# PUMP OPERATIONS

SAN FRANCISCO FIRE DEPARTMENT

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Pump Operations
January 2008

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## FOREWORD

The goal of this manual is to establish standard operating practices as authorized by the Chief of Department and implemented by the Division of Training.

The purpose of this manual is to provide all members with the essential information necessary to fulfill the duties of their positions, and to provide a standard text whereby company officers can:

- Enforce standard drill guidelines authorized as a basis of operation for all companies.
- Align company drills to standards as adopted by the Division of Training.
- Maintain a high degree of proficiency, both personally and among their subordinates.

All manuals shall be kept up to date so that all officers may use the material contained in the various manuals to meet the requirements of their responsibility.

Conditions will develop in fire fighting situations where standard methods of operation will not be applicable. Therefore, nothing contained in these manuals shall be interpreted as an obstacle to the experience, initiative, and ingenuity of officers in overcoming the complexities that exist under actual fire ground conditions.

To maintain the intent of standard guidelines and practices, no correction, modification, expansion, or other revision of this manual shall be made unless authorized by the Chief of Department. Suggestions for correction, modification or expansion of this manual shall be submitted to the Division of Training. Suggestions will be given due consideration, and if adopted, notice of their adoption and copies of the changes made will be made available to all members by the Division of Training.

Joanne Hayes-White
Chief of Department

## Table of Contents

# SECTION 1. INTRODUCTION

## GENERAL THEORY

Fire pumps are machines used for the purpose of transmitting energy to water. This energy is transferred to water in the form of velocity and it is this velocity which, when confined to the interior of the pump and to the inside of a hose line, is converted into pressure.

Pressure is the energy that enables water to flow through the hose lines from the point at which it is available to the point of application. It is the force that overcomes the retarding effects of back pressure and friction loss and provides the necessary velocity of discharge at the nozzle.

Water is the most commonly used fire-extinguishing agent and is the primary agent with which the pump operator is concerned. Every pump operator should have a working knowledge of the physical laws and theories which govern the supply of water to the pump, the transfer of energy to water within the pump, and the flow of water through the hose lines, fittings, and nozzles to the point of application.

## METHODS OF WATER SUPPLY

There are two methods by which water may be supplied to the inlet of a pump.

## SUPPLY UNDER PRESSURE

This method is provided mainly by our municipal water supply and high pressure hydrant system (Auxiliary Water Supply System, AWSS). Water is also supplied under pressure when relayed by another pump, when taken by gravity pressure from a booster tank or a down pipe connected to a roof tank or pressure tank.

## DRAFTING

Drafting is the process by which atmospheric pressure is utilized to induce water to enter the pump from a source below the level of the pump. A vacuum is created within the pump and hard suction hose, thus allowing the weight of the atmosphere (atmospheric pressure) to push water into this void. The terms suction and drafting are used to describe the process. However, the term suction may be misunderstood by pump operators undergoing instruction, and it is therefore pointed out that no engine has the power to suck or pull water to its inlet.

Locating and using engines to their best advantage at fires is a field operations concern and is the responsibility of the Incident Commander. However, it is the duty of the company officer to place their engine in position for service at an incident. This does not relieve the pump operator from spotting water supply sources, visualizing what hose leads can be made and knowing where to position the apparatus for most optimum service. Once the apparatus has been positioned and ordered to go to work, supplying and maintaining an adequate water supply for the pumper is mainly the responsibility of the pump operator. Company Officers and members of other responding companies should comply with requests from pump operators requesting a supply line.

# SECTION 2. FIRE PUMPS

## FIRE PUMPS

The two types of water pumps used in the fire service are:

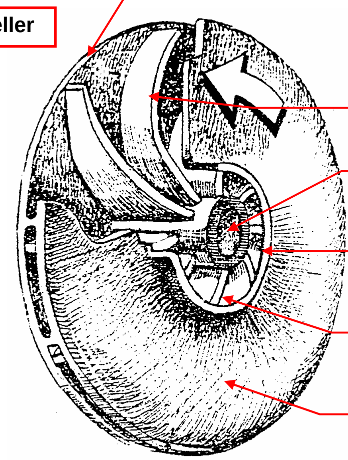
1. Centrifugal Pumps
2. Positive Displacement Pumps

## CENTRIFUGAL PUMPS

The Centrifugal Pump is most widely used type of pump and all pumps in the SFFD are centrifugal pumps.

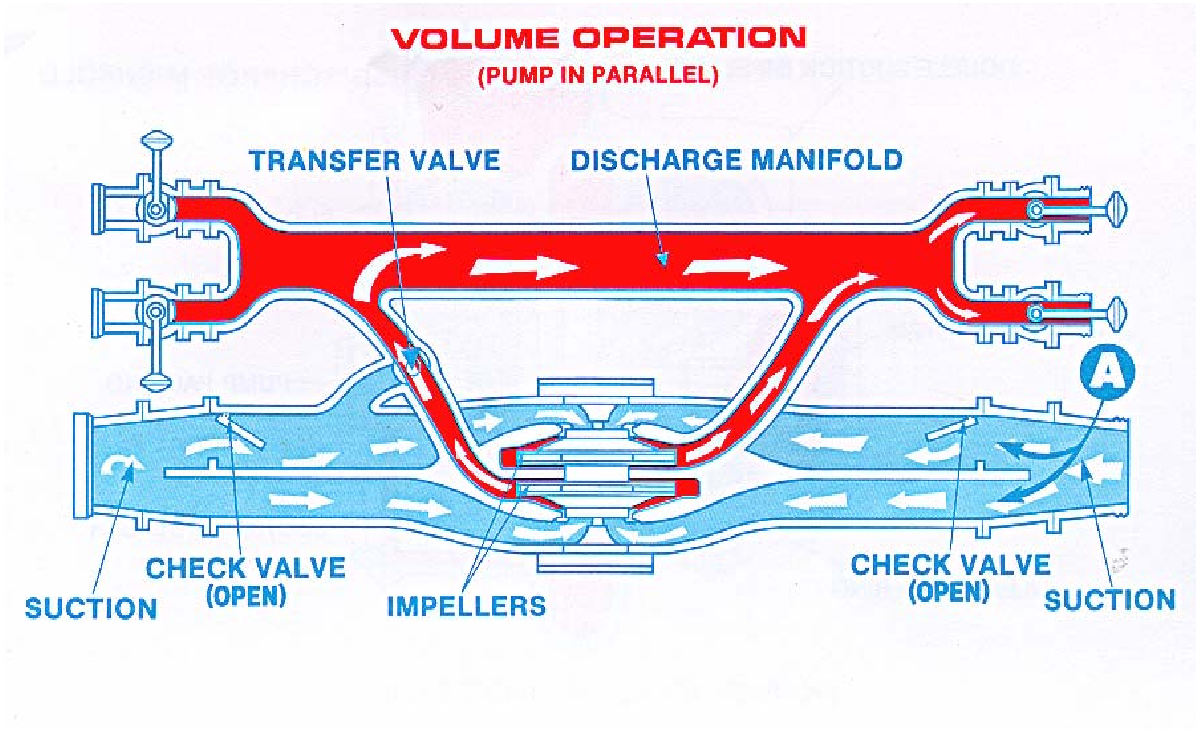
The Centrifugal Pump is based on the principal of centrifugal force - tendency of water within a revolving body to flow outward from the center of rotation. The pump consists essentially of a disc known as the ***impeller*** that receives water at its center and discharges it at its outer edge. This action creates pressure energy in the water that the pump handles by first imparting velocity energy to the water, due to rotation of the ***impeller***, and then changing the velocity energy to pressure energy as the water passes through the confining passages of the pump casing.

**Figure 1. Centrifugal Pump Impeller**



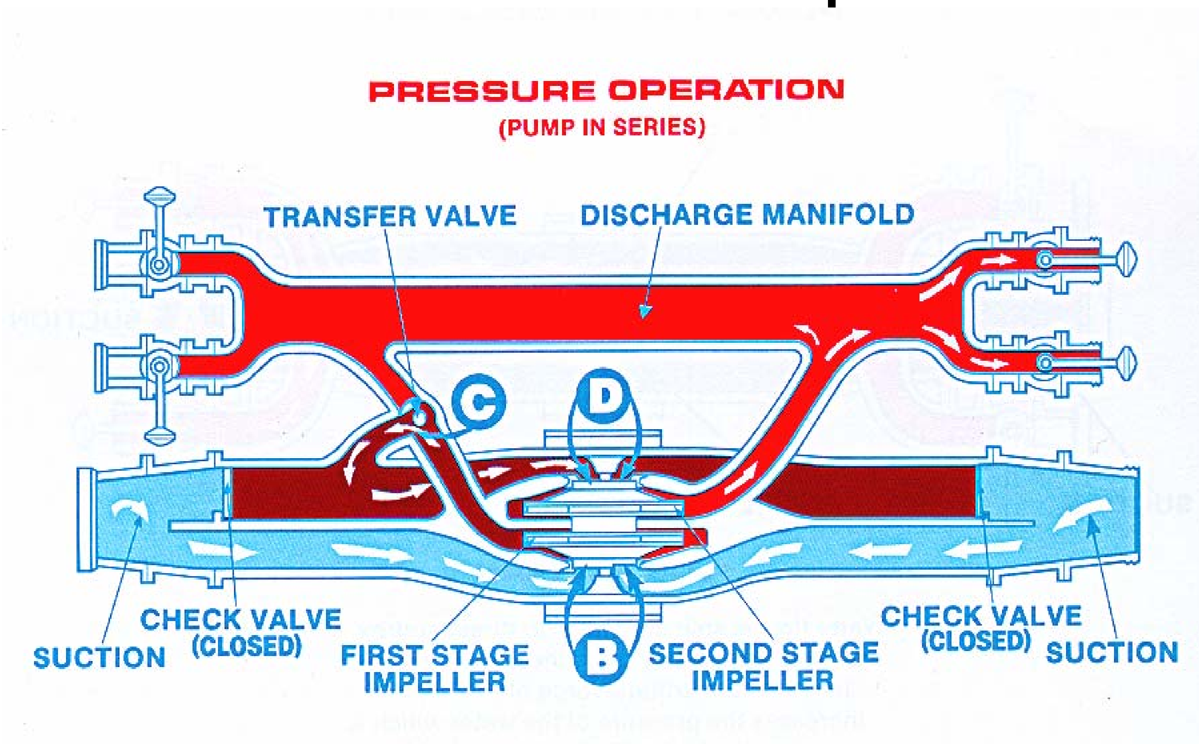

Centrifugal pumps have two main parts—the ***impeller***, and the ***volute*** (or diffusion casing). Each part has a separate function—the ***impeller*** imparts velocity to the water, the volute transforms this velocity energy into pressure energy.

# Typical Two-Stage Water Flow Pattern




Centrifugal pumps are designed to operate with either one or a series of impellers. Each impeller is referred to as a **stage**. Pumps with one impeller are commonly classified as **single stage pumps**. Pumps equipped with a series of impellers are classified as **multi-stage pumps**.

# Volume Vs. Pressure Operation



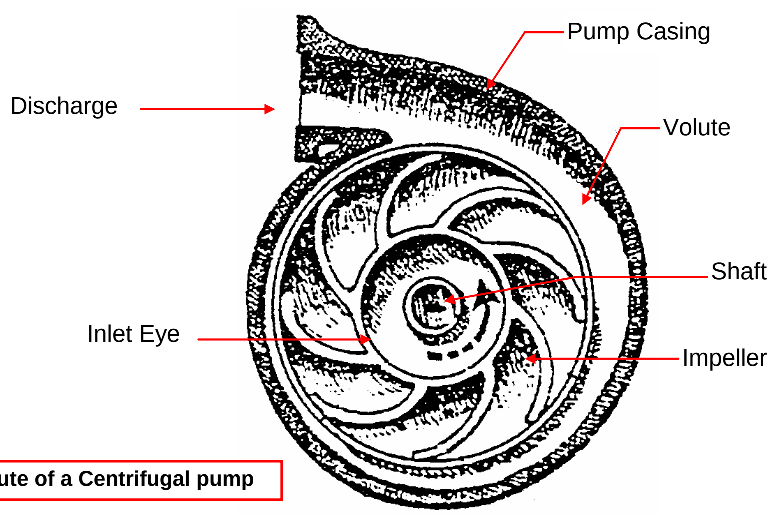




**Figure 2. Volute of a Centrifugal pump**

The term **multiple** is further clarified by the number and arrangement of the impellers. If the pump is equipped with a series of two impellers so designed that the discharge will flow successively from one impeller to the other, the pump is then commonly referred to as a **two-stage series pump**. If the design is such that each impeller may discharge individually to the pump outlet, as well as in series, the pump is then termed a **two-**

**stage parallel/series pump**. All of the pumps presently in our Department are equipped with two impellers and are classified as two-stage parallel/series pumps.

