This section is designed to give pump operators a quick and fairly easy process for determining fire ground hydraulics. Supplying water is a critical part of the control, and the efficient use of this water requires maintaining specified pressures and flow rates. Remember, like everything else there is an acceptable margin of error. If pressures are within 5 or 10 psi of the required psi, little of the effectiveness is lost. Also, gauges are not precise. They vibrate with the engine and two people reading the same gauge will probably read slightly different pressures.

The objective of this section is to enable the pump operator to solve any hydraulic problem within one minute with 100% accuracy. This, together with fire-ground experience, will enable the operator to supply a continuous flow of water at the desired pressure.
OBJECTIVES

- Define pump pressure and energy resistance. Describe sources of energy resistance.
- State the weight of one foot of water and elevation friction loss to the nearest tenth.
- State the friction loss rate formula for specific gpm.
- Describe, in detail, the facts a pump operator must know in order to determine pump pressure.
- State the initial set-up pressures when a request is made for water before hydraulic calculations can be made.
- Calculate pump pressure (PP) for a variety of instances.
- Identify the conversion factors to 2 1/2” hose when using other sizes of hose.
- Calculate equivalent flow conversions when converting from 2 1/2” hose to all other sizes of hose used by the Bonita-Sunnyside Fire Protection District.
- Calculate the approximate amount of available water flow at a specific hydrant.
- Describe the specific information needed to set up a relay pumping operation.
- Describe the considerations that should be examined before and during relay pumping operations.
- Calculate pump discharge maximums given the rated capacity, rated pressure, and given pressure.
- Determine, by estimation; water flow availability from specific hydrants.
- Estimate the static water pressure at a given city hydrant.
- Estimate the water capacity for water containers (e.g., Tanks, rooms, etc.)
- Describe considerations that should be made concerning the weight of water and nozzle reaction (i.e., water discharge).
- State the measurements that are specific to determining hydraulic pressure.
- Identify and recognize the gpm flow for nozzles used by the Bonita-Sunnyside Fire Protection District.
- Describe operations necessary to prepare a pumper for a service test, and when and where the test should take place.
- Describe each portion of the service test in detail.
DETERMINING PUMP PRESSURE

PUMP PRESSURE

Pump pressure is the amount of pressure in pounds per square inch (psi) indicated on the pressure gauge or any given discharge gauge. Visualize running the pump on a fire engine. You are standing at the pump panel. You are running the throttle out which increases the rpm's of the engine (and thereby the pump) and you notice the pressure gauge at the pump panel increase from 50 psi to 100 psi. This is energy created by the pump which makes the water move through the plumbing on the fire engine. The pump pressure is telling you the amount of pressure being developed at the discharge side of the pump and up to the discharge outlets on the fire engine.

In fire ground hydraulics the basic pump pressure formula for a level lay is:

\[
\text{Pump Pressure} = \text{Nozzle Pressure} + \text{Total Friction Loss}. \text{ This equation is: } PP = NP + TFL
\]

The pressure registering on the pump pressure gauge will not be the same at the nozzle because energy (pressure) is being used up overcoming friction within the hose. Friction loss is determined by recognizing that water, as a non-compressible fluid, exerts pressure equally against its confining material. Therefore, fluid pressure must be determined as a rate of water flow versus the friction index of the substance it is flowing through. Fortunately, in the case of fire hose, the friction loss rate (FLR) is a simple function of the square of the amount of water flowing. Specifically, the total gallons per minute (gpm) divided by 100 and then squared and then doubled, has been found to be an adequate fire ground formula for computing the friction loss rate.

\[
\text{FLR} = 2Q^2 \quad \text{Where } Q = \frac{\text{gpm}}{100}
\]
DETERMINING PUMP PRESSURE

As a pump operator, you must have certain facts to determine pump pressure (PP). These facts are listed in order of importance for calculating the pump pressure:

- Nozzle Pressure
- GPM flowing or Size of the nozzles tip
- Size of hose
- Length of hose in lay
- Elevation differential between pump and nozzle
- Appliance Loss
- Sprinkler System or Stand Pipe Loss,

The first five facts are needed, in all cases, to solve pump pressure. Make sure you gather these facts and put them on your scratch pad or memory bank.

NOZZLE PRESSURE

The next step in the simplification of fire ground hydraulics is to establish nozzle pressures for all nozzle streams. The Bonita-Sunnyside Fire Protection District has established the following as the desired Nozzle Pressures (NP):

<table>
<thead>
<tr>
<th>Nozzle Pressure</th>
<th>Nozzle Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 psi</td>
<td>Hand lines with smooth bore nozzles</td>
</tr>
<tr>
<td>80 psi</td>
<td>Deluge sets, monitor nozzles, or water tower equipped with a smooth bore tip</td>
</tr>
<tr>
<td>100 psi</td>
<td>All adjustable or fog nozzles</td>
</tr>
</tbody>
</table>
GPM FLOWS FOR FOG NOZZLES AND SMOOTH BORE

Fog nozzles have adjustable gpm flows that can be found labeled on the nozzle. The gpm flow depends on the settings used by the firefighter.

When pumping to an adjustable gpm fog nozzle and the gpm setting is NOT KNOWN:

- When a hose line is used for an **INTERIOR ATTACK**, use 150 gpm as your **MAXIMUM** gpm flow.
- When a hose line is used for an **EXTERIOR ATTACK**, use 200 gpm as your **MAXIMUM** gpm flow.
- When the use and gpm setting are both unknown, pump to the **highest** gpm for that nozzle. Example: When a 95, 125, 150 and 200 gpm fog nozzle is used, pump to the 200 gpm setting.

**Smooth Bore Nozzles.** The size of the straight tip nozzle plus pressure determines the gallon per minute flow, which is the major factor causing friction loss in fire hose. The larger the tip or nozzle, at a given nozzle pressure, the more friction loss involved. For any size **SMOOTH BORE** nozzle, the discharge for fresh water can be approximately determined by this formula.

\[ GPM = 30 d^2 \sqrt{NP} \]

Where \( d \) = diameter of smooth bore tip, and \( NP \) = Nozzle Pressure

**HINT**

There are only two square root numbers to choose from for these calculations.

- Hand held smooth bore - 50 psi = 7
- Deck gun, Deluge or Monitor - 80 psi = 9

See Nozzle Pressures section.
GPM FLOWS FOR SMOOTH BORE (Continued)

After calculating nozzle gpm it is necessary to round off. Round off according to the following rules:

- **Handheld (NP = 50)** smooth bore tips (wildland) ¼" to 3/8", to the **NEAREST 1 gpm**
- **Handheld (NP = 50)** smooth bore tips ½" to 1 1/8", to the **NEAREST 10 gpm**
- **Appliances (NP = 80)** 1 ¼" to 2", to the **NEAREST 100 gpm**

A list of nozzles with their respective gpms is presented near the end of this section.

**SIZE OF HOSE**

The size of hose and gpm flowing determine the amount of friction loss for each 100-foot section. With a given flow, the smaller the diameter, the more friction loss involved. This is because a greater proportion of the water pushed through actually comes into contact with the interior surface of the hose than in the case of a larger hose. A larger diameter hose allows a relatively larger percentage of the water volume to go through without contacting the interior surface.
Fire hose is limited in the amount of pressure it can sustain. Because of this, the maximum pressure we can pump to any given hose is its annual service test pressure.

The maximum Pump Pressure for fire hose is:

<table>
<thead>
<tr>
<th>TYPE</th>
<th>SIZE</th>
<th>COLOR</th>
<th>SERVICE PRESSURE &amp; MAXIMUM PUMP PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booster Line</td>
<td>¾” and 1”</td>
<td>RED</td>
<td>400 PSI</td>
</tr>
<tr>
<td>Cotton Single Jacket (Wild land)</td>
<td>1” and 1 ½”</td>
<td>TAN</td>
<td>200 PSI</td>
</tr>
<tr>
<td>Synthetic Double Jacket (Attack Line)</td>
<td>1”, 1 ¾”, 2 ½”, 3, 3 ½, &amp; 4”</td>
<td>YELLOW GREEN</td>
<td>300 PSI</td>
</tr>
<tr>
<td>Hard Suction</td>
<td>4”</td>
<td>BLACK</td>
<td>150 PSI</td>
</tr>
</tbody>
</table>

REMEMBER: When pumping through a combination of hoses, the lowest pressure hose is the determining factor for maximum pump pressure.
DETERMINING PUMP PRESSURE

EQUIVALENT FLOWS

The first step is to determine the actual number of gallons per minute flowing through the size of hose used in the lay. This is a function of the nozzle used and the pressure supplied at the nozzle.

The formula for determining friction loss rate \( FLR = 2Q^2 \) is based on gpm through 2 1/2" hose.

All flow rates through various size hoses must be converted to an equivalent flow \( EF \) as if it were flowing through 2 1/2" hose.

Converting gpm flow in other than 2 1/2" hose to equivalent flow of 2 1/2" hose

To calculate friction loss in hose other than 2 1/2", we have developed factors to convert the larger and smaller hose flows to gpm flow that creates the same amount of friction loss as in 2 1/2" hose.

These factors are based on comparison of friction in hose other than 2 1/2" to that of 2 1/2" hose

<table>
<thead>
<tr>
<th>HOSE SIZE</th>
<th>CONVERSION FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot;</td>
<td>25</td>
</tr>
<tr>
<td>1&quot;</td>
<td>9</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>3.6</td>
</tr>
<tr>
<td>1 3/4&quot;</td>
<td>2</td>
</tr>
<tr>
<td>2 1/2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>.67 OR 2/3</td>
</tr>
<tr>
<td>3 1/2&quot;</td>
<td>.4</td>
</tr>
<tr>
<td>4&quot;</td>
<td>.25</td>
</tr>
</tbody>
</table>

* THE BONITA-SUNNYSIDE FIRE PROTECTION DISTRICT NO LONGER HAS 3” HOSE ON ANY OF ITS APPARATUS. HOWEVER 3” HOSE MAY STILL BE FOUND ON OTHER DEPARTMENTS.
DETERMINING PUMP PRESSURE

EQUIVALENT FLOWS

When converting:

- ¾” hose to equivalent flow of 2 ½” hose. Multiply gpm flow from ¾” hose by 25.
- 1” hose to equivalent flow of 2 ½” hose. Multiply gpm flow from 1” hose by 9.
- 1 ½” hose to equivalent flow of 2 ½” hose. Multiply gpm flow from 1 ½” hose by 3.6.
- 1 ¾” hose to equivalent flow of 2 ½” hose. Multiply gpm flow from 1 ¾” hose by 2.0.
- 2 ½” hose does not need converting to 2 ½ “ hose.
- 3” hose to equivalent flow of 2 ½” hose. Multiply gpm flow from 1 ¾” hose by .67
- 3 ½” hose to equivalent flow of 2 ½” hose. Multiply gpm flow from 3 ½” hose by .4.
- 4” hose to equivalent flow of 2 ½” hose. Multiply gpm flow from 4” hose by the factor .25.

After the flow is computed it is treated as a 2 ½” hose, this flow is rounded off as 2 ½” hose to the NEAREST 10 gpm.

LENGTH OF HOSE IN LAY

In order to solve the amount of friction loss in a hose lay you must know the entire length of the hose lay. Friction loss rate factors are computed on 100' lengths of hose. When hose is doubled, as in the case of a siamese lay, it is necessary to average the lengths. This procedure will be described later. Remember: \( L = \frac{\text{total length of hose in feet}}{100} \).
DETERMINING PUMP PRESSURE

ELEVATION DIFFERENTIAL BETWEEN PUMP AND NOZZLE

Elevation differential is also called head, gravity loss or gravity gain. When hose lines are laid up or down an elevation, such as inclines, stairways, fire escapes, canyons, or the face of a building, the pressure loss or gain in pounds per square inch, which is exerted by the head of water, must be compensated for. If energy (pressure) is gained by water going down then you must subtract head. If energy (pressure) is lost by pushing water up then you must add head.

Head is the height of water. One foot of head is equivalent to a column of water one-foot high. Head becomes pressure because a column of water one foot high by one square inch weighs 0.434 pounds. For fire ground hydraulics this weight has been rounded to 0.5 pounds. The pressure is proportional to the height of the liquid column alone, and not to the size or shape of the vessel.

Head is very much like climbing up or down a ladder. As you climb up a ladder you must exert strength (pressure) in your legs and arms to reach the desired elevation. When descending a ladder gravity exerts a pull upon your body. If you lost your footing and fell, your body would gain tremendous downward pressure. The amount of pressure developed would determine the force of impact. The longer the fall in elevation, the greater the pressure.

Energy (pressure) is used up when pumping water higher than the pump. Water weighs 8.35 pounds per gallon and the effort of lifting this weight uses up some of the engine pressure. It takes 0.434 psi to lift water one foot. For fireground hydraulics this figure has been rounded off to 0.5 psi.

Just as it takes energy to lift water, energy is gained by dropping water. In fact, an equal 0.434 psi is gained in energy for every one-foot water drops in elevation. For fireground hydraulics this figure has been rounded off to 0.5 psi.

When calculating the Gravity Loss in a high-rise building calculate 5 pounds per floor.
DETERMINING PUMP PRESSURE

ELEVATION DIFFERENTIAL BETWEEN PUMP AND NOZZLE

REMEMBER

\[ \text{Gravity Loss (GL) - ADD Pressure} \]
\[ \text{Gravity Gain (GG) - SUBTRACT Pressure} \]

INITIAL PUMP PRESSURE

Often a pump operator will get the request for water before accurate hydraulic calculations can be made. In this situation the standard operating procedure will be to pump the pressures given below for the following cases:

- **ALL HAND LINES**: 0-400’ = 125 psi, 400-800’ = 175 psi, 800+ =200 psi
  OR
  Initial Pump Pressure = NOZZLE PRESSURE + GL or – GG

- **ELEVATED STREAMS**: Initial Pump Pressure = **150** psi

- **SPRINKLER and STANDPIPE SYSTEMS**: Initial Pump Pressure = **150** psi.
EXAMPLE OF FIRE GROUND HYDRAULICS AND WRITTEN HYDRAULICS

NOTE: RULES WILL HAVE AN ASTERISKS (*) AND BE UNDERLINED

The following example will show how fire ground hydraulics is tied directly to written hydraulics:

250 gpm SOF nozzle, 250 gpm setting, 450' of 2 ½" hose, PP =?

Initial pump pressure = 100 psi

In fire ground hydraulics the pump pressure formula for a level lay is:

\[
PP = NP + TFL \\
TFL = FLR \times L \\
FLR = 2Q^2 \\
Q = \frac{GPM}{100}
\]

Working this out step-by-step would look like this:

- **Step One**: Determine the **Nozzle Pressure** (NP) for a fog nozzle. **NP = 100 psi**
- **Step Two**: Determine the **GPM Flow** = 250 gpm
EXAMPLE OF FIRE GROUND HYDRAULICS AND WRITTEN HYDRAULICS

- **Step Three**: Calculate the Friction Loss Rate (FLR)

  \[
  \text{FLR} = 2Q^2 \\
  \text{FLR} = 2 \left(\frac{\text{gpm}}{100}\right)^2 \quad \text{for } 2\frac{1}{2}'' \text{ flows} \\
  \text{FLR} = 2 \left(\frac{250}{100}\right)^2 = 2.5 \\
  \text{FLR} = 2(2.5)^2 \\
  \text{FLR} = 2 \times 6.25 = 12.5 \\
  \text{Round off } 12.5 \text{ to } 13 \\
  \text{FLR} = 13 \text{ psi}
  \]

- **HINT**

  Squaring a .5 number such as (2.5), subtract .5 from one 2.5 and add .5 to the other.

  \[
  2.5 - .5 = 2 \quad \text{and} \quad 2.5 + .5 = 3
  \]

  In this example it would give you the numbers 2 and 3.

