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**Rural Fire Command**

by

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# Bigger is Better

*When purchasing a pump, don't be afraid to go big!*

RFI
RURAL FIREFIGHTING INSTITUTE

*Training America's Rural Fire & Emergency Responders*

# 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.

# Bigger is Better

## *When purchasing a pump, don't be afraid to go big*

The workhorse of the fire service—whether in urban or rural operations—is the fire apparatus pump. Whether installed on pumpers, tankers, aerials or other apparatus, we rely on it to move water where we need it.

With all the available Fire Act grant money, many rural departments now have the funding to purchase new or used pumpers. But how do you choose which capacity pump to purchase? The answer is simple: *Get the biggest pump you possibly can based on the engine's horsepower.*

Figure 1. The stream from the 1-1/2” tip on the left supplied by the 40-year-old 500-gpm pumper is much better than the stream from the 1-1/2” tip on the right, which is supplied by the new 1500-gpm pumper.

# Big Pumps in Small Towns

Looking back through fire service history, we see that, as a general rule, the big cities had custom pumpers with big (1000- to 1500-gpm) pumps and rural departments had commercial-chassis pumpers with 500- or 750-gpm pumps. Although there was never any real rationale behind this fact, the underlying idea was that since rural departments didn't have much water, they didn't need big pumps.

In recent years, things have changed; we see more and more rural departments opting for pumps larger than those used by most city departments. Of course, to some people, this just doesn't make sense. I just read a column in another fire service publication written by an apparatus "expert" who pointed out that rural departments are foolish to buy any pump larger than 1000 gpm. He pointed out that New York City buys nothing but 1000-gpm pumpers and that if these pumps are good enough for FDNY, they should be good enough for rural departments — especially since rural departments don't have that much water to begin with.

From my perspective, we have historically done things bass ackward. Rural departments need the biggest pumps, and the cities need the smallest pumps. Why? Because although they may not have as many water sources as the cities, rural departments must pump the water they do have over a greater distances. Our city brothers and sisters have hydrants at 300-500 ft intervals and really don't need big pumps as much as they need lots of discharges from their pumps — the result is that they often buy larger pumps to get the extra discharges they need so any pumper close to the fire can supply the multiple lines they need.

***Rural departments need the biggest pumps. Why? Because although they may not have as many water sources as the cities, rural departments must pump the water they do have over greater distances.***

# Buying the Ability to Move Water

When a fire department purchases a pump and hose, it's purchasing a lot more than just fire equipment—it's purchasing the ability to transport gpm. Figure 1 shows two pumpers drafting from a lake under the same set of circumstances: Each is discharging through 1000 feet of hose to identical portable monitors located on the opposite side of the lake. As you can see from the photo, the stream on the left supplied by the 500-gpm pumper is much better than the stream on the right, which is supplied by the 1500-gpm pumper. The 500-gpm pump had a pump discharge pressure of 100 psi while the 1500-gpm pumper was discharging at 250 psi. Why the difference in streams? Because the 500-gpm pumper was pumping through a 5" line, and the 1500-gpm pumper was discharging through a single 2-1/2" line.

So, based on this example, can a brand-new, custom-built 1500-gpm pump "out-pump" a 40-year-old, 500-gpm pump? In this case, no. The reason: The 1500-gpm pump expends most of its energy overcoming the friction loss created by the single 2-1/2" hoseline, while the 500-gpm pump uses its energy to push gpm through the 5" hose.

Although I’ve never been employed as a sales rep for a hose company, this demonstration has done more across North America to show the value of LDH than all of the sales literature printed. To make it even more dramatic, I’ve even broken the 2-1/2" line at the 500' point and set up another 1500-gpm pumper in relay with the first. And with both 1500s operating at 250-psi discharge pressure, the 500-gpm pump still out-performs them.

During the demonstration conducted in Elizabethville, Pennsylvania, which is shown in Figure 1, one of the older members of the department, who was walking around taking it all in, came over to me and said, “Ya know, I don’t think we needed to buy the 1500-gpm pumper. I think all we needed to buy was the 5" hose.”