Most parallel-series fire pumps are usually constructed with impellers of identical design and mounted on a single shaft so that they all revolve at the same speed. Transfer from series to parallel operation, and vice versa, is accomplished by an arrangement of waterways within the casing. This process is also assisted by the use of hydraulically or manually operated change-over or transfer valves supplemented by automatically operated pressure check or clapper valves.

Assuming that each stage of the pump shown has a rating of 750 gpm at 150 psi with the pump in parallel operation each stage is capable of discharging 750 GPM at 150 psi, the total discharge being 1500 GPM at 150 psi. (Figure 3)

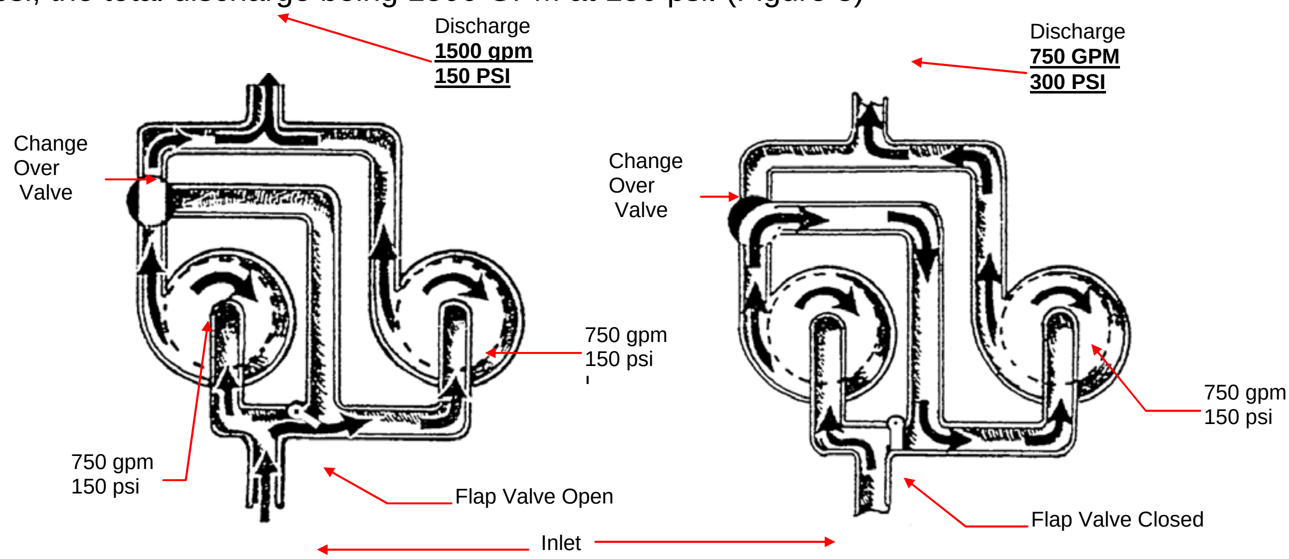



**Figure 3. Parallel Operation - Volume**

**Figure 4. Series Operation - Pressure**

When in series operation, the second stage of the pump receiving 750 GPM at 150 psi, adds an equal amount of pressure thereby providing an ultimate pump discharge of 750 GPM at 300 psi. (Figure 4) These figures are theoretical; however do not take into account any pressure loss developed by eddy and shock formation within the flow and friction loss within the impellers, pump casing, and waterways.

The method employed in transferring the operation of the parallel/series pump varies with different makes, depending upon the design of the pump, the number of impellers used, and the waterway arrangement.

The ability of the parallel/series type of pump to operate either at maximum designated volume or at its maximum designated pressure with either operation being within a comparatively close range of engine speed, provides great flexibility in meeting pumping requirements. In this type of pump, with a constant motor and pump speed, considerably higher pressure is obtained in series operation, with a reduction in maximum discharge volume. With discharge pressure remaining constant, a change from parallel to series operation will result in reduced motor and pump speed. Conversely, when changing from series to parallel operation, maintaining a constant pressure will require increased motor and pump speed, or maintaining a constant motor and pump speed will result in reduced discharge pressure. Maximum discharge volume is possible only in parallel operation.

## PUMP TRANSMISSION

Most pumpers are capable of operating at a capacity (volume/parallel) rating within 80% of the peak speed and at high pressure (series) ratings within 90% of the peak motor speed, (peak speed is the maximum speed of the motor at which it develops its greatest power). The peak speed rating is required to assure some degree of reserve power in the motor.

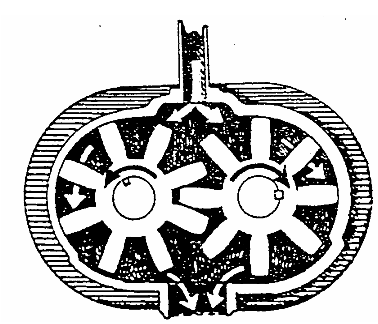
All SFFD fire pumpers should initially be operated with their changeover valves in the **volume/parallel** position (With exception of those purchased before 1983 should initially operate with their changeover valves in the **pressure or series position**. **These are the 5" Ward LaFrance Hose Tenders).**

## PUMP PRIMERS

The process of exhausting air from the pump and hard suction hose, thus allowing water pushed by the weight of the atmosphere (atmospheric pressure) to fill the void is called **priming**.

Positive displacement pumps are capable of exhausting this air from the pump and the suction hose, and thus have no need of an auxiliary primer. Positive displacement pumps move a given amount of water through the pump chamber with each stroke. For this reason they are frequently described as "self priming" pumps.

Figure 5. Rotary Gear Pump



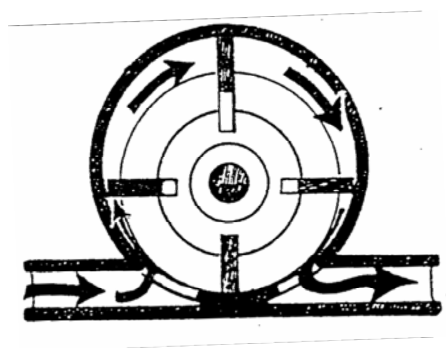
Centrifugal pumps are not capable of creating a vacuum sufficient to exhaust the air from the suction hose and pump. The centrifugal pump, being unable to prime itself, accomplishes this by the use of auxiliary devices commonly referred to as “primers” or “priming pumps”.

The modern method is to provide a small auxiliary pump (priming pump) of the positive displacement type to create vacuum. This method is utilized on all presently maintained SFFD engines.

**All** SFFD priming pumps are rotary vane type priming pumps.

On the rotary vane priming pump, the suction side of the primer is connected directly to the casing of the main pump so that when the primer is operated, a vacuum is created in the main pump, permitting the water to rise and fill the pump.

Figure 6. Rotary Vane Pump



During drafting operations the entire pump should be primed within 30 to 45 seconds. This can be determined by pressure showing on the pressure gauge, by a change in the sound of the pump when water hits the impellers, or by water being discharged from the primer. Do not run a pump dry for a period longer than 45 seconds; failure to prime within that period usually indicates that air is leaking into the pump. Check all suction connections to see that they are tight and all valves, drains, washers etc., to see that they are closed; then try again. A high reading on the vacuum gauge with no water entering the pump within 30 to 45 seconds may indicate that the suction lift is too high or that the strainer may be obstructed. Failure of the type of primer that runs in a bath of oil or grease to secure a prime may indicate that the priming pump is dry and needs lubrication. The 2006 American LaFrance and engines purchased after, have EPA-approved antifreeze for lubrication. The reservoir is located on the forward panel inside the pump compartment. Notify the BOE when fluid needs to be added.

Weekly operation of the primer pump is recommended for proper lubrication of the pump.

***<u>AT NO TIME SHOULD THE PRIMER PUMP BE ACTIVATED WHILE CONNECTED TO A POSITIVE PRESSURE WATER SOURCE</u>***.

The pump panel (a.k.a. ground control panel) is the control center for getting water into and out of the pumper. It is located on the outer body of the apparatus. Gauges, operating devices, and controlling devices are located on the panel. Department Engines although different, the pump panels are similar in style. Use this as a reference and compare to the engine you are operating.


**Rear**


**Front**


**Driver's Side**


Officer's Side

Fire pumps are classified by their capacities.  These capacities are more commonly referred to as the "rated capacities" of the pump.  All pumpers in the SFFD have a minimum rated capacity of 1250 gpm with those apparatus purchased after 1983 having a 1500 gpm rated capacity, and a 500-gallon capacity on the onboard tank.

## UL AND NFPA STANDARDS

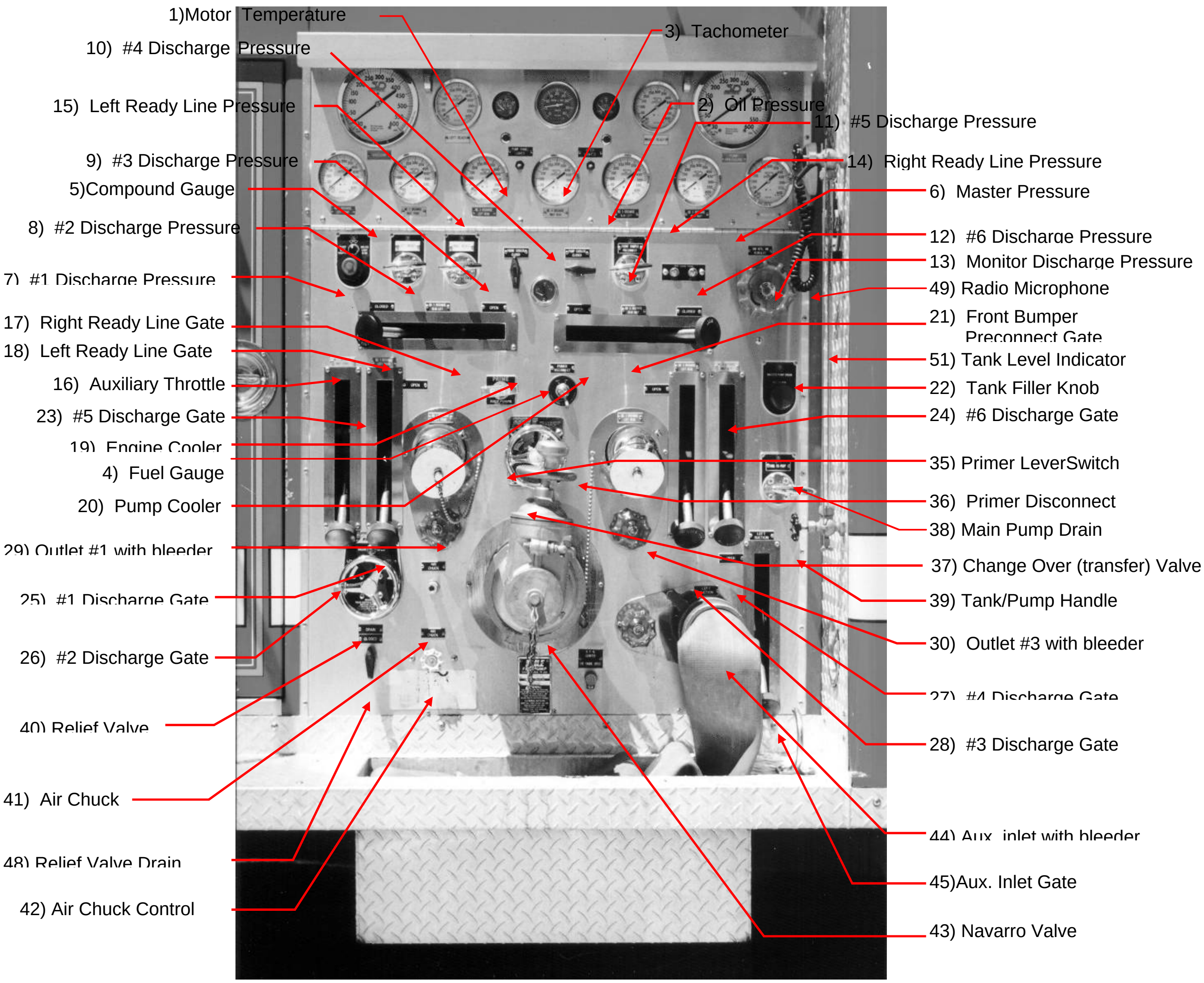
Standards for modern fire pumps also provide that the pump shall deliver the percentage of its rated capacity at pressures stated below:

- 100% of rated capacity at 150 psi net pump pressure
- 70% of rated capacity at 200 psi net pump pressure
- 50% of rated capacity at 250 psi net pump pressure.