  Multiply 2 x 3 = 6 - Now Add .25

  Answer 6.25

- **HINT**

  For 2 ½” flows between 180 & 320 subtract 12 from the first 2 numbers.

  \[
  (250 - 12 = 13)
  \]

  See friction loss table in appendix

- **Step Three**: Determine Length (L) of the hose

  \[
  L = \frac{\text{total feet}}{100} \\
  L = 450 \\
  L = 4.5
  \]

- **Step Four**: Calculate Total Friction Loss (TFL)

  \[
  \text{TFL} = \text{FLR} \times L \\
  \text{TFL} = 13 \times 4.5 = 58.5 \\
  \text{Round off } 58.5 \text{ to } 59 \\
  \text{TFL} = 59 \text{ psi}
  \]

- **Finally**: Add together the Nozzle Pressure and Total Friction Loss to equate the Pump Pressure.

  \[
  \text{PP} = \text{NP} + \text{TFL} \\
  \text{PP} = 100 + 59 \\
  \text{PP} = 159 \text{ psi}
  \]
Hand lines - Straight Lay – Smooth Bore Tip

Example: 1" tip, 650' of 2 ½" hose, PP =?

Initial pump pressure = 50 psi

- **Step One:** NP = 50 psi.

- **Step Two:** GPM = 30d²√NP
  
  GPM = 30 x 1² x √50
  
  GPM = 30 x 1 x 7
  
  GPM = 210

- **Step Three:** FLR = 2Q²
  
  FLR = 2(gpm)²
  
  100
  
  FLR = 2(210)² = 2.1
  
  100
  
  FLR = 2 x (2.1)²
  
  FLR = 2 x 4.41
  
  FLR = 8.82, round to nearest one psi = 9 psi
  
  FLR = 9 psi

**HINT**

For 2 ½" flows between 180 & 320 subtract 12 from the first 2 numbers.

(210 - 12 = 9)

See friction loss table in appendix
**Hand Lines - Straight Lay – Smooth Bore Tip**

- **Step Four**: \( L = \frac{\text{total feet}}{100} \)
  
  \[
  L = \frac{650}{100} = 6.5
  \]

- **Step Five**: \( \text{TFL} = \text{FLR} \times L \)
  
  \[
  \text{TFL} = 9 \times 6.5 = 58.5 \text{ round to nearest one psi} = 59 \text{ psi}
  \]

\[
\begin{align*}
\text{PP} &= \text{NP} + \text{TFL} \\
\text{PP} &= 50 + 59 \\
\text{PP} &= 109 \text{ psi}
\end{align*}
\]
**Hand lines - Gravity Loss**

Example: 2 ½" SOF nozzle, 250 gpm setting, 600' of 2 ½" hose, nozzle 40' Above pump level, PP = ?

**Initial Pump Pressure = NP + GL**

\[
IPP = 100 + 20 = 120 \text{ psi}
\]

**Step One:** Flow = 250 gpm

**Step Two:** FLR = \(2Q^2\)

\[
\begin{align*}
\text{FLR} & = 2 \left( \frac{\text{gpm}}{100} \right)^2 \\
& = 2 \left( \frac{250}{100} \right)^2 \\
& = 2 \times 6.25 = 12.5 \\
\text{Round off 12.5 to 13} \\
\text{FLR} & = 13 \text{ psi}
\end{align*}
\]

**HINT**

For 2 ½" flows between 180 & 320 subtract 12 from the first 2 numbers.

\[
(250 - 12 = 13)
\]

See friction loss table in appendix

**HINT**

Squaring a .5 number such as (2.5), subtract .5 from one 2.5 and add .5 to the other.

\[
2.5 - .5 = 2 \quad 2.5 + .5 = 3
\]

In this example it would give you the numbers 2 and 3.

Multiply 2 x 3 = 6, now Add .25

Answer 6.25
HYDRAULIC SET-UPS AND CALCULATIONS

**Hand lines - Gravity Loss**

GRAVITY LOSS OR GRAVITY GAIN, ALLOW .5 PSI FOR EACH VERTICAL FOOT OF ELEVATION*

- **Step Three:** \( L = \frac{\text{total feet}}{100} \)
  
  \[
  \begin{align*}
  L &= \frac{600}{100} \\
  L &= 6 
  \end{align*}
  \]

- **Step Four:** \( TFL = \text{FLR} \times L \)
  
  \[
  \begin{align*}
  TFL &= 13 \times 6 = 78 \\
  TFL &= 78 \text{ psi} 
  \end{align*}
  \]

- **Step Five:** \( ^*\text{GL} = .5 \times H \)
  
  \[
  \begin{align*}
  \text{GL} &= .5 \times 40 = 20 \\
  \text{GL} &= 20 \text{ psi} 
  \end{align*}
  \]

**HINT**

Multiplying a .5 number is the same as halving or dividing by 2. 
\((40 \div 2 = 20)\)

\[
\begin{align*}
\text{PP} &= \text{NP} + \text{TFL} + \text{GL} \\
\text{PP} &= 100 + 78 + 20 \\
\text{PP} &= 198 \text{ psi}
\end{align*}
\]
Hand lines - Gravity Gain

Example: 1 1/8" tip, 500' of 2 1/2" hose, nozzle 30' below the pump level, PP =?

Initial pump pressure = NP - GG

\[ \text{IPP} = 50 - 15 = 35 \text{ psi} \]

\[ \text{Initial pump pressure} = \text{NP} - \text{GG} \]

\[ \text{IPP} = 50 - 15 = 35 \text{ psi} \]

\[ \text{HINT} \]

To convert a fraction to a decimal: divide the numerator by the denominator.

\[ 1 ÷ 8 = .125 \]

\[ \text{Step One: } 1-1/8" \text{ tip @ 50 psi} \]

\[ 30 \frac{d^2}{\sqrt{NP}} \]

\[ 30 \times (1.125)^2 \times 7 \]

\[ 30 \times 1.265 \times 7 = 265.78 \]

Round 265.78 to 270

Flow = 270 gpm

\[ \text{Step Two: } \text{FLR} = 2Q^2 \]

\[ \text{FLR} = 2 \left( \frac{\text{gpm}}{100} \right)^2 \]

\[ \text{FLR} = 2 \left( \frac{270}{100} \right)^2 = 2.7 \]

\[ \text{FLR} = 2 \left( 2.7 \right)^2 \]

\[ \text{FLR} = 2 \times 7.29 = 14.58 \]

Round off 14.58 to 15

FLR = 15 psi

\[ \text{HINT} \]

For 2 1/2" flows between 180 & 320 subtract 12 from the first 2 numbers.

\[ 270 - 12 = 15 \]

See friction loss table in appendix
Hand Lines - Gravity Gain

GRAVITY LOSS OR GRAVITY GAIN, ALLOW .5 PSI FOR EACH VERTICAL FOOT OF ELEVATION.*

- **Step Three**: \( L = \frac{\text{total feet}}{100} \)
  
  \[
  L = \frac{500}{100} = 5
  \]

- **Step Four**: \( \text{TFL} = \text{FLR} \times L \)
  
  \[
  \text{TFL} = 15 \times 5 = 75 \text{ psi}
  \]

- **Step Five**: \( *\text{GG} = .5 \times H \)
  
  \[
  \text{GG} = .5 \times 30 = 15 \text{ psi}
  \]

**HINT**

Multiplying a .5 number is the same as halving or dividing by 2. 
(30 ÷ 2 = 15)

**PP = NP + TFL - GG**

\[
\text{PP} = 50 + 75 - 15 \\
\text{PP} = 110 \text{ psi}
\]
CONVERTING 1 ¾" HOSE FLOW TO EQUIVALENT FLOW FROM 2 ½" HOSE. MULTIPLY GPM FLOW FROM 1 ¾" HOSE BY FACTOR 2.*

Example: 1 ¾" SOF nozzle, 200' of 1 ¾" hose, nozzle set at 125 gpm.

Initial pump pressure - NP = 100

Step One: Flow = 125 gpm
*EF = Factor x gpm
EF for 1 ¾" hose = 2 x 125
EF = 250 gpm

Step Two: FLR = 2Q^2
FLR = 2 (gpm)^2
FLR = 2 (250)^2 = 2.5
FLR = 2(2.5)^2
FLR = 2 x 6.25 = 12.5
Round off 12.5 to 13
FLR = 13 psi

HINT
For 2 ½" flows between 180 & 320 subtract 12 from the first 2 numbers.
(250 – 12 = 13)
See friction loss table in appendix

HINT
Squaring a .5 number such as (2.5), subtract .5 from one 2.5 and add .5 to the other.
2.5 - .5 = 2
2.5 + .5 = 3
In this example it would give you the numbers 2 and 3.
Multiply 2 x 3 = 6, now Add .25
Answer 6.25
Hand lines – 1 ¾” Hose

- **Step Three:** \[ L = \frac{\text{total feet}}{100} \]
  
  \[
  L = \frac{200}{100} \\
  L = 2
  \]

- **Step Four:** \[ TFL = FLR \times L \]
  
  \[
  TFL = 13 \times 2 = 26 \\
  TFL = 26 \text{ psi}
  \]

\[
\begin{array}{|c|c|}
\hline
PP &= NP + TFL \\
PP &= 100 + 26 \\
PP &= 126 \text{ psi} \\
\hline
\end{array}
\]

**Time to Recap:**

1st: NP
2nd: Flow (either the GPM setting (FOG) or (smooth bore) GPM= \(30 \sqrt{d^2 \times NP}\))
3rd: FLR
4th: Length
5th: TFL= FLR x L
6th: PP= NP + TFL
**HYDRAULIC SET-UPS AND CALCULATIONS**

**Hand lines – Multiple 1 ¾” Hose lines**

PUMP TO THE HIGHEST LINE AND GATE DOWN THE SECOND LINE *

Example: Two 1 ¾” hand lines, one 200’ and 175 gpm, the second is 150’ and 150 gpm.

Initial pump pressure - NP = 100

- **Step One**: EF = Factor x gpm
  - Flow (a) = 175 gpm
  - EF (a) for 1 ¾” hose = 2 x 175 = 350
  - EF (a) = 350 gpm
  - Flow (b) = 150 gpm
  - EF (b) for 1 ¾” hose = 2 x 150 = 300
  - EF (b) = 300 gpm

- **Step Two**: FLR = \(2Q^2\)
  - FLR (a) = \(2 \times (350)^2 = 3.5 \times 350 = 1225\)
  - FLR (a) = \(24.5\)
  - Round off 24.5 to 25
  - FLR (a) = \(25\)
  - FLR (b) = \(2 \times (300)^2 = 3 \times 300 = 900\)
  - FLR (b) = \(18\)
**Hand lines – Multiple 1 ¾” Hose lines**

**HINT**

Squaring a .5 number such as (3.5), subtract .5 from one 3.5 and add .5 to the other.

3.5 - .5 = 3  
3.5 + .5 = 4

In this example it would give you the numbers 3 and 4.

Multiply 3 x 4 = 12, now Add .25

Answer **12.25**

**Step Three:**

L = \( \frac{\text{total feet}}{100} \)

L (a) = 200  
\( \frac{100}{100} \)

L (a) = 2  
L (b) = 150  
\( \frac{100}{100} \)

L (b) = 1.5

**Step Four:**

TFL = FLR x L

\* 1\textsuperscript{st} Pressure (a)  
\* 2\textsuperscript{nd} Pressure (b) (Gated Down)

TFL = 25 x 2 = 50  
TFL = 18 x 1.5 = 27

TFL = 50 psi  
TFL = 27 psi

\[ PP = NP + TFL \]

(a) PP = 100 + 50  
(b) PP = 100 + 27

*PP = 150 psi  
2\textsuperscript{nd} or GP = 127

(a) **Pump Pressure = 150**

(b) **Gated Pressure = 127 psi**
Hand lines – 1 ¾” Hose – Structure Progressive Lay

Example: 150’ of 1 ¾” hose with 95 gpm SOF, - ADD 150’ of 1 ¾” hose. PP = ?

Initial pump pressure - NP = 100

➢ Step One: Flow = 95 gpm

*EF = Factor x gpm

EF for 1 ¾” hose = 2.0 x 95

EF = 190 gpm
Hand lines – 1 ¾” Hose – Structure Progressive Lay

- **Step Two:** $FLR = 2Q^2$
  
  FLR = 2 \( \left( \frac{gpm}{100} \right)^2 \)
  
  FLR = 2 \( \left( \frac{190}{100} \right)^2 \) = 1.9
  
  FLR = 2(1.9)^2
  
  FLR = 2 \times 3.61 = 7.22
  
  Round off 7.22 to 7
  
  FLR = 7 psi

- **Step Three:** $L = \text{total feet} \times \frac{1}{100}$
  
  L = \( \frac{150}{100} \)
  
  First L = 1.5
  
  With Second line added, L = 3

- **Step Four:** $TFL = FLR \times L$
  
  First TFL = 7 \times 1.5 = 10.5
  
  Round off 10.5 to 11
  
  TFL = 11
  
  Second TFL (line added) = 7 \times 3 = 21
  
  TFL = 21

**HINT**

For 2 ½” flows between 180 & 320 subtract 12 from the first 2 numbers.

\((190 - 12 = 7)\)

See friction loss table in appendix

$$PP = NP + TFL$$

PP#1 = 100 + 11  
PP#2 = 100 + 21

PP #1 = 111 psi  
PP #2 = 121 psi
Hand lines – 1 ½” Hose

CONVERTING 1 ½” HOSE FLOW TO EQUIVALENT FLOW FROM 2 ½” HOSE. MULTIPLY GPM FLOW FROM 1 1/2” HOSE BY FACTOR 3.6.*

Example: 3/8” straight tip, 800’ of 1 ½” hose. PP = ?

Initial pump pressure - NP = 50

Step One: 3/8” tip @ 50 psi

\[ 30 \times \left( \frac{d}{2} \right)^2 \sqrt{\text{NP}} \]

\[ 30 \times \left( \frac{3}{2} \right)^2 \times 7 \]

\[ 30 \times 0.141 \times 7 = 29.61 \]

Round off 28.61 to 30

Flow = 30 gpm

*EF = Factor x gpm

EF for 1 ½” hose = 3.6 x 30 = 108

EF = 110 gpm

HINT

To convert a fraction to a decimal: divide the numerator by the denominator.

\[ \frac{3}{8} = 0.375 \]

OR

\[ 30 \times d^2 \times \sqrt{\text{NP}} \]

\[ \frac{30 \times 3 \times 3 \times 7}{1 \times 8 \times 8 \times 1} = 1890 = 29.53 = 30 \text{ gpm} \]

HINT

Convert and round off to the nearest 10 gpm.
**Hand lines – 1 ½” Hose**

- **Step Two**: \( FLR = 2Q^2 \)
  
  \[
  FLR = 2 \left( \frac{gpm}{100} \right)^2 \]
  
  \[
  FLR = 2 \left( \frac{110}{100} \right)^2 = 1.1
  \]
  
  \[
  FLR = 2(1.1)^2
  \]
  
  \[
  FLR = 2 \times 1.21
  \]
  
  \[
  FLR = 2.42
  \]
  
  \[
  FLR = 2 \text{ psi}
  \]

- **Step Three**: \( L = \frac{\text{total feet}}{100} \)
  
  \[
  L = \frac{800}{100}
  \]
  
  \[
  L = 8
  \]

- **Step Four**: \( TFL = FLR \times L \)
  
  \[
  TFL = 2 \times 8 = 16 \text{ psi}
  \]

\[
PP = NP + TFL
\]

\[
PP = 50 + 16
\]

\[
PP = 66 \text{ psi}
\]
**Hand lines – 1” Hose**

CONVERTING 1” HOSE FLOW TO EQUIVALENT FLOW FROM 2 1/2” HOSE. MULTIPLY GPM FLOW FROM 1” HOSE BY FACTOR 9.*

Example: 1” SOF nozzle, 24 gpm, and 250’ of 1” hose, PP =?