***When a fire department purchases a pump & hose, it's purchasing a lot more than just fire equipment — it's purchasing the ability to transport gpm.***

# Class A and B Pumps

A fire pump is a machine that, like any machine, has certain limits to its capabilities. All the fire pumps manufactured today are Class A pumps, but at one time, two classes of pumps were available — Class A and Class B. While manufacturers no longer make Class B pumps, many of them are still in service.

Class A pumps must deliver the following capacities at the specified net pump discharge pressures:

100% of rated capacity at 150 psi;
70% of rated capacity at 200 psi; and
50% of rated capacity at 250 psi.

In contrast, Class B pumps must deliver the following capacities at the specified net pump discharge pressures:

100% of rated capacity at 120 psi;
50% of rated capacity at 200 psi; and
33-1/3% of rated capacity at 250 psi.

So what does all of this mean? These specifications define the minimum performance capabilities of a pump. As you can see, as the flow decreases, the net discharge pressure increases, and vice versa. While only three performance points are specified for each pump, they perform over a broad range of flows and pressures. For instance, if a pump only delivers 10% of its rated capacity, the pressure will be more than 250 psi. By the same token, if the pump supplies 150% of its rated capacity (either with dual suctions from draft or with a strong hydrant supply), the pressure will be less than the rated pressure at 100% capacity.

# Work, Energy, & Power

To better understand the potential of a pump, we must define some basic terms. Work is the result of a force causing a mass to move some distance. If a firefighter pushes, pulls or lifts an object from one place to another, they've performed some amount of work. However, if they try to move an object and it doesn't move, they haven't performed any work. You accomplish work only when the object you apply force to moves. By the same token, a pump does work when it forces 1 gallon (8.34 lb) of water 1 foot.

*Work* is a measure of what is accomplished, not of the effort expended, and for our purposes, it's expressed in terms of foot-pounds (ft-lb). You can calculate work by using the following formula:

Work (ft-lb) = distance (ft) x force (lb)

*Energy* is defined as the capacity to do work. Power is defined as the rate of doing work expressed in terms of foot-pounds per minute (ft-lb/min) or foot-pounds per second (ft-lb/sec), and can be calculated using the following formulas:

Power (ft-lb/min) = work (ft-lb) ÷ time (min)

Power (ft-lb/sec) = work (ft-lb) ÷ time (sec)

A person walking, a car moving along a road, a crane lifting a load or water moving through a pipe or hoseline are all examples of actions that involve energy, work and power.

If a 175-lb firefighter carrying 25 lb of gear walks 100 feet, he has done 20,000 ft-lb (100 ft x 200 lb) of work, and has demonstrated his energy (capacity to do work). If, however, he attempts to carry 100 lb of fire hose a distance of 500 feet, and can't, he has demonstrated that he does not have the energy to do 150,000 ft-lb [500 ft x (175 lb + 25 lb + 100 lb)] of work. But, if our 175-lb firefighter carrying 25 lb of gear walks 100 ft in 1 min, he has demonstrated 20,000 ft-lb/min (20,000 ft-lb ÷ 1 min) of power.

# Horsepower

As shown in Figure 2, horsepower (hp) represents the rate of doing a given amount of work in a given amount of time as compared to that of a horse. James Watt, an Englishmen in the late 18th century, coined the term to compare the performance of his new invention — the steam engine — to that of a horse when powering a pump to remove water from a coal mine, and to prove that the power of the steam engine was superior to that of a horse.

Watt tested a number of horses and determined that a typical horse could lift 330 lb a distance of 100 feet in 1 minute and that 1 "horsepower" equaled 33,000 ft-lb/min (100 ft x 330 lb ÷ 1 min), or 550 ft-lb/sec (33,000 ft-lb/min ÷ 60 sec/min).

You can calculate horsepower using the following formula:

hp = power (ft-lb/min) ÷ 33,000 ft-lb/min

If a 175-lb firefighter carrying 25 lb of gear walks 100 feet in 1 minute, his rate of work in horsepower equals 20,000 ft-lb/min ÷ 33,000 ft-lb/min = 0.67 hp.

