Quantities, or amounts, of water are measured in a variety of ways depending on whether we are measuring its weigh (expressed in pounds, lbs) or its amount, which is known as *volume* (gallons, g).

For example, the weight of water in pounds is:

1 gallon (g) of water weighs 8.33 pounds (lbs)

Each pound of water occupies a certain amount of space. To describe how water can occupy space, we use the term *cubic foot*. A cubic foot is the area enclosed within a cube that is 12 inches tall, 12 inches wide, and 12 inches deep. So, 12" x 12" x 12" means that we are describing a cubic foot ($ft^3$).

1 Cubic Foot of water = 62.4 pounds[2]

1 Cubic Foot of water = 7.48 gallons

1 Cubic Foot of water = 62.4 lbs/ft$^3$ ÷ 7.48 gal/ft$^3$ = 8.34 lbs per gallon[2]

Another useful term relating to water (and other substances as well) is *density*. Density refers to the ratio of a substance's weight to its volume. This term is expressed as "pounds per gallon."

Figure 3-1 illustrates one cubic foot of water. This figure also shows that each cubic foot is made up of 144 1-inch columns of water. The area of one "face" of this cube is measured as 12" x 12" to give 144 square inches ($in^2$) of surface area for each of the cube's "faces." Additional details about this figure will be discussed in the next section.



Figure 3-1.
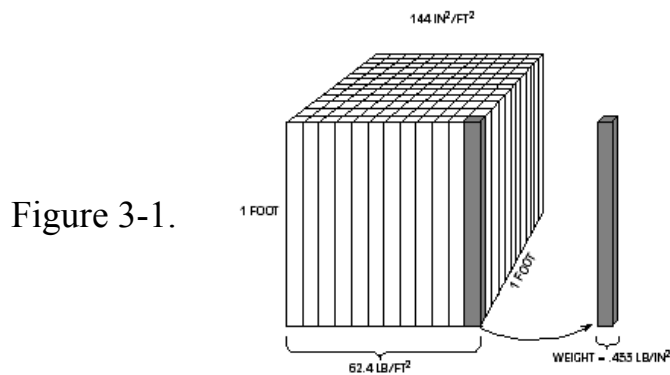
The separated column illustrates one square inch column of water 12 inches tall. This results in a pressure of 0.434 pounds per square inch (psi). For fire pump operations, pressure is described in pounds per square inch, "psi."

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[2]http://ga.water.usgs.gov/edu/waterproperties.html; accessed 2-13-07.

## Lesson 2 – Pressure and Fire Pumps

Pressure is generally defined as the force exerted by a material on its surroundings.  Pressure is expressed as weight per unit area.

There are six principles of pressure.  They are:

1. In an open vessel (a portable tank, for example) fluid pressure is exerted at right angles to all surfaces it touches.  This is due to the weight of the water.

2. For pressurized water at rest in a hose line, pressure is the same in all directions.  This principle is shown in Figure 3-2 below.  The arrows represent the lines of *force* exerted by the water pressure.  Putting a pressure gauge at any of the arrowheads in Figure 3-2 would give the same pressure reading.

**Figure 3-2.**
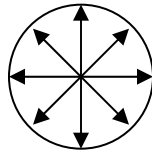


**Charged Hose**

3. Pressure is transmitted equally in all directions when an external force is applied to a confined fluid.

4. Water pressure in an open vessel is proportional to its depth. For example, two booster tanks of different capacities will exert the same pressure if the depths are the same.

A cubic foot of water (1' × 1' × 1') with a surface contact area of 1 square foot weighs 62.4 lbs., exerts a pressure of 0.434 lbs./square inch (See Figure 3-1).

5. Pressure of a liquid in an open container is directly related to the density of the liquid.  For example, water exerts a pressure of 0.434 psi whereas gasoline exerts a pressure of 0.304 psi.

6. Regardless of the shape of the vessel, the pressure of a liquid on the bottom does not change.  This means that pressure at the bottom of an elevated water tank is the same for a different shaped tank as long as the height of the water is the same.

## Apply Your Knowledge

If a second 12-inch tall column of water is placed on top of the first (as in Figure 3-1), the total weight is exerting a pressure of 0.868 psi. Doubling the depth doubles the pressure.

## Water Hammer – Caution (!)

For example, when one or more hose lines is/are shut down while operating multiple hose lines, the pressure and flow from that line may be distributed to the pump and/or other lines still in operation. This is why it is important to open and close all valves slowly. Rapid changes in pressure can be reduced by using pressure control devices.

When a nozzle or other valve is closed too quickly, the rapid stopping of the water flow can result in a *Water Hammer*. A water hammer is the pressure that results from this shut-down and moves in the opposite direction of the original water flow. The pressure that develops from a water hammer can often be much greater than the pressure at which the shut-down line was operating.

## Practical Tip (!)

It is important to remember pressure is universal within an appliance (eg, gated wye). When using wyed lines with 2 identical hose lines and nozzles, the pressure used when calculating the pump discharge pressure only needs to be provided for one hose line. If two different size lines and/or nozzles are used, the driver/operator must set the higher pressure and the second line must be gated-down at the wye.

**Lesson 3 – Math Skills Review**

**Instructor Note:  for review prior to next class - use as needed.**

This pump operator's course is designed to teach the student the necessary skills to properly and successfully deliver the required amount of water to the hose team regardless of conditions or available apparatus.

An important part of the pump operator's knowledge comes from being able to calculate the amount of water needed (number of gallons), the rate (gpm) at which it must be delivered, the pressure required for this delivery, and any effects the needed devices (such as gates, wyes, or master stream devices) have on water delivery.

In order to perform the necessary calculations, certain basic math skills are needed.  This lesson is designed to refresh these basic skills so that the calculations needed for proper water delivery can be routinely done.

# What you need to know…

Along with addition and subtraction, the necessary math skills include the following:

> - multiplication
> - division
> - square
> - square root
> - substitution

Let's review each of these operations in turn.

Multiplication:  this operation takes two numbers and multiplies one by the other.  We often say "2 times 5," for example, which means to add 2, five times, or $2 + 2 + 2 + 2 + 2 = 10$. This is the same as $2 \times 5 = 10$.

Commonly used multiplication symbols are the "x" or having one number next to another number that is in parentheses, such as 2 x 3 or 2(3).  Both of these examples mean "2 times 3."

Division:  this operation takes one number and seeks to find how many times that number "goes into" a second number.  We often say "10 divided by 5," for example, which means "how many times can the number 5 go into the number 10?"  This is the same as asking how many 5s is 10 made up of; or $10 \div 5 = 2$.

Commonly used symbols for division are the divide sign "÷" or writing one number directly above another number, with a line between them; these mean "divided by," such as $10 ÷ 5$, or $\underline{10}$.
$$5$$

Square; This operation takes a number and "multiplies it by itself." We say, "3 squared" and write it like this: $3^2$, with the raised (superscript) "2" used to mean "squared."

For example, $5^2$ is the same as "5 squared," which is 5 x 5, or 25.

Square Root; This operation takes a number and seeks to find "what number multiplied by itself" will give that starting number. If one asks to find the square root of 16, that means to find the number that, when multiplied by itself, equals 16. So, the square root of 16 is 4, because 4 x 4 = 16. Often, the square root of a number is not a whole number. This means that the number has a remainder, or a "left over" portion that is noted as a fraction of the number.

For example, the square root of 25 is 5 (5 x 5 = 25), but, the square root of 20 is 4.4721, because 4.4721 x 4.4721 = 20.

The symbol for Square Root looks like this: $\sqrt{}$

Substitution; This is not a mathematical operation, but rather, it is a way to simplify working with many numbers, or with numbers that are used repeatedly. Letters are used in formulas and specific numbers are then "plugged in" to these letters, replacing the letters with the numbers needed in order to figure out the formula.

An example of substitution would be: 5 x A + 2, where A would be substituted by a number taken from a table of numbers provided. If the number needed for the "A" is 4, then the formula would be: 5 x 4 + 2, which turns out to be 20 + 2, or 22.

By reviewing these basic skills you will be able to use all of the formulas in this workbook. These skills will now be applied to the pump operator's formulas in the next lesson in this chapter.

## Lesson 4 – Determining Fire Flow

Fire Flow can be thought of as the amount of water needed to extinguish a given amount of fire. In today's firefighting operations, buildings contain many types of plastic or synthetic furnishings that burn at much higher temperatures and give off more British Thermal Units (BTUs) than ordinary wood or natural materials. Because of the change in how clothing and furniture are made, hotter fires are now the rule. These hotter fires, which give off more BTUs, need more water for safe and rapid extinguishment. By using the Fire Flow formula (below), an estimate of the quantity of water needed for a particular fire can be derived. Keep in mind that this is only an estimate and that should conditions change, the incident commander must consider the potential for needing more or less water than originally estimated.

## Calculation of Required Fire Flow

NFA Fire Flow Formula → (L x W) ÷ 3 = gpm required per floor

This represents the fire flow for a knockdown within five minutes. In large buildings, where total involvement is unlikely, base flow is calculated based on the largest compartment. In groups of buildings, the fire flow is calculated for each building and the highest rate used.

Further, the required gpm per floor represents the flow for 100% involvement of one floor. Flow is reduced by percentages for less involvement. Each exposure will require 25% of the base fire flow.

**Note:** This formula requires knowing (or estimating) the length and width of the structure containing the fire to be extinguished. Then, by using the formula an estimate of the minimum amount of water required to extinguish the fire can be obtained. This value is in gallons per minute, *not* the total number of gallons needed to extinguish the fire. More detailed information about water supply calculations are addressed in the Water Supply Operations course.

NOTES

**Example**: Calculate the Fire Flow for a single-family, 1-story dwelling that is 30' wide x 60' long.

> Fire flow = $\dfrac{(L \times W)}{3}$
>
> 30' x 60' = 1,800'
>
> 1,800 ÷ 3 = 600 gpm → the required fire flow

**Important Note**: It is critical to understand that in order to safely and properly extinguish a given fire, a minimum number of gallons per minute is to be delivered. The target flow rates, in gallons per minute, for a room and contents dwelling fire should be between 150 gpm and 200 gpm. For larger fires, increased flows are required, as per the NFA Fire Flow Formula.

> *INSTRUCTOR'S NOTE:* You may choose to use the calculation worksheets provided or develop one of your own. It is recommended to work through the problems with the class systematically by using a dry erase board, chalkboard, or overhead projector.

Flow rate ranges for commonly used hand lines are provided in the table below.

| Hose Diameter (inches) | Flow Rate Range (gpm) |
|:---:|:---:|
| 1.5 | 125 to 175 |
| 1.75 | 150 to 200 |
| 2 | 175 to 250 |
| 2.5 | 250 to 350 |

**Note:** See NFPA 1961 and NFPA 1962 for details on construction of and the working and test pressures of fire hose.

In addition to the table of gpm values above, the flow rate for a given hose line can be calculated by using the following GPM Formula:

## GPM Formula

$$GPM = 29.7(d^2) \times \sqrt{p}$$

where, d is the diameter of the nozzle opening, and p is the nozzle pressure.

The following section will discuss the formulas needed for delivering proper fire flow.  It is important to remember that all of the calculations are done in order to find the Pump Discharge Pressure (PDP).  This is the pressure that the fire pump must deliver to properly supply each line and/or appliance needed for a given evolution.  To find the pump discharge pressure, follow the sequence below when working through the formulas.

What is **Friction**?

> Friction can be thought of as the resistance to motion when two objects or materials contact each other.

In hydraulics, Friction Loss (FL) is the resistance created when water moves through a hose or other conduit.  FL is expressed in pounds per square inch (psi), and is usually calculated in 100-foot increments.

In 1899 John C. Freeman developed a formula for calculating friction loss in 2-1/2" leather fire hose. The Freeman Formula for friction loss is:

$FL = 2(Q)^2 + Q$, where Q = gpm flowing divided by 100

Due to the evolution of fire hose construction, a newer formula has been derived to account for better hose construction/material, resulting in lower friction losses overall.  The Freeman formula only applies to 2 ½" hose, whereas the IFSTA formula, below, applies to all diameters of hose.

**The IFSTA Friction Loss Formula**

> $FL = C\,(Q)^2\,L$
>
> where C is a coefficient related to each hose diameter; Q is gpm divided by 100; and L is the length of hose divided by 100.

## Principles of friction loss

1. Friction loss varies directly with the length of hose, if all other variables are constant.

When the hose length doubles, the friction loss doubles, for the same hose being considered.

FL = 144          2,000 ft, 3″

1,000 ft, 3″

FL = 72

FL = 36          500 ft, 3″
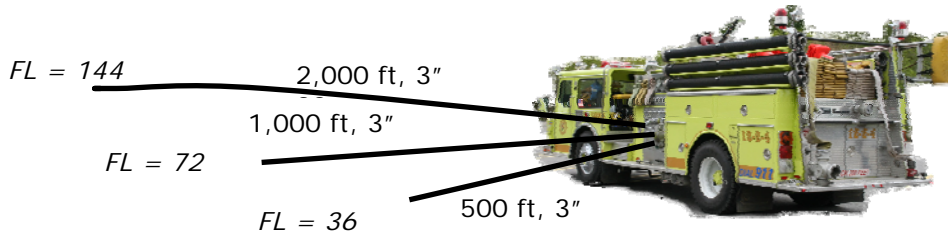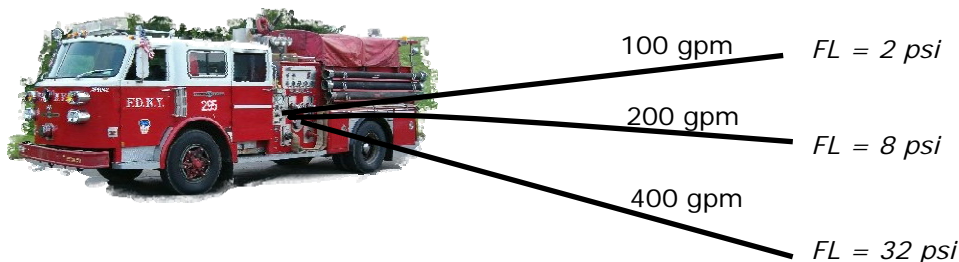
### Note: Each line is flowing 300 gpm

Apply Your Knowledge

500 ft of 3-inch hose flowing 300 gpm has a FL of 36 psi; 1,000 ft of 3-inch hose will have a FL of 72 psi

2. Friction Loss varies approximately with the square of the flow rate—this means that…

…the rate of increase of **FL** is much greater than the rate of increase in flow, because…

…when the flow doubles (× 2), the friction increases by a factor of 4.

100 gpm          FL = 2 psi

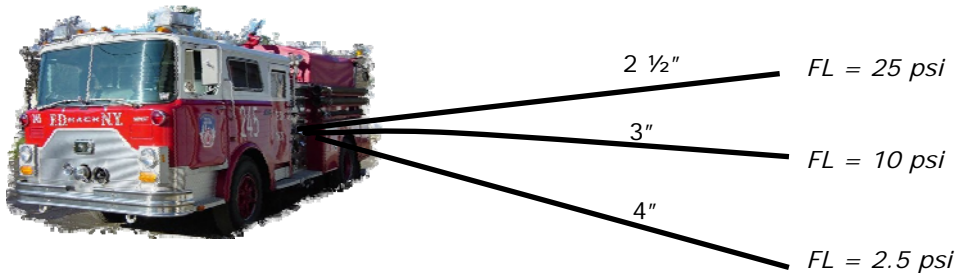200 gpm          FL = 8 psi

400 gpm          FL = 32 psi

### Note: Each line is 100 ft of 2 ½″ hose

3. When the flow rate remains constant, FL varies *inversely* with hose diameter.  This means that…

   …FL will *decrease* (↓) when the hose diameter *increases* (↑).

2 ½"                    *FL = 25 psi*

3"                      *FL = 10 psi*

4"                      *FL = 2.5 psi*

**Note: Each line is flowing 250 gpm through 200 ft of hose**

4.  For any given water velocity (speed), the FL will be about the same regardless of the pressure.  This means that…

   …FL will not change very much when pressures are increased or decreased as long as the flow rate stays the same.  And, for practical purposes, one needs to have water move faster through smaller hoses, compared with larger hoses, for the same amount of water to be delivered.

**Factors that affect Friction Loss**

- Hose size and length
- Bends and kinks in a hose
- Type of hose lining
- The presence of couplings or adapters
- Water flow (includes the pressure, velocity, and volume of water)

## Friction Loss Applications and Formula

*Friction Loss* (FL) is the loss of pressure created by the turbulence of a liquid moving through a hose or pipe. In addition to hose, appliances such as a gated wye or a clappered Siamese will also have a friction loss value.

Note: In this course, the term "appliance" refers to wyes, siameses, adapters, and portable hydrants, etc. and the friction loss must be accounted for with flows above 350 gpm.

To determine the Friction Loss (FL) in hose, use the following formula:

$$FL = CQ^2L$$

where, C = coefficient from chart (see Appendix), and
Q = gpm supplied ÷ 100, and
L = length ÷ 100

**Note:** this formula has each letter written next to each other. This is another way of indicating that these substituted numbers are to be multiplied by one another. This is the same as C x $Q^2$ x L.

**Example: Find the FL in 500 feet of 2 ½" hose flowing 250 gpm with a handheld smooth bore tip nozzle.**

$FL = CQ^2L$

Step 1) Look up the value of "C" in the Table in Appendix I. In this example, C = 2 for 2 ½" hose.

Step 2) Substitute the letters with the numbers given in the starting problem. This gives…
Q = 250 gpm ÷ 100
L = 500 feet ÷ 100

Step 3) Complete the formula with the information above:

$$FL = (2) \times (250 \div 100)^2 \times (500 \div 100)$$

$$FL = (2) \times (2.5)^2 \times (5)$$

$$FL = (2) \times (2.5 \times 2.5) \times (5)$$
$$FL = (2) \times (6.25) \times (5)$$
$$FL = 12.5 \times (5)$$
$$FL = 62.5 \text{ psi}$$

This answer, 62.5 psi, is the amount of pressure that must be overcome in order to get water to the nozzle in this example.

**Practical Tip (!)**

Remember that friction loss is a *resistance* to water flow and actually must be accounted for when pumping through any fire hose or appliance.

**Pump Discharge Pressure**

Pump Discharge Pressure (PDP) is the *highest* pressure that a fire pump is set (by the operator) to deliver to an output gate.

Operating nozzle pressures for commonly used nozzles are shown in the table below.

| Nozzle Type | Operating Pressure (psi) |
|---|---|
| Smooth-bore, hand-held | 50 |
| Low-pressure | 50 or 75 |
| Smooth-bore, master stream | 80 |
| Combination and Automatic | 100 |

The PDP that the operator sets at the pump control panel is actually the sum of the pressure caused by the friction loss in the hose + the nozzle pressure + any appliance friction loss on the line being operated, + or – any elevation of the nozzle *relative to the pump*. This can be written as a formula as shown:

**PDP = FL + NP + AFL ± EL**

**Example:** Find the PDP needed to supply 500 feet of 2 ½ ″ hose flowing 250 gallons per minute through a hand-held smooth-bore nozzle.

Pump Discharge Pressure (PDP) = **FL** + NP + AFL + EL

---

**NOTE:** To find the PDP you must *first* calculate the **FL** for the hose line in operation because the value for FL is part of the PDP formula.

---

Step 1) Find the friction loss using the formula: $\mathbf{FL} = CQ^2L$

$$\mathbf{FL} = 2 \times (250 \div 100)^2 \times (500 \div 100)$$

Step 2) Substitute the **FL** answer above (62.5 psi)

Step 3) Next, substitute the **NP** value that you look up in the table in the Appendix.