Initial pump pressure = **100** psi

**Step One:** Flow = 24 gpm

*EF = Factor x gpm
EF for 1” hose = 9 x 24 = 216
Round off 216 to 220
EF = **220** gpm

**Step Two:** FLR = \(2Q^2\)

\[
FLR = 2 \cdot \left(\frac{gpm}{100}\right)^2
\]

\[
FLR = 2 \cdot \left(\frac{220}{100}\right)^2 = 2.2
\]

FLR = \(2(2.2)^2\)

FLR = \(2 \times 4.84 = 9.68\)
Round 9.68 off to 10
FLR = **10** psi

**HINT**
Convert and round off to the nearest 10 gpm.

**HINT**
For 2 ½” flows between 180 & 320 subtract 12 from the first 2 numbers.

\((220 - 12 = 10)\)

See friction loss table in appendix
Hand lines – 1” Hose

- **Step Three:** \( L = \frac{\text{total feet}}{100} \)
  
  \[
  L = \frac{250}{100} = 2.5
  \]

- **Step Four:** \( TFL = \text{FLR} \times L \)
  
  \[
  TFL = 10 \times 2.5 = 25
  \]

\[
PP = NP + TFL
PP = 100 + 25
PP = 125 \text{ psi}
\]
**Hand lines – Red line**

CONVERTING ¾" AND 1" HOSE FLOW TO EQUIVALENT FLOW FROM 2 ½" HOSE: MULTIPLY GPM FLOW FROM ¾" HOSE BY FACTOR 25 and 1" HOSE BY FACTOR 9.*

Example: 1" SOF nozzle, 24 gpm, and 100' of 1" and 150' of ¾" hose PP =?

Initial pump pressure = 100 psi

**Step One:** Flow = 24 gpm

*EF = Factor x gpm

FLOW THROUGH 1"

EF(a) = 9 x 24 = 216

Round off 216 to 220

EF(a) for 1" hose = 220 gpm

FLOW THROUGH ¾"

EF(b) = 25 x 24 = 600

EF(b) for ¾" hose = 600 gpm

**Step Two:** FLR = \(2Q^2\)

FLR = \(2 \frac{(220)^2}{100}\) = 2.2

FLR(a) = 2(2.2)^2

FLR(a) = 2 x 4.84 = 9.68

Round 9.68 off to 10

FLR(a) = 10 psi

FLR = \(2 \frac{(600)^2}{100}\) = 6

FLR(b) = 2(6)^2

FLR(b) = 2 x 36

FLR(b) = 72 psi
Hand lines – Red line

**HINT**

For 2 ½" flows between 180 & 320 subtract 12 from the first 2 numbers.

\((220 - 12 = 10)\)

See friction loss table in appendix

- **Step Three**: \( L = \frac{\text{total feet}}{100} \)
  - \( L = \frac{100}{100} = 1 \)
  - \( L = \frac{150}{100} = 1.5 \)

- **Step Four**: Line A Line B
  - \( \text{TFL} = (FLR \times L) + (FLR \times L) \)
  - \( 1" \) hose FL (a) = 10 x 1 = 10
  - \( ¾" \) hose FL (b) = 72 x 1.5 = 108
  - \( \text{TFL} = 10 + 108 = 118 \)

**PP = NP + TFL**
- \( \text{PP} = 100 + 118 = 218 \text{ psi} \)
Siamese Lines (Equal Length)

FOR EQUAL SIAMESE LINES DIVIDE FLOW AND CALCULATE FOR ONE LINE.*

Example: 1 1/8" tip, 50 psi NP, two 400' lines of 2 1/2" hose into one 100' line of 2 1/2" hose.

Initial pump pressure = 50 psi

Step One: 1 1/8" tip @ 50 psi

30 d² \( \sqrt{NP} \)
30 x (1.125)² x 7
30 x 1.27 x 7 = 266.7
Round off 266.7 to 270
Flow = 270 gpm

*Flow through one line (a) = \( \frac{270}{2} \)

Flow (a) = 135 gpm (round off to 140)

HINT

When the problem has equal siamese lines, halve the gpm through the two lines and calculate as if it was a single line.
Siamese Lines (Equal Length)

- **Step Two**: FLR = \(2Q^2\)
  - FLR = \(2 \left(\frac{\text{gpm}}{100}\right)^2\)
  - FLR = \(2 \left(\frac{140}{100}\right)^2\)
  - FLR(a) = \(2(1.4)^2\)
  - FLR(a) = 2 x 1.96
  - FLR(a) = 3.92 round off to 4 psi
  - FLR(b) = \(2 \left(\frac{\text{gpm}}{100}\right)^2\)
  - FLR = \(2 \left(\frac{270}{100}\right)^2\)
  - FLR(b) = \(2(2.7)^2\)
  - FLR(b) = 2 x 7.29
  - FLR(b) = 14.58 round off to 15 psi

- **Step Three**: \( L = \frac{\text{total feet}}{100} \)
  - L(a) = \(\frac{400}{100}\)
  - L(a) = 4
  - L(b) = \(\frac{100}{100}\)
  - L(b) = 1

- **Step Four**: Line A \hspace{1cm} Line B
  - TFL = (FLR x L) + (FLR x L)
  - FL(a) = 4 x 4 + FL(b) = 15 x 1
  - FL(a) = 16 + FL(b) = 15
  - TFL = 16 + 15 = 31 psi

\[
\text{PP} = \text{NP} + \text{TFL} \\
\text{PP} = 50 + 31 \hspace{1cm} \text{PP} = 81 \text{ psi}
\]
Siamese Lines (Unequal Length)

UNEQUAL SIAMESE LINES, AVERAGE THE LENGTHS AND CALCULATE FLOW.*

Example: 250 gpm SOF nozzle connected to 50’ of 2 ½” hose and two siamese lines:
One siamese line (a) = 250’ of 2 ½” hose. Second siamese line (b) = 350’ of 2 ½” hose. PP = ?

Initial pump pressure = 100 psi

**Step One:** Flow = 250 gpm

*Flow through one siamese line = \( \frac{250}{2} \)

Flow through one siamese line = 125 gpm

Round off Flow through one siamese line (ab) to = 130 gpm

**Step Two:** FLR = \( 2Q^2 \)

<table>
<thead>
<tr>
<th>Line A &amp; B</th>
<th>Line C</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLR = ( 2 \frac{(gpm)^2}{100} )</td>
<td>FLR = ( 2 \frac{(gpm)^2}{100} )</td>
</tr>
<tr>
<td>FLR = ( 2 \frac{(130)^2}{100} = 1.3 )</td>
<td>FLR = ( 2 \frac{(250)^2}{100} = 2.5 )</td>
</tr>
<tr>
<td>FLR (ab) = ( 2(1.3)^2 )</td>
<td>FLR(c) = ( 2(2.5)^2 )</td>
</tr>
<tr>
<td>FLR (ab) = 2 x 1.69 = 3.38</td>
<td>FLR(c) = 2 x 6.25 = 12.5</td>
</tr>
<tr>
<td>Round off 3.38 to 3</td>
<td>Round off 12.5 to 13</td>
</tr>
<tr>
<td>FLR (ab) = 3</td>
<td>FLR(c) = 13</td>
</tr>
</tbody>
</table>
Siamese Lines (Unequal Length)

- **Step Three**: Determine average lengths of siamesed supply lines

  TO DETERMINE L, AVERAGE THE LENGTHS OF SUPPLYING LINES. *

  When the average comes out to a $\frac{1}{4}$ or $\frac{3}{4}$ length, round off to the nearest $\frac{1}{2}$ or full length respectively.

  *Average Length of Siamese lines = $\frac{L(a) + L(b)}{2}$

  *Average length = $\frac{250 + 350}{2} = 300$

  Siamese lines - Average length (ab) = 300'

  Length (c) - Single line = 50

  \[
  L = \frac{\text{total feet}}{100} \\
  L(ab) = \frac{300}{100} = 3 \\
  L(c) = \frac{50}{100} = .5
  \]

- **Step Four**: Line A&B Line C

  \[
  \text{TFL} = (\text{FLR} \times L) + (\text{FLR} \times L) \\
  \text{TFL} = \text{FL} = 3 \times 3 + \text{FL} = 13 \times .5 \\
  \text{TFL} = \text{FL} = 9 + \text{FL} = 6.5 \text{ (round off to 7)} \\
  \text{TFL} = 9 + 7 = 16
  \]

  \[
  \text{PP} = \text{NP} + \text{TFL} \\
  \text{PP} = 100 = 16 \\
  \text{PP} = 116 \text{ psi}
  \]
**Wyed Lines (Equal Length and Flow)**

Example: Two 1 1/8" tips; two 2 ½" hose lines, each 100' long, wyed from one 2 ½" hose line 200' long. PP = ?

Initial pump pressure = 50 psi

![Diagram of fireground hydraulics](image)

**TO DETERMINE THE FLOW IN THE SUPPLY LINE, COMBINE NOZZLE FLOWS.***

**Step One:** 1 1/8" tip @ 50 psi

\[
30 \cdot \frac{d^2}{\sqrt{NP}}
\]

\[
30 \times (1.125)^2 \times 7
\]

\[
30 \times 1.266 \times 7 = 268.8
\]

Round off 265.8 to 270

Flow = 270 gpm through **ONE** line

*Double gpm flow for **SINGLE LINE** (a) = 270 + 270 = 540

*Flow through single line (a) = **540** gpm

Flow in one line of wye (b) = **270** gpm
Wyed Lines (Equal Length and Flow)

- **Step Two**: FLR = \(2Q^2\)
  
  \[
  \begin{align*}
  &FLR = 2 \left( \frac{540}{100} \right)^2 = 5.4 \\
  &FLR = 2 \left( \frac{270}{100} \right)^2 = 2.7 \\
  &FLR(a) = 2(5.4)^2 \\
  &FLR(b) = 2(2.7)^2 \\
  &FLR(a) = 2 \times 29.16 \\
  &FLR(b) = 2 \times 7.29 \\
  &FLR(a) = 58.32 \\
  &FLR(b) = 14.58 \\
  &\text{Round off 58.32 to 58} \\
  &\text{Wye line FLR(b) = 15} \\
  &\text{Single line FLR(a) = 58 psi}
  \end{align*}
  \]

- **Step Three**: \(L = \text{total feet} \times \frac{1}{100}\)
  
  \[
  \begin{align*}
  &L(a) = 200 \\
  &L(b) = 100 \\
  &\text{Single line - } L(a) = 2 \\
  &\text{Wye line - } L(b) = 1
  \end{align*}
  \]

- **Step Four**: TFL = FLR(a) \times L(a) + FLR(b) \times L(b)
  
  \[
  \begin{align*}
  &TFL = FL(a) = 58 \times 2 + FL(b) = 15 \times 1 \\
  &TFL = FL(a) = 116 + FL(b) = 15 \\
  &TFL = 116 + 15 = 131 \text{ psi}
  \end{align*}
  \]

**HINT**

Only pump for one of the Wyed lines

\[
\begin{align*}
PP &= NP + TFL \\
PP &= 50 + 131 \\
PP &= 181 \text{ psi}
\end{align*}
\]
Wyed Lines (Unequal Length)

Example: Two 1" tips; Line (c) 400' of 2 ½" hose, Line (b) 200' of 2 ½" hose wyed from 150' of 2 ½" hose Line (a). PP =?

Initial pump pressure = 50 psi

TO DETERMINE L, AVERAGE LENGTHS OF WYED LINES. * When the average comes out to a ¼ or ¾ length, round off to the nearest ½ or full length respectively.

**Step One:** 1" tip @ 50 psi

\[ 30 \frac{d^2}{\sqrt{NP}} \]

\[ 30 \times (1)^2 \times 7 \]

\[ 30 \times 1 \times 7 = 210 \]

Flow = 210 gpm through **ONE** line

Double gpm flow for **SUPPLY LINE** (a) = 210 + 210

Flow through single line (a) = **420** gpm

Flow for one wye line = **210** gpm

**Step Two:** \( \text{FLR} = \frac{2Q^2}{100} \)

\[ \text{FLR} = 2 \left( \frac{420}{100} \right)^2 = 4.2 \]

\[ \text{FLR} = 2 \left( \frac{210}{100} \right)^2 = 2.1 \]
Wyed Lines (Unequal Length)

Step Two continued:

\[
\begin{align*}
\text{FLR}(a) &= 2(4.2)^2 \\
&= 2 \times 17.64 \\
&= 35.28 \\
\text{Round off 35.28 to 35} \\
\text{FLR in single line (a) } &= 35 \text{ psi}
\end{align*}
\]

\[
\begin{align*}
\text{FLR}(b) &= 2(2.1)^2 \\
&= 2 \times 4.41 \\
&= 8.82 \\
\text{Round off 8.82 to 9} \\
\text{FLR in one wye line (b) } &= 9
\end{align*}
\]

Step Three: \( L = \frac{\text{total feet}}{100} \)

TO DETERMINE \( L \) FOR THE WYED LINES, AVERAGE THE LENGTHS OF THE TWO LINES.*

\[
\begin{align*}
* \quad L(b) &= \frac{L(b) + L(c)}{2} \\
*\text{Average Length} &= \frac{400' + 200'}{2} \\
*\text{Average Length} &= \frac{600}{2} \\
*\text{Average Length} &= 300'
\end{align*}
\]

\[
\begin{align*}
L(a) &= \frac{150}{100} \\
&= 1.5 \\
L(bc) &= \frac{300}{100} \\
&= 3
\end{align*}
\]

Step Four: \( TFL = \text{FLR}(a) \times L(a) + \text{FLR}(b) \times L(b) \)

\[
\begin{align*}
TFL &= \text{FL}(a) = 35 \times 1.5 + \text{FL}(b) = 9 \times 3 \\
&= 52.5 + 27 \\
&= 80 \text{ psi}
\end{align*}
\]

\[
\begin{align*}
PP &= \text{NP} + TFL \\
&= 50 + 80 \\
&= 130 \text{ psi}
\end{align*}
\]

HINT
Only calculate for one of the Wyed lines
Wyed Lines (Unequal Flows)

Example: 2 tips, Line A 1" tip, 200' of 2½" hose; Line B 7/8" tip, 200' of 2½" hose, wyed from 200' of 2½" hose. PP =?