The above classifications and standards are set by the National Fire Protection Association (NFPA) and the International Association of Fire Chiefs (IAFC).  Using these standards, a municipality can demand specifications that will insure delivery of equipment which will perform satisfactorily and provide maximum utility and value for the money expended.

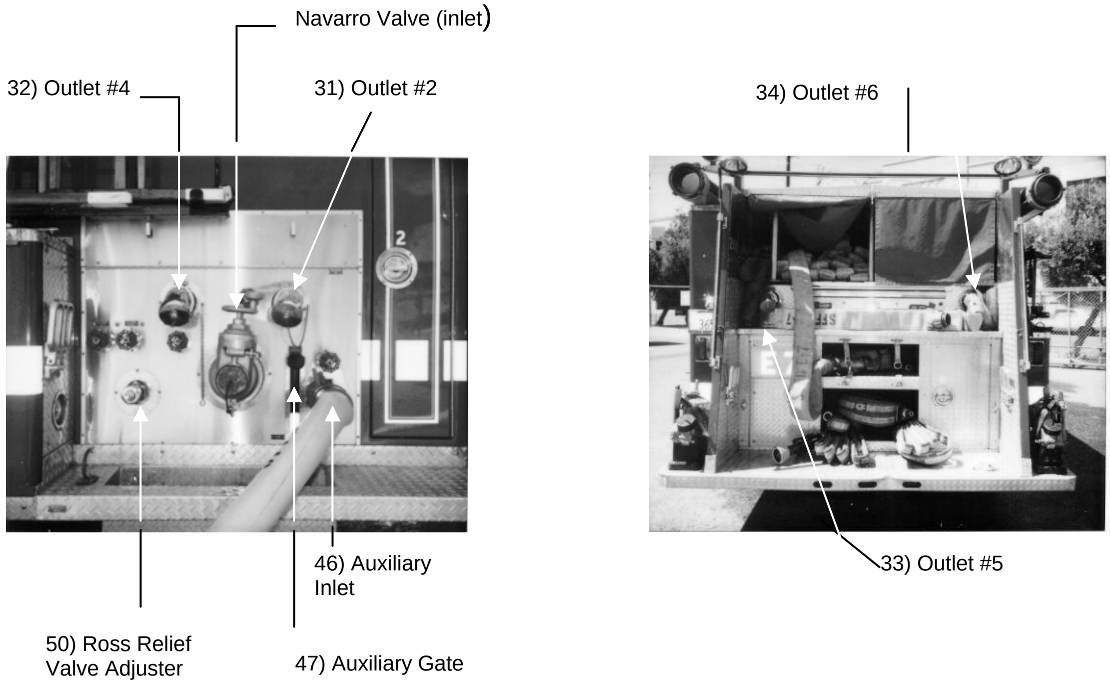
Prior to delivery of any fire engine, all pumps are tested at the factory by Underwriters Laboratory for compliance with these standards. Once delivered to the SFFD, they are again tested prior to final acceptance.

The engines purchased by the SFFD are “Triple Combination” engines. They are equipped with a pump, hose, and a water tank, hence, the term "triple." Engines of this type can be positioned for immediate attack on the fire using water from the on-board water tank. To assure continuous operation of the pre connected lines, and any other lines subsequently led from this engine, a water supply should be secured as soon as possible. This can be accomplished by connecting to a hydrant or securing a supply line from another engine company




Spartan 3D Pump Panel
(Driver's Side Pump Panel)

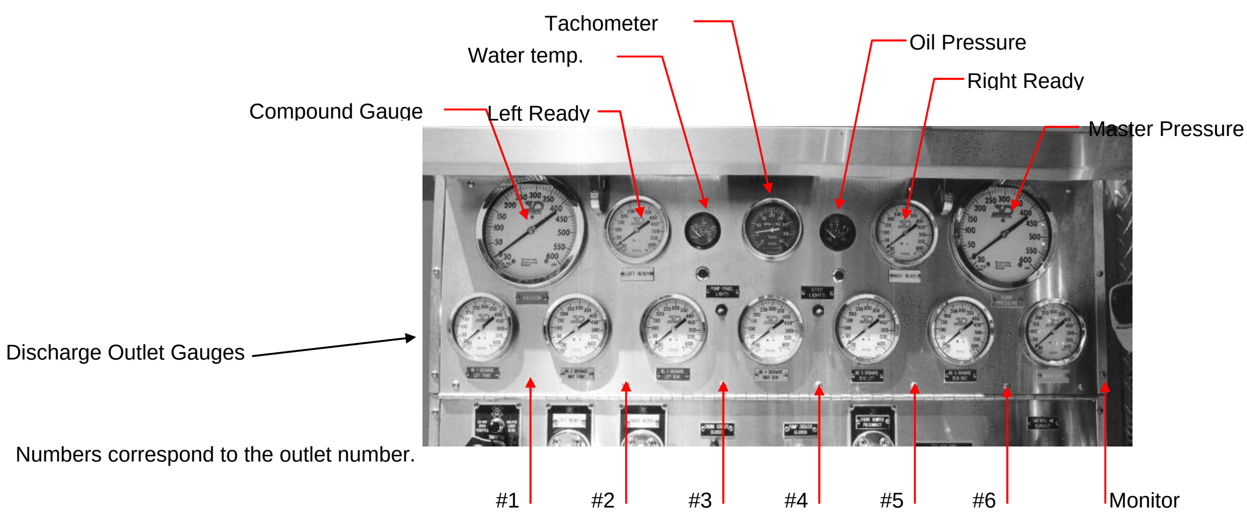
# Back of Rig




1. Motor Temperature Gauge
2. Oil Pressure Gauge
3. Tachometer
4. Fuel Gauge
5. Compound gauge
6. Master Pressure Gauge
7. #1 Discharge Pressure Gauge
8. #2 Discharge Pressure Gauge
9. #3 Discharge Pressure Gauge
10. #4 Discharge Pressure Gauge
11. #5 Discharge Pressure Gauge
12. #6 Discharge Pressure Gauge
13. Monitor Discharge Pressure
14. Right Ready Line Pressure Gauge
15. Left Ready Line Pressure Gauge
16. Auxiliary Throttle
17. Right Ready Line Gate
18. Left Ready Line Gate
19. Engine Cooler Switch
20. Pump Cooler (Recalculating Valve)
21. Front Bumper Preconnect Gate
22. Tank Filler
23. # 5 Discharge Gate
24. # 6 Discharge Gate
25. # 1 Discharge Gate
26. # 2 Discharge Gate
27. # 4 Discharge Gate
28. # 3 Discharge Gate
29. Outlet # 1 with bleeder (driver's side pump panel)
30. Outlet # 3 with bleeder (driver's side pump panel)
31. Outlet # 2 with bleeder (officer's side pump panel)
32. Outlet # 4 with bleeder (officer's side pump panel)
33. Outlet # 5 (back of rig)
34. Outlet # 6 (back of rig)
35. Primer
36. Primer Disconnect
37. Change-Over (Transfer) Valve
38. Main Pump Drain
39. Tank-to-Pump Handle
40. Relief Valve
41. Air Chuck
42. Air Chuck Control
43. Navarro Valve (inlet)
44. Auxiliary Suction Inlet with bleeder
45. Auxiliary Suction Inlet Gate
46. Auxiliary Suction Inlet with bleeder
47. Auxiliary Suction Inlet Gate
48. Relief Valve Drain
49. Radio Microphone
50. Ross Relief Valve
51. Tank Level Indicator

## PUMP PANEL GAUGES

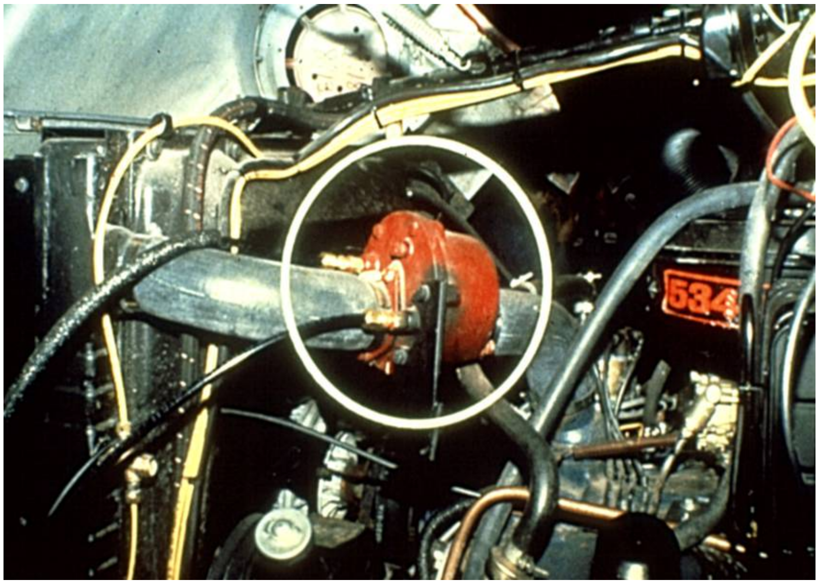
The gauges on the pump panel keep the pump operator informed of the running status of the engine motor and water pressures.




## TEMPERATURE

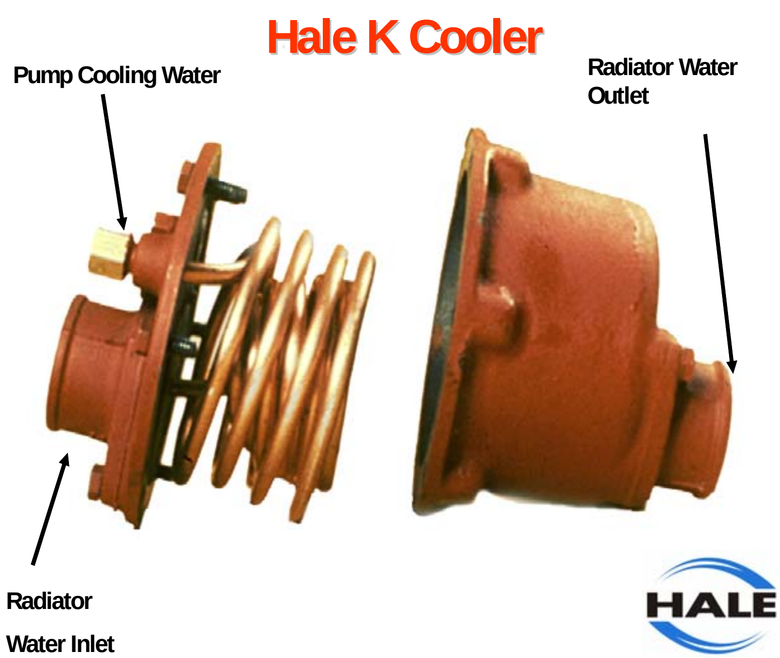
Engine temperature gauges are located on the cab instrument panel and the pump panel. These two gauges measure engine temperature only.

The ideal temperature for older apparatus (Ward and American La France) is 180-190 degrees F.  The danger temperature is 200+ degrees F°.  The ideal temperature for the newer apparatus is 210-215 degrees F., with their danger temperature being 220+ degrees F.




The radiator should be checked daily when the engine is cool. Coolant level should be 1 inch below cap level. For those engines with a radiator recovery tank, the coolant level should be as indicated on the recovery tank. Some engines have low coolant sensors; however, a visual check must be performed.

If the apparatus engine begins to overheat, gradually open the indirect cooler (direct coolers have been eliminated on all new apparatus) and monitor the temperature. If this does not reduce the temperature notify the Incident Commander immediately.



Remember, it is possible to take the engine out of pump and use the apparatus as a manifold allowing the water to flow through the pump at supply pressure.