Step 4) Substitute the **AFL** value, if any. See the following and the Appendix:

**AFL** = Appliance Friction Loss

Appliance flowing < 350 gpm = 0 psi FL
Appliance flowing ≥ 350 gpm = 10 psi FL

Master stream devices provide 25 psi of FL, when flowing at 350 gpm or more.

Step 5) Substitute the **EL** value, if any, determined by adding or subtracting 5 psi per floor above the first floor, or 5 psi for every ten feet of elevation.

Remember that:

NP   = Nozzle Pressure
AFL = Appliance Friction Loss [**no** appliance used in this problem]
EL   = Elevation [**no** elevation above (+) or below (-) the level of the pump
      is specified in this problem]

So: **PDP** = 62.5 + 50 + 0 + 0

**PDP** = 112.5, which is rounded up to 115 psi

## Suction Hose Friction Loss

Overall, the same rules of hydraulics used for supply lines also apply to suction hose. This means that friction loss in suction hose is calculated by using the friction loss formula: $FL = CQ^2L$, with the coefficients from the table at the end of this Unit and in the Appendix.

**Example:** Find the FL when drafting 1,000 gpm through 20 feet of 6-inch suction hose with an elevation of 10 feet.

$$FL = CQ^2L$$

$$FL = (0.05) \times (1,000 \text{ gpm} \div 100)^2 \times (20 \text{ ft} \div 100)$$

$$FL = 0.05 \times 10^2 \times 0.2$$

$$FL = 0.05 \times 100 \times 0.2$$

$$FL = 0.05 \times 20$$

$$FL = 1 \text{ psi}$$

So, 20 feet of 6" suction hose has a friction loss of only 1 psi – a very small amount.

## Nozzle Reaction (NR)

1.  One of Newton's laws of motion states that, "For every reaction there is an equal and opposite reaction." This is the principle behind nozzle reaction.

2.  This is the cause of the movement of the nozzle or hose line away from the direction of the stream.

3.  Nozzle reaction is proportional to the pressure being discharged and the nozzle flow rate in gpm.

4.  NR is a force that is measured in pounds.

## Nozzle Reaction Formula Examples

### A) Smooth Bore Nozzle Reaction

$NR = 1.57 \times d^2 \times NP$

Where: 1.57 is the "constant" for smooth bore nozzles, and
d = the diameter of orifice (nozzle opening), in inches, and
P is the operating **nozzle pressure** at the tip, in psi.

**Example:  What is the nozzle reaction from a 1-inch smooth bore nozzle?**

$NR = 1.57 \times d^2 \times NP$
$NR = 1.57 \times 1^2 \times 50psi$   [Remember: $1^2 = 1 \times 1$]
$NR = 1.57 \times 50psi$
$NR = 78.5$ pounds

### B) Fog Nozzle Reaction

Note:  Fog nozzles may be known by other names, including Task Force Tip (TFT), Combination, or Automatic nozzles.

For Fog Nozzles, the Nozzle Reaction (NR) is calculated as follows:

$NR = 0.0505 \times gpm \times \sqrt{NP}$

Where, 0.0505 is the constant for fog nozzles, and
gpm = flow in gallons per minute, and
NP = Nozzle pressure in psi, however, in this formula you must find the square root ($\sqrt{}$) of the NP (see Lesson 3, above).

**Example**: **What is the NR for a fog nozzle flowing 250 gpm?**

$$NR = 0.0505 \text{ x gpm} \times \sqrt{NP}$$

$$NR = 0.0505 \text{ x } 250 \times \sqrt{100} \text{ psi}$$

$$NR = 0.0505 \text{ x } 250 \times 10 \text{psi}$$

$$NR = 0.0505 \text{ x } 2500 \text{psi}$$

$$NR = 125.25 \text{ pounds}$$

## Practical Tip (!)

A "General Rule " for finding the nozzle reaction (NR) is to divide the gpm in half, as shown below.

## Apply Your Knowledge

What is the nozzle reaction from a nozzle flowing 200gpm

According to our "General Rule ," NR = GPM ÷ 2, so…

NR for a flow 200gpm = 200gpm ÷ 2

NR = 100 pounds of force

## Fire Pump Capacity Ratings

The NFPA 1901 *The Standard For Automotive Fire Apparatus* specifies the criteria for fire pump performance.   Fire pumps are tested to perform under a lift (draft) condition.  Each apparatus must be capable of producing specified flow rates to meet NFPA requirements. Pumpers are rated at draft with a lift not more than 10 feet for a 1500gpm pump or smaller, or 8 feet for pumps rated at or greater than 1750gpm using 20 feet (2 lengths) of appropriate size suction hose and strainer. The following tests are made:

- 100% of the pump capacity at 150 psi net pump pressure
- 70% of the pump capacity at 200 psi net pump pressure
- 50% of the pump capacity at 250 psi net pump pressure
- 100% of the pump capacity at 165 psi net pump pressure

During the acceptance test the pump is tested for 2 hours at 100% capacity, 30 minutes each at 70 % and 50% capacity.  The pump is also tested at 100% capacity at 165 psi for 10 minutes.

The above test criteria are the same regardless of pump size. For example a 1000 gpm Type 1 pumper must be able to achieve a minimum flow of:

- 1000 gpm (100%) at 150 psi net pump pressure.
- 700 gpm (70%) at 200 psi net pump pressure
- 500 gpm (50%) at 250 psi net pump pressure

The term Net Pump Pressure includes the pressure on the intake side of the pump as well as the discharge side.  For example, if we have 10 psi of lift on the intake side and can produce 140 psi on the discharge during a capacity test, we have met the 150 psi net pump pressure.

## Practical Tip !

As the lift exceeds 10 feet and/or the pressure increases above 150psi, the gallons per minute capacity deceases.

## Summary

This chapter has presented the principles of hydraulics and the formulas needed for determining proper fire pump operation for safe and effective firefighting.  By understanding the basic properties of water and the principles of pressure and flow rates, driver/operators can accurately provide fire crews with the amount of water needed for fire suppression.   The driver/operator needs to understand that delivering too little water will not effectively extinguish a fire and can possibly injure the crews.  Knowing the types and lengths of hose, the nozzles and appliances used, and the minimum amount of water needed to fight a fire are critical parts of each driver/operator's responsibility on the fire scene.

## Glossary

**Atmospheric Pressure –** The force exerted by the atmosphere surrounding the earth; the atmosphere has weight and exerts pressure. The pressure at sea level is 14.7 psi. As you go higher in the atmosphere, it weights less and exerts less pressure.

**Absolute Pressure –** The pressure measured in a gauge that includes atmospheric pressure. Absolute pressure is normally used with pressure vessels and its value is marked in units of **psia** (pounds per square inch, atmosphere). Similar to Gauge Pressure, the 164.7 psig is actually 164.7 psia.

**Friction Loss (FL)** – The loss of energy due to the resistance created between two materials in contact with one another.

**Gauge Pressure –** The pressure measured at idle on gauges on fire pumps. These gauges read zero having been adjusted for atmospheric pressure. When flowing water at 150 psi, the gauge reads 150, but the actual pressure, which includes atmospheric pressure, is 164.7 psi. Gauges used on fire apparatus are usually marked in units of **psig** (pounds per square inch, gauge).

**Head Pressure** – The pressure exerted by a vertical column of liquid and measured in feet. This type of pressure is also described by the relationship whereby 1 psi of pressure will raise a column of water 2.31 feet. To calculate head pressure (h) use the formula: h = 2.31 ft/psi x p, where h = head pressure and p = the amount of pressure applied to the column of water.

**Nozzle Pressure –** The pressure required for a given nozzle to deliver a specific water flow. Nozzles are designed to deliver specific amounts of water at designated pressures. To effectively extinguish a fire it is essential that the required fire flow be delivered to hose lines or master stream devices. To accomplish this, the apparatus operator must understand hydraulics and calculate the required water flow.

**Residual Pressure** – The pressure in a system when a liquid is flowing. A gauge mounted on a fire hydrant will give the static pressure when no water is flowing. Open one of the outlets and the new pressure after the water is flowing is the residual pressure of the system.

**Static Pressure –** Static is lack of motion or movement, so, static pressure is the pressure of a liquid at rest. One example would be the pressure in a municipal hydrant system when water is not flowing.

**Vacuum (Negative Pressure) –** Pressures less than atmospheric pressure are called vacuums and are expressed in inches of mercury. Usually, one gauge on the pump panel, the master intake gauge, measures vacuum. These gages are also known as compound gages because they measure both pressure and vacuum.

# Pump Operator's Formulas

1.  $FL = CQ^2L$

2.  $PDP = FL + NP + AFL \pm EL$

3.  $GPM = 29.7 \times d^2 \times \sqrt{p}$

4.  Smooth Bore Nozzles:  $NR = 1.57 \times d^2 \times NP$

5.  Combination Nozzles:  $NR = gpm \times \sqrt{NP} \times 0.0505$

6.  General Rule  $\rightarrow$  NR = ½ of gpm in pounds of force

7.  Abbreviations and variables:

> **AFL** = appliance friction loss
> Appliance flowing < 350 gpm = 0 psi FL
> Appliance flowing ≥ 350 gpm = 10 psi FL
> Master stream devices provide 25 psi of FL, when flowing at 350 gpm or more.
> **AP** = atmospheric pressure, 14.7 psi at sea level
> **C** = coefficient of friction, from table
> **d** = diameter of nozzle opening
> **EL** = Pressure increase/decrease due to elevation
> > $\rightarrow$ 10-foot decrease in elevation, **subtract** 5 psi
> > $\rightarrow$ 10-foot increase in elevation, **add** 5 psi
> **FL** = friction loss
> **GPM** = gallons per minute
> **L** = hose length divided by 100
> **NP** = nozzle pressure
> **NR** = nozzle reaction
> **p** = pressure at tip
> **Q** = gpm flowing divided by 100
> **RP** = residual pressure

**Note:** An additional copy of this page is found in Appendix H.

# Friction Loss Coefficients of Single Hose Lines

| Diameter of Hose | Coefficient |
|---|---|
| ¾" booster | 1,100 |
| 1" booster | 150 |
| 1 ¼" booster | 80 |
| 1 ½" | 24 |
| 1 ¾" with 1 ½" coupling | 15.5 |
| 2" | 8 |
| 2 ½" | 2 |
| 3" with 2 ½" coupling | 0.8 |
| 3" with 3" coupling | 0.677 |
| 3 ½" | 0.34 |
| 4" | 0.2 |
| 4 ½" | 0.1 |
| 5" | 0.08 |
| 6" | 0.05 |

## Nozzle Pressures for Commonly Uses Nozzles

| Nozzle Type | Operating Pressure (psi) |
|---|---|
| Smooth-bore, hand-held | 50 |
| Low-pressure | 50 or 75 |
| Smooth-bore, master stream | 80 |
| Combination and Auto-matic | 100 |

**Note:** An additional copy of this page is found in Appendix I.

# UNIT 4

# Hydraulic Calculations and Exercises



## Objectives

**At the completion of this lesson, the student will:**

- Successfully complete calculations for friction loss and fire flow

- Understand both written and estimated methods used when determining friction loss and fire flow

- Successfully determine pump discharge pressures and hose layouts

**Note:** A calculations worksheet can be found in Appendix J.

## Student Exercises - Instruction Guide

**$FL = CQ^2L$**
where, C = coefficient from chart (see Appendix H), and
                Q = gpm supplied ÷ 100, and
                L = length, feet ÷ 100

**PDP = FL + NP + AFL ± EL**

     **P**ump **D**ischarge **P**ressure = **F**riction **L**oss + **N**ozzle **P**ressure +

     **A**ppliance **F**riction **L**oss **(**over 350 gpm flow**)** + or **-** **E**levation

**NOTE: Because pump panel gauges display pressures in 10-pound increments, round each PDP result <u>up</u> to the nearest 5-pound value when the number does not end in zero since this is easiest to read on the gauge.**

## Determine the Pump Discharge Pressure for the following evolutions:

## A. Single Hose Lines Deployed –

**1.** Find the Friction Loss and Pump Discharge Pressure for 200 ft of 1 ¾ inch hose with an automatic nozzle flowing 200 gpm.

**$FL = CQ^2L$**

FL = (15.5) x $Q^2$ x L
FL = 15.5 x $(200 ÷ 100)^2$ x L
FL = 15.5 x $(2)^2$ x L
FL = 15.5 x 4 x (200 ÷ 100)
FL = 15.5 x 4 x 2
FL = 15.5 x 8
FL = 124 psi

**PDP = FL + NP + AFL ± EL**

PDP = 124 + NP + AFL ± EL
PDP = 124 + 100 + AFL ± EL
PDP = 124 + 100 + 0 ± 0
PDP = 224 psi (round up to 225 psi)

**2.** Find the Friction Loss and Pump Discharge Pressure for 200 ft of 1 ¾ inch hose with a smooth-bore nozzle flowing 180 gpm.

**FL = CQ²L**

**PDP = FL + NP + AFL ± EL**

**3.** Find the Friction Loss and Pump Discharge Pressure for 300 ft of 2-inch hose with a smooth-bore nozzle flowing 250 gpm.

**FL = CQ²L**

**PDP = FL + NP + AFL ± EL**

NOTES

**4.** Find the Friction Loss and Pump Discharge Pressure for 150 ft of 2½-inch hose with a smooth-bore nozzle flowing 250 gpm.

**FL = CQ$^2$L**

**PDP = FL + NP + AFL ± EL**

**5.** Find the Friction Loss and Pump Discharge Pressure for 250 ft of 2½-inch hose with an automatic nozzle flowing 300 gpm.

**FL = CQ$^2$L**

**PDP = FL + NP + AFL ± EL**

## B.  Two Or More Hose Lines Deployed:

**Practical tip!**  → For multiple lines, the overall PDP is set at the higher of the required pressures.  The pump operator must then compensate for the lower discharge pressure(s) needed by reducing the flow or "gating down" the other line(s) at the discharge control valves.

**6a.** Find the Friction Loss and Pump Discharge Pressure for 300 ft of 2½-inch hose reduced to 200 ft of 1¾-inch hose with an automatic nozzle flowing 180 gpm.

| Initial 2½-inch line | Reduced 1¾-inch line |
|---|---|
| $FL_1 = CQ^2L$ | $FL_2 = CQ^2L$ |
| $FL_1 = 2 \times Q^2 \times L$ | $FL_2 = 15.5 \times Q^2 \times L$ |
| $FL_1 = 2 \times (180 \div 100)^2 \times L$ | $FL_2 = 15.5 \times (180 \div 100)^2 \times L$ |
| $FL_1 = 2 \times (1.8)^2 \times L$ | $FL_2 = 15.5 \times (1.8)^2 \times L$ |
| $FL_1 = 2 \times 3.24 \times (300 \div 100)$ | $FL_2 = 15.5 \times 3.24 \times (200 \div 100)$ |
| $FL_1 = 2 \times 3.24 \times 3$ | $FL_2 = 15.5 \times 3.24 \times 2$ |
| $FL_1 = 19.44$ psi | $FL_2 = 100.44$ psi |

**$PDP = FL_1 + FL_2 + NP + AFL \pm EL$**

$PDP = 19.44 + 100.44 + 100 + AFL \pm EL$
$PDP = 19.44 + 100.44 + 100 + 0 \pm 0$
$PDP = 219.88$ psi (round up to 220)

**6b.** Find the Friction Loss and Pump Discharge Pressure for 300 ft of 1¾-inch hose with a straight  bore nozzle flowing 150 gpm.

**$FL = CQ^2L$**

$FL = 15.5 \times Q^2 \times L$
$FL = 15.5 \times (150 \div 100)^2 \times L$
$FL = 15.5 \times 1.5^2 \times L$
$FL = 15.5 \times 2.25 \times (300 \div 100)$
$FL = 15.5 \times 2.25 \times 3$
$FL = 104.62$ psi

**$PDP = FL + NP + AFL \pm EL$**

$PDP = 104.62 + 50 + AFL \pm EL$
$PDP = 104.62 + 50 + 0 \pm 0$
$PDP = 154.62$ psi (round up to 155)

**7.** Find the Friction Loss and Pump Discharge Pressure for two lines, each 200 ft of 1¾-inch hose with automatic nozzles flowing 150 gpm.

**FL = CQ²L**

**PDP = FL + NP + AFL ± EL**

**8.** Find the Friction Loss and Pump Discharge Pressure for two lines, as follows:

**Line 1:** 200 ft of 1¾-inch hose with an automatic nozzle flowing 200 gpm.

**Line 2:** 200 ft of 2½-inch hose with a smooth-bore nozzle flowing 250 gpm.

| **Line 1 – 1 ¾-inch** | **Line 2 – 2 ½-inch** |
| --- | --- |
|  |  |

**PDP₁ = FL₁ + NP₁ + AFL ± EL**

**PDP₂ = FL₂ + NP₂ + AFL ± EL**

**9.** Find the Friction Loss and Pump Discharge Pressure for three lines, as follows:

**Line 1:** 200 ft of 1 ¾-inch hose with an automatic nozzle flowing 200 gpm;

**Line 2:** 200 ft of 2½-inch hose with a smooth-bore nozzle flowing 250 gpm; and

**Line 3**: 200 ft of 2½-inch hose with an automatic nozzle flowing 250 gpm.

| Line 1 – 1 ¾-inch Auto | Line 2 – 2 ½-inch SB | Line 3 – 2 ½-inch Auto |
| --- | --- | --- |
| | | |

$$PDP_1 = FL_1 + NP_1 + AFL \pm EL$$

$$PDP_2 = FL_2 + NP_2 + AFL \pm EL$$

$$PDP_3 = FL_3 + NP_3 + AFL \pm EL$$

**10.** Find the Friction Loss and Pump Discharge Pressure for two lines and 1 pre-piped master stream deck gun:

**Line 1:** 150 ft of 1 ¾-inch hose with an automatic nozzle flowing 150 gpm;

**Line 2:** 200 ft of 2½-inch hose with an automatic nozzle flowing 250 gpm; and

**Deck Gun:** Pre-piped master stream with a smooth-bore 1 ½-inch tip.

| **Line 1 – 1 ¾-inch** | **Line 2 – 2 1/2 -inch** | **Pre-Piped Deck Gun** |
|---|---|---|
| $FL_1 = CQ^2L$ | $FL_2 = CQ^2L$ | $FL_3 = CQ^2L$ |

*NOTE: Friction loss in a pre-piped waterway of this size is insignificant.

$$PDP_1 = FL_1 + NP_1 + AFL \pm EL$$

$$PDP_2 = FL_2 + NP_2 + AFL \pm EL$$

Note: Because we should know how many GPM we are pumping to establish if we need to add water to correctly supply the master stream, we will use the GPM formula to determine our maximum potential flow.

$$GPM = 29.7 \times D^2 \times \sqrt{p}$$

D = diameter   P = nozzle pressure $\sqrt{}$ = square root

$$PDP_3 = FL_3 + NP + AFL \pm EL$$

## C. Wyed Lines:

When pumping to hoselines after a wye we do not add the friction loss of both lines together, but use the highest value as a base.  A firefighter should be positioned at the wye to operate the valves, and can gate down the valve to the hose that is being pumped at too high a pressure.

**11.** Find the Friction Loss and Pump Discharge Pressure for 250 ft of 2 ½-inch hose to a Wye feeding two 200-foot lengths of 1 ¾- hose with automatic nozzles, each flowing 200 gpm (Note: 400 gpm, total).