Initial pump pressure = 50 psi

TO DETERMINE GPM FLOW, AVERAGE THE FLOWS FROM THE NOZZLES. *

- **Step One**: 1" tip @ 50 psi
  - \(30 \times \sqrt{\text{NP}}\)
  - \(30 \times (1)^2 \times 7\)
  - \(30 \times 1 \times 7 = 210\)

  1" tip Flow = **210**

- 7/8" tip @ 50 psi
  - \(30 \times \sqrt{\text{NP}}\)
  - \(30 \times (0.765)^2 \times 7\)
  - \(30 \times 0.765 \times 7 = 160.65\)

  Round off 160.65 to 160

  7/8" tip Flow = **160**

Total Flow = 210 + 160 = **370**
Flow through supply line (a) = **370 gpm**

*Average Flow = \(\frac{370}{2}\)

Average Flow (bc) = **185** gpm
Round off Flow (bc) to = **190** gpm

**HINT**

To convert a fraction to a decimal: divide the numerator by the denominator.
7 ÷ 8 = .875
Wyed Lines (Unequal Flows)

- **Step Two**: \( FLR = 2Q^2 \)

\[
\begin{align*}
FLR & = 2 \left( \frac{\text{gpm}}{100} \right)^2 \\
& = 2 \left( \frac{370}{100} \right)^2 = 3.7 \\
& = 2 \left( \frac{190}{100} \right)^2 = 1.9 \\
FLR(a) & = 2(3.7)^2 \\
& = 2 \times 13.69 = 27.38 \\
& = 2 \times 3.61 = 7.22 \\
Round off 27.38 to 27 \\
FLR for Supply line & = 27 \\
FLR for one line & = 7 \text{ psi}
\end{align*}
\]

- **Step Three**: \( L = \text{total feet} \)

TO DETERMINE \( L \) FOR THE WYED LINES, AVERAGE THE LENGTHS OF THE TWO LINES.

\[
\begin{align*}
\text{Average } L (bc) & = \frac{L(b) + L(c)}{2} \\
& = \frac{200 + 200}{2} = 200 \\
L(a) & = \frac{200}{100} \\
& = 2 \\
L(b) & = \frac{200}{100} \\
& = 2
\end{align*}
\]

- **Step Four**: \( TFL = FLR(a) \times L(a) + FLR(b) \times L(b) \)

\[
\begin{align*}
TFL & = FL(a) = 27 \times 2 + FL(b) = 7 \times 2 \\
TFL & = FL(a) = 54 + FL(b) = 14 \\
TFL & = 54 + 14 = 68
\end{align*}
\]

\[
\begin{align*}
PP & = NP + TFL \\
PP & = 50 + 68 \\
PP & = 118 \text{ psi}
\end{align*}
\]
Wyed Lines (Equal Lines and Flow)

Example: Two 100' - 2 ½" hose lines with 250 gpm SOF nozzles, wyed from 200' of 2 ½" hose.  

PP = ?

Initial pump pressure = 100 psi

TO DETERMINE THE FLOW IN THE SUPPLY LINE, COMBINE NOZZLE FLOWS.*

- **Step One:** Flow through one line = 250 gpm  
  *Flow through supply line (a) = 250 + 250 = 500 gpm  
  *Flow through supply line (a) = 500 gpm

- **Step Two:** FLR = \(2Q^2\)

  \[
  \begin{align*}
  \text{FLR} &= 2 \left(\frac{\text{gpm}}{100}\right)^2 \\
  \text{FLR} &= 2 \left(\frac{500}{100}\right)^2 = 5 \\
  \text{FLR(a)} &= 2(5)^2 \\
  \text{FLR(a)} &= 2 \times 25 = 50 \\
  \text{FLR for supply line (a)} &= 50 \text{ psi}
  \end{align*}
  \]

  \[
  \begin{align*}
  \text{FLR} &= 2 \left(\frac{\text{gpm}}{100}\right)^2 \\
  \text{FLR} &= 2 \left(\frac{250}{100}\right)^2 = 2.5 \\
  \text{FLR(bc)} &= 2(2.5)^2 \\
  \text{FLR(bc)} &= 2 \times 6.25 = 12.5 \\
  \text{Round off 12.5 to 13}
  \end{align*}
  \]

  \[
  \begin{align*}
  \text{FLR for one wye line (bc)} &= 13
  \end{align*}
  \]
Wyed Lines (Equal Lines and Flow)

- **Step Three**: \[ L = \frac{\text{total feet}}{100} \]
  
  \[
  L(a) = \frac{200}{100} \quad \text{and} \quad L(b) = \frac{100}{100}
  \]
  
  \[
  L(a) = 2 \quad \text{and} \quad L(b) = 1
  \]

- **Step Four**: \[ TFL = FLR(a) \times L(a) + FLR(b) \times L(b) \]
  
  \[
  TFL = FL(a) = 50 \times 2 + FL(b) = 13 \times 1
  \]
  
  \[
  TFL = FL(a) = 100 + FL(b) = 13
  \]
  
  \[
  TFL = 100 + 13 = 113
  \]

**HINT**

If the lines are the same length and the gpm is the same – you only need to calculate for one line from the wye.

**PP = NP + TFL**

\[
PP = 100 + 113
\]

**PP = 213 psi**
Wyed Lines (2 ½ to 1 ¾)

- Determining flow from 2 ½” supply line with two 1 ¾” wyed lines.

Example: Two 1 ½” Akron nozzles, 125 gpm setting, two 200’ lines of 1 ¾” hose wyed from 400’ of 2 ½” hose. PP =?

Initial pump pressure = 100 psi

Initial pump pressure = 100 psi

**Step One:** Flow = 125 gpm per nozzle

Flow through 2 ½” hose = 125 + 125

Flow through 2 ½” hose = 250 gpm

Step Two: FLR = \(2Q^2\)

\[
FLR = 2 \left(\frac{gpm}{100}\right)^2
\]

\[
FLR = 2 \times 250^2 = \frac{2.5}{100}
\]

FLR(a) = 2(2.5)²

FLR(a) = 2 x 6.25 = 12.5

Round off 12.5 to 13

FLR for 2 ½” supply line = 13

EF = Factor x gpm

EF flow through 1 ¾” hose = 2.0 x 125

EF flow through 1 ¾” hose = 250 gpm

**HINT**

For 2 ½” flows between 180 & 320 subtract 12 from the first 2 numbers.

\((250 - 12 = 13)\)

See friction loss table in appendix

FLR for 1 ¾” line = 13 psi
WYED LINES (2 ½ TO 1 ¾)

- **Step Three:**
  \[
  L = \frac{\text{total feet}}{100}
  \]
  
  \[
  L(a) = \frac{400}{100} = 4 \\
  L(b \text{ or } c) = \frac{200}{100} = 2
  \]

- **Step Four:**
  \[
  TFL = FLR(a) \times L(a) + FLR(b \text{ or } c) \times L(b)
  \]
  
  \[
  TFL = FL(a) = 13 \times 4 + FL(b)13 \times 2
  \]
  
  \[
  TFL = FL(a) 52 \text{ psi } + FL(b) 26 \text{ psi}
  \]
  
  \[
  TFL = 78
  \]

**HINT**

If the lines are the same length and the gpm is the same — you only need to calculate for one line of the wye.

\[
PP = NP + TFL
\]

\[
PP = 100 + 78
\]

\[
PP = 178 \text{ psi}
\]
Appliances (Heavy Stream) - Deluge set

Example: 2" tip on monitor nozzle supplied by three 200' x 2 ½" hose lines. PP =?

Initial pump pressure = 80 psi

ALLOW 15 PSI APPLIANCE LOSS WHEN USING A DELUGE SET OR MONITOR NOZZLE*

NOTE: To be considered an appliance it must meet three things:
1. Made of metal (other than hose)
2. Water flows through it
3. A change of direction greater than 90°

➢ Step One: 2" tip @ 80 psi

30 d² \sqrt{NP}
30 \times (2)^2 \times 9
30 \times 4 \times 9 = 1080
Round off 1080 to 1100
Flow = 1100
Flow through one line = \frac{1100}{3}
Flow through one line = 367
Round off 367 to 370 gpm

HINT
Average flow and calculate as a single line.
Appliances (Heavy Stream) - Deluge set

- **Step Two**: \( FLR = 2Q^2 \)
  
  \[
  FLR = 2 \left( \frac{370}{100} \right)^2 = 3.7
  \]
  
  \[
  FLR = 2(3.7)^2
  \]
  
  \[
  FLR = 2 \times 13.69 = 27.38
  \]
  
  Round off 27.38 to 27
  
  \[ FLR = 27 \text{ psi} \]

- **Step Three**: \( L = \text{total feet} / 100 \)
  
  \[
  L = \frac{200}{100}
  \]
  
  \[ L = 2 \]

- **Step Four**: \( TFL = FLR \times L \)
  
  \[
  TFL = 27 \times 2
  \]
  
  \[ TFL = 54 \text{ psi} \]

\[
PP = NP + TFL + AL^*
\]

\[
PP = 80 + 54 + 15
\]

\[
PP = 149 \text{ psi}
\]
Appliances (Heavy Stream) - Deluge set

Example: 1000 gpm Fog Nozzle supplied by three 100' x 2 ½“ hose lines. PP =?

Initial pump pressure = 100 psi

ALLOW 15 PSI APPLIANCE LOSS WHEN USING A DELUGE SET OR MONITOR NOZZLE*

- **Step One**: Flow = 1000 gpm
  
  Flow through one line = \( \frac{1000}{3} \)

  Flow through one line = 333

  Round off single line flow to 330 gpm

  Flow = 330

- **Step Two**: FLR = \( 2Q^2 \)

  \[ FLR = \frac{2 \times (gpm)^2}{100} \]

  FLR = \( 2 \times (330)^2 \) = 3.3

  FLR = \( 2 \times (3.3)^2 \)

  FLR = 2 x 10.89 = 21.78

  Round off 21.78 to 22

  FLR = 22 psi

**HINT**

Average flow and calculate as a single line.
Appliances (Heavy Stream) - Deluge set

- **Step Three**: \( L = \frac{\text{total feet}}{100} \)
  
  \[
  L = \frac{100}{100} = 1
  \]

- **Step Four**: \( \text{TFL} = \text{FLR} \times L \)
  
  \[
  \text{TFL} = 22 \times 1 = 22 \text{ psi}
  \]

\[
\text{PP} = \text{NP} + \text{TFL} + \text{AL}^*
\]

\[
\text{PP} = 100 + 22 + 15 = 137 \text{ psi}
\]
Appliances (Heavy Stream) – Apparatus Deck Gun

Example: 2” tip from apparatus mounted deck gun, PP =?

Initial pump pressure = 80

*ALLOW 15 PSI APPLIANCE LOSS WHEN USING A DELUGE SET OR MONITOR NOZZLE*

- **Step One:** Flow = 1100 gpm
- **Nozzle Pressure = 80**
- **Appliance Loss = 15**

**HINT**

DISCHARGE IS DIRECTLY OFF THE PUMP. NO HOSE FRICTION LOSS CALCULATIONS NEED TO BE MADE.

\[
PP = NP + AL^* \\
PP = 80 + 15 \\
PP = 95 \text{ psi}
\]
TRUCKS

Ladder truck configuration and hydraulics vary greatly between manufacturers.

Because of this the calculations also vary. When flow meters and nozzle pressure gauges are installed, the use of these meters and gauges will be the final guide for correct pressure and flow.
Example: 1 ¾” tip, ladder pipe elevation, 70’ up, 200’ of 4” hose line. PP =?

Initial pump pressure = 150 psi.

Step One: 1 ¾” tip @ 80 psi

\[30 \frac{d^2}{\sqrt{NP}}\]
\[30 \times (1.75)^2 \times 9\]
\[30 \times 3.06 \times 9 = 826.2\]
Round off 826.2 to 800
Flow = 800 gpm

EF(a) through 4" hose = .25 \times 800
EF(a) through 4" hose = 200 gpm

EF(b) through 3 ½” hose = .4 \times 800
EF(b) through 3 ½” hose = 320 gpm

HINT

To convert a fraction to a decimal: divide the numerator by the denominator.

3 ÷ 4 = .75

HINT

It’s easier to divide by 4 than multiply by .25
Appliances (Heavy Stream)  Ladder Pipes

- **Step Two**: \( FLR = 2Q^2 \)
  
  \[
  FLR = 2 \left( \frac{gpm}{100} \right)^2
  \]

  \[
  FLR = 2 \left( \frac{200}{100} \right)^2 = 2
  \]

  \[
  FLR = 2 \left( \frac{320}{100} \right)^2 = 3.2
  \]

  \[
  FLR(a) = 2(2)^2
  \]

  \[
  FLR(a) = 2 \times 4 = 8
  \]

  \[
  FLR(b) = 2(3.2)^2
  \]

  \[
  FLR(b) = 2 \times 10.24 = 20.48
  \]

  Round 20.48 to 20

  \[
  FLR (4") = 8
  \]

  \[
  FLR (3 \frac{1}{2"}) = 20
  \]

- **Step Three**: \( L = \text{total feet} \)
  
  \[
  L(a) = \frac{200}{100}
  \]

  \[
  L(b) = \frac{100}{100}
  \]

  \[
  L(a) (4") = 2
  \]

  \[
  L(b) (3 \frac{1}{2"}) = 1
  \]

- **Step Four**: \( TFL = FLR (4") \times L + FLR (3 \frac{1}{2"}) \times L \)
  
  \[
  TFL = 8 \times 2 + 20 \times 1
  \]

  \[
  TFL = 16 + 20 = 36 \text{ psi}
  \]

- **Step Five**: \( GL = .5 \times H \)
  
  \[
  GL = .5 \times 70
  \]

  \[
  GL = 35
  \]

\[
PP = NP + TFL + AL + GL
\]

\[
PP = 80 + 36 + 15 + 35
\]

\[
PP = 166 \text{ psi}
\]
Appliances (Heavy Stream) Aerial Platform Operations

Example: Aerial Platform up 50 feet with 1000 gpm fog nozzle supplied by three 100' lengths of 2 ½" hose. PP =?

Initial pump pressure = 150 psi.

**Step One:**

Flow = 1000 gpm

Flow through one line = \( \frac{1000}{3} \)

Flow through one line = 333

Round off single line flow to 330

Flow = 330 gpm

**Step Two:**

\( \text{FLR} = 2Q^2 \)

\( \text{FLR} = 2 \left( \frac{\text{gpm}}{100} \right)^2 \)

\( \text{FLR} = 2 \left( \frac{330}{100} \right)^2 = 3.3 \)

\( \text{FLR} = 2(3.3)^2 \)

\( \text{FLR} = 2 \times 10.89 = 21.78 \)

Round off 21.78 to 22

FLR = 22 psi

**HINT**

Average flow and calculate as a single line.
Appliances (Heavy Stream) Aerial Platform Operations

- **Step Three:** \( L = \frac{\text{total feet}}{100} \)
  
  \[
  L = \frac{100}{100} = 1
  \]

- **Step Four:** \( TFL = FLR \times L \)
  
  \[
  TFL = 22 \times 1 = 22 \text{ psi}
  \]

- **Step Five:** \( GL = 0.5 \times H \)
  
  \[
  GL = 0.5 \times 50 = 25
  \]

\[
PP = NP + TFL + LSL + GL
\]

\[
PP = 100 + 22 + 25 + 25 = 172 \text{ psi}
\]
Appliances (Heavy Stream) PIERVILLE, LTI

Example: Pre-plumbed ladder pipe, up 100 feet with 1000 gpm fog nozzle supplied by three 100' lengths of 2 ½" hose. PP =?

Initial pump pressure = 150 psi.