## Oil Pressure

The oil pressure gauge indicates that lubricating oil is in the engine and that it is being pumped under pressure. Normal oil pressure differs by manufacturer and model. Recommended pressures are determined by the Bureau of Equipment.

As apparatus age, very little or no pressure may register at idle. This is normal; as motor speed increases, pressure will be indicated on the pressure gauge

In the event of a sudden pressure drop, immediately investigate and take steps to correct the problem before serious damage results. Remember that the gauge indicates the pressure at which the oil is being pumped; it does not indicate the quantity of oil within the engine . A shortage of oil should cause the gauge indicator to rise and fall irregularly. If this should occur, stop the engine as soon as possible and check the oil level.
Pump operators should always check the oil level:

- During daily apparatus check
- Upon the return to quarters after a working fire
- Frequently check the oil pressure gauge whenever the engine is running.

When no oil pressure is indicated on the interior instrument panel and pump panel oil pressure gauges, **do not operate the apparatus under any circumstances**. Stop the engine and report the condition to the Bureau of Equipment.

## Tachometer

A tachometer measures the revolutions per minute (rpm) of the engine . A tachometer is provided on the dash and on the pump panel.

While pumping, the pump may reach a point when increasing the motor speed does not increase the pressure. This usually indicates that the capacity of the pump or water supply has been reached or exceeded. When this occurs, the motor speed should be reduced until the pressure starts to drop. The only way to increase hose pressure, under this condition, is to shut down a hose line, reduce the nozzle tip size or add an additional supply line.

## Fuel Gauge

The fuel gauge indicates how much fuel you have remaining to operate the apparatus engine.

## COMPOUND GAUGE AND PUMP PRESSURE GAUGES

Coumpound Gauge

Master pressure discharge gauge

**A Compound Gauge** is connected to the intake side of the pump and is capable of measuring both pressure and vacuum. Compound gauges are installed on the suction side of all pumps

**The Pressure Gauge** shows the pressure the pump is producing in addition to the pressure from the incoming supply.

**The Outlet Pressure Gauges** show the individual pressure flowing corresponding outlets.

## DISCHARGE GAUGES (3D SPARTAN PUMPER)

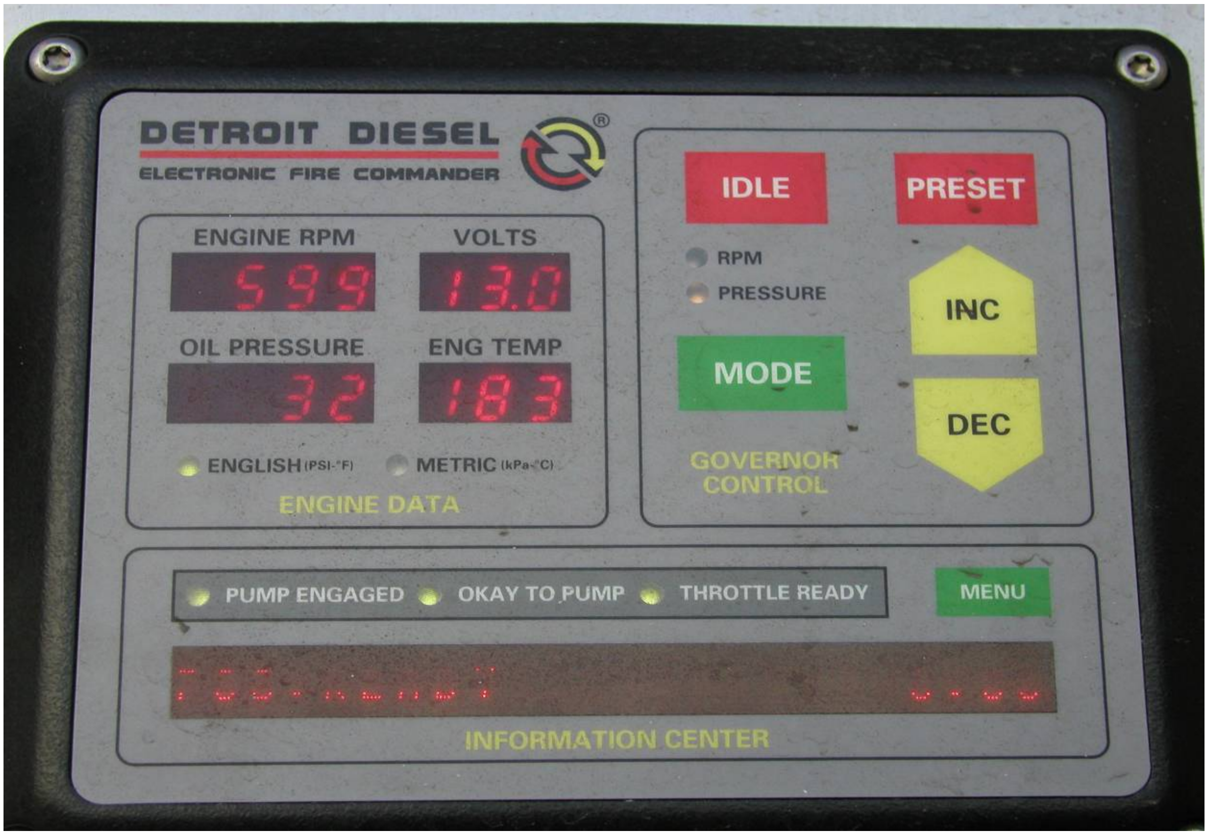
| Gauge | Outlet |
|---|---|
| Discharge Gauge #1 | Driver's side pump panel |
| Discharge Gauge #2 | Officer's side pump panel |
| Discharge Gauge #3 | Driver's side pump panel |
| Discharge Gauge #4 | Officer side pump panel |
| Discharge Gauge #5 | Back of rig (driver's side) |
| Discharge Gauge #6 | Back of rig (officer's side) |
| Monitor Discharge Gauge | Top of rig |
| Right Ready Line Discharge Gauge | Officer's side of hose bed |
| Left Ready Line Discharge Gauge | Driver's side of hose bed |

## AUXILIARY THROTTLE


The auxiliary throttle on the operating panel is provided to control motor speed, and thus pressure, when the pump is in operation. Turning the black outer portion of the knob increases the speed slowly when turned counter clockwise, and decreases the speed slowly when turned clockwise. By depressing the spring activated center portion, the knob may be pulled out directly without rotation for a rapid increase in speed, and pushed in without rotation for quickly reducing the speed. **Use the spring activated control only for emergencies.**

Auxiliary throttles on some of the newer apparatus will not adjust the engine speed if the emergency brake has not been applied.  If this happens, **reduce** the auxiliary throttle **before** applying the brake.

## FIRE COMMANDER PANEL




The newer engines have replaced the auxiliary throttle with the “Detroit Diesel Electronic Fire Commander panel, or Class 1 Electronic Control panel.

Presently, there are three different variations. The earlier versions “defaulted” to RPM Mode when placed into pump

The Ferrara Engines “default” to Mode when placed into pump. The pump operator must activate the proper mode to pump in

The American LaFrance engines have been programmed to “default” into pressure mode

Operation of these panels is controlled  by pushing the appropriate button to increase or decrease pressures and to change modes.

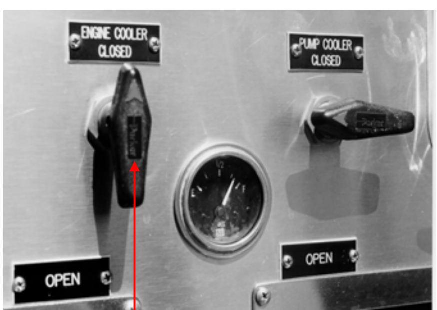
"Pressure mode" is to be used any time you're pumping into a line that ends with a tip—handheld, large line, Multiversal, ladderpipe, standpipes, etc

"RPM Mode" is to be used at all other times.

## READY LINE GATE CONTROLS


The ready line gate valve controls are connected to sliding gates that control the flow of water to the ready lines. Adjust these controls only while horizontal. Any other position is a locked position.

## ENGINE COOLER SWITCH



Engine Cooler Switch

**Auxiliary Cooling Systems.** Fire engines have normal radiator cooling systems, consisting of a radiator, fan and water pump. This system of cooling is quite adequate except when the apparatus is working under pumping conditions. When an engine is working from a hydrant or at draft, there is no forward motion, and the only cooling effect of air passing through the radiator cells is that created by the fan. The motor is usually turning over at high speed and this normal cooling system is sometimes not adequate to prevent overheating. Therefore, an auxiliary means of cooling is used to augment the normal radiator cooling system.

All Department engines are equipped with the indirect system of auxiliary cooling. This system consists of a large cylinder or tank located within the top or bottom of the radiator or attached to the chassis. An inlet and outlet is provided which allows water to flow through the cylinder from the discharge to the suction side of the pump. Contained within the cylinder is continuous copper tubing connected to the radiator supply. Cool water from the discharge side of the pump circulates around the copper tubing, allowing the transfer of heat to take place, and then returns to the suction side of the pump. In some designs of indirect cooling, the course of pump water is directed through the tubing with radiator supply flowing through the cylinder.

Some pumps are also equipped with the system of indirect cooling extended to the pump transmission that places water from the pump through a water jacket built into the pump transmission. The purpose being to cool the oil or lubricant as well as the gears contained within the transmission.

The direct cooling system has been eliminated from new SFFD engines. The direct cooling system allows a small amount of water from the pump to flow directly into the radiator. On the engines that still have this feature, it is labeled Direct Cooling or Radiator Filler. The Direct cooling system is not to be used!

Of the two types of auxiliary cooling systems, the indirect system is the more practical and efficient as it provides for more positive control of temperature. There is no possibility of bursting the radiator through sudden admission of excessive pump pressure; and it eliminates any possibility of contamination of the normal radiator supply with salt water or water containing abrasive matter.

## PUMP COOLER CONTROL

Pump Cooling Control

Opening this valve allows a small amount of water to discharge from the pump into the tank. This assists in keeping the water in the pump cool when little or no water is being discharged from hose lines and the pump is operating. The normal position for this valve should be "open." If left open after an external supply of water is connected to the pump, the tank will eventually fill up and overflow. This overflow will not be injurious in any manner.

Depending upon the apparatus, this valve may be referred to as the:

- Booster Line Cooling Valve
- Recirculating Valve
- Pump Cooler Valve

During drafting operations, or when the pump is being supplied by an engine that is operating from salt or dirty water, this valve must be closed. If not closed, it will be necessary to thoroughly flush out the tank.

## FRONT BUMPER PRECONNECT

The pre-connected outlet on the front bumper of Fire Department pumpers is used to connect small line (1¾-inch) for use at small fires such as trash. **This line shall not be used as a third ready line**.

## TANK FILLER CONTROL/REFILL-RECIRCULATION VALVE


The tank filler / refill-recirculation valve allows an amount of water to enter and fill the tank when the pump is connected to an external source of supply, as well as allowing water to circulate from tank to pump when not discharging water. This keeps the pump temperature down. Maintain a constant level on the sight gauge or the over fill outlet from the tank. When tank is full you can adjust the Re-fill, Re-Circ Valve by closing down and adjust throttle to maintain proper discharge pressures. Always allow some discharge from the overflow. This will guarantee a full tank and protect your handheld lines if your supply becomes compromised.


Shown above is the 2006 ALF engine “Tank Refill” valve. It also serves as the recirculation valve. The size of this valve is much larger than the Spartan engines. Adjust this valve accordingly and remember this also will divert a large volume of water. You are not losing your prime; adjust the handle.

***DO NOT ACTIVATE THE PRIMER MOTOR WHILE CONNECTED TO A POSITIVE PRESSURE WATER SOURCE.***

## DISCHARGE GATE CONTROLS (3D SPARTAN PUMPER)

| Gate Handle | Outlet Location |
|---|---|
| # 1 Discharge Gate Handle (vertical) | Drivers side pump panel |
| # 2 Discharge Gate Handle (vertical) | Officers side pump panel |
| # 3 Discharge Gate Handle (vertical) | Drivers side pump panel |
| # 4 Discharge Gate Handle (vertical) | Officers side pump panel |
| # 5 Discharge Gate Handle (horizontal) | Back of hose bed |
| # 6 Discharge Gate Handle (horizontal) | Back of hose bed |


The purpose of the discharge outlets is to control the water supply from the pump to any one of the connected hose lines. Pumpers are equipped with all gate control handles at or adjacent to the pump operating panel. Handles are numbered indicating the particular gate controlled, and are controlled by moving these handles in, out, sideways, or up and down. Gate controls on most engines are provided with a locking control to secure the gate in any desired position.