**Line A**:  250 ft of 2 ½ hose

$FL_A = CQ^2L$
$FL_A = 2 \times Q^2 \times L$
$FL_A = 2 \times (400 \div 100)^2 \times L$
$FL_A = 2 \times (4)^2 \times L$
$FL_A = 2 \times 16 \times (250 \div 100)$
$FL_A = 2 \times 16 \times 2.5$
$FL_A = 80$ psi

**Line B:**  200 ft of 1 ¾-inch hose with an auto nozzle flowing 200 gpm.

$FL_B = CQ^2L$
$FL_B = 15.5 \times Q^2 \times L$
$FL_B = 15.5 \times (200 \div 100)^2 \times L$
$FL_B = 15.5 \times (2)^2 \times L$
$FL_B = 15.5 \times 4 \times (200 \div 100)$
$FL_B = 15.5 \times 4 \times 2$
$FL_B = 124$ psi

**Line C:**  200 ft of 1 ¾-inch hose with an auto nozzle flowing 200 gpm.

$FL_C = CQ^2L$
$FL_C = 15.5 \times Q^2 \times L$
$FL_C = 15.5 \times (200 \div 100)^2 \times L$
$FL_C = 15.5 \times (2)^2 \times L$
$FL_C = 15.5 \times 4 \times (200 \div 100)$
$FL_C = 15.5 \times 4 \times 2$
$FL_C = 124$ psi

$PDP = FL_1 = FL_2 + NP + AFL \pm EL$
$PDP = 80 + 124 + 100 + 10 \pm 0$
PDP = 314*  **Instructor Note:** this pressure exceeds hose test pressure. The PDP for this scenario exceeds the test pressure of both the 2 ½-inch and 1 ¾-inch hose.  Changes need to be made to bring down the Master PDP such as changing the nozzles to smooth-bore or changing to 3-inch hose with 2 ½-inch couplings.

**12.** Find the Friction Loss and Pump Discharge Pressure for 500 ft of 3-inch hose with 2 ½-inch couplings feeding a wye with one 150-ft length of 2 ½-inch hose with a smooth-bore nozzle, flowing 200 gpm, and one 200-ft length of 1 ¾" hose with a smooth-bore nozzle, flowing 175 gpm.

**Line 1:** 500 ft of 3-inch hose with 2 ½-inch couplings

**Line 2**: 150 ft of 2½-inch hose with a smooth-bore nozzle, flowing 200 gpm.

$FL_2 = CQ^2L$

**Line 3**: 200 ft of 1 ¾-inch hose with a smooth-bore nozzle, flowing 175 gpm.

$FL_3 = CQ^2L$

$PDP_{1,2} = FL_1 + FL_2 + NP + AFL \pm EL$

$PDP_{1,3} = FL_1 + FL_3 + NP + AFL \pm EL$

NOTES

*Add 10 psi for appliance flowing over 350gpm.

**Note:** To successfully accomplish this evolution, one must pump to the higher pressure, 215 psi, and use a gated wye valve to control the pressure for the line requiring less pressure (130 psi).

# D. Siamese Lines:

**13.** Find the Friction Loss and Pump Discharge Pressure for two 50-ft stretches of 3-inch line with 3-inch couplings supplying a Siamese that feeds 200 ft of 4-inch line to a ground monitor with a fog (automatic) nozzle flowing 800 gpm.

$$FL_{1,2} = CQ^2L$$

$FL_{1,2} = 0.677 \times (400 \div 10)^2 \times L$
$FL_{1,2} = 0.677 \times (4)^2 \times L$
$FL_{1,2} = 0.677 \times 16 \times (50 \div 100)$
$FL_{1,2} = 0.677 \times 16 \times 0.5$
$FL_{1,2} = 5.416 \text{ psi}$

$$FL_3 = CQ^2L$$

$FL_3 = 0.2 \times (800 \div 100)^2 \times L$
$FL_3 = 0.2 \times (8)^2 \times L$
$FL_3 = 0.2 \times 64 \times (200 \div 100)$
$FL_3 = 0.2 \times 64 \times 2$
$FL_3 = 25.60 \text{ psi}$

$$PDP = FL_{1,2} + FL_3 + NP + (AFL + AFL) \pm EL$$

$PDP = 5.416 + 25.60 + 100 + (25 \pm 10) \pm 0$
$PDP = 166 \text{ psi (round up to 170)}$

**14.** Find the Friction Loss and Pump Discharge Pressure for two 300-ft lines of 2 ½-inch hose supplying a ground monitor with a 1 ¾-inch tip.

**GPM = 29.7 x d$^2$ x √p**

**Supply Lines 1 and 2:   FL$_{1,2}$ = CQ$^2$L**

Note that because 2 identical lines are supplying the ground monitor, Q (gpm) is *half* the value determined above.  Thus, half of 812.87 is 406.44; this value is substituted in the FL formula below.

**PDP = FL$_{1,2}$ + NP + AFL ± EL**

# E. Standpipes

**15.** Find the Friction Loss and Pump Discharge Pressure for two 300-ft lines of 2 ½-inch line to a Fire Department Connection (FDC) of a high-rise building. At the 8th floor, the standpipe connection is wyed to supply two 150-ft lines of 2 ½-inch hose (from high-rise packs) with smooth-bore nozzles, each flowing 200 gpm.

**2 ½-inch Supply Line:**

$$FL = CQ^2L$$

$FL = 2 \times (200 \div 100)^2 \times L$
$FL = 2 \times (2)^2 \times L$
$FL = 2 \times 4 \times L$
$FL = 2 \times 4 \times (300 \div 100)$
$FL = 2 \times 4 \times 3$
$FL = 24$ psi

**2 ½" High-rise Packs:**

$$FL = CQ^2L$$

$FL = 2 \times (200 \div 100)^2 \times L$
$FL = 2 \times (2)^2 \times L$
$FL = 2 \times 4 \times L$
$FL = 2 \times 4 \times (150 \div 100)$
$FL = 2 \times 4 \times 1.5$
$FL = 12$ psi

$$PDP = FL_{(supply)} + FL_{(high\text{-}rise)} + NP + AFL \pm EL$$

$PDP = 24 + 12 + 50 + 20 \pm 35$
$PDP = 171$ psi (round up to 175)

To account for elevation (EL), we add 0.5 lbs per foot when pumping to elevation in standpipes, uphill, or to elevated water streams. Since the average height of each story is 10 feet this can be converted to 5 psi per floor.

**16.** Find the Friction Loss and Pump Discharge Pressure for 200 ft of 4-inch hose connected to an FDC. At the 12$^{th}$ floor, the standpipe is wyed to supply a 150-ft, 1 ¾-inch high-rise pack with an automatic nozzle flowing 200 gpm, and a 150-ft, 2-inch high-rise pack with an automatic nozzle flowing 250 gpm.

**4-inch Supply Line:**

$$FL = CQ^2L$$

**1 ¾-inch High-Rise Pack:**

$$FL = CQ^2L$$

**2-inch High-Rise Pack:**

$$FL = CQ^2L$$

$$PDP = FL_{(supply)} + FL_{(high-rise\ 1)} + FL_{(high-rise\ 2)} + NP + AFL \pm EL$$

***Note:** This scenario is **unsafe** and **does not work.** The maximum working pressure is 185 psi for 4-inch supply line. When pumping to hose lines after a wye we do not add the friction loss of both lines together, but use the highest value as a base. This problem further illustrates that using an LDH (4-inch) supply line does not provide adequate pressure to properly attack high-rise fires. **How can this be made safe?** (Answer: change nozzles or remove the LDH).

# F. Aerial Operations

**17.** An engine is pumping through 300 feet of 5-inch LDH to an aerial apparatus operating at 80 feet of elevation, flowing 600 GPM through a smooth-bore nozzle.  Find the Friction Loss and Pump Discharge Pressure for the engine feeding this aerial device.

**5-inch Supply Line:**

$FL = CQ^2L$
$FL = 0.08 \times (600 \div 100)^2 \times L$
$FL = 0.08 \times (6)^2 \times L$
$FL = 0.08 \times 36 \times (300 \div 100)$
$FL = 0.08 \times 36 \times 3$
$FL = 8.64$ psi (round to 10)

$$PDP = FL_{(supply)} + NP + AFL_{(Master\ Stream\ device)} + AFL_{(2\ LDH\ adaptors)} \pm EL$$

$PDP = 10 + 80 + 25 \pm 40 + 10 + 10$
$PDP = 175$ psi

Note:  what is the service test pressure of 5-inch LDH?  Answer: 200 psi; with the operating pressure being 185 psi.

**18**. An engine is pumping through 800 ft of 5-inch LDH to a Quint, operating at 100 ft of elevation, flowing 1,000 GPM through a smooth bore nozzle.  Find the PDP for the supply engine <u>and</u> the PDP for the Quint. (Instructor note:  Supply engine must pump to this quint, and residual pressure must be taken into consideration.)

**5-inch Supply Line:**

$$FL = CQ^2L$$

$$PDP_{(Supply\ Engine)} = FL \pm EL + RP_{(20\ PSI\ residual^*)} + AFL_{(2\ LDH\ adaptors)}$$

$$PDP_{(Quint)} = AFL + NP \pm EL$$

(*20 psi residual pressure is a "rule of thumb.")

# G. Relay Pumping Operations

**19.**  Engine 1 is drafting, supplying 1,000 ft of 5-inch hose to Engine 2 which is supplying two 3-inch lines with 2 ½-inch coupling, each 200 feet in length, feeding a master stream device with a 2-inch smooth-bore tip. Find the Friction Losses, the Pump Discharge Pressures, and the total GPM flowing from the master stream device.

$GPM = 29.7 \times d^2 \times \sqrt{p}$

$GPM = 29.7 \times (2)^2 \times \sqrt{80}$ (master stream device)

$FL_{Relay\ Line} = CQ^2L$

$PDP_{Engine\ 1} = FL_{(Relay\ Line)} + NP + RP + AFL_{(2\ LDH\ Adapters)} \pm EL$

**Note:**  Because the master stream device is being fed with 2 identical lines, the GPM amount (1,062) is divided by 2 for the following calculations.  Thus, we use 531 GPM to determine the FL and PDP.

$FL = CQ^2L$

$PDP_{Engine\ 2} = FL + NP + AFL \pm EL$

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# UNIT 5

## Operating A Fire Pump



## Objectives

**At the completion of this lesson, the student will:**

- Understand the concept of priming

- Have the basic knowledge of three methods of establishing water supply for initial attack; Booster Tank Operations, Drafting, and Hydrant Operations

- Understand the importance maintaining water flow requirements

- Understand fire pump procedures for Sprinklers, Standpipes, Foam, and Relay operations

## Three Water Sources

The booster tank is the primary water supply upon arrival at the fire scene.

Drafting from a pond, portable pond, lake, stream or river can be a primary water supply once the apparatus is set up for the drafting evolution.

Hydrants are a primary water supply adding positive pressure to the water, which will aid in the pump's performance.

## The Concept of Priming

A common misconception is that priming devices pull water into the pump, which gives the pump prime.  This is not the case.  In order to prime the pump we must rely on atmospheric pressure to push water up into the pump.  The priming device is used to create a vacuum inside the pump.  This negative pressure within the pump casing and suction hose allows atmospheric pressure to push the water into the pump. Atmospheric pressure at sea level is 14.7 psi which gives you a maximum **theoretical** lift capability of 33.9 feet while drafting. However if we live in Denver, which is almost a mile high above the ocean, we see less atmospheric pressure and may have a difficult time obtaining prime for our apparatus. Due to design constraints of the pump, we need to keep the fire apparatus within 10 to 15 feet above the water's surface.

A priming device is required to:

- Exhaust air from the pump and suction hose
- Raise water into a dry pump in not more than 30 seconds at 10 feet of lift, through 20 feet of appropriate-sized suction hose
- Prime pumps of 1500 gpm or greater in 45 seconds
- Function efficiently at all times

Refer to NFPA 1901 for additional information about priming.

In order for priming to be successful, the pump needs to be airtight.  This means the valves closed, seals are tight, hard suction is properly fitted to the pump, and the suction hose is in an adequate water supply.

To prime a centrifugal pump, close all the outlets and drains on the output or impeller side.  Remove the air from the pump housing so that atmospheric pressure will force water into the impeller eye, and fill the housing.

## Booster Tank Operations

- Normally the first source of water for initial attack at the fire scene.
- The pump relies on gravity feed to get water from the tank to the pump.
- Booster tanks come in various sizes, usually 500 to 2,000 gallons.
- Many times the size of the tank depends on the Fire Department's preference.

NFPA Standard on Automotive Fire Apparatus 1901 2003.   If the water tank has a certified capacity of less than 500 gal (1,900 L), the piping and valve arrangement shall be capable of delivering water to the pump at a minimum rate of 250 gpm (950 L/min). If the water tank has a certified capacity of 500 gal (1,900 L) or greater, the piping and valve arrangement shall be capable of delivering water to the pump at a minimum rate of 500 gpm (1,900 L/min) or the rated capacity of the pump, whichever is less.  The flow shall be sustainable while pumping a minimum of 80% of the tank capacity with the apparatus on level ground be capable of producing 500 gpm between the tank and pump.

## Booster Tank Setup

- Position the vehicle for optimal use and safety
- Avoid parking under wires or within the collapse zone
- Consider future water supply which could be a tanker/tender shuttle, hydrant supply or pumper relay
- Set the parking brake
- Transfer power from road gear to pump gear (Follow the manufacturer's guidelines)
- Chock the wheels
- Open the booster tank to the pump valve
- Activate primer to exhaust any trapped air (if pressure fails to register on the master discharge gauge; 50 to 60 psi at engine idle). Remember, if a pump is kept "wet," you may not need to activate the primer.
- When instructed open appropriate discharge valve slowly to avoid water hammer
- Increase engine rpm using throttle or governor to achieve the required PDP

Remember that the booster tank contains a limited amount of water. If needed, a more adequate water supply should be established as soon as possible. Once a more adequate water supply is established, switch from the booster tank to the continuous water supply. When the change over has been completed the booster tank must be refilled as soon as possible. Achieve this by slightly opening the tank fill valve and allowing water to be pumped back into the booster tank. Watch for a PDP drop when you open the tank fill valve and if necessary adjust the throttle. If you have a governor this should happen automatically. Perform this while firefighting operations are going on.

**\*\*Important Safety Note:**  <u>Do not</u> fully open the tank fill valve as this will reduce the pressure to the initial attack lines and may cause injury to the interior firefighters. Only a slight flow back to the booster tank is needed. The tank will fill over time.

**Always maintain the booster tank at full capacity.** It may be the last line of defense should anything go wrong with the primary water supply. The booster tank's water can aid the interior attack crews in getting out of the structure until a new water supply can be established.

If at any time, the system needs to be shut down, the fire attack crew(s) must be advised and allowed to retreat to a safe area. <u>Under no circumstances</u> should a shut down be made without proper notification.

## Principles of Drafting

Operating a pumper at draft is a skill that every driver/operator needs to perform. Drafting is the most difficult evolution that both the driver/operator and apparatus will be required to do. Properly operating the pump at draft requires the driver/operator to have an understanding of how atmospheric pressure affects the operation, gauge behavior, and lift.

Successful drafting relies on the understanding that incoming water and atmospheric pressure are always balancing one another. This balance can be influenced by changes in the atmospheric pressure, changes in engine rpm (it is more difficult to draft water at high flow rates than it is at low flow rates), and changes in the height of the lift being used.

Atmospheric pressure is measured with a barometer, and is 14.7 psi at sea level. Theoretically, a perfect pump could create a vacuum that will cause water to move vertically as much as 33.9 feet, at sea level. This means that each psi will move water 2.31 feet (14.7 psi divided by 0.434 psi per ft). Importantly, this theoretical lift decreases as the altitude increases.

This theoretical lift is never attained with fire apparatus because they cannot produce or maintain a perfect vacuum due to operating clearances and general mechanical inefficiency. The NFPA standard 1901 requires that fire department priming systems be capable of producing a vacuum of 22 inches of mercury, which is equivalent of a 25-foot lift at sea level. The standard also specifies that the unit produce its full rated capacity through 20 feet of suction hose, with a 10-foot lift.

**Drafting → What the gauges tell us…**

The pump operator must always observe the master intake and master discharge gauge closely. Changes in these gauge readings indicate changes in available water flow and can point toward possible problems.

Two of the most important changes that might produce a high or increasingly higher vacuum reading are a clogged suction strainer or a falling water supply level. As noted earlier, a pump in good condition should draw 22" Hg. If we equate this 22" to stored energy, we have this amount of energy available to draft water. When drafting water through 20' of suction hose with a 10-foot lift, we would use approximately 9" of mercury out of the available 22"; this is to fill the hose and prime pump.

If our pump is capable of maintaining a 22-inch vacuum, we will have about 13 available inches of vacuum left to move water into the pump, and overcome all friction loss in the suction hose and strainer after our prime is complete.  If the height of lift is increased, or more suction hose added, we will need more of our available energy to overcome these additions, thus reducing our overall capacity of the pump to move water.

The general rule  is that as the lift goes up above 10 feet, the gallons per minute capability (flow rate of the pump) goes down.  The loss in pressure during drafting, from elevation and friction loss, can be observed by watching the master intake gauge.  At approximately 10 feet of suction lift, with the pump fully primed and no hose streams flowing, the master intake gauge will read about 9 inches of mercury.  As we discharge water, some of our total available energy (inches of Hg left in our energy bank) will be depleted.  When we reach 22 inches of Hg, we no longer have any available energy to move more water.  At 20 feet of lift, we would only have about four or five inches of mercury providing energy to flow water. Thus, the pumping capacity will markedly decrease.

**Practical Tip (!)** ➔ When operating an engine at draft, the driver/operator must always have a corresponding increase in pump discharge pressure for every increase in engine RPM.

| Drafting Height Efficiency | | | | |
|---|---|---|---|---|
| Lift | 15' | 20' | 23' | 26' |
| Capacity reduced by | 1/7 | 1/3 | ½ | 2/3 |

## Summary

As a general rule , lifts above 15' should be avoided if possible. The vertical distance between the pump and water should be as short as possible. Experience gained by pumping from local draft sites will indicate exactly what can be expected from pumpers before emergencies arise. Two of the most important things a pump operator needs to know are, do not hurry, and know your apparatus and water supply sites.

## Drafting Setup

- Position the vehicle for optimal use and safety
- Avoid parking under wires or within the collapse zone
- Position the apparatus for ease of obtaining the water supply
- Set the parking brake
- Transfer power from road gear to pump gear (Follow the manufacturer's guidelines)
- Chock the wheels
- Attach appropriate strainer to suction hose
- Attach the needed lengths of suction hose to main steamer connections
- Ensure all fittings are tight and all bleeder valves are closed; check that all capped fittings and drains are closed tightly
- Place strainer end of suction hose in water source; try to maintain 2 feet of water above and below the strainer
- Increase throttle to slightly over 1,000 rpm
- Activate primer for no more than 30 (1,250 gpm or less) to 45 seconds (1,500 gpm or greater).  For pull-type activators, be sure to pull and hold the primer lever to keep the motor running and open the priming valve
- Observe master discharge pressure gauge for positive discharge pressure
- When instructed open appropriate discharge valve slowly to avoid water hammer
- Increase engine rpm using throttle or governor to achieve the required PDP

**Note:** Some apparatus is specified to have front or rear mounted suction inlets.  Although these may be very handy when setting up for drafting, they may not allow you to get capacity flows.

**Practical Tips (!)**

- Be sure the apparatus leaves enough room for portable pond(s).  If the engine is parked in the center of the road, there may not be enough room for the portable pond.
- Avoid setting the portable tank too close to the apparatus.  This may result in not being able to gain access to some of the compartments and the pump operator may not be able to get access to equipment needed for operation.
- If setting up at a lake, pond, or stream make sure, the vehicle is within ten to fifteen *vertical* feet of the surface of the water.  As explained earlier the further off the surface of the water the harder it is for the pump to perform and prime may be lost.
- Apparatus with 1,750 gpm plus capacity will require both suction inlets to be used in order to achieve maximum capacity flows.