**Step One:** Flow = 1000 gpm

Flow through one line = \( \frac{1000}{3} \)

Flow through one line = 333

Round off single line flow to 330

Flow = 330 gpm

**Step Two:** FLR = \( 2Q^2 \)

FLR = \( \frac{2 \times (gpm)^2}{100} \)

FLR = \( 2 \times \frac{(330)^2}{100} = 3.3 \)

FLR = \( 2 \times (3.3)^2 \)

FLR = 2 x 10.89 = 21.78

Round off 21.78 to 22

FLR = 22 psi

**HINT**

Average flow and calculate as a single line.
Appliances (Heavy Stream) PIERVILLE, LTI

- **Step Three:**  \( L = \frac{\text{total feet}}{100} \)
  
  
  \[
  \frac{100}{100} = 1
  \]

- **Step Four:**  \( TFL = FLR \times L \)
  
  \[
  TFL = 22 \times 1 = 22 \text{ psi}
  \]

- **Step Five:**  \( GL = .5 \times H \)
  
  \[
  GL = .5 \times 100 = 50
  \]

\[
PP = NP + TFL + LSL + GL
\]

\[
PP = 100 + 22 + 25 + 50 = 197 \text{ psi}
\]
Appliances (Heavy Stream) Aerial Platform Operations 4” Hose

Example: Aerial Platform up 70 feet with 1000 gpm fog nozzle supplied by 200' of 4” hose. PP =?

Initial pump pressure = 150 psi.

**Step One:** Flow = 1000 gpm
EF = 1000 x .25
EF = 250 gpm

**Step Two:** FLR = 2Q^2
FLR = 2 (gpm)^2 100
FLR = 2 (250)^2 100
FLR = 2(2.5)^2
FLR = 2 x 6.25 = 12.5
Round off 12.5 to 13
FLR = 13 psi

**HINT**
For 2 ½" flows between 180 & 320 subtract 12 from the first 2 numbers.
(250 – 12 = 13)
See friction loss table in appendix
Appliances (Heavy Stream) Aerial Platform Operations 4” Hose

- **Step Three:** \( L = \frac{\text{total feet}}{100} \)
  
  \[
  L = \frac{200}{100} \\
  L = 2
  \]

- **Step Four:** \( TFL = \text{FLR} \times L \)
  
  \[
  TFL = 13 \times 2 \\
  TFL = 26 \text{ psi}
  \]

- **Step Five:** \( GL = 0.5 \times H \)
  
  \[
  GL = 0.5 \times 70 \\
  GL = 35
  \]

\[
\text{PP} = \text{NP} + \text{TFL} + \text{LSL} + \text{GL}
\]

\[
\text{PP} = 100 + 26 + 25 + 35
\]

\[
\text{PP} = 186 \text{ psi}
\]
Appliances (Heavy Stream) PIERVILLE, LTI

Example: Pre-plumbed ladder pipe, up 100 feet with 1000 gpm fog nozzle supplied by 400' of 4" hose. PP =?

Initial pump pressure = 150 psi.

- **Step One:** Flow = 1000 gpm
  
  \[ EF = 1000 \times 0.25 \]
  
  \[ EF = 250 \text{ gpm} \]

- **Step Two:** FLR = \( 2Q^2 \)
  
  \[ FLR = 2 \left( \frac{250}{100} \right)^2 = 2.5 \]
  
  \[ FLR = 2 \times 2.5^2 \]
  
  \[ FLR = 2 \times 6.25 = 12.5 \]
  
  Round off 12.5 to 13
  
  FLR = 13 psi

**HINT**

For 2 ½” flows between 180 & 320 subtract 12 from the first 2 numbers.

(250 – 12 = 13)

See friction loss table in appendix
Appliances (Heavy Stream) PIERVILLE, LTI

- **Step Three:** \( L = \frac{\text{total feet}}{100} \)
  
  \[
  \frac{400}{100} = 4
  \]

- **Step Four:** \( TFL = \text{FLR} \times L \)
  
  \[
  TFL = 13 \times 4 = 52 \text{ psi}
  \]

- **Step Five:** \( GL = 0.5 \times H \)
  
  \[
  GL = 0.5 \times 100 = 50
  \]

\[
\begin{align*}
PP &= \text{NP} + TFL + LSL + GL \\
PP &= 100 + 52 + 25 + 50 \\
PP &= 227 \text{ psi}
\end{align*}
\]
**Standpipes – Red Hose and High-rise pack**

Example: Two 200' lines of 2 ½" hose are laid from the pump to the standpipe intake.

Two 100' 1 ¾" Fire fighting lines, each flowing 200 gpm on the 15 floor. One is connected to the standpipe on the 15 floor, the other is connected on the 14th floor. PP = ?

Initial pump pressure = Maintain **150** psi at the pump until proper pump pressure can be determined.

**ALLOW 25 PSI LOSS FOR STANDPIPE SYSTEMS (SL) REGARDLESS OF SIZE.** *

**ALLOW 5 PSI GRAVITY LOSS (GL) PER FLOOR, ABOVE THE GROUND FLOOR, INCLUDING THE FLOOR THE NOZZLE IS ON.** *(DO NOT COUNT THE FIRST FLOOR. **)*

**Step One:** 200 gpm flow for each 1 ¾

Total Flow through stand pipe = **400** gpm nozzle

1 ¾" EF through 2 ½" = 2 x 200 = 400

EF = **400**

Total flow = 400 gpm

Flow through single supply line = 400 = **200** gpm

(number of lines) 2

**HINT**

This lay is a version of the Siamese lay. Divide flow by number of supply lines and treat...
HYDRAULIC SET-UPS AND CALCULATIONS

Standpipes – Red Hose and High-rise pack

2 ½” 1 ¾”

- Step Two: $FLR = 2Q^2$
  
  $FLR = 2 \left( \frac{200}{100} \right)^2 = 2$
  
  $FLR = 2 \left( \frac{400}{100} \right)^2 = 2$
  
  $FLR(2 ½") = 2(2)^2$
  
  $FLR(1 ¾") = 2(4)^2$
  
  $FLR(2 ½") = 2 \times 4 = 8$
  
  $FLR(1 ¾") = 2 \times 16 = 32$
  
- Step Three: $L = \frac{\text{total feet}}{100}$
  
  $L = \frac{200}{100} = 2$
  
  $L = \frac{100}{100} = 1$
  
- Step Four: $TFL = FLR (2 ½") \times L(2 ½") + FLR (1 ¾") \times L(1 ¾")$
  
  $TFL (2 ½") = 8 \times 2 + 32 \times 1$
  
  $TFL (2 ½") = 16 + 32 \text{ psi}$
  
  $TFL = 48$

- Step Five: **GL = 5 \times 14**
  
  $GL = 70 \text{ psi}$

\[ PP = NP + TFL + SL^* + GL^{**} \]

\[ PP = 100 + 48 + 25 + 70 \]

\[ PP = 243 \text{ psi} \]
Standpipes – Blue Hose and High-rise Pack

Example: Two 200' lines of 2 ½" hose are laid from the pump to the standpipe intake.

Two 200' 1 ¾" Fire fighting lines, each flowing 200 gpm on the 31st floor. One is connected to the standpipe on the 31st floor, the other is connected on the 30th floor. PP = ?

Initial pump pressure = Maintain 150 psi at the pump until proper pump pressure can be determined.

BLUE HIGH PRESSURE HOSE HAS A SERVICE PRESSURE OF 600 POUNDS.

ALLOW 25 PSI LOSS FOR STANDPIPE SYSTEMS (SL) REGARDLESS OF SIZE. *

ALLOW 5 PSI GRAVITY LOSS (GL) PER FLOOR, ABOVE THE GROUND FLOOR, INCLUDING THE FLOOR THE NOZZLE IS ON. (DO NOT COUNT THE FIRST FLOOR. **) 

Step One: 200 gpm through each nozzle

EF through 1 ¾" 200 x 2 = 400

Total Flow through stand pipe = 400 gpm

Flow through single supply line = 200 gpm

Hint

This lay is a version of the Siamese lay. Divide flow by number of supply lines and treat.
### Standpipes – Blue Hose and High-rise Pack

#### 2 ½”

- **Step Two:** FLR = 2Q²
  
  \[
  \text{FLR} = 2 \left( \frac{\text{gpm}}{100} \right)^2
  \]

  - FLR = 2 \left( \frac{200}{100} \right)^2 = 2
  
  - FLR(2 ½") = 2
  
  - FLR(2 ½") = 2 \times 4 = 8
  
  - FLR(2 ½") = 8

- **Step Three:** L = \frac{\text{total feet}}{100}
  
  \[
  L = \frac{200}{100}
  \]

  - L(2 ½") = 2

- **Step Four:**
  
  TFL = FLR(2 ½") \times L(2 ½") + FLR(1 ¾") \times L(1 ¾")

  - TFL (2 ½") = 8 \times 2 + 32 \times 2
  
  - TFL (2 ½") = 16 + 64 psi
  
  - TFL = 80

- **Step Five:** **GL = 5 \times 30**
  
  - GL = 150 psi

#### 1 ¾”

- **Step Two:** FLR = 2Q²
  
  \[
  \text{FLR} = 2 \left( \frac{\text{gpm}}{100} \right)^2
  \]

  - FLR = 2 \left( \frac{400}{100} \right)^2 = 2
  
  - FLR(1 ¾") = 2(4)²

  - FLR(1 ¾") = 2 \times 16 = 32

- **Step Three:** L = \frac{\text{total feet}}{100}
  
  \[
  L = \frac{200}{100}
  \]

  - L(1 ¾") = 2

- **Step Four:**
  
  TFL = FLR(2 ½") \times L(2 ½") + FLR(1 ¾") \times L(1 ¾")

  - TFL (1 ¾") = 2

- **Step Five:** **GL = 5 \times 30**
  
  - GL = 150 psi

**HINT**

THE FIRST FLOOR IS NOT INCLUDED WHEN CALCULATING GL FOR STANDPIPES

**PP = NP + TFL + SL* + GL**

**PP = 100 + 80 + 25 + 150**

**PP = 355 psi**
Sprinkler System

Example: Twenty heads are fused on the 8th floor; sprinkler system is supplied by two 500' lengths of 2 1/2" hose. PP = ?

Initial pump pressure = Maintain 150 psi at the pump until proper pump pressure can be determined.

IN RAPID METHOD HYDRAULICS ALLOW 30 GPM PER SPRINKLER HEAD.*
IN RAPID METHOD HYDRAULICS 25 PSI CAN BE CONSIDERED AS EFFECTIVE SPRINKLER NOZZLE PRESSURE.**
ALLOW 25 PSI LOSS FOR SPRINKLER SYSTEM (SPR. L)***
ALLOW 5 PSI PER FLOOR FOR GRAVITY LOSS, INCLUDING THE FIRST FLOOR.***

- **Step One**: Flow = 30* x 20
  
  Flow = 600 gpm
  
  Flow through one line = \(\frac{600}{2}\) = 300 gpm

**HINT**

This lay is a version of the Siamese lay. Divide flow by number of supply lines and treat as a single line.
Sprinkler System

- **Step Two**: $FLR = 2Q^2$
  
  $FLR = 2 \left(\frac{gpm}{100}\right)^2$
  
  $FLR = 2 \left(\frac{300}{100}\right)^2 = 3$
  
  $FLR = 2(3)^2$
  
  $FLR = 2 \times 9 = 18$
  
  $FLR = 18$ psi

- **Step Three**: $L = \frac{\text{total feet}}{100}$
  
  $L = \frac{500}{100}$
  
  $L = 5$

- **Step Four**: $TFL = FLR \times L$
  
  $TFL = 18 \times 5$
  
  $TFL = 90$ psi

- **Step Five**: $**GL = 5 \times 8$
  
  $GL = 40$ psi

\[
PP = NP^{**} + TFL + Spr. L^{***} + GL^{****}
\]

\[
PP = 25 + 90 + 25 + 40
\]

\[
PP = 180$ psi
Foam Appliance and Application

Example: 1 1/2" foam eductor

1 1/2", 60 gpm aeration foam tube
200' of 1 3/4" between eductor and the foam tube

PP = 200 psi

NOTE: NO HYDRAULIC CALCULATIONS FOR ANY 1 ¾” FOAM LAY UP TO 600 FEET.

ALWAYS PUMP 200 PSI.
Foam Appliance and Application

Example: 400’ of 2 ½” hose, connected to a 1 ½” foam eductor with 200’ of 1 ¾” hose with a 60 gpm aeration foam tube.

- **Step One**: Flow = 60 gpm

- **Step Two**: FLR = 2Q^2
  
  FLR = 2 (gpm)^2 / 100
  
  FLR = 2 (60)^2 / 100 = .6
  
  FLR (2 ½") = 2(.6)^2
  
  FLR (2 ½") = 2 x .36 = .72
  
  Round off .72 to = 1

- **Step Three**: \( L(2 \ ½") = \frac{\text{total feet}}{100} \)
  
  \( L(2 \ ½") = \frac{400}{100} \)
  
  \( L(2 \ ½") = 4 \)

- **Step Four**: TFL = FLR (2 ½") x L
  
  TFL = 1 x 4 = 4 psi

\[ PP = TFL + 200 \]
\[ PP = 4 + 200 \]
\[ PP = 204 \text{ psi} \]

**HINT**

FOR FOAM CALCULATIONS, 200 POUNDS FOAM SYSTEM LOSS IS USED FROM THE EDUCTOR TO THE NOZZLE.
Foam Appliance and Application

Example: 2 100’ of 2½” hose to Foam 28, Foam 28 has 2 100’ lengths of 2 ½” connected to a pre-plumbed Ladder pipe with a 1000 gpm fog at 80’ elevation.

ALLOW 25 PSI LOSS FOR LADDER SYSTEM LOSS (LSL)***

ALLOW 15 PSI LOSS FOR FOAM 28 APPLIANCE LOSS (AL)***

- **Step One**: Flow = 1000 gpm
  Flow through one line = \( \frac{1000}{2} = 500 \) gpm
  Flow per line = 500 gpm

- **Step Two**: FLR = \( 2Q^2 \)
  FLR = \( 2 \left( \frac{gpm}{100} \right)^2 \)
  FLR = \( 2 \left( \frac{500}{100} \right)^2 = 5 \)
  FLR = \( 2(5)^2 \)
  FLR = 2 \times 25 = 50
  FLR = 50
Foam Appliance and Application

- **Step Three**: \( L = \frac{\text{total feet}}{100} \)
  
  \[
  L = \frac{200}{100} = 2
  \]

- **Step Four**: \( TFL = FLR \times L \)
  
  \[
  TFL = 50 \times 2 = 100 \text{ psi}
  \]
  
  \[
  TFL = 100 \text{ psi}
  \]

**HINT**

1 LENGTH FROM THE ENGINE TO FOAM 28, ANOTHER 1 LENGTH FROM FOAM 28 TO THE TRUCK

\[
PP = NP + AL + TFL + GL + LSL
\]

\[
PP = 100 + 15 + 100 + 40 + 25
\]

\[
PP = 280 \text{ psi}
\]
Relay Pumping Operations

Relaying of water can be accomplished when the activities of personnel and equipment involved are coordinated by the officer in charge, and upon receipt of specific information such as:

- Amount of water needed to extinguish the fire.
- Size and length of available hose.
- Apparatus available for pumping purposes.
- Time required setting up the relay.
- Maximum distance one pumper can deliver the gpm.
- Topography of the district over which relay is to be made.

The quantity of water (gpm) needed to effectively handle the situation must be estimated, because every succeeding phase of the relay will be governed by this estimate.