All parts of gate controls should be regularly inspected for possible defects and should receive regular (light) lubrication with silicone spray; do not use WD-40. Gate controls should be operated gradually; never open or close them suddenly except in an emergency when a hose line may be out of control. In these instances the gate should be rapidly closed to prevent injury or damage to property. Avoid slamming gate controls as this may result in sheering off stop pins or cause irreparable damage to the internal valve mechanism.

## Three-Inch Outlets And Bleeders


The number of three-inch discharge outlets is determined by the rated capacity of the pump, i.e., one 3-inch outlet for each 250 gpm of rated capacity. Pumps with 1250 gpm have five outlets. Pumps with 1500 gpm have six outlets, etc. Thorough washing and lubrication of the discharge outlet gates after each pumping operation is extremely important. Use silicone spray, not WD-40

Bleeder valves are provided at discharge outlet gates for the purpose of releasing pressure from hose lines after pump operations. Draining hose is then accomplished by disconnecting the hose from the pump and by breaking the hose line at each coupling connection.

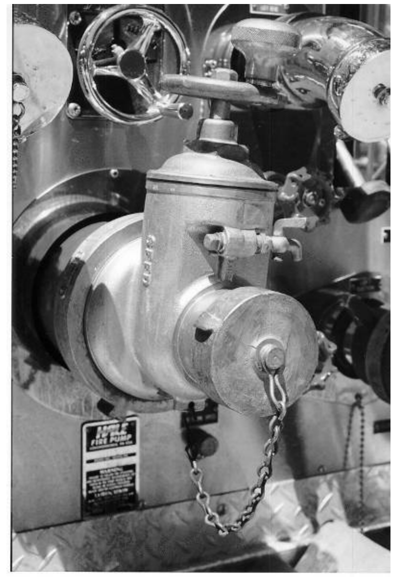
If a discharge gate has been left open, pressure will build up between the valve and outlet cap when the pump is put into operation. Pressure may be sufficient to prevent removal of the cap, in which case opening the bleeder valve will relieve the pressure and permit its removal. It is recommended to operate with all bleeders open, and adjust as each inlet or discharge is used.

Pump operators are occasionally required to keep their pump in operation after nozzles on hose lines have been shut down. To avoid the churning water creating increased water temperature within the pump, open refill-recirculation valve, if closed.

## PUMP INLETS

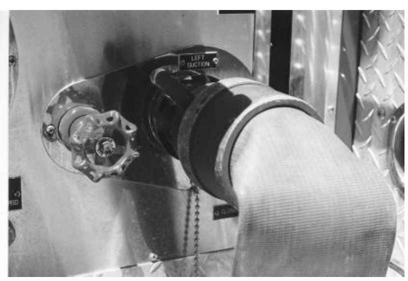
Most engines in our Department currently have only 6 inch and 3 inch diameter inlets. Only the 3 inch inlets are equipped with a shutoff control and a bleeder.

Control of the 6 inch inlets is provided by attaching a Navarro or Keystone valve. Both of these valves have a 6" female swivel coupling for connection to the 6" male threads (on the pumper) and a 3 inch male inlet equipped with a cap. These valves have a control to open or close them and a bleeder for bleeding air from the suction hose or supply hose. ALF engines have a master intake valve. It consists of a butterfly valve behind a cap (or one way on demand valve) and does have a bleeder.



**NAVARRO VALVE**

## AUXILIARY SUCTION INLETS




A 3 inch inlet is provided on each side of the apparatus. This inlet is provided to augment or act as an adjunct to the 6" inlet. It is highly recommended that the 6" inlet be used first.

## PRIMER DISCONNECT


This switch provides electrical power to the priming pump. It must be turned to the ON position in order for the priming pump to operate.

Turn to OFF position after pump is primed.

## PRIMER


When the primer handle is pulled, it activates a small positive displacement pump. This pump will evacuate air from the centrifugal pump housing and hard suction hose.  Creating this vacuum is a necessary prerequisite to operating the pump at draft.

**AT NO TIME SHALL THE PRIMER PUMP BE ACTIVATED WHILE CONNECTED TO A POSITIVE PRESSURE WATER SOURCE**

## CHANGE-OVER (TRANSFER VALVE)

Note on Terminology.
The terms ***Change-Over*** and ***Transfer Valve*** mean the same thing. The terms ***Pressure*** and ***Series*** are interchangeable and so are ***Volume, Capacity,*** and ***Parallel***

The Change-Over or Transfer Valve is used to change the parallel /series centrifugal pump from parallel (volume) to series (pressure) operation, or vice versa.

It is recommended that all engines operate in the volume (parallel) setting except under the following conditions:  when extreme pressure is needed to overcome back pressure in high-rise buildings, or to overcome friction loss resulting from extremely long hose leads.

When operating in the Pressure setting, it has been found that engines will create 45 to 60 psi while at idle.  Adding this pressure to the pressure received from a hydrant or supplying engine creates a pressure that can be dangerous and difficult to control.  It must be remembered that if one engine is supplying another, both engines are creating pressure in addition to the pressure attained from the hydrant.  If both engines are in the Pressure setting at idle, approximately 100 psi is created.  When both are operating in the Capacity setting, the created pressure would be cut to about 50 psi (or approximately half), thus providing a more safe and workable pressure.

The  Ward LaFrance 5” Hose Tender engines should have their transfer valves set to start in the Pressure position.  The pumps on these 5” Hose tenders do not create an unacceptable high pressure at idle, and therefore are operated in the most efficient position—Pressure. The Pressure position will give the desired flow and pressure at the lowest motor speed.

Changing from Volume to Pressure or Pressure to Volume, pump pressure should be at 60 psi, or idle, if incoming pressure is higher than 60 psi.

Regardless of the year and make of the engine, all change-over valves **will be** in the Volume position at the start of drafting operations. The Volume position should also be used when supplying another engine.

## TANK-TO-PUMP HANDLE OR VALVE

Allows water from the tank to enter the pump for discharge into hose lines. Apparatus are normally operated with this handle in the out/open position to insure that water is always available to the pump as quickly as possible.

## AUTOMATIC PUMP PRESSURE CONTROLS AND FIRE COMMANDER

The purpose of an automatic-pressure-control mechanism on a fire pump is to maintain a constant pressure under all operating conditions. Pressure control is most needed when two or more lines are in operation. If there were no automatic pressure control device, and one of the working lines were shut down, a surge of pressure would be transferred to the other line. The amount of pressure increase depends on:

1. The amount of water flowing
2. The amount of pressure being used
3. Whether the pump is operating in Pressure or Volume

If these pressure increases were permitted to take place every time discharge valve or hose lines were shut down, serious injury could be sustained by firefighters operating the charged lines.

To provide against such increases in discharge pressures when nozzles or discharge gates are shut down, pumpers are equipped with pressure control devices. There are two types of pressure control devices in use: Pressure Relief Valves and Automatic Pressure Governors. (Fire Commander).

## PRESSURE RELIEF VALVE


The **Pressure Relief Valve** is an automatic valve which, when activated by the relief valve control, will divert the pump pressure when discharge valves, in-line shutoffs, or nozzles are closed. The valve maintains its given pressure by dumping the excess pump discharge flow into the pump suction. *[It is common to think the installed relief valves protect under all conditions. They do not.* [***Hale Pump Manual relief valve pg. 2***] REMEMBER TO SET YOUR RELIEF VALVE WHEN TWO (2) OR MORE HANDHELD LINES ARE WORKING Readjust after opening another supply. "*It important to realize for the relief valve to function properly, the discharge pressure should be at least 50 to 60 psi greater than the suction or incoming pressures"**[Hale Pump Manual relief valve pg. 2].*** [1]

Prior to setting the relief valve, pump operators should have set the relief valve adjustment to a pressure setting much higher than any pressure which would possibly be used. This is done during the morning apparatus check by turning the relief valve adjustment fully clockwise. Do not preset the relief valve.

To set the relief valve:

1. Adjust the pump to the desired operating pressure when 2 or more lines are flowing
2. If equipped with a relief valve switch, turn this relief valve switch to the on position.
3. Turn the hand wheel of the relief valve adjustment counterclockwise until the relief opens. (When the relief valve opens, a decrease in discharge pressure of the pump will occur.)
4. Slowly turn the hand wheel of the relief valve adjustment clockwise until the pump returns to its desired pressure setting (if equipped with indicator light, this light should now be off)

**Note**: Once set, the relief valve **does not** take into consideration any pressure added from additional incoming supply lines. It must therefore be reset when additional supply lines are added or increased supply pressure observed.

## THE GOVERNOR /FIRE COMMANDER

The governor is actually an automatic throttle that controls the rpm of the engine. The governor differs from the relief valve in that instead of opening a by-pass between the suction and discharge side of the pump (as pressure relief valves do) they control the

[1] Hale Pump Manual Safe Pump Operations, Relief Valve pg 2

setting of the fuel supply to the motor, thereby affecting directly the engine rpm and, in turn, the speed of the pumps impellers..

## DETROIT DIESEL ELECTRONIC FIRE COMMANDER


## OPERATING INSTRUCTIONS

### INTRODUCTION

The Detroit Diesel Electronic Fire Commander (EFC) is designed to support Detroit Diesel engines in the fire fighting market. It combines a Pressure Sensor Governor (PSG) controller, a system monitor, and a display for vital engine operating parameters into one compact, durable package. It also provides complete control and monitoring of the DDEC III engine control system on a fire engine when pumping.

### PRESSURE SENSOR GOVERNOR OPERATING MODES

The EFC commands the Detroit Diesel PSG system to operate in one of two modes. The RPM Mode controls the engine speed to a constant number of revolutions per minute. The Pressure Mode varies the engine speed to maintain a constant pump discharge pressure. The operating mode of the PSG can be changed from RPM Mode to Pressure Mode and back by pressing the MODE button.  When the unit is first turned on, the RPM Mode is active.  Pressing the MODE switch engages the Pressure Mode and another press brings the system back to RPM Mode.  The PSG system utilizes the engine speed or pump pressure that is current at the time the button is pressed.

In the Pressure Mode, the PSG system operates like cruise control for the water pump pressure and maintains the pressure at a chosen setting.  Engine speed is constantly adjusted to maintain the desired pump discharge pressure.  A pressure sensor in the output side of the fire pump is used to measure and feed this pressure back to the DDEC III Electronic Control Module (ECM).

The RPM Mode keeps the engine speed constant even when the load varies within the engine's operating capability.  The pump output pressure may vary in this mode, but the engine speed does not.  The EFC also allows the pump operator to finely adjust the pressure setting or the engine speed setting to match prevailing conditions.

## SETTING THE RPM MODE

1. Start the engine and make certain the EFC is on.
2. Be sure the conditions are met for the Throttle Ready lamp to be on. (These are usually interlocks necessary to allow increased throttle operation).
3. The RPM Mode lamp should be lit indicating the system is in RPM Mode.
4. Engine speed can be adjusted using the following buttons:
    a. Press the PRESET button to command the engine to go to the preset speed.
    b. Press the INC button to increase engine speed in 25 RPM increments each time the button is pressed.
    c. Press and hold the INC button to increase the speed at a faster rate equivalent to 2 increments per second.
    d. Press the DEC button to decrease engine speed in 25 RPM increments.
    e. Press and hold the DEC button to decrease the speed at a faster rate equivalent to 2 increments per second.
    f. Press the IDLE button to return the engine immediately to the normal idle speed.

## SETTING THE PRESSURE MODE

1. Start the engine and adjust the system to run in the RPM Mode as described in the previous sections.
2. Be sure conditions are met for the PUMP ENGAGED and OKAY TO PUMP and THROTTLE READY lamps to be on.  (This usually requires that required safety interlocks for engine speed increase and pump operation are met.)