## Hydrant Setup

Every pump operator needs to understand basic principles of water supply and flow from hydrants and be able to estimate the total available flow from the hydrant for fire ground operations.

When a pumper is connected to a hydrant and is not discharging water, the pressure shown on the master intake gauge is the **static pressure (SP)**. Once the operator begins to flow water, the intake gauge will show the **residual pressure (RP)**, or left over pressure.  The operator can estimate the total available flow of the hydrant by using the difference between the static and residual pressures.

The most common method for calculating the available flow from hydrants is to use the percentage drop formula:

**Percentage Drop = [(SP – RP) x 100] ÷ SP**

Once a hoseline is flowing, the residual pressure is evident on the master intake gauge.  If the hydrant pressure dropped 10% when the line was opened, this means that this line is using 10% of the available hydrant pressure.  The following table illustrates this process:

| Percentage Drop | Additional Flow |
| --- | --- |
| 0 to10 | 3 times the current flow |
| 11 to 15 | Twice the current flow |
| 16 to 25 | May have additional flow |

It is important to keep in mind that more than a 25% drop usually means that no more lines can be flowed; however, a line of <u>lesser</u> flow may be used.  The operator must maintain a 20 psi residual pressure on the master intake gauge.

**Example 1**.  Hydrant static pressure is 100 psi; the first line flowed is 1 ¾" preconnect flowing 200 gpm.  After the line is charged, the master intake gauge reads 90 psi.  This is a 10% drop, so the operator should expect to flow an additional 600 gpm from the hydrant.

**Example 2**. Hydrant static pressure is 70 psi; the first line charged is a master stream device with a flow of 500 gpm. After the device is charged, the master intake gauge reads 35 psi. This is a 50% drop, so the operator should expect that no more flow at this rate is available.

Operators need to practice various evolutions and flows to gain an understanding of hydrant capabilities. Every department should flow-test and color-code all hydrants in their response area.

Hydrant operations aid in pump performance because of the hydrant pressure. This pressure allows the pump to work more efficiently. The pump may be capable of delivering more than its rated capacity if connected to a positive-pressure source, such as a good hydrant.

**Instructor note**: explain pump function and increased pressure capability due to good hydrant flow.

**Three issues that defeat hydrant operations**

- Water distribution system too small to provide adequate flow
- Distribution system not clean and pipe diameters reduced (necked-down) due to build up on pipe walls
- Hydrant is on a dead-end main (Water main extends from the water source but does not loop back to the water source). This limits the amount of water available.
- Supply line that is too small for adequate flow; for example, 2 ½" or 3" vs 4" or 5" LDH.

## Hydrant Setup

- Position the vehicle for optimal use and safety
- Avoid parking under wires or within the collapse zone
- Set the parking brake
- Transfer power from road gear to pump gear (Follow the manufacturer's guidelines)
- Chock the wheels
- Connect the appropriate size supply hose to its designated intake, while the other end is being connected to the hydrant
- Once water has entered the pump casing open the appropriate discharge valve slowly to avoid water hammer
- Increase engine rpm using throttle or governor to achieve the required PDP

**Practical Tips (!)**

- Provide water to the pump as soon as possible to avoid pump wear.

- Slowly open the suction inlet valve(s) and allow water to enter the pump. Priming is not necessary, as the water pressure within the hydrant system will cause the water to fill the pump casing.

- Set the pressure relief valve or pressure governor once the fire flow has been established. The pressure relief valve or governor will need to be reset for each attack line added or subtracted from the evolution.

- If using LDH, be sure to bleed air from the supply line.

# Sprinkler System Operations

Many jurisdictions have buildings equipped with some type of sprinkler system. However, most driver/operators may only get a limited amount of experience supplying these fire suppression systems. It is important for driver/operators to train regularly and have a working knowledge of how to supply sprinkler systems properly.

## Pre-plan Factors to Consider

Every fire department should have pre-fire plans for the structures that contain sprinkler systems.  Part of the pre-fire plan should include the following:

- an inspection of the system, noting such basic information as type of system (wet or dry)
- the location of the Siamese connection, generally know as the FDC (fire department connection)
- the overall flow requirement of the system

## Types of Sprinkler Systems

Generally, sprinkler systems are either a "wet" or "dry" systems. The wet system has water throughout its plumbing and is usually supplied by a municipal or private water system. When fire activates a sprinkler head, water is immediately available for fire suppression. In a dry system, used in areas where the possibility of freezing exists, the sprinkler lines are pressurized with air. When a head is activated, the air pressure in the system drops and this opens the dry pipe valve that allows water to flow to the activated heads.

## Supplying Sprinkler Systems

When responding to a structure equipped with a sprinkler system the first-due engine should establish an adequate water supply, connect the required hose to the sprinkler FDC, and prepare to pressurize the system. These procedures are usually explained in the department's SOPs. Driver/operators need to understand that for any type of sprinkler system, the water supply for the system is only designed to provide water to a limited number of sprinkler heads. It is the responsibility of the fire department to augment the system with adequate flow and pressure if a large fire occurs that causes additional heads to activate.  If additional hose lines are needed, care should be taken to not draw water from a hydrant that is part of the water supply that feeds the sprinkler system; this will deplete water otherwise needed for the sprinklers.

A general rule for fires in sprinkled buildings is that **a 1,000 gpm pumper is required for every 50 heads in operation**. If the system is to be supplied by the fire department, the driver/operator should slowly develop the pressure that is needed to properly supply the system.  The required discharge pressure for a given sprinkler system can sometimes be found on a plate at or near the FDC. If this information is not posted, and pre-plan calculations have not been done, the driver/operator  should  slowly increase the discharge pressure to **150 psi**. After the driver/operator has achieved the desired PDP, the residual pressure should be noted. If more heads open, the driver/operator will notice a drop in PDP and residual pressure. The engine throttle will need to be increased in order to maintain the correct PDP that takes into account the additional water flow.

## References

NFPA 13-E, Recommended Practice for Fire Department Operations In Properties Protected by Sprinkler and Standpipe Systems, 2005.

# Standpipe Operations

Many jurisdictions have buildings equipped with standpipe systems. However, most driver/operators may only get a limited amount of experience supplying these fire suppression systems. It is important for driver/operators to train regularly and have a working knowledge of how to supply standpipe systems properly.



## Pre-plan Factors to Consider

Every fire department should have pre-fire plans for the structures that contain standpipe systems. Part of the pre-fire plan should include the following:

- An inspection of the standpipe system
- Pre-calculated fire flows and pump discharge pressures for different evolutions within the structure
- The types of nozzles, hose, appliances, and supply lines used
- The available hydrant flow
- Mapping of standpipe connections and the nearest water sources

Many departments have SOPs for operating at buildings equipped with standpipes. One factor that must be included in any SOP is that the first-due pumper establish a water supply and prepare to pump to the standpipe connection.

## Types of Standpipe Systems

Generally, two types of systems will be found in structures—"wet" or "dry." The "wet" system has water throughout, supplied by a pressurized municipal water supply, or by a private water supply and pump system. These wet systems are ready to use as soon as attack lines are attached to outlets within the building. Importantly, fire department apparatus always should augment these wet systems. "Dry" systems do not have water and

must be supplied by fire department pumpers, which connect to the fire department connection (FDC) outside the building.

Below is an example of a highrise pack for standpipe operations.



### Driver/Operator Responsibilities

At high-rise structure fires, the driver/operator will have the additional burden of providing adequate water to engine companies operating many floors above the ground. Proper gallons per minute flows and proper nozzle pressures are critical for firefighters' safety and effective fire extinguishment. In addition, a thorough knowledge of the department's hi-rise packs is essential. The driver/operator must know hose size, length, nozzle type, appliances, and expected fire flow on the fire floor.

The pump operator will be required to establish the proper pump discharge pressure (PDP) for the evolution used. The proper PDP is determined by the following factors:

1. Friction loss in the hose supplying the fire department connection (FDC)
2. Friction loss in the standpipe—usually figured at 25 psi
3. Friction loss due to elevation—½ psi per foot, or 5 psi per floor
4. Friction loss in the attack line
5. Friction loss for any appliances being used (wyes, etc.), and
6. The required nozzle pressure

These calculations may take the driver/operator some time to figure out. A general rule is for driver/operators to supply 150 psi initially to the standpipe system. Pre-planning can be used to establish the proper PDPs before an incident occurs.

PDPs above 200 psi should be avoided unless the building's standpipe system is specifically designed to carry higher pressures. Buildings with pressure reducing valves in the systems should be noted (in any pre-plans), along with the pressures that the valves are set to deliver. These pressures should be used in the SOP discharge pressure calculations.

## References

NFPA 13-E, Recommended Practice for Fire Department Operations In Properties Protected by Sprinkler and Standpipe Systems, 2005.

"General Rule " for different nozzles used during standpipe operations:

Fog Nozzles:              1 to 10 floors   → 150 psi
                         10+ floors      → 200 psi

Smooth Bore Nozzles:     1 to 10 floors   → 100 psi
                         10+ floors      → 150 psi

### Problems Encountered with Standpipe Systems

Occasionally driver/operators may have difficulty hooking up to fire department connections due to vandalism, age/thread compatibility of the fittings, lack of maintenance, etc. If the FDC is totally unusable, a hook-up can be made inside the structure at one of the standpipe connections. To help make a fast hook-up, double female adapters can be used. If the entire building's standpipe system is out of service, an aerial ladder with pre-piped waterway, or a ladder tower could be used as a makeshift standpipe.

**Note:**  Many departments are supplying standpipe systems with large diameter hose (LDH). When this is done, care must be taken that the maximum operating pressure of the hose is not exceeded, or hose failure and injury may result. Some departments continue to supply standpipe and sprinkler systems with 3" double jacket hose with higher pressure ratings than LDH.  Departments that use automatic nozzles in their high-rise kits will require much higher PDPs than those using smooth bore or low-pressure fog nozzles.

It also should be noted that because it takes more time to reach the fire floor in high-rise fires, fire flows in high-rise structures may be significantly greater than what would normally be required for the average single or two-story dwelling fire. Flow rate requirements of 200 gpm or more per line are desirable in these types of operations. Many department SOPs specify at least 2" hose and smooth bore nozzles for high-rise fires. Whatever size hose or nozzles are used, the driver/operator must be able to provide adequate flow to the firefighters on the attack lines.

# Relay Pumping

Relay pumping is defined as pumping between two or more apparatus equipped with fire pumps to overcome friction loss or loss due to elevation to deliver required fire flows or pressures.

The pumper closest to the water source is generally referred to as the "supply" pumper, and the pumper closest to the fire is referred to as the "attack" pumper. Any additional pumpers located between the "source" and the "attack" pumper would be referred to as "relay" or "in-line" pumpers.

## Practical Considerations

Four considerations for relay pumping are the:

1) required fire flow needed at the scene,
2) distance of the water source from the scene,
3) the size of the supply hose, and the
4) practicality of a tanker operation

For example, the water source may be thousands of feet from the scene of our emergency, but still close enough to allow us to establish a relay evolution instead of using a tanker shuttle operation. In addition, the municipal water system may have better flow capabilities further away from our scene and our only way to effectively get the water to where it's needed is by using a relay pumping operation.

**Note:**  For a more detailed discussion of the capabilities of relay operations see the NYS Water Supply Operations course.

## Relay Pumping Operations

Relay pumping can be done with the source pumper drafting from a static source, or attached to a hydrant system. If drafting, the source pumper must do all the work to supply the proper flow. The additional pumpers in the relay can increase pressure but cannot increase the flow. If operating from a hydrant system, the supplied pressure of the municipal system already does some of the work.

Any time the relay operation needs to be shut down, each driver/operator must be made aware of this. It is preferred that all of the pumpers in the relay throttle-down simultaneously. This must be done with all gates open in order to prevent mechanical damage. Once the pump discharge pressure for each pumper is at or below 50 psi, gates can be closed and lines shut down.

**Minimum Residual Pressure is Important**

In order to protect the municipal water system and the pumpers in a relay evolution, a minimum residual pressure of 20 psi **must** be maintained. This pressure is indicated on the master intake gauge.  If the residual pressure drops below 20 psi this could result in a vacuum and possibly collapse water system piping, fire hose, cause cavitation, or cause contaminants to be drawn into the municipal water system.

**Making Relay Pumping More Effective**

We can influence the effectiveness of the relay operation by increasing the number of relay lines used to move the water.  We can also increase the size (diameter) of the relay line, or the number of pumpers, shortening the distance between the pumpers, or increasing the pump discharge pressure. All of these changes make the relay operation more efficient in delivering larger flows.

**Practical Tip (!)**  The pump discharge pressure can only be increased to the manufacturer's specified limits for the size and working pressure of the hose line being used.  Failure to follow these guidelines could result in ruptured hose lines and injury to personnel.

→ When drafting, it is important  to understand that more pressure means less volume.  The pump capacities are noted on the pumper specifications plate on the vehicle, on the pump panel.*

*__Instructor note:__  try to demonstrate this principle during outside evolutions.

Relay pumping requires good radio communication between all pump operators involved in the operation.  As pumping requirements (flows and pressures) change, adjustments in pump discharge pressures must be made.  Driver/operators should be able to tell from the master gauges what changes are happening within the relay and make adjustments in pump discharge pressure accordingly.

**Pumping to Aerial Apparatus During Relay Operations**

An aerial apparatus not equipped with a pump requires a pumper to supply its water.  This requires a pumper to overcome the friction loss in the supply hose and the appliance friction loss in the aerial waterway.  In addition, any pressure loss due to the elevation and nozzle on the aerial device must be factored in as well.

**NOTE:** It is important to understand that even with LDH supply line being used, the pump discharge pressure required to flow 1,000 gpm through the waterway **may be above** the working and/or test pressure of the hose. This could require changing the evolution significantly.

If a "Quint" apparatus is to be supplied, the objective and concerns are the same as those for a relay pumping evolution. A Quint is equipped with its own fire pump and in this case it becomes much more efficient to deliver high(er) flows to the elevated master stream appliances. When the Quint's pump is used in-line with the relay operation, less work is being done by the source pumper (also due to the fact that the source pumper need only overcome the friction loss in the supply hose). The pump on the Quint then provides only the pressure necessary to compensate for the friction loss in the aerial waterway, the elevation, and the nozzle.

**Open Relays**

One variation on conventional, or "closed" relay operations, is an "open" relay operation. In "open" relays, portable tanks are used at each intake for the relay pumpers, providing a contingency water source in the event of a problem at the source pumper. In addition, using tanks allows driver/operators to not need various adapters to connect their intake hoses, and the pumps are not subject to pressure surges is in "closed" relays. More details for this type of evolution are discussed in the NYS Water Supply Operations course.

# Foam Operations

The use of foam in today's fire service is becoming more widely accepted, with a variety of delivery systems being used as well. The driver/operator is responsible for correct operation of the foam systems and must understand how foam proportioning and application works.

Foam concentrate is mixed with water creating a useful dilution effective for firefighting. Once the foam dilution is prepared, introducing air into this solution produces the finished foam product used for extinguishment.

Class A foams are used on Class A fires and Class B foams are used on Class B fires. Working foam dilutions can vary from 0.1% to 6% depending upon type of foam used and the application required.

**Principles of foam use for fire suppression**

Foam's ability to extinguish fires is based on several characteristics.

- Correct proportion of concentrate to water
- Application rate, in gpm
- Correct aeration
- Heat resistance
- Foam/fuel compatibility
- Vapor suppression

**Foam-making equipment**

- Foam is an extinguishing agent that requires a device to combine the foam concentrate with water and an aerating nozzle that introduces air into the stream.
- An eductor is often used to deliver the foam, and works on the venturi principle (a suction effect caused by high-pressure water passing over a small opening within the eductor).
- Electronic foam proportioning systems are now more widely used to deliver foam.
- Foam can also be delivered by a **c**ompressed **a**ir **f**oam **s**ystem (CAFS) that is built into a pumper.
- Foam nozzles have the ability to aspirate proper quantities of air into the solution and apply the foam to the fuel.
- The nozzle must be matched with the eductor to ensure proper foam delivery.
- Foam nozzles are designed for low and medium expansion foams. Fog nozzles can also make foam, but are not optimal.
- Clip-on foam aeration adapters attach to fog nozzles.

**Note:** See foam manufacturer's information for details on complete operation of foam equipment.

Below are examples of different types of foam eductors. These manually operated appliances generally require 200 psi at the inlet and are often setup by the driver/operator. The flow capacity of the nozzle must match the eductor being used.

For example: a 95 gpm eductor must have a nozzle capable of delivering 95 gpm (either fixed or varibale gpm nozzle set at 95 gpm; or an automatic nozzle set with the bail fully open).

When operating bypass eductors, the driver/operator must be sure to turn the handle in order for the foam concentrate to enter the water stream and thus, produce foam solution. The foam solution leaving the eductor mixes with water and then becomes aerated as the mixture leaves the nozzle.

Importantly, 1 ½" to 1 ¾-inch hose lines leaving the eductor are limited in length by the flow rate of the eductor being used, and generally do not exceed 150 feet. However, each eductor may have different requirements that are specified by the manufacturer. Review the specifications for each eductor prior to use.

**In-line eductor**

**Bypass eductor**

**Automatic Foam Systems –**

Many different automatic foam systems that are integrated with the fire pump/apparatus are now in use. Review your department's equipment and follow the manufacturer's specifications for safe and proper operation of these foam systems. Following are examples of components of the FoamPro foam systems that are found on today's pumpers.
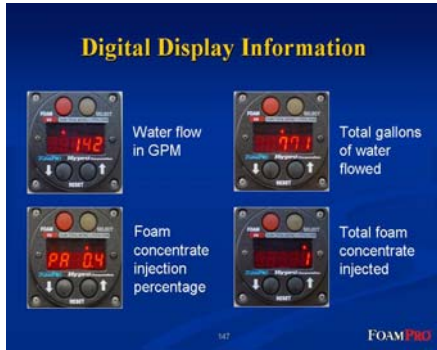






Slides of FoamPro systems provided by FoamPro and are used with permission of the company.

## Summary

This unit has reviewed the basic fire pump operations including establishing a water supply and priming the fire pump. In addition, the three main water supply operations – drafting, using hydrants, and using booster tanks – were reviewed in detail along with setting and using pressure control devices, which are an important safety mechanism. The supplying of sprinkler systems and standpipes was reviewed, as were fundamentals of relay pumping. The basics of foam operation and equipment were also reviewed. However, because of the wide variety of foam delivery systems it is critical that individuals research and review the foam systems available to their department.

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# Units 6 and 7 – Operating Fire Pumps



## Objectives

**At the conclusion of these lessons the student will:**

- Have a working knowledge of pump operations

- Be able to operate a fire pump in the following types of operations

    → Booster tank operations

    → Drafting operations

    → Hydrant operations

- Be able to apply the knowledge from this course to fireground evolutions specific to their individual department's needs and equipment.

The instructor will evaluate the participating Fire Department's equipment and most common operational needs. The Instructor will design evolutions utilizing the participating department's resources to support or disprove current suppositions made about preplans and hose lays in effect. The Instructor will outline and solve these hydraulic problems and demonstrate the solutions to the class utilizing the available resources of the fire departments involved in the class.

# Unit  8 – Evaluation and Testing



## Objectives

**At the conclusion of this unit the student will:**

- Demonstrate successful pump operation

- Successfully pass a written test demonstrating mastery of the pump knowledge they have gained

## Appendices - Table of Contents

# Appendix A – Selected Information from NFPA 1901 – 2003 Edition

**Chapter 5 – Pumper Fire Apparatus**

### 5.7.1 Ground Ladders

**5.7.1.2** At a minimum, the following ladders shall be carried on the apparatus*:
  1) One straight ladder equipped with roof hooks
  2) One extension ladder
  3) One attic ladder

*See Annex A, below for additional equipment recommendations.