# Weight, Force, Work, and Horsepower

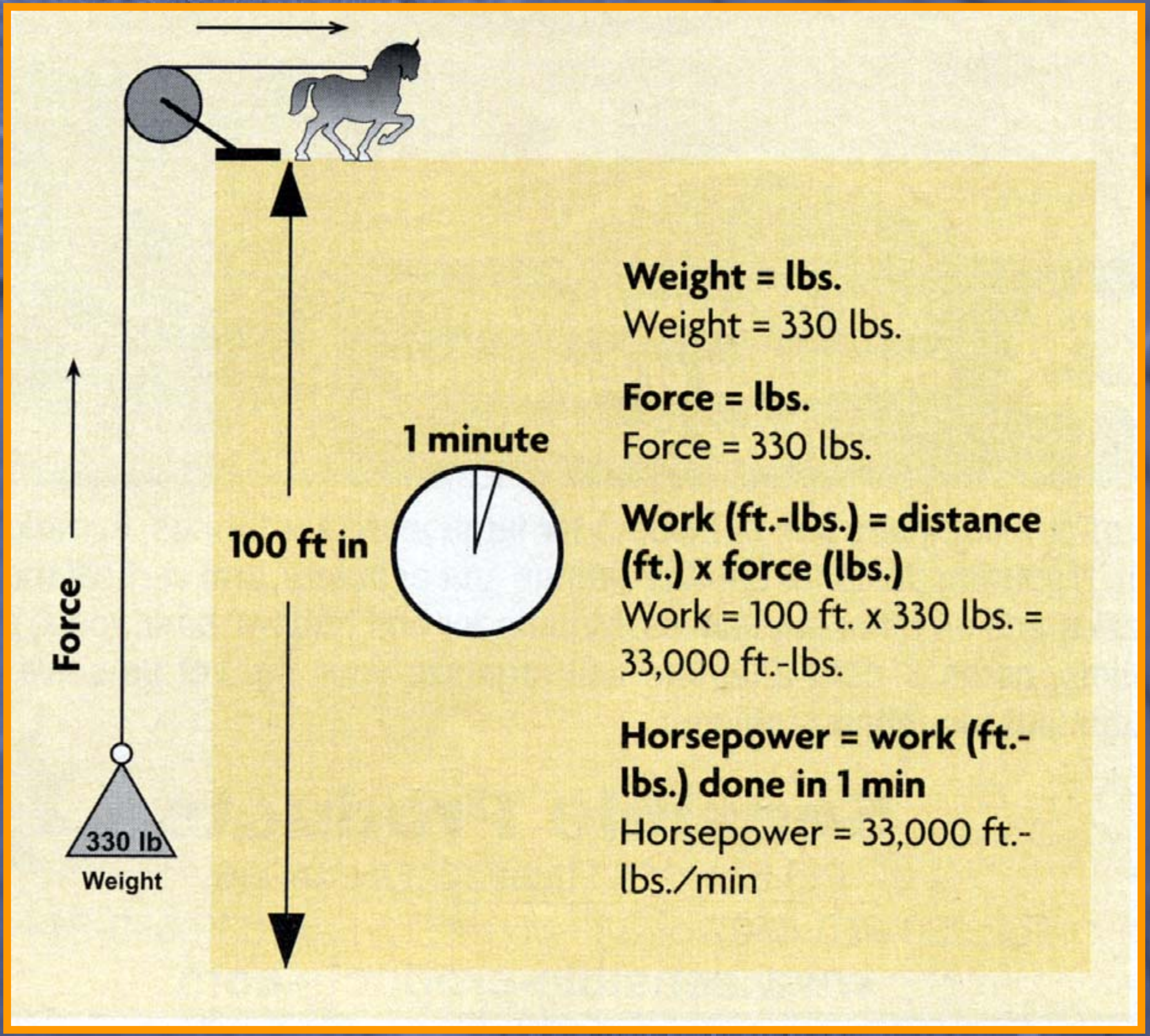


Figure 2.