3. Press the MODE button and the PRESSURE lamp will turn on.
4. Pump discharge pressure can now be adjusted with the following buttons:
    a. Press the PRESET button to command the engine to go to the preset pump pressure.
    b. Press the INC button to increase discharge pressure in 4 PSI increments each time the button is pressed.
    c. Press and hold the INC button to increase the speed at a faster rate equivalent to 2 increments per second.
    d. Press the DEC button to decrease engine speed in 25 RPM increments.
    e. Press and hold the DEC button to decrease the speed at a faster rate equivalent to 2 increments per second.
    f. Press the IDLE button to return the engine immediately to the normal idle speed.
    g. When the Fire Commander adjusts engine rpm and returns to idle that is the lowest pressure in the pump. If your pressure is still too high, you must gate down the incoming supply

## CAVITATION

If the water pump discharge pressure falls below 30 PSI and the engine RPM rises a minimum of 400 RPM above the current set point for more than 5 seconds, the system considers cavitation to have occurred. It takes the following actions:

- The engine will return to idle.
- The current engine speed and discharge pressure set points will be cleared.
- The check engine light will illuminate and a cavitation code will be logged.

## ENGINE PARAMETER DISPLAY

Engine RPM, Oil Pressure, Temperature, and System Voltage are displayed continuously while the EFC is in operation. In addition to this, any diagnostic code accompanying a Check Engine or Stop Engine condition will be displayed on the Information Center message display. An audible alarm will also be activated with the code.

## AIR CHUCK & CONTROL


The air valve connection and control is provided to take advantage of the apparatus compressor. It can be used to supply air for such purposes as filling tires, charging pressurized water extinguishers, or for other purposes where compressed air may be required. Maximum available air pressure will be about 120 psi. Air in the system should always be replaced after the air valve is used. When a considerable amount of air is being used, the engine should be running to keep the air tanks up to maximum pressure.

## PUMP DRAIN


Pump drains are valves that permit all the water to be drained from the pump. . Only members of the BOE or central shops operate this valve. Apparatus operators shall not operate this valve.

## DUMP VALVE

The dump valve is installed on all apparatus. It is designed to divert static pressure from the pump. These valves are currently set at 120 psi by the Central Shops. When STATIC pressure above 120 psi is attained in the pump, the valve will dump. Flowing pressures above 120 psi will not affect the valve.

Minor leaks from the valve are acceptable. However, if major leaks occur it will be necessary to flush sediment from the valve seat. This may be done by utilizing a pressure source higher than 120 psi. This could be from another engine or a High Pressure hydrant using the Gleeson Valve If this does not free the valve, contact the Bureau of Equipment.

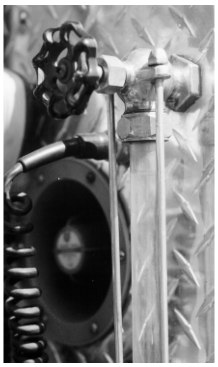
## RADIO MICROPHONE & SPEAKER

This is a speaker and microphone connected to the apparatus radio. It is for use when the pump operator is working at the panel and it becomes necessary to transmit a message over the apparatus radio. Pump operators should keep the speaker volume turned up when working at the panel so they may here any radio traffic for their unit. The radio should be on the Tactical channel.

### PANEL LIGHT SWITCH

This switch turns on the pump panel lights for night viewing of the pump panel gauges in low light situations.

### TANK LEVEL INDICATOR



This device will show the water level in the apparatus tank. There is usually a small "float" at the top of the water column for ease of reading the tank supply. Pump operators should monitor this gauge frequently during pump operations and particularly when operating from a tank supply prior to obtaining an outside water supply source. The indicator will not operate if the connection to tank is closed.

# SECTION 3.   OPERATING GUIDELINES AT HYDRANTS

## LOW PRESSURE HYDRANTS

For fire fighting purposes, low pressure hydrants can be classified as:

- **SINGLE HYDRANTS** can supply only one pumper
- **DOUBLE HYDRANTS** can supply two pumpers

**Single Hydrants**. There are some low pressure hydrants that are classified as single hydrants.  These were designed to supply only one Fire Department pumper.  The **single** hydrant is identified by either a ball top or, on the newer hydrants, a flat top with a 6” by ¾” black stripe painted above the main size number or both.  These hydrants are slowly being replaced with **double** low pressure hydrants.

**Double Hydrants**. Due to the pumping capacity of our newer apparatus, only one pumper shall connect to **any** (double or single) low pressure hydrant. All low pressure hydrants supplied with water under pressure are painted white.

Low pressure hydrants painted white with a green bonnet indicate that a Fire Department cistern is located nearby, usually within the intersection.

Low pressure hydrants painted white with a light blue bonnet indicate that this hydrant is supplied by brackish water.

Low pressure hydrants are the primary source of water supply for fire fighting in San Francisco.  Pressure is provided either by gravity, or by gravity with supplemental pumping.

A **gravity system** is one in which the water is stored at an elevated location and flows by gravity to the point of consumption. A **gravity and supplemental pumping system** is one in which the water is pumped from a source of supply to an elevated reservoir or tank.

The pump operators chief concerns at any hydrant hookup are **volume** and **pressure -** how much water can the hydrant supply and is there enough pressure.  A hydrant should not only give the initial quantity of water needed to supply an engine, but it should also have a reserve capacity in the event of additional demands.

**Three factors limit a hydrant's water capacity:**

**1. Available pressure to the hydrant.**

The average static pressure of a low pressure hydrant is stamped on the upper spindle of the hydrant, and is normally 40 to 60 psi. This pressure may vary throughout the day due to domestic usage; however it would seldom be more than 15 to 20 psi less than indicated.

The pressure at any low pressure hydrant or series of low pressure hydrants is determined by the location of the source of water feeding that zone or the pressure being pumped to the zone by a pump station. In the event of abnormally low pressure below that needed for effective fire fighting operations, San Francisco Water Department personnel can activate specific gate valves in the area to divert and increase pressures.

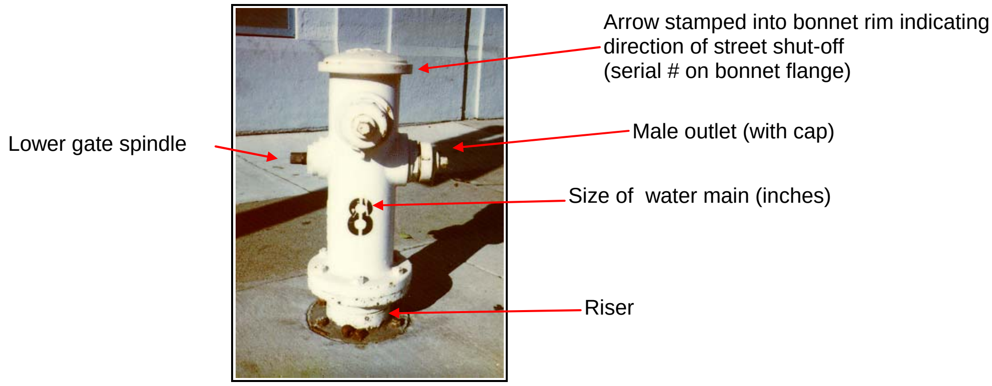
**2. Size of the supply main.**

The size of the water main supplying the low pressure hydrant is stenciled on the barrel of the hydrant. Hydrants are connected to mains that range in size form 4 inches to 44 inches in diameter.  The size of the hydrant branch pipe from the main to the hydrant ranges in size from 4 inches to 6 inches in diameter.

**3. Size of the hydrant outlets.**

The final factor which determines the amount of water that can be obtained from a hydrant is the size of the hydrant outlet. Drawing a large supply of water through a hydrant outlet will, in itself, result in friction loss and will deduct from the pressure available in the supply system.

All city low pressure hydrants are equipped with 3 inch outlets. Many hydrants found in industrial complexes, military installations, and surrounding cities will be equipped with 2½- inch and 4½-inch outlets.  Suction connections have 6 inch outlets, and some pool suction connections are 3 inches.




The following table gives some comparative figures on the flow capabilities of hydrant outlets. Note that the pressure shown is flowing pressure (water moving through the outlet).

| **Flowing Pressure** | **Discharge Volume** | | |
|---|---|---|---|
| | | **3 inch** | |
| 10 PSI | | 760 GPM | |
| 20 PSI | | 1080 GPM | |
| 30 PSI | | 1320 GPM | |
| 40 PSI | | 1530 GPM | |

**<u>Remember</u>, the pressures shown above are flowing pressures, <u>not</u> static pressures.**

For practical purposes, the residual pressure, indicated on the **compound gauge** of the pump panel, will show the pump operator the quantity of water still available at the hydrant to which the pump is connected. It should therefore be apparent to the pump operator that the readings given by the **compound gauge** are as important when operating from a hydrant as when drafting.

Low pressure hydrants are designed to provide adequate supply under normal conditions. However, conditions can arise when the hydrant will not supply enough water. Therefore, pump operators should promptly advise the Incident Commander if the supply at the hydrant is, or threatens to become, inadequate.  It is very important that the Incident Commander know the capacity and potential problems of the water supply.

## Low Pressure Hydrant Guidelines

### Reading the Pressure

After connecting an engine to a low pressure hydrant, a reading should always be taken of the static pressure on the compound gauge. This reading should be noted and remembered. Make another reading when a line is connected to the pump, charged, and put into operation.

If a line is being supplied from the tank before a hydrant supply line is added, the initial reading can be taken from the upper outlet spindle on the low pressure hydrant. Note the drop in the pressure at the inlet side of the pump. If the difference between the two readings is not over 25%, the pump operator can assume that the hydrant has an ample supply and enough reserve for additional lines. However, should this difference be over 25%, the amount of water from that particular hydrant is limited and probably will not supply additional lines.

### Additional Streams

Lines for additional streams should never be taken from a pump where the residual pressure is less than 20 psi unless the size of the nozzle tip being supplied is reduced or an additional supply is obtained. The gauge on the inlet side of the pump (Compound Gauge) shows positive pressure when the hydrant is providing water at a rate greater than the output of the pump. When discharge from the pump exceeds the output of the hydrant, the gauge will fall below zero (or atmospheric pressure) and will register a partial vacuum. This will result in defective streams due to air leakage and inadequate supply. It may also cause damage to the pump, the hydrant, and/or the supply mains.

Occasionally, compound gauges do not give reliable readings at or near zero; however, there are other indications that give warning when the demand on the pump is greater than the output of the hydrant. When the pump is connected to the hydrant with a soft suction or a length of hose, or if the pump is relaying, the point near zero can be detected by feeling the soft suction or supply hose where it enters the pump inlet. If it is soft and flabby when squeezed, the point of maximum delivery by the source of supply has been reached and any further attempt to get more water will only result in collapse of the supply hose. When these conditions occur, the pump operator should reduce the speed of the pump to the point where the soft suction or supply hose becomes firm and then advise the Incident Commander and obtain an additional supply line.

### Guidelines for Hydrant Use and Laying Lines

All companies must consider every alarm as a working fire. Upon approaching the scene of the alarm, the officer and all company members should be alert to spot a hydrant from which the company may make as short a lead as possible. The officer of an engine company reporting to the Incident Commander should do so with a lead in mind and with the knowledge that the company is in position for immediate service.

All leads should be made from the nearest hydrant available to the fire, laid as close to the curb and as straight as possible.  The shorter the lead, the smaller the amount of friction loss. The smaller the amount of friction loss, the greater the amount of pressure available at the pump for maximum discharge.

1. When spotting an engine at a hydrant, place the apparatus so that the suction inlet is either slightly ahead or behind the hydrant outlet. This position will usually prevent kinking of the suction hose while making connections.

2. Always check female couplings for washers and make certain that connections are spanner tight.

3. Remove all hydrant outlet caps. It sometimes happens that under the stress of a working fire, the pump operator may operate the wrong hydrant outlet valve spindle. In this case no water would be supplied to the pump. With both hydrant caps removed, such a mistake would be apparent immediately due to the flow of water from the open outlet.

4. Be certain that the hydrant outlet is opened fully to provide an unobstructed flow of water.

5. Pump operators may encounter difficulty when opening a hydrant outlet valve.  This is usually due to the use of extreme force to close the outlet valve during a prior use of the hydrant.  An operator encountering this condition should immediately try the other outlet.  Do not move your engine to another hydrant until both outlets have been tried and found to be inoperative.

6. Don't bypass a hydrant blocked by an illegally parked car or other obstruction.  If the car or obstruction cannot be moved, use two soft suctions connected together or a 50’ length of large line.

7. Always be alert and watch for hydrants with either a black or yellow disk attached behind one of the outlet caps.

    - A “Black Disk” indicates the entire hydrant is out-of-service
    - A Yellow Disk” indicates the marked outlet is out of service

8. When replacing the outlet caps on a hydrant, set them spanner-tight to prevent their being removed or the outlet being maliciously packed with paper, rags, etc.