### 5.7.2 Suction Hose

**5.7.2.1** A minimum of 15 ft (4.5 m) of soft suction hose or 20 ft (6 m) of hard suction hose shall be carried.

**5.7.2.1.1** Where hard suction hose is provided, a suction strainer shall be furnished.

**5.7.2.1.3** Where soft suction hose is provided, it shall have couplings compatible with the local hydrant outlet connection on one end and the pump intake connection on the other end.

**5.8.2  Fire Hose and Nozzles.**  The following fire hose and nozzles shall be carried on the apparatus:
  1) 800 ft (240 m) of 21/2 in. (65 mm) or larger fire hose
  2) 400 ft (120 m) of 1 1/2 in. (38 mm), 13/4 in. (45 mm), or 2 in. (52 mm) fire hose.
  3) One combination spray nozzle, 200 gpm (750 L/min) minimum
  4) Two combination spray nozzles, 95 gpm (360 L/min) minimum
  5) One playpipe, with shutoff and 1 in. (25 mm), 11/8 in. (29 mm) and 11/4 in. (32 mm) tips.

**5.8.3**   **Miscellaneous Equipment.**  The following additional  equipment shall be carried on the apparatus.

1) One 6 lb (2.7 kg) flathead axe mounted in a bracket fastened to the apparatus
2) One 6 lb (2.7 kg) pickhead axe mounted in a bracket fastened to the apparatus
3) One 6 ft (2 m) pike pole or plaster hook mounted in a bracket fastened to the apparatus
4) One 8 ft (2.4 m) or longer pike pole mounted in a bracket fastened to the apparatus
5) Two portable hand lights mounted in  brackets fastened to the apparatus
6) One approved dry chemical portable fire extinguisher with a minimum 80-B:C rating mounted in a bracket fastened to the apparatus
7) One 21/2 gal. (9.5 L) or larger water extinguisher mounted in a bracket fastened to the apparatus
8) One self-contained breathing apparatus (SCBA) complying with NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for Fire and Emergency Services,* for each assigned seating position, but not fewer than four, mounted in brackets fastened to the apparatus or stored in containers supplied by the SCBA manufacturer
9) One spare SCBA cylinder fore each SCBA carried, each mounted in a bracket fastened to the apparatus or stored in a specially designed storage space
10) One first aid kit
11) Four combination spanner wrenches mounted in brackets fastened to the apparatus
12) Two hydrant wrenches mounted in brackets fastened to the apparatus
13) One double female 21/2 in. (65 mm) adapter with National Hose threads, mounted in a bracket fastened to the apparatus
14) One double male 21/2 in. (65  mm) adapter with National Hose threads, mounted in a bracket fastened to the apparatus
15) One rubber mallet, suitable for use on suction hose connections, mounted in a bracket fastened to the apparatus
16) Two salvage covers each a minimum size of 12 ft x 14 ft (3.7 m x 4.3 m)
17) Two wheel chocks, mounted in readily accessible locations, each designed to hold the apparatus, when loaded to is maximum in-service weight, on a 10 percent grade with the transmission in neutral and the parking brake released.

## Annex A

The following additional equipment is recommended to be carried on the pumper fire apparatus. The equipment list provided does not detail each item sufficiently for purchasing purpose. The purchaser should clarify the detailed specifications for these items.

1) One fire service claw tool
2) One smoke ejector, 5,000 ft$^3$/min (140 m$^3$/min) minimum capacity, and, if the ejector is electrically driven, a suitable adapter cord to fit standard house "U" ground outlets and extension cords and outlets on line voltage power sources used in fire departments
3) One crowbar [36 in. (1 m) minimum] with brackets
4) One pair of insulated bolt cutters with 7/16 in. (11 mm) minimum cut
5) One Halligan-type tool with brackets
6) One 2 1/2 in. (65 mm) hydrant valve (screw-type gate)
7) One double-gated reducing leader wye, sized to fit hose used in department
8) Two shovels  (one pointed and one scoop)
9) Four hose straps
10) One 125-ft (38 m) length of utility rope having a breaking strength of at least 5,000 lb (2,200 kg)
11) One 3,000 W (minimum) portable generator if the apparatus does not have a fixed line voltage power source
12) Two 500 W portable lights
13) Two cord reels with minimum 200 ft (60 m) cord on each with connectors that are compatible with lights, generator, and smoke ejector
14) One portable pump
15) Toolbox with hammers, wrenches, screwdrivers, and other assorted tools
16) Master stream appliance, 1,000 pgm (4,000 L/min) minimum
17) Foam delivery equipment compatible with onboard foam system
18) One hose clamp

# Appendix B – ISO Considerations for Engine and Service Companies

**Source:** http://www.isomitigation.com/ppc/3000/ppc3003.html

## Engine-Company Equipment

Here's a list of the items ISO considers when evaluating an engine company. The table gives the Fire Suppression Rating Schedule (FSRS) credit points available for each item. You may substitute equivalent equipment for some of the items listed in the FSRS. See the FSRS Equivalency list for details.

| Engine-Company Equipment and Hose | Needed | Points Credit/Unit | Total Points |
|---|---|---|---|
| Booster tank | 300 gallons | 1/10 gallons | 30 |
| **Hose** | | | |
| Booster (Extra preconnected 1-1/2" hose may substitute for booster hose) | 200 feet | 3/50 feet | 12 |
| 1-1/2" carried | 400 feet | 3/50 feet | 24 |
| spare (may also be carried) | 200 feet | 2/50 feet | 8 |
| 2-1/2" [spare (may also be carried)] | 200 feet | 3/50 feet | 12 |
| Heavy-stream appliance (1,000 gpm). A heavy-stream device is not needed for a Basic Fire Flow of less than 1,500 gpm. | 1 | 100 | 100 |
| Distributing nozzle | 1 | 1 | 5 |
| Foam nozzle (1-1/2" minimum) | 1 | 4 | 4 |
| **Foam** | | | |
| Carried | 10 gallons | 3/5 gallons | 6 |
| Spare (may also be carried) | 15 gallons | 2/5 gallons | 6 |
| **Nozzles** | | | |
| 2-1/2" straight stream with shutoff | 2 | 20 | 40 |
| 2-1/2" combination with shutoff | 2 | 30 | 60 |
| 1-1/2" combination with shutoff | 2 | 10 | 20 |
| SCBA equipment (30-minute minimum) | 4 | 16 | 64 |
| Extra cylinders (carried) | 4 | 4 | 16 |
| Salvage covers (12-ft. x 18-ft.) | 2 | 2 | 4 |
| Handlight (4V wet or 6V dry) | 2 | 2 | 4 |
| Hose clamp | 1 | 4 | 4 |
| Hydrant gate (2-1/2") | 1 | 4 | 4 |
| Burst hose jacket (2-1/2") | 1 | 4 | 4 |
| Gated wye (2-1/2" x 1-1/2" x 1-1/2") | 1 | 4 | 4 |

| Engine-Company Equipment and Hose | Needed | Points Credit/Unit | Total Points |
|---|---|---|---|
| **Radio** | | | |
| Mounted | 1 | 32 | 32 |
| Portable | 1 | 16 | 16 |
| **Ladders** | | | |
| 12-ft. or 14-ft. roof | 1 | 10 | 10 |
| 24-ft. extension | 1 | 15 | 15 |
| **Annual tests** | | | |
| Pumper (see table A, below) | 1 | 100 | 100 |
| Hose (see table B, below) | 1 | 50 | 50 |

*Total:* 654

The fire apparatus should also have supply hose and fire-fighting hose. For maximum credit, the engine company should carry 1,200 feet of hose. This can be 1,200 feet of 2-1/2" or larger supply hose or a combination of 2", 2-1/2", or 3" hose (up to 400 feet) and 2-1/2" or larger hose (up to 800 feet).

## Table A.  Pumper Service Tests

| Average Interval between 3 Most Recent Tests | Maximum Points Credit |
|---|---|
| 1 year | 100 |
| 2 years | 75 |
| 3 years | 50 |
| 4 years | 25 |
| 5 years | 0 |

NFPA Standard 1911, *Standard for Service Tests of Fire Pump Systems on Fire Apparatus*, describes pumper service tests. A pumper service test is similar to the certification test described in NFPA Standard 1901, except that the duration is reduced to 20 minutes at 150 psi, 10 minutes at 200 psi, and 10 minutes at 250 psi. The overload test is not a necessary part of the ISO review.

## Table B.  Hose Service Tests

| Average Interval between 3 Most Recent Tests | Maximum Points Credit | | |
|---|---|---|---|
| | 250 psi | 200 psi | 150psi |
| 1 year | 50 | 37 | 28 |
| 2 years | 37 | 27 | 18 |
| 3 years | 25 | 18 | 12 |
| 4 years | 12 | 9 | 6 |
| 5 years | 0 | 0 | 0 |

NFPA Standard 1962, Care, *Maintenance and Use of Fire Hose*, describes fire hose tests.

When the hose-test frequency, pressure, or both vary for 2-1/2" and larger hose and for 1-1/2" hose, ISO prorates the credit using 65% for the 2-1/2" and larger hose and 35% for the 1-1/2" hose. Large diameter hose (LDH) in excess of 3" in diameter should be tested in accordance with NFPA 1962. The highest test pressure needed for 3" diameter and smaller hose is 250 psi.

**Note:** If the community conducts tests but keeps no records of the tests, ISO will reduce the applicable points credit by 20% for Tables A and B.

Either the fire department or an independent testing agency can perform the tests. In either case, the tests should conform with the appropriate NFPA standard.

For information on how adding certain pieces of equipment will affect your community's preliminary FSRS score, see ISO's relative-value tables.

**For more information . . .**
. . . on any topic related to the PPC™ program or the Fire Suppression Rating Schedule, click Talk to ISO Mitigation or call the ISO mitigation specialists at 1-800-444-4554.


For a listing of equivalent equipment, see the following Web link:
**http://www.isomitigation.com/ppc/3000/ppc3007.html**.  This link provides alternative equipment that can be carried on engines and other service vehicles.

# Service-Company Equipment

Here's a list of the items ISO considers when evaluating a service company. The table gives the Fire Suppression Rating Schedule (FSRS) credit points available for each item. You may substitute equivalent equipment for some of the items listed in the FSRS. See the FSRS Equivalency list for details.  For information on how adding certain pieces of equipment will affect your community's preliminary FSRS score, see ISO's relative-value tables.

| Equipment | Needed | Points Credit/Unit | Total Points |
|---|---|---|---|
| Large spray nozzle (500 gpm minimum) | 1 | 16 | 16 |
| SCBA equipment (30-minute minimum) | 6 | 16 | 96 |
|     Extra cylinders (carried) | 6 | 4 | 24 |
| Salvage covers (12-ft. x 18-ft.) | 10 | 2 | 20 |
| Electric generator (2,500 watt) | 1 | 25 | 25 |
| Floodlight (500 watt) | 3 | 4 | 12 |
| Smoke ejector | 1 | 20 | 20 |
| Oxyacetylene cutting unit | 1 | 20 | 20 |
| Power saw | 1 | 20 | 20 |
| Handlight (4V wet or 6V dry) | 4 | 2 | 8 |
| Hose roller (equipment hoist) | 1 | 4 | 4 |
| **Pike pole (plaster hook)** | | | |
| 6-foot | 2 | 2 | 4 |
| 8-foot | 2 | 2 | 4 |
| 12-foot | 2 | 2 | 4 |
| **Radio** | | | |
| Mounted | 1 | 32 | 32 |
| Portable | 1 | 16 | 16 |
| **Ladder** | | | |
| 10-ft. collapsible | 1 | 4 | 4 |
| 14-ft. extension | 1 | 5 | 5 |
| | | | *Total: 334* |

**For more information . . .**
. . . on any topic related to the PPCᴛᴍ program or the Fire Suppression Rating Schedule, click Talk to ISO Mitigation or call the ISO mitigation specialists at 1-800-444-4554.

## Appendix C – Apparatus Typing Worksheet

**Student Exercise –  Use the charts on next page to classify your department's apparatus.**

| Pump GPM | Tank Size (gal) | Personnel (Number) | Hose (Size) | Type |
|---|---|---|---|---|
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
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|  |  |  |  |  |
|  |  |  |  |  |

Note:  The typing guidelines provided in Unit 1 are based on wildland firefighting classifications.  When typing apparatus it is necessary to consider the total amount and size of the hose carried on the apparatus.

| Resource: Engine, Fire (Pumper) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Category: Firefighting (ESF #4)**<br>**Kind: Equipment** | | | | | | | | |
| **Minimum Capabilities (Component)** | **Minimum Capabilities (Metric)** | **Type I** | **Type II** | **Type III** | **Type IV** | **Type V** | **Type VI** | **Type VII** |
| Pump Capacity | | 1,000 GPM | 500 GPM | 120 GPM | 70 GPM | 50 GPM | 50 GPM | 50 GPM |
| Tank Capacity | | 400 Gallon | 400 Gallon | 500 Gallon | 750 Gallon | 500 Gallon | 200 Gallon | 125 Gallon |
| Hose, 2.5 inch | | 1,200 Feet | 1,000 Feet | | | | | |
| Hose, 1.5 inch | | 400 Feet | 500 Feet | 1,000 Feet | 300 Feet | 300 Feet | 300 Feet | 200 Feet |
| Hose, 1 inch | | 200 Feet | 300 Feet | 800 Feet | 300 Feet | 300 Feet | 300 Feet | 200 Feet |
| Personnel | | 4 | 3 | 3 | 2 | 2 | 2 | 2 |

**Comment:**

The engine typing needs to be taken out to Type VII.  Compromise between FIRESCOPE and NWCG is to use NWCG Standards for Engines and Crews.  NWCG has seven engine types.

| Resource: Water Tender, Firefighting (Tanker) | | | | | |
|---|---|---|---|---|---|
| **Category: Firefighting (ESF #4)**<br>**Kind: Equipment** | | | | | |
| **Minimum Capabilities (Component)** | **Minimum Capabilities (Metric)** | **Type I** | **Type II** | **Type III** | **Type IV** | **Other** |
| Tank | | 2,000 gallon | 1,000 gallon | 1,000 gallon | | |
| Pump | | 300 GPM | 120 GPM | 50 GPM | | |

# Appendix D – National Wildfire Coordinating Group (NWCG) Apparatus Classification System

**Source:**  http://www.nwcg.gov/teams/fewt/reports/typ-std.pdf; accessed 19 April 2007

**NATIONAL WILDFIRE COORDINATING GROUP**

**EQUIPPING
FIRE APPARATUS FOR USE IN THE
WILDLAND/URBAN INTERFACE**

1. SCOPE

1.1 Scope. This document identifies equipment and appliances, as well as training for personnel, for safe and effective cooperative operations of wildland and structural apparatus in the wildland/urban interface environment.

2. PUBLICATIONS

2.1 Publications.

NWCG Publication
The following are reference documents:

S-130 - Firefighter Training
S-190 - Introduction to Wildland Fire Behavior
I-200 - Basic ICS
S-205 - Fire Operations in the Urban Interface
S-212 - Wildfire Power saws
310-1 - NWCG Training and Qualifications System
410-1 - Fireline Handbook
416 - Standards for Survival

NWCG Training Publications and Full Courses are available from the National Interagency Fire Center, Great Basin Cache Supply Office, 3833 S. Development Ave., Boise, ID  83705.  For a Catalog order NFES #3362.

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

1901 - Fire Apparatus
1906 - Wildland Fire Apparatus
1963 - Fire Hose Connections
1971 - Protective Clothing for Structural Firefighting
1977 - Protective Clothing and Equipment for Wildland Fire Fighting

NFPA documents are available from NFPA, One Batterymarch Park, PO Box 9101, Quincy, MA  02269-9101.

2.2 Order of precedence.  In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence.  Nothing in this document, however, supercedes applicable laws and regulations unless a specific exemption has been obtained.

2.3 Paragraphs with an asterisk (*) have explanatory information in section 4.

3. REQUIREMENTS

3.1 Engine classification.  The NWCG Fireline Handbook, 410-1 has a classification system that types structure and wildland fire engines as well as water tenders

3.2 Vehicle.

3.2.1 General.  All fire apparatus shall conform to the laws and regulations of the United States and the authority having jurisdiction. Fire apparatus should conform to the applicable NFPA (1901 and 1906) purchasing and operations standards and NWCG member agency requirements.  All vehicles should be reviewed periodically to evaluate their status in comparison to the updates in vehicle regulations and standards, and modifications made as necessary.

3.2.2  <u>Safety</u>.  As a minimum the fire apparatus is required to  have the following:

  Baffled water tank.
  Seatbelts for all personnel.

In addition, it is recommended that the apparatus have the following:

  Enclosed cab.
  Backup alarm.
  DOT emergency kit with reflective triangles, flares, fire extinguisher.
  First aid kit.
  No equipment in cab or all secured.
  Mirrors on both sides usable by driver.
  Spare tire.
  At least one scene work light.
  360° reflective markings.
  Pull points clearly marked.

3.2.2.1*  <u>Emergency vehicles</u>.  Fire apparatus requesting right-of-way on public roads shall be equipped with state compliant emergency warning lights and audible warning devices.

3.2.3*  <u>GVWR</u>.  The vehicle shall not be operated above the manufacturer's gross vehicle weight rating (GVWR) fully loaded, including fuel, water, personnel, and equipment.

3.2.4*  <u>Ground clearance</u>.  Due to the road conditions found in interface situations, it is recommended that only vehicles with high ground clearance and steep approach and departure angles be utilized.  It is recommended that vehicles have a minimum approach/departure angles of 20°, a minimum axle clearance of 8", and a minimum ground clearance of 12".

3.3*  <u>Equipment</u>.  In order to be more effective and enable various vehicles to work together, fire apparatus being utilized in an interface fire should consider carrying the following equipment, as part of their normal complement of tools:

  2-1/2" NH x 1-1/2" NH (female-male) hydrant adapter.
  2" NPSH x 1-1/2" NH (female-male) adapter.
  1-1/2" NH x 1-1/2" NH double female.
  1-1/2" NH x 1-1/2" NH double male.
  1-1/2" NH x 1" NPSH (female-male) reducer.
  1" NPSH x 1-1/2" NH (female-male) increaser.
  1" NH x 1" NPSH (female-male) thread adapter.
  1" NPSH x 1" NH (female-male) thread adapter.
  1-1/2" NH x 1-1/2" NH x 1-1/2" NH gated wye.
  Hydrant wrench, adjustable.
  1-1/2" - 2-1/2" Spanner wrench with gas shut-off slots.
  Bolt cutters (18" minimum).
  Wildland handtool per crew member.
  Class "A" foam capable
  Hose clamp for 1" and 1-1/2" hose.
  1-1/2" nozzle to fit 1-1/2" hose.
  Draft hose.
  Strainer/foot valve for draft hose.
  Chainsaw, kit & fuel.
  Hose and ladder requirements should be based on current NWCG Engine Typing.

3.4*  <u>Personal protective equipment (PPE)</u>.  All firefighters shall be equipped with personal protective clothing that meets the performance characteristics of NFPA 1977.  This includes a fire resistant shirt and pants or coveralls, helmet, eye protection, heavy-duty leather gloves, 8" tall laceup leather boots, and a fire shelter for each person.  Wildland firefighting may involve long periods away from the apparatus and it is recommended that each person have a backpack for personal equipment and at least 2 quarts of drinking water.