Since friction loss in hose used for relays will one of the factors determining the distance between pumpers, the largest hose available should be used to minimize the number of pumpers required in the relay.

The distance from the water supply to the fire is secondary in estimating the amount of hose required for the relay. Primarily, it is the length of hose between individual pumpers that must be determined.

The hose line or lines leading to the fire from the last pump do not materially effect relay operations, and there is no need for them to enter relay computations. The operator of this pump may assume it is connected to a water supply for the purpose of extinguishing the fire.

The condition of the hose will also have an effect on the length of hose lines between pumps. The pump pressure of the pumps in the relay should not exceed the pressure of the annual hose test.
When calculating pump pressure to be pumped by a relay pumper, an intake pressure of 10 psi must be maintained at the next pumper in line. On this basis the pressure that the hose can withstand, minus intake pressure, could be used to overcome friction loss and gravity loss, if it exists. \(250 - 10 = 240 \text{ psi}\)

With friction loss rate determined, as a result of the gpm flow, the maximum amount of hose between pumps, without exceeding the maximum pump pressure, can be determined.

When distance is not a determining factor, (short relays) a pump pressure less than maximum could provide sufficient intake pressure at the next pump in line.

It is logical to expect pumpers of varying capacities to be used in each relay operation. It must be considered that the capacity of a pump diminishes as the pump pressure exceeds a certain pressure. Class A pumps will deliver about one half of capacity at 250 psi PP. Low discharge capacity compared to those of high discharge capacity should be taken into consideration. The largest capacity pumper should be placed at the source of supply.

More time will be needed to complete a relay than would be necessary to make a regular hose lay. This unavoidable delay should be considered in determining how large the fire will be by the time relayed water is available.

Differences in elevation between water supply and the nozzle will have a decided effect on the placement of pumpers in the relay, and also upon the total number required.

It is now evident that several things must be considered to keep within the maximum allowable pump pressure:

- Total friction loss developed by the quantity of water flowing, which has to be overcome by the pump.
- The gravity loss or gravity gain, if it exists.
- The intake pressure at the next pump in line.
After the size and number of hose lines are decided upon, the number of pumps necessary to transport the desired flow to the pump engaged in the fire fighting can best be determined by the following formula:

\[ \text{Number of pumps} = \frac{TFL + GL}{\text{Maximum PP} - IP} \]

Example: In a relay operation 1000 gallons per minute will be required to extinguish a barn fire. Three thousand feet of 4" hose will be used to transport water from the source to the pumper at the fire scene, which is 100 feet above the water source. How many pumpers will be needed to complete this lay? Hose is tested to 300 psi.
HYDRAULIC SET-UPS AND CALCULATIONS

- **Step One:** \( gpm = 1000 \)

- **Step Two:** \( EF = \text{Factor} \times gpm \)
  
  \[
  EF = .25 \times 1000 \\
  \text{EF} = 250 \text{ gpm}
  \]

  \( \text{FLR} = 13 \text{ psi} \)

- **Step Three:** \( L = \frac{\text{total feet}}{100} \)
  
  \[
  L = \frac{3000}{100} \\
  L = 30
  \]

- **Step Four:** \( TFL = \text{FLR} \times L \)
  
  \[
  TFL = 13 \times 30 \\
  TFL = 390 \text{ psi}
  \]

- **Step Five:** \( GL = .5 \times 100 \)
  
  \[
  GL = 50 \text{ psi}
  \]

**Total Pressure** = \( TFL + GL \)

\[
\text{Total Pressure} = 390 + 50 \\
\text{Total Pressure} = 440
\]

Using the above formulas, 2 pumps would be required for the relay to keep from pumping an excessive pressure.
**Example:** Assuming the pumpers are equidistant and the rise in elevation is equal between them, the distance between pumpers $= \frac{3000}{2} = 1500$ feet. PP = ?

- $FLR = 13 \text{ psi}$
- $TFL = FLR \times L$
- $TFL = 13 \times 15$
- $TFL = 195 \text{ psi}$

- $Head = \text{Total elevation} \div \text{No. pumps}$
- $Head = \frac{100}{2}$
- $Head = 50$
- $GL = 0.5 \times H$
- $GL = 0.5 \times 50$
- $GL = 25 \text{ psi}$

$$PP = TFL + GL + IP$$

- $PP = 195 + 25 + 10$
- $PP = 230 \text{ psi}$

230 psi would be the proper pressure for each pump in the relay to furnish the last pump doing the pumping for the fire.
EXAMPLE: How many gpm can you flow from a hydrant with 100 lbs. static pressure through 450 feet of 2 ½” hose?

➤ **Step One:** Determine Length of hose

\[
\frac{450}{100} = L = 4.5
\]

➤ **Step Two:** Determine Available Pressure loss through each length

Subtract intake pressure (10 lbs) from hydrant pressure

\[100 - 10 = 90\]

➤ **Step Three:** Determine FLR per length

\[90 \div 4.5 = 20\]

FLR = 20

Compare FLR in the Friction Loss Table or calculate \(2Q^2\) in reverse.

\[20 \div 2 = 10\]
\[\sqrt{10} = 3 \text{ (round off)}\]

\[Q = 3 \times 100\]

Estimated GPM = 300

Around 300 GPM can be expected from a 100 lb. Hydrant with 450 feet of supply hose.
Fire Pump Capacities

Fire pumps now encountered on the Bonita-Sunnyside Fire Protection District are of the centrifugal type. ISO (Insurance Service Organization) rates centrifugal fire pumps as standard from 500 to 1500 gpm. Acceptable modern pumps can deliver capacity discharge at 150 psi pump pressure from draft (10’ lift) at sea level. Theoretical variations from capacity discharge can be computed by the application of the following formula:

\[ PD = \frac{RC \times RP}{GPM} \]

Where:
- \( PD \) = Pump discharge
- \( RC \) = Rated capacity
- \( RP \) = Rated pressure
- \( GPM \) = Given pressure

Example: Theoretically, how many gpm can a pumper rated at 1000 gpm and at 150 psi Pump Pressure deliver at 200 psi?

Solution:

\[ PD = \frac{1000 \times 150}{200} = 750 \text{ gpm} \]

**Note:**
1. Now that the discharge has been determined as 750 gpm, the number of lines that can be used can be computed by knowing nozzle gpm and NP.
2. Operating at a pressure lower than 150 psi could result in discharge of greater than capacity.
3. Pump discharge could be increased if connected to a hydrant, due to positive pressure on the intake side of the pump.
4. Net pump pressure is pump pressure minus intake pressure.
Fire Pump Capacities

Example: An apparatus connected to a fire hydrant is supplying several hose lines. Pump pressure reads 160 psi, intake pressure reads 20 psi on the compound gauge. What is the net pump pressure?

Solution: Net PP = PP - Intake pressure
Net PP = 160 - 20
Net PP = 140 psi

Estimating Available Flow from Hydrant

The ability to calculate the available flow (gpm) remaining in a hydrant can be of great advantage to both pump operator and the command officer, particularly at the fire ground, as well as in pre-planning surveys. REMEMBER that to be an efficient firefighter you should know as much about the water supply in your district as possible prior to an emergency.

To estimate the available flow from a hydrant the rule is: determine the percentage of drop between static (at rest) and residual (in motion) pressures.

This percentage of drop will indicate the estimated available flow:

- 10 % drop, 3 more like volumes (4 like lines total)
- 15 % drop, 2 more like volumes (3 like lines total)
- 25 % drop, 1 more like volume. (2 like lines total)

Therefore, to estimate the available flow from a hydrant, the following must be applied:

- Note the static pressure on the compound gauge after the hydrant has been opened to let water into the pump, but before opening any discharge valves.

- Note the residual pressure on the compound gauge after getting the line into operation at the proper pump pressure; and
Estimating Available Flow from Hydrant

- Determine the percentage of drop.

  Example: The static pressure on the compound gauge when the hydrant is delivering water into the pump is 60 psi. When the first line (250 gpm nozzle) is put into operation, the residual pressure is 54 psi. Estimate the remaining available gpm flow.

  Solution: With a decrease from static pressure of 60 psi to a residual pressure of 54 psi (a drop of 6 psi), the percentage of drop is \( \frac{6}{60} = 0.1 \) or 10 percent; therefore, 3 more like volumes is the estimated available flow, or a total estimated flow of 4 volumes (1000 gpm total).

Estimating Static Pressure

Estimating static pressure if it was not noted when the hydrant was opened, will usually be impractical because of allowable time. However, if it is deemed necessary, the following procedure may be used:

- Note the flowing pressure on the compound gauge with the first line in operation.

- Place another nozzle delivering the same gpm into operation and note the drop in flow pressure.

- Divide the drop pressure by 2 and add to the flow pressure when the first line was in operation. This is the estimated static pressure.

Example: A line delivering 160 gpm is put into operation, and the residual pressure on the compound gauge reads 68 psi. A second line delivering the same gpm is placed into operation and the residual pressure now reads 44 psi. Estimate the remaining available flow.
Estimating Static Pressure – Available Flow

Solution: First, to estimate the static pressure with a decrease in residual pressure of 24 psi (from 68 psi to 44 psi), divide the drop in pressure by 2 which equals 12 psi. This can then be added to the residual pressure that was noted when the first line was put into operation. We now have 68 + 12, which equal an estimated static pressure of 80 psi.

Next, to estimate the remaining available flow with a decrease from static to Residual pressure of 12 psi (80 to 68), the percentage of drop is 12/80 or 15%; therefore, 2 more like volumes is the estimated available flow, or a total estimated flow of 3 like volumes.

Note: When pumping at a fire, the hydrant residual pressure should never drop from positive to negative, preferably it should be at least 10 psi whenever possible.
How to Estimate Quantities of Water

➢ To determine the capacity in gallons of water in a rectangular container or on a floor of a building if the dimensions are in feet, use the formula:

\[ C = L \times W \times H \times 7.5 \]

- \( C \) = Capacity in gallons
- \( L \) = Length in feet
- \( W \) = Width in feet
- \( H \) = Height in feet
- 7.5 = gallons per cubic foot

\[ C = 60 \times 30 \times .5 \times 7.5 \]

\[ C = 6750 \text{ gallons} \]

Example: Determine approximate capacity of rectangular tank 20' x 15' x 5'.

\[ C = L \times W \times H \times 7.5 \]

\[ C = 20 \times 15 \times 5 \times 7.5 \]

\[ C = 11,250 \text{ gallons} \]
How to Estimate Quantities of Water

The rapid method for finding the approximate capacity of water in gallons in a cylindrical tank, when the dimensions are in feet is as follows:

\[ C = 6d^2 \times H \]

- \( C \) = Capacity in gallons
- \( 6 \) = Constant
- \( d \) = Diameter in feet
- \( H \) = Height of water in feet

Example: Determine approximate capacity of tank 20' in diameter by 5' deep.

\begin{align*}
C &= 6d^2 \times H \\
C &= 6(20)^2 \times H \\
C &= 6(400) \times 5 \\
C &= 2400 \times 5 \\
C &= 12,000 \text{ gallons}
\end{align*}

For greater accuracy, subtract 2 percent of the total;

Example: 12,000 \times 0.02 = 240 then;

12,000 - 240 = \mathbf{11,760} \text{ gallons.}
How to Estimate Weight of Water

Example: Determine the weight of water in a room 60' by 30' by 6" deep.

Weight = L x W x H x 62.5
Weight = 60 x 30 x .5 x 62.5
Weight = 56,250 pounds
Weight = \frac{56,250}{2000}
Weight = 28 \frac{1}{8} tons
How to Estimate Weight of Water

To determine weight:

1. multiply the number of gallons by 8.35 pounds or
2. multiply the number of cubic feet by 62.5 pounds.

Example: Determine the weight of water in a cylindrical tank 30' in diameter and 2' deep:

\[ \text{Weight} = 6d^2 \times H \times 8.35 \]

\[ \text{Weight} = 6(900) \times 2 \times 8.35 \]

\[ \text{Weight} = 90,180 \text{ pounds} \]

\[ \text{Weight} = \frac{90,180}{2000} \]

\[ \text{Weight} = 45 \text{ tons} \]
Available Flow from a Hydrant

The formula, \( \text{gpm} = 27 \times d^2 \times \sqrt{P} \), is used to find the amount of water flowing from any non-restricted opening such as a hydrant port or the end of a hose (without a nozzle).

- \( 27 \) = Constant
- \( d \) = Diameter of opening
- \( P \) = Pressure per square inch using pitot gauge

Example: What is the approximate gpm flow from two 2 1/2” hydrant ports flowing simultaneously? Residual pressure is 25 psi.

\[
gpm = 27 \times d^2 \times \sqrt{P} \times 2 \\
gpm = 27 \times (2.50)^2 \times \sqrt{25} \times 2 \\
gpm = 27 \times 6.25 \times 5 \times 2 \\
gpm = 1687.5 \text{ or } 1690 \text{ gpm}
\]

For pressure \( (P) \) go to the nearest number from which the square root can be easily extracted, such as 49 for 50.
Weight of Water Delivered

It is useful to know that a standard fire stream, 250 gpm, represents approximately one ton of water per minute delivered into a building or structure. Consideration should be given to the safety of personnel due to the possibility of structural collapse, and provision made for the removal of water from the building.

Below is a table relating nozzle size to the approximate weight of water being delivered per minute.

<table>
<thead>
<tr>
<th>NOZZLE</th>
<th>PSI</th>
<th>GPM</th>
<th>WATER PER MINUTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/8&quot;</td>
<td>50</td>
<td>270</td>
<td>1 1/4 ton</td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>80</td>
<td>400</td>
<td>1 1/2 ton</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>80</td>
<td>600</td>
<td>2 1/2 ton</td>
</tr>
<tr>
<td>1 3/4&quot;</td>
<td>80</td>
<td>800</td>
<td>3 1/3 ton</td>
</tr>
<tr>
<td>2&quot;</td>
<td>80</td>
<td>1100</td>
<td>4 1/2 ton</td>
</tr>
</tbody>
</table>

Master Stream

A master stream can be defined as a large caliber fire stream too heavy for convenient or safe manual operation and therefore discharged through a monitor nozzle, deluge set, ladder pipe, portable monitor, or turret. It commonly produces a fire stream in excess of 400 gpm, and may consist of two or more hose lines siamesed into a single heavy stream appliance.
Nozzle Reaction

Water being discharged from a nozzle under pressure is not unlike the thrust from a jet aircraft engine, in that it causes an opposite reaction. The danger of this reaction upon a firefighter handling the nozzle cannot be over emphasized; especially the reaction encountered from a nozzle on a long lay with high engine pressure to overcome friction. The engine pressure is built up right to the nozzle when the water is static. The reaction is greatest when the nozzle is first opened.

This reaction can be calculated in total force by a formula if the diameter of the orifice is known, and the pressure at the orifice is known. The force will be in pounds.

\[ NR = 1.5 \times d^2 \times NP \]

1.5 = a constant
\[ d^2 = \text{Diameter of orifice squared} \]
\[ NP = \text{Pressure at the orifice when flowing} \]

Example: What is the nozzle reaction from a 2" tip with 80 psi NP?

\[ NR = 1.5 \times d^2 \times NP \]
\[ NR = 1.5 \times 2^2 \times 80 \]
\[ NR = 480 \text{ lbs. (not psi)} \]

Size limits for hose control.