# Water Horsepower

*Water horsepower (whp)* is one way of measuring the output of a pump. You can calculate the whp using the following formula:

$$whp = (gpm \times psi) \div 1714$$

By multiplying the gpm flow by the discharge pressure at that flow and then dividing the product by the constant of 1714, you can determine the whp a pump is delivering. Figure 3 shows the whp values for the three capacity ratings of fire apparatus pumps with ratings from 250 to 3000 gpm.

# Class A Pump Performance & Water Horsepower

| Rated Capacity (gpm @ 150 psi) | whp | 70 percent Capacity (gpm @ 200 psi) | whp | 50 percent Capacity (gpm @ 250 psi) | whp |
|---|---|---|---|---|---|
| 250 | 22 | 175 | 20 | 125 | 18 |
| 500 | 44 | 350 | 41 | 250 | 37 |
| 750 | 66 | 525 | 61 | 375 | 55 |
| 1,000 | 88 | 700 | 82 | 500 | 73 |
| 1,250 | 109 | 875 | 102 | 625 | 91 |
| 1,500 | 131 | 1,050 | 123 | 750 | 110 |
| 1,750 | 153 | 1,225 | 143 | 875 | 128 |
| 2,000 | 175 | 1,400 | 163 | 1,000 | 146 |
| 2,250 | 197 | 1,575 | 184 | 1,125 | 164 |
| 2,500 | 219 | 1,750 | 204 | 1,250 | 182 |
| 3,000 | 263 | 2,100 | 245 | 1,500 | 209 |

Figure 3.

# Brake Horsepower

*Brake horsepower (bhp)* is the power produced by an engine, and it is determined by dynamometer tests performed by the manufacturer. Bhp depends on the speed of the engine, which is measured in revolutions per minute (rpm), and the torque or the ability of the engine to produce a rotating force.

With regard to fire pumps, bhp is the term used to quantify the input hp required to drive a pump.

# Efficiency

*Efficiency* is a comparison of pump output (whp) to pump input (bhp) in terms of percent, and it is calculated using the following formula:

$$\text{Efficiency (\%)} = \text{whp} \div \text{bhp}$$

No machine is 100% efficient, and fire pumps are no different. The engine provides bhp to rotate the shaft that drives the pump, which delivers whp. Between the input and the output, there are losses due to the driveline and gear train. Thus, the output horsepower (whp) never equals the input horsepower (bhp).

The ratio of whp to bhp represents the efficiency of the pump, and it is measured in terms of percent. Today's (Class A ) apparatus fire pumps operate in various ranges of efficiency, depending on their particular design. Some pumps produce peak efficiency as low as 65% while others produce efficiency as high as 75%. The peak efficiency of a pump is only achieved around the 100% capacity point. As the pump delivers smaller capacities at higher pressures or larger capacities at lower pressures, efficiency drops below its peak. While the whp produced at the 50%-capacity point and the 70%-capacity point is less than the whp produced at the 100%-capacity point, the bhp required is actually greater.

# What Capacity Pump Should You Buy?

So with all of this said, what capacity pump should a rural department purchase? Should it base its decision on what it has always had, what neighboring departments have, what FDNY buys, the number of discharges it wants, the number of 2-1/2" nozzles it wants to carry, etc.? This question reminds me of the people who ask me what they should use for supply lines: 2-1/2", 3", 4", 5", 6" or multiple lines? The answer to both these questions: Buy what you need to move the gpm you need from the sources to the hazards in your community.

Obviously, if the department has an unlimited amount of money or grant money available, get a 3000-gpm pump and a 6" hose — when in doubt, get the biggest pump and the biggest hose. However, from a practical standpoint, the department should buy the biggest pump their engine can power. Figure 4 lists the various capacities of fire pumps that can be powered by engines of various horsepower ratings.

I recently worked with a department that decided to purchase a 2500-gal tanker equipped with a 1250-gpm pump. When I asked the firefighters there why they weren’t getting a bigger pump, they explained that they figured the 1250 was big enough. When I suggested they investigate a larger pump, they found their engine’s rating was high enough to drive a 2250-gpm pump. In essence, it cost about $1,000 more to go from the 1250 to the 2250 pump. And on a $300,000+ apparatus, that’s a small chunk of change for an additional 88 whp.