3.5 <u>Communications</u>. At an interface incident, communications is critical for coordinating multiple agency response, as well as the safety of all personnel. It is recommended that as a minimum, each apparatus be equipped with a two-way radio with local mutual aid frequencies. The FCC has set aside the following frequencies as national Fire Mutual Aid frequencies: 154.265 (red), 154.280 (white), and 154.295 (blue).

3.6 <u>Training</u>. NWCG offers numerous training course on wildland operations, see the NWCG course catalog for more details. Refer to 310-1, NWCG Training and Qualification System or equivalent.

3.7 <u>Staffing</u>. The Engine Typing Standard in 410-1, NWCG Fireline Handbook identifies minimum staffing standards for each engine type.

4. NOTES

This document is intended to provide an equipment guide to federal, state, local and private firefighting organizations. This allows for effective integration of all fire suppression resources.

A3.2.3. NFPA 1906 (1995 revision, paragraph A-3-2.1) recommends operating vehicles at less than the GVWR when intended for off-road use. Operating fully loaded engines off-road adversely impacts handling and braking, increases maintenance, and shortens the life of the vehicle.

A3.2.4 Incidents have occurred where vehicles with low-ground clearance have become high-centered while attempting to traverse unimproved roads. This occurrence can block access and exit of others.

A3.3 The equipment listed in 3.3 is primarily intended so that wildland and structure apparatus can physically connect to each other and support each other in interface operations. NFPA 1963 is the national standard for fire hose threads and connections, which use the designation "NH". Numerous other thread forms can be found throughout the country, the next most common is the national pipe thread, designated "NPSH". If the area from which the vehicle works commonly uses thread forms other than NH, it is recommended that thread adapters be carried, IN ADDITION to the ones listed by this document, to allow connection to NH threads. For example, the federal wildland firefighting agencies have standardized with NH thread except for 1" connections, which are commonly NPSH connections.

A3.4 An interface fire is a wildland fire in an area that has houses and other man-made structures intermixed with wildland fuels. Wildland firefighting often involves extended operation in elevated temperatures that make structural bunker gear impractical. The PPE described by NFPA 1977 was specifically designed for wildland firefighting. NWCG Publications Catalog, NFES 3362, lists other available firefighter safety publications.

## Engine and Water Tender Resource Types
### Minimum Requirements

### Engine Types

| Components | STRUCTURE ENGINES | | WILDLAND ENGINES | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Pump Rating | | | | | | | |
| minimum flow (gpm) | 1000+ | 250+ | 150 | 50 | 50 | 30 | 10 |
| at rated pressure (psi) | 150 | 150 | 250 | 100 | 100 | 100 | 100 |
| Tank Capacity Range (gal) | 400+ | 400+ | 500+ | 750+ | 400-750 | 150-400 | 50-200 |
| Hose (feet) | | | | | | | |
| 2.1/2 inch | 1200 | 1000 | - | - | - | - | - |
| 1.1/2 inch | 400 | 500 | 500 | 300 | 300 | 300 | - |
| 1 inch | - | - | 500 | 300 | 300 | 300 | 200 |
| Ladders | 48' | 48' | - | - | - | - | - |
| Master Stream (GPM) | 500 | - | - | - | - | - | - |
| Personnel (minimum) | 4 | 3 | 2 | 2 | 2 | 2 | 2 |

**Common additional needs. Request as needed.**

All wheel drive

Pump & Roll

High pressure pump (minimum 40 gpm @ 250 psi)

Class A Foam Proportioner

Compressed air foam system (CAFS) with minimum 40 cfm compressor.

Additional personnel

### Water Tender Types

| Components | Water Tender Types | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Tank Capacity (gallons) | 5000+ | 2500+ | 1000+ |
| Pump Capacity (GPM)* | 300+ | 200+ | 200+ |
| Off Load Capacity (GPM) | 300+ | 200+ | 200+ |
| Max. Refill Time (minutes) | 30 | 20 | 15 |

* Portable pump acceptable.

10/27/98

# Appendix E – Class 1 Electronic Pressure Governors

## Electronic Engine Pressure Governor

The Class1 Pressure Governor is designed to maintain a selected pump pressure or engine speed setting.

### Modes of Operation

**Power On**    When the unit is first powered up, the display will show [MODE] and the engine will remain at idle until the mode switch is pressed to select the desired operating mode
(**PRESSURE** or **RPM**).
There is an internal relay that should be used to turn on the remote throttle at the engine ECU. This relay will not energize until the MODE switch is pressed and a valid throttle ready input is present at Pin 2 of the 12 pin connector. If the pump is engaged and the OK to Pump LED is illuminated, PRESSURE will be the first mode selected otherwise Throttle will be the first mode.

**RPM Mode**   When the unit is in RPM mode, the display will read "**THROTTLE**" and the green RPM LED will be illuminated. Engine speed is controlled by the **INC**rease and **DEC**rease switches, the display will indicate "**INCREASE**" or "**DECREASE**" as appropriate when these switches are depressed. The governor will maintain the last output signal attained with these switches. The engine will maintain an RPM appropriate for the throttle signal being sent.

NOTE: IF WHILE OPERATING IN **RPM** MODE THE PRESSURE INCREASES MORE THAN **50 PSI** FROM THE PRESSURE LOGGED AT THE LAST SWITCH PRESS, THE GOVERNOR WILL LIMIT THE PRESSURE INCREASE TO NO MORE THAN A **50 PSI** DIFFERENTIAL.
THE GOVERNOR MAY REDUCE ENGINE RPM TO ACHIEVE THIS AND THE MESSAGE **PSI LIMIT** WILL BE DISPLAYED IN THE MESSAGE CENTER.
NOTE: THE GOVERNOR WILL NOT ATTEMPT TO REGULATE PRESSURE IN THIS MODE, ONLY LIMIT THE DIFFERENTIAL PRESSURE TO **50 PSI** FROM THE PRESSURE PRESENT WHEN THE LAST SWITCH WAS PRESSED.

**Pressure Mode**    When the unit is operating in the Pressure mode, the display will show "**PRESSURE**" and the amber PRESSURE LED will be illuminated. Pump pressure is set by using the **INC**rease and **DEC**rease switches. The governor will attempt to maintain the last pressure achieved with these switches. The display will indicate "**INCREASE**" or "**DECREASE**" as appropriate.
The governor maintains pump pressure by controlling engine RPM in response to a signal from the pressure transducer mounted on the pump.
When controlling in this manner, the display will show **CTRL DEC** or **CTRL INC**.

**Switching between modes**      Pressing the mode switch will change the governor from RPM to Pressure mode without a significant change in engine speed or pump pressure. The message center will indicate "**PRESSURE**" or "**THROTTLE**" as appropriate once the mode change has been made. When switching to PRESSURE, the pressure setpoint is whatever pressure is on the transducer at the change.

### Preset Mode
Pressing the **PRESET** switch in either mode will control the engine to attain the preset RPM or pump pressure programmed in governor memory. If there is more than 10 PSI pressure on the pump, the RPM Preset is disabled. If the Preset Switch is pressed, **DISABLED** will be displayed momentarily.

## High Idle Mode

An input is available to bring the engine speed to a PRESET RPM (High Idle) from a remotely mounted switch. While operating in this mode, the display will show "**HIGHIDLE**". This function is inoperative when the pump engaged input is active, there is more than 10 PSI on the pressure transducer or if the MODE switch on the governor has been pressed. Pressing the **IDLE** switch causes the high idle to drop out and the high idle input must be toggled off and then on again to reinstate high idle. The **INC** and **DEC** switches are active in high idle mode and the engine speed can be adjusted, changing engine speed in this manner will not change the preset RPM that is set in memory.

**Idle Mode**     Pressing the **IDLE** switch at any time returns the engine to idle speed.

*NOTE: **A** FIRM, POSITIVE SWITCH DEPRESSION IS NECESSARY TO ACTIVATE THIS FEATURE AND A QUICK PRESS MIGHT BE IGNORED.*

**SENSOR**

⚠️ CAUTION

Whenever the transducer signal is below 0.3 VDC or above 4.8 VDC, a sensor fault will be logged and **SENSOR** will be displayed in the message center. ( **SENSOR** will flash if the failure occurs while operating in PSI Mode) Once a failure is detected, the governor can no longer maintain a pressure setting. It will hold the current engine RPM and only operate as a throttle.

Once the **SENSOR** message is displayed, it will not clear until power to the governor is reset. It is extremely important that the cause for this message is investigated.

The governor *cannot* control discharge pressure properly unless the sensor signal is reliable and correct.

## Switch Session Pressure

If the **INC** switch is held the governor will not allow a change greater than **80 PSI** without releasing the **INC** switch and pressing it again. This is only applicable when the pressure is above **90 PSI**. This prevents high pressures from being introduced by a distracted operator.

## Pressure / Water Loss

If the discharge pressure drops below **30 PSI** for any reason, engine speed will not be increased. The governor output voltage will reduce to the last known value (engine RPM) where the pressure setpoint was obtained. The display will flash **-INTAKE-** during this low pressure condition. If the pressure increases above 30 PSI, **OPERATOR** will flash and the governor will not increase output unless the operator presses the **INC** or **PRESET** switches. If pressure above **30 PSI** is not regained within **5 seconds**, the governor will return the engine to idle and display **LoSupply**. The operator must make certain that the water supply is adequate and then reinstate governing using the **MODE, INC** and/or **PRESET** switches.

## Pressure Recovery / Cavitation (TRIM)

The governor has a trim adjustment, this can be set between 5% and 20% of maximum throttle. This parameter limits the governor's maximum increase in a pressure recovery attempt. The message center will flash **OPERATOR** when this limit is reached and the RPM will not increase further. The operator must take positive action to restore discharge pressure. If pressure is not restored within 4 seconds, the governor will reduce output to the last known output where pressure was maintained. The operator must input a new setpoint with the **INC/DEC** or **PRESET** switches. If the pressure rises above the original setpoint and the governor decreases the engine speed, the governor will resume normal governing operations.

## Version Display

While the governor is at idle and [MODE] is being displayed, if the **IDLE** switch is depressed for 7 seconds, the message center will scroll through the version number, governor settings and I/O voltage. When the sequence is complete, the display will return to [MODE] and normal operation is available.

## PSI Enable

The pressure governor will not control pressure until a discharge pressure of **70 PSI** is attained. It will act as a throttle until this pressure point is achieved.

## RPM Preset Disable

If there is pressure on the pump transducer, RPM Preset is disabled and a **DISABLED** message will be displayed in the Message Center.

## Pressure Preset

While the governor is attempting to reach the preset PSI, the increase is tested at intervals and if the pressure is not increasing, the governor will maintain the engine speed at the point the pressure stops increasing and uses that as the pressure setpoint.

## High Idle

The High Idle feature is disabled if there is **> 10 PSI** at the pump transducer.

## Switch Session Pressure

If the **INC** switch is held and the operating pressure is above **90 PSI**, the governor will not allow a change greater than **80 PSI** without releasing the **INC** switch and pressing it again. This is to prevent high pressures from being introduced by a distracted operator.

## New Messages

**OPERATOR** will flash anytime the governor can't achieve a desired pressure.
This indicates that the governor will not increase engine speed until the pump operator intervenes.
**-INTAKE-** will be displayed anytime the governor is operating in pressure mode and the discharge pressure drops below **30 PSI**.
If pressure remains below **30 PSI**, the display will change to **LoSupply** and engine speed will be reduced to idle. At this point, the operator must correct the supply or discharge problem and reinstate governing

**OPERATOR** will be displayed anytime the governor can't achieve a function or pressure.
This indicates that the governor will not increase engine speed until the pump operator intervenes.
**CTRL INC** will be flash in the display if the governor cannot regain the set pressure. It will change to **OPERATOR** (flashing) if pressure cannot be regained within 4 seconds.
During these periods, the governor will not command an increase in engine speed and will return to the last known engine speed command where the setpoint was achieved.

Source: Hale Corporation, used with permission.

## Appendix F – Priming, Cavitation and Fire Pumps

# PRIMING CENTRIFUGAL PUMPS

Despite common fire service terminology concerning pumping at draft it is not quite true to say, that a pump is *lifting water from the source*. Actually the pump is creating a partial vacuum within its suction chambers, that is, a pressure lower than atmospheric. The atmospheric pressure on the surface of the water being pumped then forces the water up through the suction hose and into the pump.

When the pump is full of water, it will create quite a high vacuum, but when the pump has been drained, containing only, air, it is a very poor vacuum pump. In order to obtain water we then need to create a vacuum within the pump by some other means, so we use a priming pump, which should develop a vacuum of at least 22 inches of mercury. The priming pump withdraws air from the fire pump, reducing the pressure within its casing substantially below atmospheric pressure.

The question is often asked, "Should a pump be primed from the top of the pump or from the suction of the pump?" The answer depends upon whether the pump is running or stationary during the priming operation. It is the purpose of this discussion to illustrate why, for consistently reliable priming, the pump should be primed from the suction side near the impeller eye when the pump is running and why it should be primed from the top of the pump when it is stationary.

The sketches illustrate the reason for this. For simplicity,, no discharge valves, relief valves, priming pump or other accessories are shown. A single-stage pump is sketched, the principle being the same with two or more stages. The source of vacuum may be an electric priming pump, ejector, or other hand operated priming pump.

When priming from the top with the pump stationary, the primer is operated until a steady stream of water flows from the primer discharge. It is then shut off and the main pump is put in gear. When priming from the suction of the pump, pump running, the primer is not shut off until a steady stream is flowing through the discharge hose. Any unavoidable air trap in the suction hose is more easily removed by priming from the suction of the pump.

Periodically the priming system should be used to create a vacuum of at least 22 inches of mercury within the pump and attached capped suction hose. With the priming pump shut off, the vacuum should drop no faster than 10 inches in 10 minutes. For such a test a mercury manometer should be used rather than the compound gage, because it is easier to read and more accurate. The operating manual furnished with the pumper should be carefully followed.

Air leaks in a pump make priming uncertain. If the pump is primed in spite of air leaks, operation will be rough and efficiency will be lowered. The maximum capacity of the pump will be substantially reduced, especially on lifts higher than normal and at high altitudes. While it is hard to define the size of an air leak-, any air leak that drops vacuum faster than 10 inches in 10 minutes will cause reduced performance, rough operation, hose pulsation and a ragged discharge stream.

When pumping from draft, or the booster tank, through a 3/4-inch or 1 inch booster hose, the flow through the pump is so small compared to the capacity of the pump that it is difficult to always scavenge all the air from the pump, resulting in unexpectedly low pressure. It is a good practice when this occurs to momentarily open a 2-1/2 inch discharge valve. The larger flow for a few seconds while the priming pump is still running completes the removal of air.

Figure I shows a typical air trap in the suction. The unit shown is a portable centrifugal pump primed from the suction inlet with an exhaust ejector while the pump is running. The effect of an air trap on priming is the same, however, regardless of the size of the pump or method of producing vacuum.
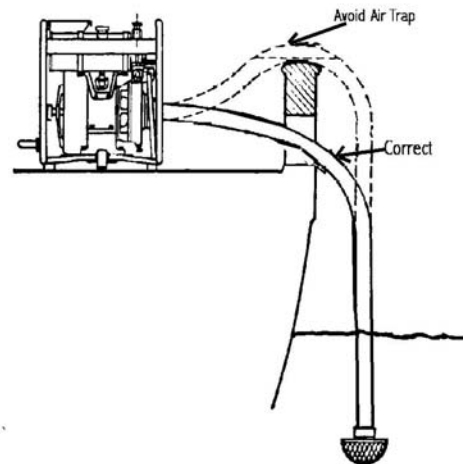


*Figure 1*

With an inverted air trap in the suction hose, water rising in the suction flows over the **"hump""** and runs into the pump, leaving air trapped at the top of the "hump." The pump, full of water, shows pressure. The discharge valve is opened, flow through the suction hose increases sweeping air down into the pump, resulting in temporary loss of prime.

As under priming procedure (3), the priming is continued until all or nearly all of the air swept over from the trap is scavenged from the suction of the pump. The discharge valve need not be closed while scavenging, but, depending on the lift, it may speed priming to do so. If the air trap volume is large, scavenging will take longer than if the air trap is small.

When the pump is primed stationary from the top of the pump (Procedure I), each time the primer is shut off and the pump is started some of the air is swept into the eye of the impeller, breaking the prime, and the pump is running as in Procedure 2. It is now necessary to stop the pump. Start priming again until water runs from the priming pump. Shut off primer, start pump, etc., until a complete prime is reached. This may take two, three or more trials to finally prime depending on the size of the air trap. It is for this reason that air traps are more easily handled by priming from the eye with the pump running than by priming from the top of the pump with the pump stationary
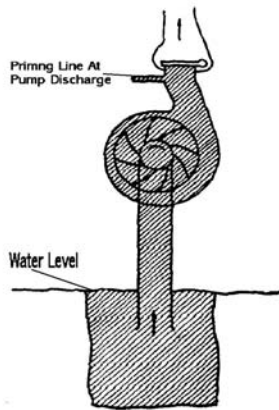
## PROCEDURE 1

PRIMING FROM DISCHARGE,
PUMP NOT RUNNING WHEN PRIMING

This method primes consistently:

1. Pump fills with water
2. Priming line shut off.
3. Pump started.

Water flows into suction
and out discharge

Priming Line At
Pump Discharge

Water Level

## PROCEDURE 2

PRIMING FROM DISCHARGE,
PUMP RUNNING WHEN PRIMING

This method **does not** prime consistently:

1. Pump suction fills with water and enters pump.
2. Water flows by centrifugal force to outside of impeller and into discharge.
3. Air goes to center of pump, being lighter than water.
4. Priming system keeps on working but pulls only water, which slips through the air in the center of the impeller. Air remains in center.
5. Impeller cannot start moving water through the suction, pump and discharge line until it is full or nearly full of water.
6. When pump is running, remove the air from where the air is - the center of the pump.

Priming Line At
Pump Discharge

Water Level
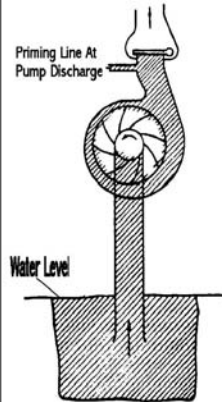
## PROCEDURE 3

PRIMING FROM SUCTION
PUMP RUNNING WHEN PRIMING

This method primes consistently:

1. Water rises in suction tube and fills pump.
2. Air goes to center of pump, being lighter than water.
3. Primer removes air from center of pump, near impeller eye.
4. Water will start to flow out discharge before all the air is removed, but full stream will not flow until all or nearly all air is removed from center of pump.
5. Primer to be kept in operation after opening discharge valves until steady stream flows.

Priming Line At
Pump Suction

Water Level
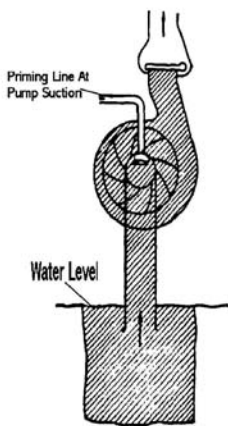
## PROCEDURE 4

PRIMING FROM SUCTION
PUMP NOT RUNNING WHEN PRIMING

This method **does not** prime consistently:

Fig A: 1. Primer raises water to top of suction, continues sucking water only, leaving air in top of pump and discharge.
2. Primer shut off.
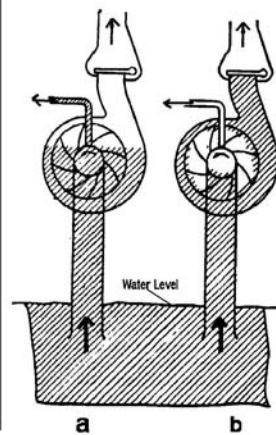
Fig.B: 1. Pump started, throwing water to outside of impeller and discharge. Air comes into center.
2. Pump not yet primed because running impeller cannot move water through suction, pump, and discharge until it is full or nearly full of water (as in Procedure 3). This method does not, therefore, prime consistently.
3. To complete the prime, restart the primer to exhaust the air from the center of the pump, while the pump is running (as in Procedure 3). For consistent priming a pump should be primed at the top when not running, and at the suction close to the impeller when running.