- Appliance mandatory for straight tip greater than 1 1/8"
- Flowing 250 gpm or greater = Two person operation
Abbreviations and Definitions

AL  Appliance Loss - Appliance loss is the amount of energy (psi) lost in the turbulence of the water flowing through an appliance. AL=15psi

C  Capacity in gallons

d  Diameter

EF  Equivalent Flow - The amount of water flowing through a hose that is not a 2 1/2" hose which creates the same friction loss rate as that created in 2 1/2" hose.

F  Factor

FLR  Friction Loss Rate - The amount of energy or pounds pressure (psi) lost due to the turbulence of water in contact with the lining of a hose. It is measured in 100' lengths of 2 1/2" hose. FLR=2Q^2

GG  Gravity Gain - The amount of pressure (psi) gained when going down. GG=.5 psi

GL  Gravity Loss - The amount of pressure (psi) lost when pushing water up. GL=.5 psi

gpm  Gallons Per Minute

H  Head in feet – a column of water measured in feet

Hg  Mercury - Measured in inches. Thirty inches of mercury is equal to 14.7 psi.

HP  Head Pressure in psi - H x .434

IP  Intake Pressure - The pressure exerted by a water source on the intake side of a pump.

L  Length of hose equal to p 100'

LSL  Ladder System Loss – 25 lbs for Snorkel and Pre-plumbed ladder system loss

NP  Nozzle Pressure - Pressure at which water leaves the nozzle. 50, 80 or 100psi

NR  Nozzle Reaction - Water leaving a nozzle produces a reaction equal to 1.5 x d^2 x NP

PP  Pump Pressure - Pressure (psi) at which water is discharged from the pump

psi  Pounds Per Square Inch

RS  Residual Pressure - Water pressure (psi) remaining when a valve or hydrant is open and the water is flowing

Spr. L  SPRinkler System Friction Loss - 25 psi

SL  Standpipe Friction Loss - 25 psi

Slug Flow  When the foam solution in not rich enough or unevenly mixes with air, inadequate mixing occurs sending pockets of water and air to the nozzle

T  Ton - 2000 pounds

TFL  Total Friction Loss, TFL = FLR x L
DEFINITIONS, MEASUREMENTS, AND CHARTS

Measurements

- Atmospheric pressure at sea level is 14.7 psi = 30 inches of mercury = 33.9 feet of water. Therefore, 1 inch of mercury = 1.13 feet of water.

- One gallon of water occupies 231 cubic inches and weighs 8.35 pounds.

- 1 Cubic foot = 1728 cubic inches.

- 1 Cubic foot of water weighs 62.5 pounds and contains 7.5 gallons.

Nozzle and Gallons per Minute Flow

In fire ground hydraulics the flow from nozzles at standard pressures will be listed. The friction loss rates will be in the form of a table for reference purposes.

<table>
<thead>
<tr>
<th>NOZZLES</th>
<th>GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1&quot; NOZZLES</strong></td>
<td></td>
</tr>
<tr>
<td>1&quot; Select-O-Flow (SOF)</td>
<td>20-40-60</td>
</tr>
<tr>
<td>1&quot; Select-O-Flow SOF (Redline)</td>
<td>5-10-24-40</td>
</tr>
<tr>
<td><strong>1 ½&quot; NOZZLES</strong></td>
<td></td>
</tr>
<tr>
<td>1 ½&quot; Select-O-Flow SOF (Hi Rise Pack)</td>
<td>30-60-95-125-150-175-200</td>
</tr>
<tr>
<td>1 ½&quot; Select-O-Flow SOF (Hi Rise Pack)</td>
<td>30-60-95-125-150-180-200</td>
</tr>
<tr>
<td>1 ½&quot; Select-O-Flow (SOF)</td>
<td>30-60-95-125</td>
</tr>
<tr>
<td>1 ½&quot; Select-O-Flow (SOF)</td>
<td>95-125-150-200</td>
</tr>
<tr>
<td><strong>2 ½&quot; NOZZLES</strong></td>
<td></td>
</tr>
<tr>
<td>2 ½&quot; Select-O-Flow (SOF)</td>
<td>125-150-200-250</td>
</tr>
<tr>
<td>2 ½&quot; Select-O-Flow (SOF)</td>
<td>500-750-1000-1250</td>
</tr>
<tr>
<td>2 ½&quot; Select-O-Flow (SOF)</td>
<td>750-1000-1250</td>
</tr>
<tr>
<td>2 ½&quot; Turbojet Master</td>
<td>1000</td>
</tr>
</tbody>
</table>
## SMOOTH BORE TIPS - Hand Lines

<table>
<thead>
<tr>
<th>Diameter</th>
<th>NP</th>
<th>GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/16&quot;</td>
<td>50 psi</td>
<td>7</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>50 psi</td>
<td>13</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>50 psi</td>
<td>30</td>
</tr>
</tbody>
</table>

### Notes:
- When calculating gpm round off to the nearest **1 gpm.**

## SMOOTH BORE TIPS - Appliances

<table>
<thead>
<tr>
<th>Diameter</th>
<th>NP</th>
<th>GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/8&quot;</td>
<td>80 psi</td>
<td>300</td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>80 psi</td>
<td>400</td>
</tr>
<tr>
<td>1 3/8&quot;</td>
<td>80 psi</td>
<td>500</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>80 psi</td>
<td>600</td>
</tr>
<tr>
<td>1 3/4&quot;</td>
<td>80 psi</td>
<td>800</td>
</tr>
<tr>
<td>2&quot;</td>
<td>80 psi</td>
<td>1100</td>
</tr>
</tbody>
</table>

### Notes:
- When calculating gpm round off to the nearest **100 gpm.**
**DEFINITIONS, MEASUREMENTS, AND CHARTS**

*** REDLINE***

<table>
<thead>
<tr>
<th>GPM</th>
<th>PP</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>106 psi</td>
</tr>
<tr>
<td>10</td>
<td>125</td>
</tr>
<tr>
<td>24</td>
<td>218</td>
</tr>
<tr>
<td>30</td>
<td>285</td>
</tr>
<tr>
<td>35</td>
<td>350</td>
</tr>
<tr>
<td>40</td>
<td>426</td>
</tr>
</tbody>
</table>

**EF FACTORS (x GPM)**

<table>
<thead>
<tr>
<th>Size</th>
<th>GPM x 3/4&quot;</th>
<th>GPM x 1&quot;</th>
<th>GPM x 1 1/2&quot;</th>
<th>GPM x 1 3/4&quot;</th>
<th>GPM x 3&quot;</th>
<th>GPM x 3 1/2&quot;</th>
<th>GPM x 4&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 106 psi</td>
<td>x 25</td>
<td>x 9</td>
<td>x 3.6</td>
<td>x 2</td>
<td>x .67</td>
<td>x .4</td>
<td>x .25</td>
</tr>
</tbody>
</table>

**MISC. INFORMATION**

| G = | +.5 / ft or 5 lbs per floor |
| AL = | 15 psi |
| LSL = | 25 lbs for snorkel & ladder |
| SL = | 25 + 5 lbs per floor – 1 |
| SPR. L = | 25 + 5 lbs per floor |
| SPR. = | 30 GPM per HEAD |
| FOG NP = | 100 psi |
| FOAM = | 100 AL + 100 NP (60 gpm MAX) |
| FOAM = | 200 PSI UP TO 600' |

**1 3/4" CROSSLAY**

<table>
<thead>
<tr>
<th>GPM</th>
<th>150</th>
<th>175</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP</td>
<td>118</td>
<td>125</td>
<td>132</td>
</tr>
<tr>
<td>100'</td>
<td>127</td>
<td>138</td>
<td>148</td>
</tr>
<tr>
<td>150'</td>
<td>136</td>
<td>150</td>
<td>164</td>
</tr>
</tbody>
</table>

**2-1/2" STRAIGHT TIP**

<table>
<thead>
<tr>
<th>Size</th>
<th>GPM</th>
<th>NP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot;</td>
<td>210</td>
<td>50 psi</td>
</tr>
<tr>
<td>1 1/8&quot;</td>
<td>270</td>
<td>50 psi</td>
</tr>
<tr>
<td>1 1/8&quot;</td>
<td>300</td>
<td>50 psi</td>
</tr>
<tr>
<td>1 1/4&quot;</td>
<td>400</td>
<td>50 psi</td>
</tr>
<tr>
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<td>500</td>
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<tr>
<td>1 1/2&quot;</td>
<td>600</td>
<td>50 psi</td>
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<td>1 3/4&quot;</td>
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<td>50 psi</td>
</tr>
<tr>
<td>2&quot;</td>
<td>1100</td>
<td>80 psi</td>
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</table>

**IMMEDIATE PP**

<table>
<thead>
<tr>
<th>Hand Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nozzle Pressure + GL or - GG</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Elevator Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 psi</td>
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</tbody>
</table>

**Sprinklers & Standpipes**

<table>
<thead>
<tr>
<th>Size</th>
<th>GPM</th>
<th>NP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 3/4&quot;</td>
<td>800</td>
<td>80 psi</td>
</tr>
<tr>
<td>2&quot;</td>
<td>1100</td>
<td>80 psi</td>
</tr>
</tbody>
</table>

**See Hydraulics Manual for Complete Calculation**
### Gallons per Minute and Friction Loss Tables

**Friction Loss Rate (FLR) for GPM through Hose per 100’ length Hose**

<table>
<thead>
<tr>
<th>2 ½”</th>
<th>1”</th>
<th>1 ½”</th>
<th>1 ¾”</th>
<th>3 ½”</th>
<th>4”</th>
<th>FLR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>100</td>
<td>11</td>
<td>28</td>
<td>50</td>
<td>250</td>
<td>400</td>
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<td>110</td>
<td>12</td>
<td>31</td>
<td>55</td>
<td>450</td>
<td></td>
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</tr>
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<td>120</td>
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<td>34</td>
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### Gallons per Minute and Friction Loss Tables

**FRICION LOSS RATE (FLR) FOR GPM THROUGH HOSE PER 100' LENGTH HOSE**

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**NOTE:** Please refer to equivalent flow information.
Introduction
Fire Department pumpers are tested after any extensive repairs and annually. The following is intended to standardize the testing procedures. Services tests are based on the capacity specified for each apparatus. These capacities are in the original specifications.

General Information
“B” Shift (Maintenance) will schedule annual and service testing for our apparatus. Service testing takes place at San Miguel Fire Protection District station 15. Service testing follows NFPA 1911 standards and practices.

Service Test
All of the tests will be accomplished at the test site. The service test for a Class “A” fire pump consists of the following:

- Dry vacuum
- Quick lift
- 100% capacity
- 10% overload
- 70% capacity
- 50% capacity
- Relief valve
- Monitor

NOTE: 2006 Pierce is tested at 1500gpm even though it is rated at 2000gpm
Positioning the Apparatus, Hose and Equipment

The crew will assist the Engineer in positioning the apparatus at the test pit. Set air brakes and place wheel block. Before any hook ups are made, the "dry vacuum" test will be done. The remove intake screens, hook-up hard sections, turn relief valve to highest setting. Lay proper lengths of fire hose for size of pump (see diagram) and place stream straightener and valve on outlet #1. A drip pan will be placed under primary pump oil discharge.

Test Procedures

- **Dry Vacuum** - Place pump-shifting lever in pump position, engage priming pump and draw at least 22 inches of mercury. After disengaging the primary pump a loss of no more than 10 inches of mercury in 1 minute will pass Quick Lift Test. Place pump shift lever in pump position, engage the primary pump at idle speed and advance the r.p.m. To proper priming r.p.m. (See individual apparatus manual). Water should be discharged in a maximum of 30 seconds for a 1,250-gpm pump or less, and in a maximum of 45 seconds for 1,500 gpm pumps.
ANNUAL SERVICE TEST

- **100% Capacity** - When a constant discharge of water is obtained, disengage priming pump, advance throttle, and open correct discharge valves for remaining hose lines. Engineer will adjust engine rpm and choke discharge valve(s) to obtain desired nozzle and pump pressure (see Pump Test Chart). Hold for 20 minutes. This is 150 psi.

- **10% Overload** - After completion of the 100% capacity test, a 10% overload test will be conducted. The test is 10% higher pressure at 100% gpm. This is 165 psi.

- **70% Capacity** - Procedures will be the same as 100% test, with the exception of pressure (200 psi) and nozzle size. This test will last 10 minutes.

- **50% Capacity** - Procedures will be the same as 100% test, with the exception of pressure (250 psi) and nozzle size. This test will last 10 minutes.

- **Relief Valve** - At the completion of the 50% test, the relief valve will be tested. To test the valve, set it at 150 psi, shutdown a like line. The pump pressure should not increase more than 30 psi.

- **Monitor** - Remove the nozzle and cap the opening. Tighten all fittings. Pressurize the monitor to 250 psi for one minute.
CAFS (Compressed Air Foam System)

What is CAFS?

CAFS or compressed air foam system is when you take your basic water and foam mixture and add in compressed air. With compressed air added into the equation of water and foam you get a more effective firefighting agent with greater penetration and smothering effects. Simply put, CAFS are high-energy foam generators.

Why the Foam?

The foam or "soap" main function in a CAFS system is to allow the air and the water to mix. It provides a "medium" for the air and water. Without this foam (medium) or an insufficient amount of foam an inadequate mixture occurs sending pockets of water and air "slugs" to the nozzle. This condition known as "slug flow" only occurs with CAFS.

Why the compressed air?

Water has the ability to absorb a lot of heat (9300 btu’s/lb). However, as water is applied to a fire in drops, only the outer portion of each drop absorbs the heat. A large amount of the water passes by or through the fire, resulting in water damage. By pumping air into the water, each drop is blown up to a bubble forcing the entire drop to the exposed surface. This expanded "surface-to-mass ratio" (SMR) allows the entire drop to instantly absorb its full capacity of heat. No excess water passes through the fire – the fire goes out much faster and water damage is virtually eliminated.

What is the actual affect?

By fighting fire with CAFS, fully involved house fires have actually been extinguished in as little as 30 seconds using as little as 40 gallons of water. Most fires could actually be extinguished with small total amounts of water if the water could be applied effective enough for all of the initially applied drops to absorb the heat. Since water by itself is not applied effective enough form, large volumes are required, resulting in high run off and water damage. CAF application is effective enough to result in immediate heat absorption, thus resulting in the lower total water usage and damage.

How does it work?

As mentioned above, CAFS knocks out fire faster due mainly to the increased Surface-to-Mass Ratio (SMR). Expanding water drops into bubbles increases the SMR. Bubble expansion can be low, medium or high. Aspirating nozzles will expand water into higher SMR bubbles. The benefit to using CAFS over aspirating nozzles is the long distant, high energy stream for reach; combined with the expansion into small uniform bubbles that provide a stronger, longer lasting bubble than can be produced by aspirated bubbles. Foam solution is liquid drops; the SMR is the same as water. The benefit to Foam Solution over water is the decreased surface tension and it will adhere to carbon better than water. Most fog nozzles will break the Foam Solution in to smaller drops, increasing the SMR some what above water, however, Foam Solution is still in drop form and can pass through the fire wasting the water and causing damage. Foam solution also does not have the vertical holding capability to coat walls. Foal Solution will immediately run off of vertical surfaces. CAF is superior to Foam Solution
in that the compressed air expands the water to its maximum SMR, allowing it to immediately absorb heat and practically eliminate water damage. With the strong uniform bubbles, CAF can also cling to vertical surfaces.