9. In some instances it may be advantageous to turn the engine around at the intersection, back into the fire area, and then make a lead out from the fire to a hydrant or other engine. This is especially true when there is already an engine company in front of the fire and a supply line into that engine is indicated. Many areas of San Francisco have narrow streets and alleys, and are heavily congested. Fire apparatus could easily be trapped as these factors limit their maneuverability.

10. Due to the high capacity of our pumper apparatus (1500 gpm) it is policy that only one engine be connected to any low pressure hydrant. Additional engines should consider connecting lines for supply to the engine connected to the hydrant if considered feasible by the first engine pump operator **OR** proceeding to another water source.

11. Available flow from hydrants is estimated by determining the percentage drop between static pressure and residual pressure. This information can be used to determine if additional discharge lines can be supplied or if a hydrant can be utilized by another pumper. Pump operators can use the following procedure to estimate flow:

- Note the static pressure on the compound gauge after the hydrant is open, but before a discharge gate is open.
- Note the residual pressure on the compound gauge after the first line is operating at the designated pressure.
- Determine the percent of drop in pressure:

| | |
|---|---|
| 0% to 10% = | Three times the amount of water that is being delivered. |
| 11% to 15% = | Twice the amount of water that is being delivered. |
| 16% to 25% = | An equal amount of water that is being delivered. |
| Over 25% = | Less water available than is being delivered. If necessary, increase supply. |

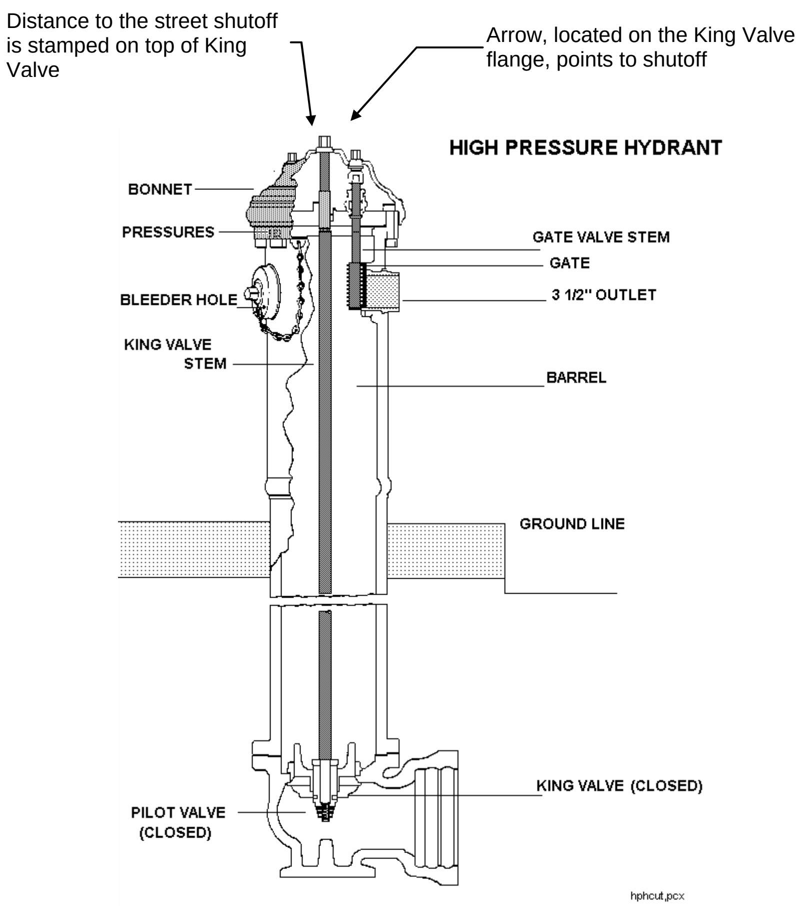
12. These percentages are only guidelines. At exactly 10%, there is not an abrupt change from three times the water available. Also, note that when maximum flow is reached, residual pressure at the inlet will be low. Again, this is just a guide to the amount of water left for fire fighting.

## HIGH PRESSURE HYDRANTS

Hydrant Design: The High Pressure hydrant barrel is constructed of an extra heavy cast iron, which has an internal diameter of 10 inches, and an average length of 6 feet, 9 inches. Normal height of the hydrant above ground level is 3 feet; the average height of the outlets above ground is 20 inches..

The hydrant is equipped with three 3½-inch male thread outlets. Each outlet is protected with a cap secured by a chain.

Each outlet has an independent vertical sliding gate-valve control, operated by a vertical valve stem. Each of these valve stems has a square operating nut on the top of the hydrant bonnet




Flow of water into the hydrant is controlled by vertical movement of a compression type valve, placed at the base of the hydrant barrel where it connects to the branch pipe elbow. This valve is named the "King Valve" and is equipped with a by-pass valve commonly called the "Pilot Valve." The function of the pilot valve is to permit equalization of water pressure on both sides of the king valve, before the king valve is opened, as explained under the subject of hydrant operation. The king valve and the pilot valve both are operated by a long vertical stem which terminates in a pentagonal operating nut located at the center of the hydrant bonnet. All hydrant valves are opened by turning the valve stem counter-clockwise and are closed by a clockwise rotation

The bonnet of each hydrant is painted either blue, red, or black to indicate the zone in which it is located and the initial supply source available at the hydrant.

| Bonnet Color | Zone | Supply |
|---|---|---|
| Red Bonnet | Upper Zone | Ashbury Tank |
| Blue Bonnet | Lower Zone | Jones Street Tank |
| Black Bonnet | West of Twin Peaks Zone | Twin Peaks Reservoir |

The Lower Zone (Blue Bonnet hydrants) can be supplied with additional pressure from Ashbury Tank or Twin Peaks Reservoir.

The Upper zone (Red Bonnet hydrants) can be supplied with additional pressure from Twin Peaks Reservoir. There is no source from which additional pressure may be supplied to the upper zone (Black Bonnet hydrants).

The normal static pressure available at each hydrant, from each source as indicated above, is stamped on the edge of the hydrant flange just under the bonnet.

**J** designates Jones Street Tank supply
**A** designates Ashbury Tank supply
**T** designates Twin Peaks Reservoir supply.

The first stamped figure is the normal supply source and pressure available at the hydrant.

Hydrants that are located approximately at the same elevation as their first supply source, with a static pressure at the hydrant of less than 120 psi, are identified by their outlet caps being painted the same color as the hydrant bonnet. Pumpers are permitted to take supply from these particular hydrants, through connection of a Gleeson valve set at 60 psi.

## HIGH PRESSURE HYDRANT GUIDELINES

Leads to or from high pressure hydrants are made in a manner similar to those that will be described for low pressure hydrants. When making leads to these hydrants, drivers of apparatus should place both Gleeson Valves at the hydrant for use. Do not leave a Gleeson Valve idle on the apparatus.

Engine companies responding on greater alarms should always give consideration to utilizing high pressure hydrants. High pressure hydrants have the ability to supply six large lines with sufficient pressure and volume to meet most demands. Whenever possible, these hydrants should be used when supplying master stream appliances. Generally, when a high pressure hydrant is used, the hose lead from the hydrant should be led through the Gleeson Valve directly to the appliance being supplied and not through the pumper.

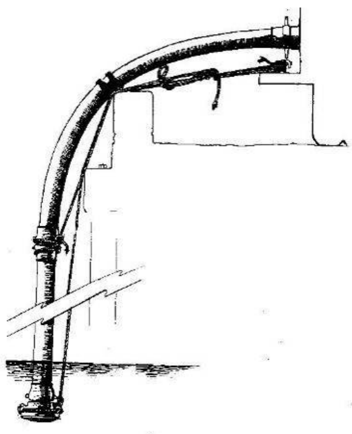
When connecting to a high pressure hydrant, immediately determine the pressures available at that hydrant. If additional pressure from another zone is needed, notify the Incident Commander

High pressure hydrants with outlet caps painted the same color as the bonnet are under comparatively low pressure (less than 120 psi). Engines may be connected to these hydrants, but SFFD guidelines require that high pressure hydrants shall not be used without first connecting a Gleeson Valve to the hydrant. When supplying engines the Gleeson Valve regulator shall be set at 60psi. This 60 psi will assure ample water supply and eliminate the possibility of injury to firefighters on hose lines or damage to the pump due to excessive inlet pressure. If a Gleeson Valve is supplying an engine it cannot be used for any other purpose.

When using a high pressure hydrant with a black bonnet and black caps, engine companies **SHALL** be hooked up to the hydrant through a Gleeson Valve. Since black top hydrants are not capable of having their pressure increased, all needed hose leads for any appliance or hand held line shall be taken from the apparatus outlets.

Do not supply pumpers with both low pressure and high pressure water sources. This may cause cross connection and contamination of low pressure supply by high pressure water being introduced. Pumpers shall be supplied by either low pressure or high pressure supply, but not both simultaneously. (Refer to GO 02 A-46) When members are directed to change from low pressure hydrants to high pressure hydrants, members shall shut down low pressure inlet at the pump panel, then the hydrant. This will avoid the possibility of admitting high pressure water into the domestic water supply system should a pressure imbalance occur at the pump.

# SECTION 4. DRAFTING



When the source of water supply to an engine is a static source below the inlet side of the pump, the pump operator must draft in order to supply water to the pump.

We often hear the terms "lift" or "lifting water by suction" in connection with drafting operations. These phrases are incorrect because water cannot be pulled upward due to the fact that it has no tensile strength. However, water is practically incompressible and if it is confined in a conductor and pushed by an agent such as pressure, it will flow vertically just as readily as it will flow horizontally. When drafting, the conductor is the suction hose, and the pressure is provided by the weight of the atmosphere.

Atmospheric pressure (14.7 psi at sea level) acts uniformly on the surface of any open body of water, just as on the earth's surface. However, if this pressure is removed by vacuum from a portion of the surface of the water, a condition of unequal pressure is created. The water will not compress into a stronger mass in its effort to resist this disturbance of pressure balance. Instead, it will rise to a height where the quantity of water above the surface has weight that will establish a pressure equal to that of the atmosphere.

Thus, the formation of a vacuum over an open body of water and the restoration of pressure balance are of fundamental importance to all pump operators. It's only by this process that a pump may be supplied with water from a source below its own level.

For example, a column of water with an area of 1 square inch and a height of 1 foot weights 0.434 pounds. The height of this column at which it would balance atmospheric pressure is 14.7 divided by 0.434 or 34 feet. Conversely, a pressure of one pound per square inch will force a square inch column of water under vacuum to a height of 2.304 feet.

Mercury is approximately 13.5 times as heavy as water. If mercury were substituted for the water in the above example, the mercury would rise to a height of 34 divided by 13.5, which equals 2.5 feet or 30 inches of mercury. We use this 30 inches of mercury rather than 34 feet of water as a measure of atmospheric pressure. Therefore, we find that barometer readings as well as readings of vacuum on compound gauges are normally given in inches of mercury. One inch of mercury, for all practical purposes, is equal to approximately one foot of water, and exerts a pressure of about 0.5 psi.

Remember, when a vacuum is formed in the long tube, the water is not pulled or sucked up by the formation of the vacuum, but it is forced or pushed up by the external pressure of the atmosphere (atmospheric pressure) acting on the exposed surface of water.

The hard suction hose (connected to the pump) in the water may be regarded as a tube with the top closed and the lower end submerged in water. If we remove the air from this tube, the water will rise to the pump inlet. The priming pump is the device that effects this removal of air. If an absolute vacuum were created, it would induce water to a theoretical height of 34 feet; however, even with the most delicate scientific apparatus it is impossible to create this vacuum.

Rotary vane pumps are positive displacement pumps and are capable of pumping air as well as water without the aid of an auxiliary device. The close fit between the vanes and casing acts as a seal between the suction and the discharge sides of the pump. When all connections on the suction side of this type pump are airtight, a vacuum is affected by simply pumping air from the suction side and expelling it out through the discharge side of the pump.

Centrifugal pumps are not positive displacement pumps. They cannot pump air because there **is an open waterway from the suction to the discharge side of the pump.** An auxiliary priming device or priming pump is used to remove the air and create a vacuum in the pump and in the suction hose. Therefore, all discharge outlets and other controlled openings on the apparatus must be closed tight when drafting. This will prevent entrance of air through the discharge as well as the suction side of the pump.