Water Level

a          b

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## HALE Products

## Cavitation:  Warning Signs and Reasons Why it Occurs

BY LT. G. E. REEVES
*Bureau of Training  Montgomery, Alabama Fire Dept.*

One of the most common errors on the fireground is the tendency of pump operators to try and pump more water to hose lines than the pump is receiving. This procedure is often referred to as ' running away from the water supply' or cavitation.

Most fire department pump operators have a general idea of what cavitation is and some of the ways to go about reducing or avoiding it, but when probing beyond these very general concepts, knowledge seems to be somewhat limited in most cases.

It is a known fact that cavitation does serious damage to fire pumps. This is especially true if the pump is subjected to cavitation over a long time. Since the effects are cumulative, the damage that occurs each time the pump cavitates is added to the damage previously caused by cavitation. If prolonged or repeated cavitation is allowed to occur, pretty soon the pump will no longer function properly and it will have to be overhauled.

### Understanding cavitation

Engineers or pump operators are usually trained with this in mind, but it might prove beneficial to take the training a step further and examine some of the causes and effects of cavitation in more detail. A better understanding of what is taking place inside the pump will enable pump operators to foresee and avoid unnecessary and costly damage to equipment.

First of all, to gain a better insight into what takes place inside the pump, we need to take into consideration a few of the unique characteristics of water.

We know that at sea level water will boil if its temperature is raised to approximately 212°F. This assumes a normal atmospheric pressure of 14.7 psi. If we place the water in a closed container and add pressure the boiling point rises. This is why we use pressure caps on auto radiators and pressure cookers to prepare food. It stands to reason that food will cook faster when boiled at 250 degrees than it will at 212 degrees. This elevated boiling point is obtained by adding 15-psi pressure. An auto will also stand a much less chance of running hot and boiling out its coolant if the boiling point of the coolant is raised several degrees.

So far, the best way found to achieve an elevated boiling point is with the addition of pressure. Without it, water will reach 212° and continue boiling until it has completely vaporized. The temperature of the water will not rise above 212°. Additional heat only speeds the evaporation or boiling rate. Boiling is nothing more than rapid vaporization of water. It occurs whenever the vapor pressure within the liquid becomes equal to atmospheric pressure.

We most often associate this equalization of pressures with the addition of heat, but the same results can be obtained by reducing atmospheric pressure. At higher elevations, water boils at a temperature less than 212° due to lower atmospheric pressure. Of course, lower atmospheric pressure is normal at higher elevations, but we can create the same effect at any elevation by placing water under a vacuum.

| Boiling Point of Water | | | |
|------------------------|--|--|--|
| *At sea level, 14.7 psia,* | | | |
| Positive Pressure | | Vacuum | |
| PSIG | Degrees F | In. Hg | Degrees F |
| 5 | 227.96 | 5 | 203.08 |
| 10 | 240.07 | 10 | 192.37 |
| 15 | 250.33 | 15 | 179.14 |
| 20 | 259.28 | 20 | 161.49 |
| 25 | 267.25 | 25 | 133.76 |
| 30 | 274.44 | 27 | 101.96 |
| 35 | 281.01 | 29 | 79.03 |
| | | 29.5 | 58.80 |
| | | 29.8 | 34.57 |

The boiling point of water is raised according to the amount of pressure applied and it is lowered according to the amount of vacuum to which it is subjected.  In other words, if water in a closed container is subjected to positive pressure, the boiling point will go up. How far up it will go is determined by the amount of pressure applied. But if this same container is subjected to a vacuum, the boiling point will be lowered from the normal 212°. The greater the vacuum, the lower the boiling point will be.

### Pressure and vacuum effects

The effects of pressure and vacuum on the boiling point of water are shown in the accompanying table. The boiling point of water is 212°F at sea level, where the atmospheric pressure is 14.7 pounds per square inch absolute (psia). Pressure gages at sea level show a reading of 0 pounds per square inch gage (psig). Thus, positive pressures in the table are psig, which means they are in addition to the normal sea level atmospheric pressure of 14.7 psia. Negative pressure in the table, stated in inches of mercury, are less than 14.7 psia, the normal sea level atmospheric pressure.

As you can see from the table, at 29.8 inches of mercury, the boiling point of water is 34.57°F. This is close to the normal freezing point of water, but the freezing point also is lowered when water is subjected to a vacuum. This particular characteristic of water is not important to the phenomenon of cavitation, however, and will not be pursued further.

## HALE IDEX
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|-----------|------|------------|

When a centrifugal pump is attempting to discharge more water than it is receiving, a vacuum is created near the eye of the impeller. This may happen while pumping from draft or a hydrant. The real problem in either case is running away from the supply and causing a vacuum to occur.

### Water flashes into vapor

As the vacuum increases, the boiling point of the water is lowered until it reaches a point near the impeller eye where it flashes into vapor and enters the impeller.

Once the vapor pockets, or bubbles, enter the impeller, the process begins to reverse itself. As the vapor reaches the discharge side of the pump, it is subjected to a high positive pressure which condenses the vapor back to a liquid. The sudden change from vapor pockets to a liquid generates a shock effect that damages the impeller and pump housing. Usually there are thousands of tiny vapor pockets rather than a few large ones. The collapse of these vapor pockets is referred to as implosions. To implode means to burst inwardly.

The damage done during any one period of cavitation is not great, but if cavitation is repeated over a long period, the effects can disable an otherwise perfectly good pump. Implosions occurring during cavitation tend to break away or erode tiny pieces of metal from moving parts and from the pump casing. When enough metal has been chipped away, the impeller becomes unbalanced thereby causing an undue strain and vibration on bearings, bushings and shafts.

The sound created by a pump while cavitating has been described as similar to that of a handful of pebbles circulating throughout the pump. This sound is not made by the numerous vapor pockets passing through the pump, as is often assumed, but it is the sound resulting from the implosion of these vapor pockets as they become subjected to positive pressure and condense.

Once cavitation begins, the pump is working at its maximum output unless the water supply can be increased. Speeding up the pump in the vain hope of increasing pressure and flow will ill only cause cavitation to become much worse increase the chances of pump damage and may cause an even worse occurrence, interruption of fire fighting streams already in use.

The fact that subjecting water to a vacuum has the result of lowering the boiling point, can also have a real bearing on the pump's ability to draft warm or hot water. One reason is because water that is already hot requires only a small amount of vacuum to make it give off excessive vapors. This may cause the pump to lose its prime much the same way it would if an air leak occurred from the outside.

Remember that the warmer water becomes the faster it gives off vapors until the boiling point is reached. At the boiling point, the vapor pressure of water is equal to atmospheric pressure and water reaches its maximum vaporization rate.

When taking suction from a hydrant, the temperature does not have a significant effect until the pump begins to exceed the capacity of the hydrant. Once this happens and a vacuum is created, it has the same effect of increasing vaporization because the water is nearing its boiling or equalization point just the same.

### Cavitation while drafting

As stated earlier, cavitation occurs any time the pump tries to deliver more water than it is received thereby creating a vacuum on the suction side of the pump. When the pump is operating at draft, it has a vacuum on the suction side. However, when it tries to pump more than it is drafting, the pressure on the discharge side is reduced and the amount of vacuum on the suction side is increased until cavitation or loss of prime occurs.

This situation can be brought about by pumping at high altitudes, which has the same effect as low atmospheric pressure, a partially blocked suction strainer, a suction hose too long or too small, a lift that is too high, a drafting source that is too warm, or a combination of these conditions.

### Don't depend on gages

It is poor practice to depend entirely on vacuum gage to indicate that a pump is nearing cavitation. This is because gage are usually tapped into the intake chamber several inches away from the leading edge of the impeller eye where the greatest amount of vacuum occurs. Some of the most experienced pump operators may he able to judge by the gage, but it is a poor indication at the best.

### Indication of cavitation

Whether taking water from a hydrant or drafting, the most reliable indication that a pump is approaching cavitation is when an increase in engine rpm does not cause an increase in pump discharge pressure Small capacity pumpers usually are not overly concerned with cavitation while pumping from a hydrant, but with modern 1250, 1500 and 2000 gpm pumpers, the problem is becoming more prevalent.

If the pump is approaching cavitation and more pressure is needed but no more water is available, discharge gates may have to be choked down. This will allow pressure to increase but will result in a reduction of flow to hose lines At no time should a pump be operated under cavitation-producing conditions for long periods. There is nothing to gain by such practices but an unnecessary repair bill.

Pump operators who are knowledgeable about the causes and effects of cavitation can better operate to avoid it, thereby saving substantial amounts of money and preventing unnecessary shop time for equipment that is needed on the fireground.

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# Appendix G –  Apparatus Inspection Worksheet

**Generic Inspection Sheet**

| Date | | Unit # | Odometer | |
| --- | --- | --- | --- | --- |
| Pre-trip Inspection | ☐ | | Post-trip Inspection | ☐ |
| Check all items that need attention and specify defect in remarks box at bottom of page. | | | | |
| General Appearance Of Vehicle | | | | |

| | EXTERIOR | | | INTERIOR |
| --- | --- | --- | --- | --- |
| ☐ | Head lights | | ☐ | Cab Doors |
| ☐ | Tail Lights | | ☐ | Windows & Operation |
| ☐ | Stop Lights | | ☐ | Windshield Wipers (Cond. & Operation) |
| ☐ | Turn Signals & Flashers | | ☐ | Heater & Defroster |
| ☐ | Clearance & Marker Lights | | ☐ | Mirrors |
| ☐ | Reflectors | | ☐ | Seats |
| ☐ | Emergency Warning Lights | | ☐ | Passenger Restraints |
| ☐ | Brakes Foot & Parking | | ☐ | All Gauges Operation |
| ☐ | Brake System (adjust. & condition) | | ☐ | All interior lighting (Gauges) |
| ☐ | Vehicle Body & Body Doors | | ☐ | Horns & Sirens |
| ☐ | Wheels, Tires, and Lugs | | ☐ | Interior Mounted Equipment |
| ☐ | Steering Components | | ☐ | Steering Operation |
| ☐ | Fuel System,  Cap & Tank | | ☐ | Cleanliness |
| ☐ | Leaks | | ☐ | Chassis Electrical |
| ☐ | Fluid Levels (Oil, PS level, Coolant, Trans., Primer Oil) | | ☐ | Battery Condition |
| ☐ | Engine & Transmission Noise | | ☐ | |
| ☐ | Pump & Transfer Case Noise | | ☐ | |
| ☐ | Air Systems | | ☐ | |
| ☐ | Drain Air Tanks | | ☐ | |

**Remarks**

Action Taken

| Inspected By: | Reviewed By: |
| --- | --- |
| Action taken by: | |

## Appendix H – Pump Operator's Formulas

1. $FL = CQ^2L$

2. $PDP = FL + NP + AFL \pm EL$

3. $GPM = 29.7 \times d^2 \times \sqrt{p}$

4. Smooth Bore Nozzles: $NR = 1.57 \times d^2 \times NP$

5. Combination Nozzles: $NR = gpm \times \sqrt{NP} \times 0.0505$

6. General Rule → $NR = \frac{1}{2}$ of gpm in pounds of force

7. Abbreviations and variables:

   **AFL** = appliance friction loss
         Appliance flowing < 350 gpm = 0 psi FL
   Appliance flowing ≥ 350 gpm = 10 psi FL
   Master stream devices provide 25 psi of FL, when flowing at 350 gpm or more.
   **AP** = atmospheric pressure, 14.7 psi at sea level
   **C** = coefficient of friction, from table
   **d** = diameter of nozzle opening
   **EL** = Pressure increase/decrease due to elevation
         → 10-foot decrease in elevation, **<u>subtract</u>** 5 psi
         → 10-foot increase in elevation, **<u>add</u>** 5 psi
   **FL** = friction loss
   **GPM** = gallons per minute
   **L** = hose length divided by 100
   **NP** = nozzle pressure
   **NR** = nozzle reaction
   **p** = pressure at tip
   **Q** = gpm flowing divided by 100
   **RP** = residual pressure

## Appendix I – Friction Loss and Nozzle Pressure Reference Tables

# Friction Loss Coefficients of Single Hose Lines

| Diameter of Hose | Coefficient |
|---|---|
| ¾" booster | 1,100 |
| 1" booster | 150 |
| 1 ¼" booster | 80 |
| 1 ½" | 24 |
| 1 ¾" with 1 ½" coupling | 15.5 |
| 2" | 8 |
| 2 ½" | 2 |
| 3" with 2 ½" coupling | 0.8 |
| 3" with 3" coupling | 0.677 |
| 3 ½" | 0.34 |
| 4" | 0.2 |
| 4 ½" | 0.1 |
| 5" | 0.08 |
| 6" | 0.05 |

## Nozzle Pressures for Commonly Uses Nozzles

| Nozzle Type | Operating Pressure (psi) |
|---|---|
| Smooth-bore, hand-held | 50 |
| Low-pressure | 50 or 75 |
| Smooth-bore, master stream | 80 |
| Combination and Automatic | 100 |

## Appendix J – Calculations worksheet

$$FL = CQ^2L$$

| C = | Q = | L = |
|-----|-----|-----|
|     |     |     |

| FL | C | $(Q^2)$ | L | FL | C | $(Q^2)$ | L | FL | C | $(Q^2)$ | L |
|----|---|---------|---|----|---|---------|---|----|---|---------|---|
|    |   |         |   |    |   |         |   |    |   |         |   |
|    |   |         |   |    |   |         |   |    |   |         |   |
|    |   |         |   |    |   |         |   |    |   |         |   |
|    |   |         |   |    |   |         |   |    |   |         |   |
|    |   |         |   |    |   |         |   |    |   |         |   |
|    |   |         |   |    |   |         |   |    |   |         |   |
|    |   |         |   |    |   |         |   |    |   |         |   |
|    |   |         |   |    |   |         |   |    |   |         |   |

$$PDP = FL + NP + AFL \pm EL$$

| FL = | NP = | AFL = | EL = |
|------|------|-------|------|
|      |      |       |      |

| PDP = | FL + | NP + | AFL + | EL | PDP = | FL + | NP + | AFL + | EL |
|-------|------|------|-------|----|-------|------|------|-------|----|
|       |      |      |       |    |       |      |      |       |    |
|       |      |      |       |    |       |      |      |       |    |
|       |      |      |       |    |       |      |      |       |    |
|       |      |      |       |    |       |      |      |       |    |
|       |      |      |       |    |       |      |      |       |    |
|       |      |      |       |    |       |      |      |       |    |
|       |      |      |       |    |       |      |      |       |    |
|       |      |      |       |    |       |      |      |       |    |
|       |      |      |       |    |       |      |      |       |    |

| GPM = | 29.7 × | $d^2$ × | $\sqrt{p}$ |
|-------|--------|---------|------------|
|       |        |         |            |
|       |        |         |            |
|       |        |         |            |
|       |        |         |            |

## Appendix K – Trident Air Prime System

# PUMP PRIMER
# COMPARISON OF FEATURES

**TRIDENT**
EMERGENCY PRODUCTS, LLC

**AIR PRIME**

NEW TECHNOLOGY                    OLD TECHNOLOGY

| FEATURE | AIRPRIME | ROTARY-VANE |
|---------|----------|-------------|
| BODY MATERIALS | BRASS & STAINLESS | ALUMINUM |
| WEIGHT | 7 LBS. | 27 LBS |
| SIZE (L x W x H) | 4" x 3-3/4" x 8" | 12-3/4" x 7-1/4" x 6-1/2" |
| MOVING PARTS | NONE | 6 |
| WEAR ITEMS | NONE | VANES / BODY |
| LUBRICANT TANK | NONE | ON SOME MODELS |
| NOISE @ PANEL | < 65 dBA | > 92 dBA |
| SELF DRAINING | YES | NO |
| CONTROL TYPE | PUSH BUTTON | PULL "TEE" HANDLE |
| MAX AMP DRAW | ZERO | 300 AMPS |
| ALLOWED RUNTIME | UNLIMITED | 60 SECONDS MAX |
| NFPA COMPLIANT | YES | YES |
| WARRANTY | 5 YEARS | 2 YEARS |
| PANEL SPACE | 5-1/2 SQUARE INCHES | 5-1/2 SQUARE INCHES |
| PRIMING VALVE | BUILT INTO PRIMER | MOUNTED AT PANEL |
| OWNERSHIP COST | LOW | HIGH |

### DETAILED SPECIFICATIONS:

**PRIMING PUMP:** The priming pump shall be a Trident Emergency Products compressed air powered, high efficiency, multi-stage, venturi based AirPrime™ System. All wetted metallic parts of the priming system are to be of brass and stainless steel construction. A single panel mounted control will activate the priming pump and open the priming valve to the pump. The priming system shall have a five year warranty.

**ADDITIONAL PRIMER CONTROL:** An additional primer control valve shall be furnished to prime the front/rear suction line plumbing. The Trident Emergency products RPV (remote priming valve) shall activate using the same air that powers the AirPrime™ system when the coinciding panel valve is depressed. Priming the remote suction line evacuates air from that line and minimizes cavitation during remote suction operations. The valve control is to be co-located next to the main priming valve control on the pump operator's panel.

**AIR PRIME** is a Trademark of **Trident Emergency Products, LLC**

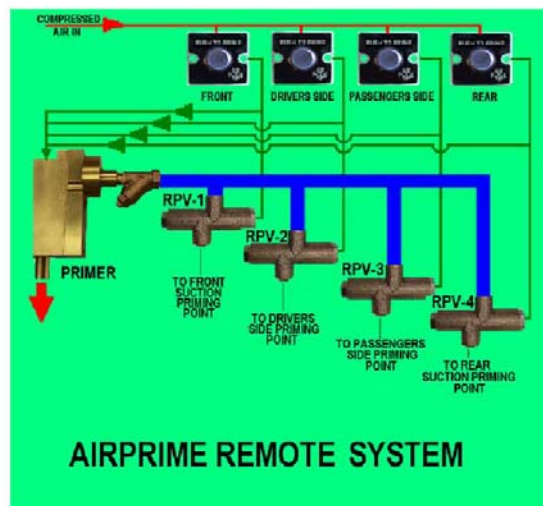© Trident Emergency Products, LLC Literature sheet # 02.004.22 Rev 1

**REVOLUTIONARY-**

NEW AIR POWERED PRIMING VALVE- ALLOWS SELECTIVE PRIMING OF MULTIPLE LOCATIONS USING ONLY ONE AIR POWERED PRIMER

**COMPLETELY AIR POWERED**

FINALLY, A PRODUCT THAT ALLOWS FOR PRIMING FROM MULTIPLE-LOCATIONS USING ONLY ONE CONTROL. UNTIL NOW, IF PRIMING FROM MULTIPLE LOCATIONS WAS REQUIRED, EITHER A SELECTOR VALVE OR MULTIPLE PRIMING PUMPS WERE UTILIZED. BY USING THE TRIDENT EMERGENCY PRODUCTS, REMOTE PRIMING VALVE(S) IN CONJUNTION WITH THE AIR-POWERED PRIMER, THE PUMP OPERATOR ONLY HAS TO DEPRESS THE PANEL PUSH-BUTTON FOR THE LOCATION TO BE PRIMED. SEE SCHEMATIC BELOW.