***When in doubt, get the biggest pump & the biggest hose.***

# Engine Horsepower and Pump Capacity

| Engine Rating (hp) | Pump that Can be Driven |
|---|---|
| 300 | 1,750 gpm |
| 360 | 2,000 gpm |
| 400 | 2,250 gpm |
| 430 | 2,500 gpm |
| 500 | 3,000 gpm |

*(Source: Hale Fire Pumps)*

Figure 4.

# Buy What You Need

Rural fire departments must purchase the pump they need to move the flow they need. They must also take into consideration the hose size they'll use to pump through. There is a very important relationship between pump capacity and hose size: *Pumps deliver whp; hose eats up whp.*

Figure 5 shows a chart I've developed as a part of *Rural Water Supply Command* — a book of water supply SOPs. The chart is intended to provide a ballpark idea of the maximum theoretical distances pumps discharging through given hoselines can pump 1000 gpm.

This chart is predicated on a pump delivering the same amount of whp at any flow and pressure. While this is not exactly true, for planning purposes, it can give us a relative idea of the maximum distances achievable.

The chart is based on a maximum discharge pressure of 250 psi and a residual pressure of 20 psi at the end of the hose lay. To use the chart, simply find capacity column for the pump being used and move down until you reach the row displaying the diameter of hose to be used. The number at the intersection is the maximum distance the given pump can deliver 1000 gpm with hose used. Notice that a 1250-gpm pump using 2-1/2" hose can move 1000 gpm a distance of 50 feet while a 750-gpm pump with 5" can deliver it 1150 feet.

# Maximum Pumping Distances — 1000-gpm Delivery Rate

| | Rated Fire Pump Capacity at 150 psi | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hose Size | 500 | 750 | 1,000 | 1,250 | 1,500 | 1,750 | 2,000 | 2,250 | 2,500 | 3,000 |
| 2 ½" | — — | — — | 150 | 50 | 100 | 100 | 100 | 100 | 100 | 100 |
| 3" x 2 ½" | 50 | 100 | 250 | 200 | 250 | 250 | 250 | 250 | 250 | 250 |
| Two 2 ½" | 100 | 150 | 350 | 300 | 400 | 400 | 400 | 400 | 400 | 400 |
| 3 ½" | 150 | 250 | 400 | 450 | 600 | 600 | 600 | 600 | 600 | 600 |
| 2 ½" & 3" | 150 | 300 | 650 | 550 | 650 | 650 | 650 | 650 | 650 | 650 |
| Two 3" | 250 | 450 | 650 | 800 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| 4" | 250 | 450 | | 800 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| Two 3 ½" | 600 | 1,000 | 1,400 | 1,850 | 2,250 | 2,250 | 2,250 | 2,250 | 2,250 | 2,250 |
| 5" | 650 | 1,150 | 1,600 | 2,050 | 2,550 | 2,550 | 2,550 | 2,550 | 2,550 | 2,550 |
| Two 4" | 1,100 | 1,850 | 2,600 | 3,350 | 4,100 | 4,100 | 4,100 | 4,100 | 4,100 | 4,100 |
| 6" | 1,100 | 1,850 | 2,600 | 3,350 | 4,100 | 4,100 | 4,100 | 4,100 | 4,100 | 4,100 |
| Two 5" | 2,750 | 4,600 | 6,500 | 8,350 | 10,250 | 10,250 | 10,250 | 10,250 | 10,250 | 10,250 |
| Two 6" | 5,500 | 9,250 | 13,000 | 16,750 | 20,500 | 20,500 | 20,500 | 20,500 | 20,500 | 20,500 |

Figure 5.

# Homework

Next month, we'll talk more about apparatus pumps. For now, determine the maximum distance each pumper in your department can deliver 1000 gpm with the hose it carries. Once you've determined the distance for each pumper, add them up to see the total distance your department can move 1000 gpm with a relay using all pumpers.

Until then, stay safe.

**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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