers less water than it should. In many cases, the very equipment we purchase to make drafting operations easier ends up making them more difficult.

But before I can discuss those issues, we must review the factors that impact our pumpers' abilities to deliver maximum flows from draft. Natural laws govern drafting. Rural departments must understand these laws in order to develop a drafting system that meets their needs and maximizes output.

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Fire Pump Limitations

A fire apparatus pump is nothing more than a machine that takes the horsepower and torque from a diesel or gasoline engine and transfers it to water, which we can then move from its location to where we need it. Fire pumps perform two tasks: 1) getting water into the pump, and 2) getting water out of the pump. Together, these equal the pump’s total work output.

Like any piece of equipment, a fire pump can perform only a limited amount of work. The work a pump expends getting water into its intake reduces the amount of work it can expend to get water out. Thus, if we want to increase pump output from draft, we must minimize the work done to get water into the pump.

Maximum Usable Pressure (MUP)

Drafting operations are dependent on a limited amount of available atmospheric pressure to force water through suction hose and piping into a pump. At the same time, we can drop the atmospheric pressure within the pump so far because we can't pull a perfect vacuum. So, between the point at which the water enters the suction strainer hose and the eye of the pump's impeller, we may can only lose a limited amount of pressure. I call this the *maximum usable pressure (MUP).*

Key MUP Factors

Key MUP Factors

Four key factors impact the MUP of any drafting operation:
- The atmospheric pressure at the draft location,
- The temperature of the water to be drafted,
- The static lift (the distance the water must be lifted), and
- The lowest atmospheric pressure we can create in the pump.

Contrary to the beliefs of some, pumps can’t suck water through suction hose from a static source. Instead, atmospheric pressure forces water from the source into the pump. Of course, for this to happen, a pump must have a primer, a device designed to drop the atmospheric pressure within the pump sufficiently below the atmospheric pressure outside the pump.

Atmospheric Pressure

Atmospheric pressure is the maximum energy available to move water in a drafting operation. At sea level, the atmospheric pressure equals 14.7. (To simplify things, we'll forget about the units of measurement for now.) As altitude increases, the atmo-spheric pressure decreases at a rate of 0.5 /1000 feet, and vice versa. Once again, we'll skip the units of measurement for now.

Altitude's Effect on Atmospheric Pressure

Elevation (feet)	Atmospheric Pressure
-1,000	15.2
-500	15.0
0 (sea level)	14.7
1,000	14.2
2,000	13.7
3,000	13.2
4,000	12.7
5,000	12.2
6,000	11.8
7,000	11.3
8,000	10.9
9,000	10.5
10,000	10.1
11,000	9.8
12,000	9.4

Figure 2. As the altitude increases, the atmospheric pressure decreases at the rate of 0.5 psi/1000 ft, and vice versa.

Water Temperature

We also can't control a body of water's temperature during a drafting operation, but temperature affects a pump's ability to lift water because it affects the vapor pressure of the water source. Vapor pressure impacts the amount of vacuum a pump primer can create. Thus, vapor pressure affects a pump's ability to lift water. Figure 3 shows how water temperature affects the loss due to vapor pressure, or L_{vp}.

Water Temperature's Effect on Vapor Pressure Loss

Temperature (□F)	L_{vp}
32	.089
50	.180
60	.260
65	.310
70	.360
75	.430
80	.520
85	.600
90	.700
100	.960

Figure 3. The warmer the water to be drafted, the greater the pressure loss due to vapor pressure. (If it's any consolation to those of you in colder climates, it's a little easier to draft in the winter than in the summer.)

Static Lift

Static lift is the vertical distance (in feet) from the water's surface to the center of the pump intake. Figure 4 shows the impact of static lift on the loss due to static lift, or L_{sl}. For each foot of lift, the loss equals 0.434.

Loss to Static Lift

Lift (ft)	Loss
3	1.3
4	1.7
6	2.6
8	3.5
10	4.3
12	5.2
14	6.1
16	6.9
18	7.8
20	8.7
22	9.6
24	10.4
25	10.9

Figure 4. The greater the static lift in a drafting set-up, the greater the pressure loss. The pressure required to raise water 1 ft is 0.434 psi. Therefore the pressure loss to static lift is 0.434 psi/ft (0.5 psi is often used for field calculations).

Minimum Atmospheric Pressure in the Pump

Finally, since a primer can’t create a perfect vacuum within a fire pump, the atmospheric pressure within a pump can’t be dropped below some minimum pressure. From a personal standpoint, a ballpark constant of 5 works pretty well.

This is an approximate and conservative value that I like to use for the maximum vacuum (lowest atmospheric pressure) we should expect to see in the pump under draft conditions.

MUP In Action

MUP is used to overcome pressure losses due to friction in any piping, hose or fittings between the water source and a fire pump. You can determine the MUP by using the formula:

$$MUP = AP - L_{vp} - L_{sl} - 5$$

where: AP equals the atmospheric pressure at the site,
L_{vp} equals the loss due to vapor pressure,
L_{sl} equals the loss due to static lift, and
5 equals the lowest practical AP in the pump.

An Example

Let’s say we’re evaluating a water source for use as a drafting source to supply a relay operation or a tanker fill site. The water source is 2,000 feet above sea level, and has a temperature of 70°F and a static lift of 15'.

Using the data in Figures 2 thru 4:

MUP = 13.7 - 0.36 - 6.5 – 5, so the MUP = 1.84.