**REMOTE PRIMING VALVE (RPV)**

**TM**    **PATENT PENDING**

**TRIDENT**
**EMERGENCY PRODUCTS, LLC**

**Tomorrow's Ideas Delivered Today**

**AIR PRIME REMOTE FEATURES:**
►SMALL AND SILENT
►LIGHT WEIGHT
►3/4" FNPT CONNECTIONS
►1/4" FNPT AIR FITTINGS
►NO CURRENT DRAW
►CORROSION RESISTANT
►NFPA 1901 COMPLIANT
►PUSH BUTTON CONTROL
  FOR EACH LOCATION
►UNLIMITED LOCATIONS
►USE WITH *AIRPRIME*

**TRIDENT EMERGENCY PRODUCTS, LLC**
www.tridentdirect.com
PHONE: 215.293.0700
FAX: 215.293.0701



**AIRPRIME REMOTE SYSTEM**

® Trident Emergency Products, LLC          Literature Sheet #02.004.3 REV2          7-24-06

**Manual covers 3-Barrel Air Prime**
**Model # 31.001.2** (Flange Direct Mount)
**Model # 31.001.7** (3/4″ NPT Mounting)

**And the 2-Barrel Air Prime Design**
**Model # 31.003.2** (Flange Direct Mount)
**Model # 31.003.7** (3/4″ NPT Mounting)

## AIR SUPPLY

The Air Prime must be connected to the vehicle's air brake system exactly as shown in Figure-1 below. In this schematic, which is typical for most trucks built today, the air compressor is shown as (**1**). The supply reservoir (wet tank) is shown as (**2**). The primary reservoir (typically for the rear brakes) is shown as (**3**). The Pressure Protection Valve for the Air Prime is shown as (**4**). The secondary reservoir (typically for the front brakes) is shown as (**5**).



FIGURE 1
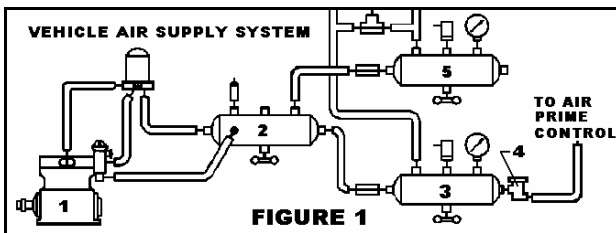
In some chassis, the supply reservoir and the secondary reservoir are combined into a dual split-tank containing two distinct air chambers. Many other variations are also possible.

## INSTALLER'S RESPONSIBILITIES

**A)** The **2-barrel** Air Prime **must** be used only on fire pumps rated **1000 GPM and smaller**. All other applications **must** use the 3-barrel Air Prime. The vehicle's air compressor **must** have a minimum rating of **13.2 CFM** when using the **2- barrel** Air Prime and a minimum rating of **15.6 CFM** when using the **3-barrel** Air Prime. For lifts greater than 10 feet, or for operations above 4000 feet of elevation a minimum air compressor size of **18.7 CFM** is required.

**B)** The air source location used for the Air Prime is the **primary reservoir** (**3**), as it will generally have the greatest volume. If an auxiliary tank is provided on the truck that is as large as the primary tank, it may be used as the air supply instead of the primary tank.

**C)** A Pressure Protection Valve (**4**) **must be used** between the air supply reservoir and the Air Prime control. This valve is **not supplied** with the Air Primer. The Pressure protection Valve used should be preset to close at **80 psig.** The 80 psig setting will allow the Air Prime enough pressure for operation and still keep the tank pressure well above the "low air pressure" alarm cut-in, which is usually set for 60 psig. This valve is to be connected as shown in Figure 1. Using this valve complies with both NFPA 1901 and the FMVSS 121 requirements, and serves to protect the air brake system from any leaks that may occur in the primer control or the line from the Pressure Protection Valve to the primer control.

**D)** The supply line from the Pressure Protection Valve to the Air Prime control should be a minimum size of 3/8" air brake tubing and connected at both ends with ¼" NPT fittings. The tubing should be kept as short as possible, free of any kinks or bends, must not be run near exhaust or rotating components, and must be secured at regular intervals. Use grommets to protect the tubing lines from contacting sharp edges at hole locations. When the length of tubing required exceeds 20 feet, a minimum size of ½" air brake tubing should be used. All tubing and fittings used must be rated for air brake service.

## PRIMER MOUNTING

The Air Prime must be ordered as follows:
   -Mounted directly to midship pumps with "diamond shaped" 2-bolt pad.
   **Trident Part # 31.001.2 – 3 Barrel**
   **Trident Part # 31.002.2 – 2 Barrel**
   -Mounted elsewhere for all other pumps
   **Trident Part # 31.001.7 – 3 Barrel**
   **Trident Part # 31.002.7 – 2 Barrel**

### Direct Pump Midship Mounting

The Air Prime can be directly mounted to the two bolt priming port for some midship pump models: Consult factory for any compatibility questions.  Figure 2, below illustrates the proper mounting of the Air Prime to Midship pumps with 2-bolt diamond shaped pads.
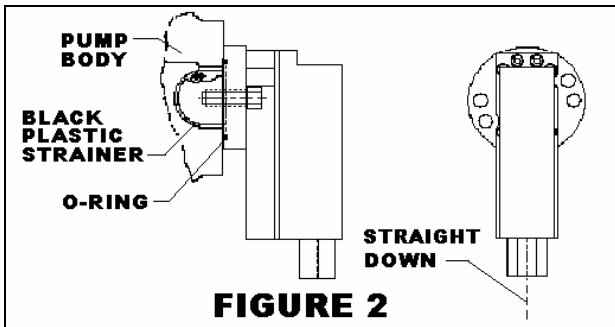


FIGURE 2

## ALL OTHER PUMP MOUNTING

For mounting the Air Prime for use on all other pumps, the Primer must be ordered and installed as shown in figure 3 below.
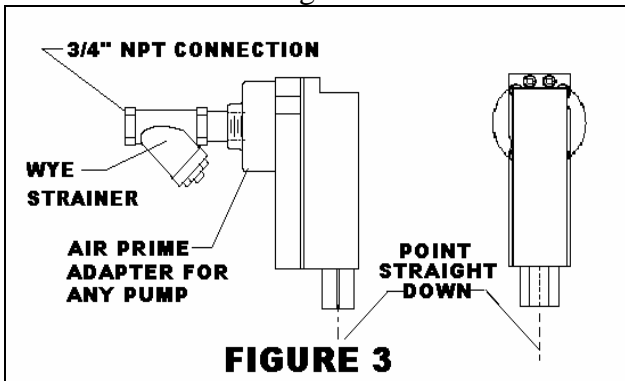


FIGURE 3

The locations of the (4) ¼"-20 Air Prime mounting holes are shown in figure 4 below. These mounting holes are available for use on all of the Air Prime designs. When fabricating a bracket to attach the primer to a structural member on the vehicle, always use all (4) of the Air Prime mounting holes.
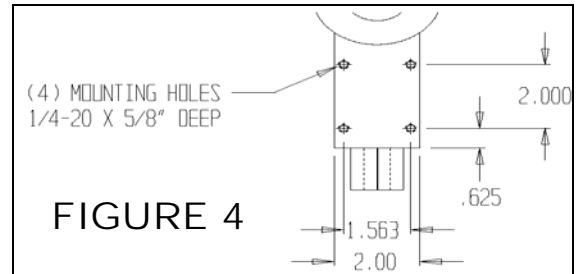


FIGURE 4

This Air Prime model comes with a ¾" wye strainer. The strainer protects the primer from debris in the water.  It should be positioned to allow easy access for periodic cleaning.

The Air Prime can be mounted to the frame rail, the bottom of the pump gearbox, or any other location that is close to the priming port of the pump. The Air Prime outlet must point down.

Finally, make a connection from the ¾" NPT Air Prime inlet to the pump's priming port using a **minimum** inside diameter of  ¾", non-collapsible, vacuum rated hose.

Note that a 1-1/4" ID hose may be connected to the primer outlet using a hose clamp to secure it in place.  This hose can be used to direct the water that is discharged from the primer to any convenient location.  Be sure this hose is properly secured, kept as short as possible, and free of any kinks, sharp bends, or potential water traps.

2

## AIR PRIME PANEL CONTROL

The control for the Air Prime is a push to operate air switch that is mounted to the pump panel. Figure 5 shows the placard, push button, and template for the panel cut-outs.
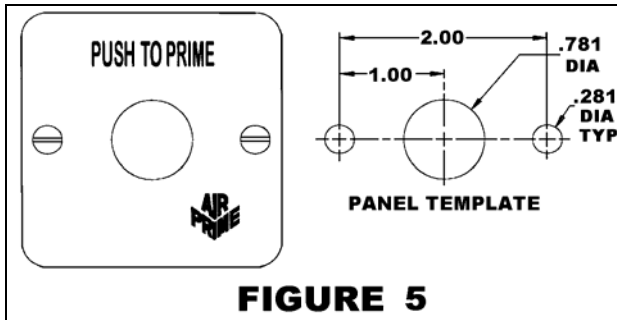


**FIGURE 5**

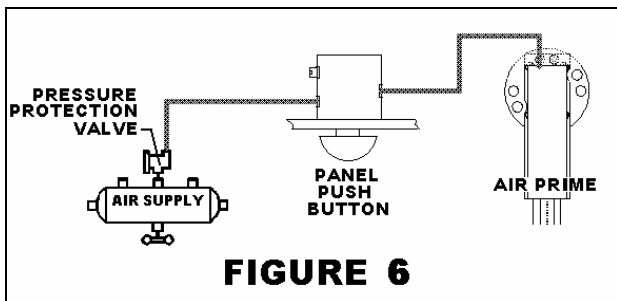The air lines for the Air Prime Manual control are connected as shown in figure 6 below.



**FIGURE 6**

Use 3/8" tubing and ¼" NPT fittings (rated for air brake service) at all connections. Keep tubing secured and free of any kinks and bends. Do not run tubing within 6" of any exhaust or other hot components.

## AIR PRIME OPERATION

The Manual Air Prime is operated simply by increasing the engine speed to a maximum of 1000-rpm and depressing the push button on the panel. Hold the button down until the discharge pressure gauge begins to rise. The primer will stop running when the push button is released. **Never run a dry pump at engine speeds above 1000 rpm.**

## ANNUAL PRIMER TESTING

There are two tests that should be performed at least on an annual basis, or whenever major repairs or modifications have been made to the pump or plumbing. They are the "Dry Vacuum Test", and the "NFPA Priming Time Test".

The **Dry Vacuum Test** checks the primer's ability to produce a 22in.-Hg vacuum, and the pump and plumbing's ability to hold that vacuum.

1. Close all valves and drains. Cap all suction openings and the outlet of the suction side relief valve (if so equipped).
2. Connect a test vacuum gauge or manometer to the intake test gauge connection on the pump panel.
3. Start with the air tanks fully charged, and run the primer until the gauge or manometer indicates 22 in-Hg or more of vacuum.
4. Watch the gauge. If the vacuum falls more than 10 in.-Hg in 5 minutes, it is a certain indication of at least one air leak. Vacuum leaks may be detected by ear if the engine is turned off. Correct leaks immediately to return the pump to a serviceable condition.

This test may be run with the pump rotating or stationary. **Never run a dry pump at engine speeds above 1000 rpm.** There is no time requirement for the vacuum to reach 22 in-Hg. If the compressor is small, it can take several minutes to reach 22 in.-Hg. This time can be shortened by not rotating the pump and increasing the engine speed to 1200 rpm.

The **NFPA 1901 Priming Time Test** demonstrates the primer's ability to lift water into the pump and create discharge pressure within the allowable time. This test is also conducted by the apparatus builder prior to delivery. The test is often run as part of an annual pump performance test, and is performed as follows:

1. Set up the apparatus in accordance with the pumping test outlined in the NFPA 1901 standard.
2. Engage the pump, and increase the throttle to a maximum engine speed of 1000 rpm.
3. With the air tanks fully charged, start the primer. Release the push button when a discharge pressure over 20 psig is obtained.
4. The time to prime should not exceed 30 seconds for 1250 gpm and smaller pumps. The time to prime should not exceed 45 seconds for 1500 gpm and larger pumps. An additional 15 seconds is allowed for pumps with auxiliary suctions having a volume of 1 cubic foot or more.

The Air Prime is designed to meet the NFPA requirements. Higher lifts and operating at higher elevations will slow down the time to prime. The air compressor rating for lifts in excess of 15 feet and elevations over 4000 feet must be at least 18.7-CFM. Operation at these extremes may require the primer to be operated at engine speeds in excess of 1000 rpm without spinning the pump, until water reaches the impeller. **Never run a dry pump at engine speeds above 1000 rpm.**

**TRIDENT**
EMERGENCY PRODUCTS, LLC

Air
Prime ™

## REPAIR / REPLACEMENT PARTS

**For Manual Air Prime Models:**
 3 Barrel  /  2 Barrel
#31.001.2 / #31.003.2 – Midship Pump Direct Mount
#31.001.7 / #31.003.7 – ¾″ NPT Mounting



WASHER
# 04.004.0

VALVE STEM
# 05.002.0

INLET COVER

2-BOLT DIRECT MOUNT
# 08.004.0 - COVER

3/4" NPT MOUNTING
# 08.004.1 - COVER
# 21.003.0 - 3/4" STRAINER

INBOARD BODY
# 07.002.1

VALVE PLATE
# 18.002.0

OUTBOARD BODY
ASSEMBLY
# 07.003.2

PISTON
# 11.001.0

REBUILD KIT
# 27.003.0
INCLUDES:
FASTENERS
SEALS
SPRING

PUSH TO PRIME

MANUAL
CONTROL
ASSEMBLY
# 27.003.1
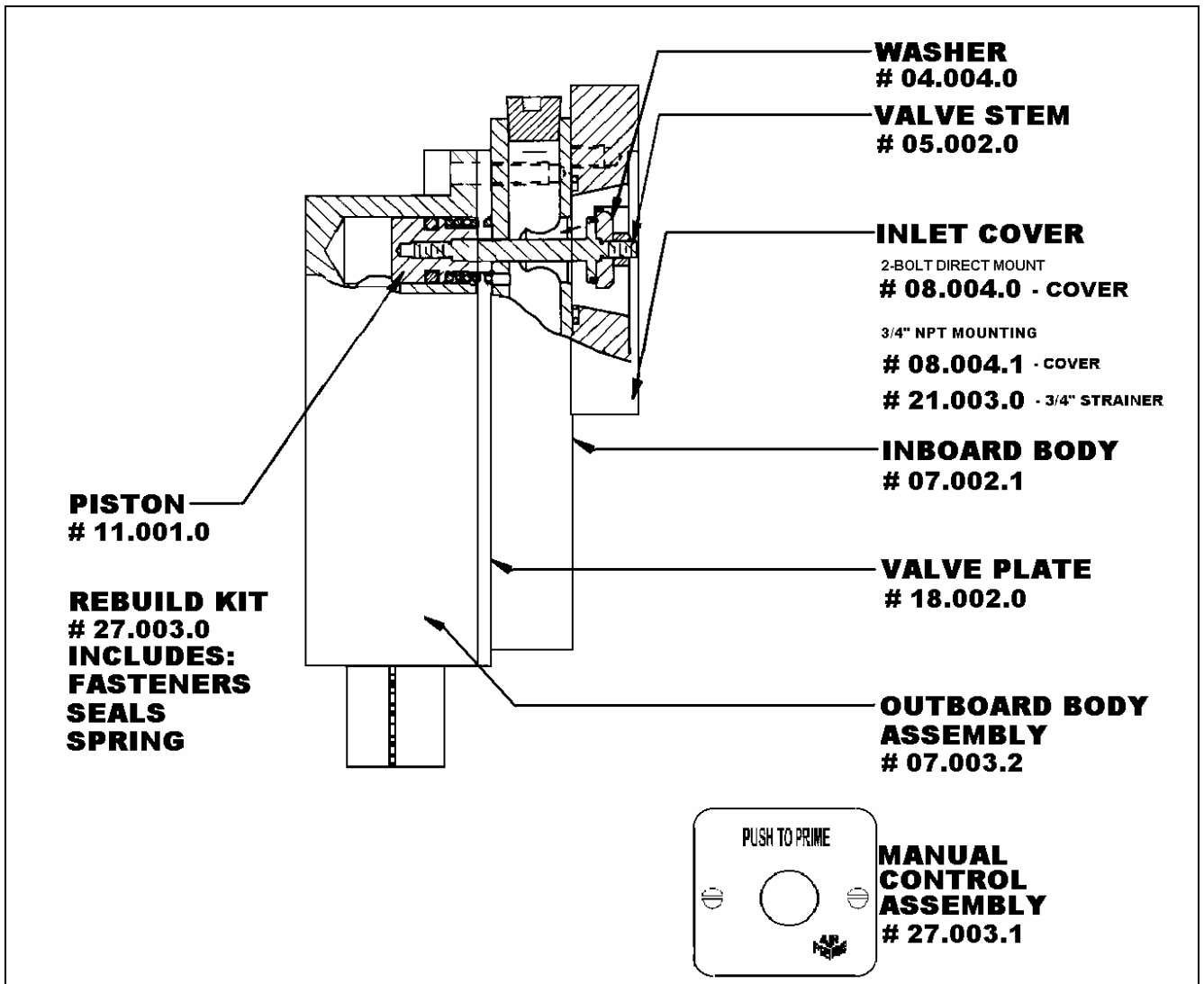
# Lift Chart

| Rated Capacity, Pump | | 500 gpm | | 750 gpm | | 1000 gpm | | 1250 gpm | 1500 gpm | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Intake Hose Size (Inches) | | 4 | 4½ | 4½ | 5 | 5 | 6 | 6 | 6 | Dual 5 | Dual 6 |
| Lift in Feet | 20' Intake Hose (Two Sections) | | | | | | | | | | |
| 4 | | 590 | 660 | 870 | 945 | 1160 | 1345 | 1435 | 1735 | 1990 | 2250 |
| 6 | | 560 | 630 | 830 | 905 | 1110 | 1290 | 1375 | 1660 | 1990 | 2150 |
| 8 | | 530 | 595 | 790 | 860 | 1055 | 1230 | 1310 | 1575 | 1810 | 2040 |
| 10 | | 500 | 560 | 750 | 820 | 1000 | 1170 | 1250 | 1500 | 1720 | 1935 |
| 12 | | 465 | 520 | 700 | 770 | 935 | 1105 | 1175 | 1410 | 1615 | 1820 |
| 14 | | 430 | 480 | 650 | 720 | 870 | 1045 | 1100 | 1325 | 1520 | 1710 |
| 16 | | 390 | 430 | 585 | 655 | 790 | 960 | 1020 | 1225 | 1405 | 1585 |
| | 30' Intake Hose (Three Sections) | | | | | | | | | | |
| 18 | | 325 | 370 | 495 | 560 | 670 | 835 | 900 | 1085 | 1240 | 1420 |
| 20 | | 270 | 310 | 425 | 480 | 590 | 725 | 790 | 955 | 1110 | 1270 |
| 22 | | 195 | 225 | 340 | 375 | 485 | 590 | 660 | 800 | 950 | 1085 |
| 24 | | 65 | 70 | 205 | 235 | 340 | 400 | 495 | 590 | 730 | 835 |

NOTES:

1-Net pump pressure is 150 psi. Operation at a lower pressure will result in an increased discharge; operation at a higher pressure, a decreased discharge.

2-Data based on a pumper with ability to discharge rated capacity when drafting at not more than a 10-foot lift. Many pumpers will exceed this performance and therefore will discharge greater quantities than shown at all lifts.

CONDITIONS: Operating at Net Pump Pressure of 150 psi; Altitude of 1000 feet; Water Temperature of 60°F; Barometric Pressure of 28.94" Hg (poor weather conditions).