**WARNING! PLAN WATER AND AIR DO NOT MIX**
When air is injected into a water stream without foam concentrate, a condition called slug flow will occur. Slug flow can damage hose lines and could cause the nozzle operator to lose control of the nozzle.
ADDITIONAL PRACTICE HYDRAULICS PROBLEMS

DETERMINE PUMP PRESSURE FOR THE FOLLOWING PROBLEMS

REFERENCE PAGE – 12 - 13

1. 125 GPM SOF NOZZLE, 600’ OF 2 ½” HOSE.
2. 150 GPM SOF NOZZLE, 550’ OF 2 ½” HOSE.
3. 200 GPM SOF NOZZLE, 800’ OF 2 ½” HOSE.
4. 250 GPM SOF NOZZLE, 650’ OF 2 ½” HOSE.

REFERENCE PAGE – 14 - 15

5. ¾” TIP, HAND HELD, 400’ OF 2 ½” HOSE.
6. 7/8” TIP, HAND HELD, 650’ OF 2 ½” HOSE.
7. 1” TIP, HAND HELD, 800’ OF 2 ½” HOSE.
8. 1 1/8” TIP, HAND HELD, 750’ OF 2 ½” HOSE.

REFERENCE PAGE – 16 - 17

9. 125 GPM SOF NOZZLE, 600’ OF 2 ½” HOSE, 60’ ABOVE PUMP.
10. 150 GPM SOF NOZZLE, 300’ OF 2 ½” HOSE, 20’ ABOVE PUMP.
11. 200 GPM SOF NOZZLE, 650’ OF 2 ½” HOSE, 80’ ABOVE PUMP.
12. 250 GPM SOF NOZZLE, 850’ OF 2 ½” HOSE, 100’ ABOVE PUMP.

REFERENCE PAGE – 18 - 19

13. 125 GPM SOF NOZZLE, 400’ OF 2 ½” HOSE, 50’ BELOW PUMP.
14. 150 GPM SOF NOZZLE, 650’ OF 2 ½” HOSE, 110’ BELOW PUMP.
15. 200 GPM SOF NOZZLE, 350’ OF 2 ½” HOSE, 70’ BELOW PUMP.
16. 250 GPM SOF NOZZLE, 550’ OF 2 ½” HOSE, 30’ BELOW PUMP.
17.  30 GPM SOF NOZZLE, 600' OF 1 ¾" HOSE.
18.  60 GPM SOF NOZZLE, 350' OF 1 ¾" HOSE.
19.  95 GPM SOF NOZZLE, 300' OF 1 ¾" HOSE.
20.  125 GPM SOF NOZZLE, 100' OF 1 ¾" HOSE.
21.  150 GPM SOF NOZZLE, 700' OF 1 ¾" HOSE.
22.  175 GPM SOF NOZZLE, 450' OF 1 ¾" HOSE.
23.  200 GPM SOF NOZZLE, 450' OF 1 ¾" HOSE.

REFERENCE PAGE – 22- 23

24.  DETERMINE PUMP & GATED PRESSURE – TWO 1 ¾" HANDLINES, LINE ONE – 125 GPM SOF NOZZLE, 450' OF 1 ¾" HOSE, LINE TWO – 125 GPM SOF NOZZLE, 600' OF 1 ¾" HOSE.
25.  DETERMINE PUMP & GATED PRESSURE – TWO 1 ¾" HANDLINES, LINE ONE – 150 GPM SOF NOZZLE, 100' OF 1 ¾" HOSE, LINE TWO – 200 GPM SOF NOZZLE, 200' OF 1 ¾" HOSE.
26.  DETERMINE PUMP & GATED PRESSURE – TWO 1 ¾" HANDLINES, LINE ONE – 125 GPM SOF NOZZLE, 450' OF 1 ¾" HOSE, LINE TWO – 125 GPM SOF NOZZLE, 600' OF 1 ¾" HOSE.
27.  DETERMINE PUMP & GATED PRESSURE – TWO 1 ¾" HANDLINES, LINE ONE – 60 GPM SOF NOZZLE, 100' OF 1 ¾" HOSE, LINE TWO – 200 GPM SOF NOZZLE, 350' OF 1 ¾" HOSE.

REFERENCE PAGE – 24- 25

28.  30 GPM SOF NOZZLE, 200' OF 1 ¾" HOSE, ADD 250' OF 1 ¾" HOSE.
29.  60 GPM SOF NOZZLE, 100' OF 1 ¾" HOSE, ADD 200' OF 1 ¾" HOSE.
30.  125 GPM SOF NOZZLE, 200' OF 1 ¾" HOSE, ADD 350' OF 1 ¾" HOSE.
31.  150 GPM SOF NOZZLE, 350' OF 1 ¾" HOSE, ADD 350' OF 1 ¾" HOSE.

REFERENCE PAGE – 26- 27

32.  3/16" WILDLAND TIP, 600' OF 1 ½" HOSE.
33.  ¼" WILDLAND TIP, 1000' OF 1 ½" HOSE.
34.  3/8" WILDLAND TIP, 950' OF 1 ½" HOSE.
35.  ½" WILDLAND TIP, 750' OF 1 ½" HOSE.
36. 5 GPM SOF NOZZLE, 200’ OF 1” HOSE.
37. 10 GPM SOF NOZZLE, 400’ OF 1” HOSE.
38. 20 GPM SOF NOZZLE, 300’ OF 1” HOSE.
39. 40 GPM SOF NOZZLE, 100’ OF 1” HOSE.

40. 5 GPM SOF NOZZLE, 100’ OF 1” HOSE, AND 150’ OF ¾” REDLINE.
41. 10 GPM SOF NOZZLE, 100’ OF 1” HOSE, AND 150’ OF ¾” REDLINE.
42. 40 GPM SOF NOZZLE, 100’ OF 1” HOSE, AND 150’ OF ¾” REDLINE.

43. 1 1/8” TIP HAND HELD ON 200’ OF 2 ½” HOSE, SUPPLIED BY TWO 2 ½” x 450’ SIAMESE HOSE LINES.
44. 250 GPM SOF ON 300’ OF 2 ½” HOSE, SUPPLIED BY TWO 2 ½” x 350’ SIAMESE HOSE LINES.
45. 1” TIP HAND HELD ON 150’ OF 2 ½” HOSE, SUPPLIED BY TWO 2 ½” x 500’ SIAMESE HOSE LINES.
46. ¾” TIP HAND HELD ON 400’ OF 2 ½” HOSE, SUPPLIED BY TWO 2 ½” x 250’ SIAMESE HOSE LINES.

47. ONE HAND HELD 1 1/8” TIP, ON 150’ OF 2 ½” HOSE, SUPPLIED BY TWO UNEQUAL 2 ½’ SIAMESE HOSE LINES, ONE 250’ THE SECOND 350’.
48. 200 GPM SOF NOZZLE, ON 300 FEET OF 2 ½” HOSE, SUPPLIED BY TWO UNEQUAL 2 ½’ SIAMESE HOSE LINES, ONE 150’ THE SECOND 250’.
49. TWO 150 GPM SOF NOZZLES EACH ON 400’ OF 2 ½” HOSE, WYED OFF OF ONE 150’ LENGTH OF 2 ½” SUPPLY LINE.

50. TWO 175 GPM SOF NOZZLES EACH ON 200’ OF 2 ½” HOSE, WYED OFF OF ONE 300’ LENGTH OF 2 ½” SUPPLY LINE.

51. TWO 1” TIPS, EACH ON 500’ OF 2 ½” HOSE, WYED OFF OF ONE 200’ LENGTH OF 2 ½” SUPPLY LINE.

52. TWO 1 1/8” TIPS, EACH ON 500’ OF 2 ½” HOSE, WYED OFF OF ONE 200’ LENGTH OF 2 ½” SUPPLY LINE.

53. TWO 150 GPM SOF NOZZLES, ONE ON 200’ OF 2 ½”, THE SECOND ON 300’ OF 2 ½” HOSE, WYED OFF OF ONE 100’ LENGTH OF 2 ½” SUPPLY LINE.

54. TWO 175 GPM SOF NOZZLES, ONE ON 200’ OF 2 ½”, THE SECOND ON 350’ OF 2 ½” HOSE, WYED OFF OF ONE 250’ LENGTH OF 2 ½” SUPPLY LINE.

55. TWO ¾” TIPS, ONE ON 300’ OF 2 ½”, THE SECOND ON 450’ OF 2 ½” HOSE, WYED OFF OF ONE 250’ LENGTH OF 2 ½” SUPPLY LINE.

56. TWO 200 GPM SOF NOZZLES, ONE ON 100’ OF 2 ½”, THE SECOND ON 250’ OF 2 ½” HOSE, WYED OFF OF ONE 100’ LENGTH OF 2 ½” SUPPLY LINE.

57. TWO STRAIGHT TIP NOZZLES, ONE IS 1” TIP ON 300’ OF 2 ½”, THE SECOND IS A 1 1/8” TIP ON 300’ OF 2 ½” HOSE, WYED OFF OF ONE 100’ LENGTH OF 2 ½” SUPPLY LINE.

58. TWO SOF NOZZLES, ONE IS 150 GPM SOF ON 150’ OF 2 ½”, THE SECOND IS A 250 GPM SOF ON 150’ OF 2 ½” HOSE, WYED OFF OF ONE 400’ LENGTH OF 2 ½” SUPPLY LINE.

59. TWO STRAIGHT TIP NOZZLES, ONE IS A ¾” TIP ON 350’ OF 2 ½”, THE SECOND IS A 1” TIP ON 350’ OF 2 ½” HOSE, WYED OFF OF ONE 250’ LENGTH OF 2 ½” SUPPLY LINE.
60. TWO 300’ x 1 ¾” HANDLINES WITH A 60 GPM SOF NOZZLE. THE TWO 1 ¾” LINES ARE WYED OFF OF ONE 400’ LENGTH OF 2 ½” SUPPLY LINE.

61. TWO 150’ x 1 ¾” HANDLINES WITH A 175 GPM SOF NOZZLE. THE TWO 1 ¾” LINES ARE WYED OFF OF A 600’ LENGTH OF 2 ½” SUPPLY LINE.

62. TWO 150’ x 1 ¾” HANDLINES WITH A 125 GPM SOF, THE TWO 1 ¾” LINES ARE WYED OFF OF A 600’ LENGTH OF 2 ½” SUPPLY LINE.

63. TWO 250’ x 1 ¾” HANDLINES WITH A 200 GPM SOF, THE TWO 1 ¾” LINES ARE WYED OFF OF A 200’ LENGTH OF 2 ½” SUPPLY LINE.

64. DELUGE SET OR GROUND MONITOR WITH A 2” TIP, SUPPLIED BY THREE 400’ LENGTHS OF 2 ½”.

65. DELUGE SET OR GROUND MONITOR WITH A 1” TIP, SUPPLIED BY TWO 500’ LENGTHS OF 2 ½”.

66. DELUGE SET OR GROUND MONITOR WITH A 750 GPM SOF SUPPLIED BY THREE 450’ LENGTHS OF 2 ½”.

67. DELUGE SET OR GROUND MONITOR WITH A TURBOJET 1000 GPM FOG SUPPLIED BY THREE 200’ LENGTHS OF 2 ½”.

68. AERIAL LADDER (NOT PRE-PLUMBED) WITH 1 ¼” TIP, AT 80’ ELEVATION, SUPPLIED BY 400’ OF 4”, TO THE TRUCKS 100’ LENGTH OF 3 ½” HOSE.

69. AERIAL LADDER (NOT PRE-PLUMBED) WITH 1 ½” TIP, AT 100’ ELEVATION, SUPPLIED BY 600’ OF 4”, TO THE TRUCKS 100’ LENGTH OF 3 ½” HOSE.

70. AERIAL LADDER (NOT PRE-PLUMBED) WITH 1 ¾” TIP, AT 75’ ELEVATION, SUPPLIED BY 350’ OF 4”, TO THE TRUCKS 100’ LENGTH OF 3 ½” HOSE.

71. AERIAL LADDER (NOT PRE-PLUMBED) WITH 1000 GPM FOG AT 50’ ELEVATION, SUPPLIED BY 200’ OF 4”, TO THE TRUCKS 100’ LENGTH OF 3 ½” HOSE.
72. PRE-PLUMBED AERIAL LADDER WITH 1 ¼” TIP, AT 100’ ELEVATION, SUPPLIED BY THREE 200’ LENGTHS OF 2 ½” HOSE.
73. PRE-PLUMBED AERIAL LADDER WITH 1 ½” TIP, AT 80’ ELEVATION, SUPPLIED BY THREE 300’ LENGTHS OF 2 ½” HOSE.
74. SNORKLE WITH 1 ¾” TIP, AT 40’ ELEVATION, SUPPLIED BY THREE 100’ LENGTHS OF 2 ½” HOSE.
75. SNORKLE WITH 2” TIP, AT 60’ ELEVATION, SUPPLIED BY THREE 350’ LENGTHS OF 2 ½” HOSE.

76. PRE-PLUMBED AERIAL LADDER WITH 1 ¼” TIP, AT 100’ ELEVATION, SUPPLIED BY A 200’ LENGTH OF 4” HOSE.
77. PRE-PLUMBED AERIAL LADDER WITH 1 ½” TIP, AT 80’ ELEVATION, SUPPLIED BY A 500’ LENGTH OF 4” HOSE.
78. SNORKLE WITH 1 ¾” TIP, AT 40’ ELEVATION, SUPPLIED BY A 600’ LENGTH OF 4” HOSE.
79. SNORKLE WITH 2” TIP, AT 60’ ELEVATION, SUPPLIED BY A 450’ LENGTH OF 4” HOSE.

80. STANDPIPE TO THE 12TH FLOOR WITH A SINGLE 1 ¾” HOSE 150’ LONG FLOWING A 150 GPM SOF NOZZLE AND SUPPLIED BY TWO 200’ LENGTHS OF 2 ½” HOSE.
81. STANDPIPE TO THE 5TH FLOOR WITH TWO 1 ¾” HOSE 150’ LONG FLOWING 175 GPM SOF NOZZLES AND SUPPLIED BY TWO 300’ LENGTHS OF 2 ½” HOSE.
82. STANDPIPE TO THE 9TH FLOOR WITH TWO 1 ¾” HOSE 150’ LONG EACH FLOWING 125 GPM SOF NOZZLES AND SUPPLIED BY TWO 100’ LENGTHS OF 2 ½” HOSE.
83. STANDPIPE TO THE 4TH FLOOR WITH TWO 2 ½” HOSE LINES 100’ LONG EACH FLOWING 200 GPM SOF NOZZLES AND SUPPLIED BY TWO 400’ LENGTHS OF 2 ½” HOSE.
84. SPRINKLER SYSTEM ON THE 1ST FLOOR WITH 8 HEADS FUSED. SYSTEM IS SUPPLIED BY TWO 100’ LENGTHS OF 2 ½” HOSE.
85. SPRINKLER SYSTEM ON THE 14TH FLOOR WITH 12 HEADS FUSED. SYSTEM IS SUPPLIED BY TWO 200’ LENGTHS OF 2 ½” HOSE.
86. SPRINKLER SYSTEM ON THE 13TH FLOOR WITH 18 HEADS FUSED. SYSTEM IS SUPPLIED BY TWO 400’ LENGTHS OF 2 ½” HOSE.
87. SPRINKLER SYSTEM ON THE 10TH FLOOR WITH 20 HEADS FUSED. SYSTEM IS SUPPLIED BY TWO 250’ LENGTHS OF 2 ½” HOSE.
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