Now we’ll apply units of measure. The MUP is 1.84 psi. This is the maximum pressure available to move water through 20 feet of suction hose and a strainer, and into the pump.

Once we know the MUP, we must determine the maximum flow possible at that MUP. To do this, we need to use Figures 5 and 6 to determine the friction losses in the suction hose and the strainer.

Friction Loss per 10-ft of Suction Hose

Flow	4-1/2"	5"	6"
100	.1	.01	ŠŠŠ
200	.1	.03	0.01
250	.1	.04	0.02
300	.1	.06	0.02
400	.2	.10	0.04
500	.3	.16	0.1
600	.4	.23	0.1
700	.5	.32	0.1
750	.6	.36	0.2
800	.7	.41	0.2
900	.9	.52	0.2
1000	1.1	.65	0.3
1250	1.7	1.0	0.4
1500	2.5	1.5	0.6
1750	3.3	2.0	0.8
2000	4.4	2.6	1.0
2250	5.5	3.3	1.3
2500	6.8	4.0	1.6
2750	8.2	4.9	2.0
3000	9.9	5.8	2.3

Figure 4. Suction hose creates pressure loss due to friction.

Friction Loss in Suction Strainers

Flow	4-1/2"	5"	6"
100	.03	.02	.01
200	.12	.08	.04
250	.18	.12	.06
300	.26	.17	.08
400	.46	.30	.15
500	.73	.48	.23
600	1.04	.68	.33
700	1.42	.93	.45
750	1.63	1.07	.52
800	1.86	1.22	.59
900	2.35	1.54	.74
1000	2.90	1.90	.92
1250	4.53	2.97	1.43
1500	6.53	4.28	2.07
1750	8.88	5.82	2.81
2000	11.60	7.60	3.67
2250	14.68	9.62	4.65
2500	18.13	11.88	5.74
2750		14.37	6.94
3000		17.10	8.26

Figure 5. The suction strainer also creates pressure loss. These values are general values — the friction losses in specific strainers may vary from this data.

If we expect to draft 1000 gpm in our example, the maximum friction loss in the suction hose and strainer cannot exceed 1.84 psi. So, to see if 1000 gpm is possible, we must determine the friction loss in 20 feet of 6” suction hose and a 6” strainer at 1000 gpm. If these losses total 1.84 psi or less, 1000 gpm can be delivered. If the total losses exceed 1.84 psi, 1000 gpm cannot be delivered.

In the example given, if we’re using a 1000-gpm pumper and drafting through 20 feet of 6" suction hose and a 6" strainer, the total friction loss at 1000 gpm would equal .6 psi (20 feet of hose) + .92 psi (6” strainer loss), or 1.52 psi.

Since the friction loss of 1.52 psi is less than the MUP of 1.84 psi, 1000 gpm can be delivered under the circumstances identified in the example.

The Next Question

The next question is, what affect would reducing the diameter of the suction hose and strainer to 5” have on the delivery rate?

If we use 5" suction hose instead of 6", the friction loss at 1000 gpm would equal 1.3 psi (20 ft of 5” suction) + 1.9 psi (5” strainer) or 3.2 psi, which is much greater than the MUP of 1.84 psi. As a result, our pump can’t deliver 1000 gpm with the 5" suction hose.

Why It’s Important

Why is it important to know the MUP and perform this type of drafting evaluation? Because it can quickly show how effective a given drafting operation can be (gpm output) or how it can be maximized.

I had a department purchase a 1000-gpm pumper with 5” suction instead of 6” because: 1) NFPA 1901 required either 5” or 6” suction, and 2) 5” is smaller and lighter than 6”. The department never considered that the 5” suctions would impede the pumper’s drafting capability.

Now, think about this:

How much water could we deliver in our previous example if the 1000-gpm pumper used dual 5" suction lines?

The answer appears on the following slide.

The Answer

The answer is 1500 gpm.

If we figure that 750 gpm travels through each suction line, the strainer loss equals 1.07 psi and the loss in 20 ft of 5" suction at 750 gpm equals 0.72 psi for a total of 1.79, which is less than the 1.84 psi available.

Naturally, the actual amount that you could draft is also a function of the pump’s ability, but this example shows the benefit of dual suctions—there will always be some gain by using dual suctions.

Conclusion

Most rural departments could probably get more water from their pumps under draft conditions if they understood how to use this procedure to evaluate drafting operations.

In the next installment, we'll talk more about maximizing drafting operations.

For Questions or comments on this or any of the Rural Fire Command articles, contact the author at ldavis@RFI411.org

About the Author

Larry Davis is a full member of the Society of Fire Protection Engineers, a Certified Fire Protection Specialist, and a Certified Fire Service Instructor II with more than 30 years experience as a fire service instructor. He is Vice President of GBW Associates, and Chairman of the Rural Firefighting Institute.

Davis has conducted more than 400 Rural Firefighting Tactics and Rural Water Supply Operations seminars throughout the United States and Canada. In addition, he has written numerous fire service texts, including *Rural Firefighting Operations*, books I, II, and III. Most recently, Davis co-wrote the *Rural Firefighting Handbook* and *Foam Firefighting Operations*, book I with Dominic Colletti.

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To obtain any or all of the other PowerPoint versions of the Rural Fire Command column, contact Larry Davis at:

rfofire@stx.rr.com
or
Phone: 361.739.3414

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Info@RFI411.org
or
RFI
13017 Wisteria Drive, #309
Germantown, MD 20874-2607
Phone: 800.251.4188