A fire pump in very good condition will have a maximum lift, from the surface of the water to the center of the pump inlet, ranging from 25 to 28 feet. After it has been in service for some time its maximum lift may drop to between 15 and 20 feet. The efficiency of any priming device or positive displacement pump demands that the pump and suction hose be completely airtight, otherwise air will leak in from the outside and destroy the vacuum. Therefore, it must be emphasized that a new suction hose washer is one of the least expensive items used by our Department and yet one of the most important.

## Other Factors

A pressure loss commonly referred to as a Pump Entry Loss can occur when water enters the pump from draft. This loss is due to the shock of resistance developed by the water entering the impellers of the centrifugal pump. It is independent of, and in addition to, the loss occurring in the lengths of suction hose and varies with the design of the pump. Entry loss also subtracts from the atmospheric pressure available to do the work of overcoming frictional resistance, and thus also has an effect on the maximum height to which a pump may lift water by draft.

Cavitation in the suction inlet of the pump is also a limiting factor in maximum suction lift. Cavitation is the formation of water vapor cavities in the flow of water through the pump, and is due to vaporization of water under low pressure. At sea level, water will completely vaporize at 212° F., but as the pressure over the water drops below that of atmospheric the vaporization temperature also falls. Thus, if the pressure in the pump inlet is sufficiently low, vaporization will take place rapidly. The vapor cavities will displace water, interrupt the flow, and may cause the pump to lose its draft.

Cavitation may occur where a pump has a suction lift approaching maximum for the discharge required. If an attempt is then made to increase the discharge, a faster flow of water through the suction hose will be required. This increased flow will result in additional friction loss in the suction hose. Pressure at the pump inlet will drop, permitting the formation of vapor cavities and an interrupted flow. At this point, the needle of the compound gauge will fluctuate back and forth indicating to the pump operator that the pump is in danger of losing water. Should this situation develop, the pump operator should immediately decrease the rate of flow and then notify the Incident Commander that the pump is operating at a maximum suction lift and cannot supply any additional water.

The efficiency of a pump when lifting cold water is much greater than when lifting hot water. Hot water has a vapor pressure that is considerably higher than that of cold water, permitting vapor cavities to form much more rapidly on the suction side of the pump. Maximum suction lift by a pump can be obtained only when the water supply is at comparatively low temperatures (in the region of 60 degrees F). The higher the temperatures of the water supply the greater the amount of vaporization, which will occur under any particular vacuum reading. Under vacuum, this greater amount of vaporization will create a larger volume of vapor cavities above the water level in the suction hose, thereby limiting the height to which the water may be raised. Thus, no matter how perfect the vacuum, water cannot be raised at a temperature of 212 degrees F.

Thus knowing the effects of pumping hot water is important, particularly in those instances where a salvage pump is pumping out a basement flooded with hot water or drafting from a heated swimming pool.

The density of water has a slight effect on maximum suction lift. For example, ordinary sea water weighs approximately 64 pounds per cubic foot as compared to 62.5 pounds per cubic foot of pure water. The pressure per square inch exerted by a column of sea water one foot high is then 0.444 psi. Under absolute vacuum, sea water would rise only 33 feet to balance an atmospheric pressure of 14.7 psi and therefore, when drafting from a supply of sea water, a slightly reduced lift will be obtained as compared to that obtained when using fresh water.

## GUIDELINES FOR DRAFT HOOKUP

***<u>PUMPING FROM SALT WATER IS ONLY TO BE DONE IN EMERGENCY SITUATIONS</u>***.

| |
|---|
| DRAFTING AT DRILLS AND MONTHLY CHECKS WILL BE DONE FROM CISTERNS, TWIN PEAKS, TREASURE ISLAND TRAINING FACILITY OR THE D.O.T. |

Hooking up a pump for draft is difficult. It requires the cooperation of each member of the company, thorough understanding of each operation, and the ability of the company to act as a team. When drafting from a source of water below the level of the pump, the procedure and instructions listed below should be followed. Modification of the procedure outlined may be necessary because of conditions of accessibility and/or shortage of personnel. Refer to the Drill Manual.

1. **Unless otherwise ordered, the officer should select the location at which the engine is to be spotted for draft.**

   The officer should consider the "lift" from the water surface to the pump inlet, the ease of access to the location selected, and the space available in which to hook up and operate the pump. The apparatus should not be placed on soft ground or on an insecure structure.

   Do not select a location that would require a sharp horizontal bend in the suction hose or would require the suction hose to be carried over an obstruction, placing some part of the suction hose above the suction inlet. This always presents the possibility of an air lock developing at the bend or at the portions of suction hose above the inlet. It may easily result in difficulty in priming, in the water dropping back as soon as an attempt is made to open a discharge valve, or in a restricted supply of water to the pump.

   Generally only one engine may be spotted at each cistern or pier suction access.

2. **Stop the engine forward or in back of the position selected for drafting.**

   Ample room should be provided for coupling and placement of the suction hose before spotting the engine into its final position.

Pump operator:

a. Put apparatus in neutral and apply brake. Do not place apparatus into pump until all preparation for drafting is complete. Running a pump without water will cause damage to the pump.

b. Close tank valve, take cap off Navarro or Keystone Valve and open same to bleed most of the water from the pump housing. American LaFrance engines do not need to drain the pump housing. Remove the 6” cap, attach the hard suction and open the Master Intake Valve. (If equipped with a one way valve attach hard suction directly to valve)

c. Obtain suction strainer, suction ropes, suction spanners, suction saddle, and mallet and place them in a position available to members handling the suction hose

d. Close pump cooler valve (booster line cooling valve); make sure all gates, drains, bleeders are closed; and all outlet and inlet caps are tight

e. Remove the Navarro or the Keystone Valve from the inlet on the side of the apparatus to which the hard suction hose will be connected The Officers side of the apparatus is preferred for drafting. This provides the operator a safer position and reduces any chance of falling into source of water.

f. Return to driver’s seat and wait for order to proceed to drafting position

Other members of the company:

a. Remove both lengths of hard suction hose from troughs and if possible place in line and at a right angle to the source of water

b. Attach suction strainer to the male end of the hard suction length closest to the source of water

c. Connect lengths of hard suction hose together (spanner tight using mallet), making sure that the female couplings of both lengths are equipped with washers.

d. Tie one suction rope to the strainer and the other to the hard suction hose below where the two lengths were coupled together. This second tie is made with a clove-hitch with a half hitch to act as a safety knot.

e. Lower strainer end of suction hose into water source

f. Motion engine to move into drafting position

3. Engine in drafting position:

Company members:

a. Connect suction hose to inlet (spanner tight using the mallet)

b. Tie the first rope to the suction hook using a firefighter's hitch. This rope takes most of the weight of the suction hose and relieves the strain at the inlet connection

c. Tie the second rope attached to the suction strainer to the suction hook (or a secure location on the apparatus) using a clove-hitch and keeper. (This rope is used to maintain the strainer at the proper depth and to raise it for inspection)

d. Attach and place the suction saddle where it will protect the suction from chafing against any edge on which it rests

Pump operator:

a. After stopping at a position indicated by the officer, set the brake; engage pump

b. Immediately upon leaving the cab, set the chock blocks

c. Prime the pump

d. Open an outlet or a bleeder to allow a small amount of water to flow from the pump before attack lines have been led - if this is not done, water will churn and heat up within the pump causing cavitation.

4. Priming the pump

In order to prime the pump, air is exhausted from the pump and hard suction hose by means of a small positive displacement pump (primer or priming pump). Turn the primer electrical switch to "On", then pull and hold the primer pull switch until a prime is attained. A prime should be attained within 45 seconds of pulling switch. If no prime has been attained within this time, push in switch and check drafting setup guidelines. Make sure all steps have been followed and everything is airtight. If nothing is apparently wrong, suspect that the hard suction connections are not airtight.

After obtaining a prime, the pump operator should throttle to maintain a pressure of 60 psi on the pressure gauge in order to hold the prime. Begin flowing some amount of water as soon as possible from a bleeder or outlet. The purpose of this is to maintain your prime and keep your pump cool.

## PUMP UNABLE TO DRAFT

**Failure of the pump to prime**. This condition will be indicated on the compound gauge by the pointer registering a "No Vacuum" (0 reading) or a very high vacuum reading. If a "No Vacuum" (0 reading) is registered, the cause may be traceable to one or more of the following:

1. Road transmission, pump transmission, or priming control improperly engaged.
2. Strainer resting on object above water surface or not sufficiently submerged.
3. Air leaks in the suction hose due to defective washers, loose connections, or a leak in the hose itself.
4. Discharge outlet gate cracked open or not seating properly.
5. Pump drains, bleeders, cooling valves, pressure relief and or tank filler valves not closed completely.
6. Defective primer due to inadequate lubrication or water seal.
7. Air leak caused by a loose packing gland at the point where the main shaft enters the pump casing, or a defect in the pump casing.
8. Electrical or mechanical failure of priming device system.

A failure of the pump to prime with the compound gauge registering a high vacuum reading is usually due to permitting the suction strainer to lie on the bottom of the water supply. This often causes the strainer to become clogged with mud or other abrasive material.

Less common causes are a collapse of the suction hose or a defective interior suction hose lining (which may come apart from the hose and be drawn inward as soon as a vacuum is created).

A decreasing vacuum reading while the pump is at work is usually an indication that the level of the source of water supply has risen. This may occur when working from tidal water.

An increased vacuum reading usually indicates a drop in the level of the water supply or that the suction strainer is becoming blocked.

Loss of vacuum after having disengaged the primer, or while pumping, is usually due to air leaks. It may also indicate that the suction strainer has become partially or wholly uncovered due to the lowering of the water supply level or attempting to discharge too much water volume too quickly.

The strainer should be placed at a depth of at least 18 inches below the surface of the water. This is necessary to prevent the formation of a whirlpool, which may permit air to enter the end of the suction hose and result in poor supply, inefficient fire stream, or eventual loss of lift. The suction strainer should always be lowered to a depth sufficient to compensate for falling tides or diminishing cistern supply. However, do not allow the strainer to settle on the bottom of the source of supply.

When drafting from shallow water, whirlpools can be prevented by placing a baffle at the water surface over the strainer, or by digging a sump in the bottom of the water source which to place the strainer at a lower depth. Baffles may be improvised from a salvage cover secured to a ladder, a wood door, sign, or similar object.

When working in the dark, make certain that the strainer is actually in the water and not resting on a ledge or other object above the water surface. Keep the strainer away from pilings to prevent marine growths from entering the pump. If necessary to raise the strainer for inspection, do not raise it to a height that will permit air to enter the suction. If air is allowed to enter the suction, the vacuum will be lost, and the pump will have to be primed again.

## AIR LEAKS

If the pump fails to attain sufficient vacuum at the scheduled drafting drills, air leaks can usually be detected by connecting the pump to a hydrant and putting the pump under pressure. Remove the caps from all of the discharge outlets. Close all discharge outlet gates except one, which should remain open to allow air to escape. Close the open discharge gate as soon as all air has been displaced from the pump.

Leaks will manifest themselves by water leaking out through the same defect that permits air to enter the pump. If possible, the pump operator should correct these defects immediately. If the defect is of major proportion, the officer should notify the Bureau of Equipment immediately. These same leaks will also be apparent when the pump is working from a hydrant at a fire. Whenever a pump is under pressure at a hydrant, pump operators are strongly advised to take the opportunity to check their pumps for defects that may lead to a failure to draft. If defects exist, this is the time to correct them, not during an emergency incident.

***A dry vacuum test may be required and performed by the B.O.E.*** This will test the ability of the pump to draw and hold a vacuum. The dry test should be carried out in the following manner: Close tank to pump valve. Drain water from pump Close suction inlet caps tightly. Proceed to prime the pump as though at a regular drafting hookup. (CAUTION; In the dry test of centrifugal pumps equipped with a rotary vane primer, particular attention should be given to preventing damage to the primer caused by inadequate lubrication),

Priming should cease after a period of not more than 45 seconds. The primer should then be disengaged and the vacuum reading noted. Any loss of vacuum should be very gradual. If it is not, an air leak is indicated. The rapidity of the loss of vacuum is a measure of the seriousness of the leak.

If the primer fails to create a vacuum within 45 seconds, or if a serious leak is indicated, the source of the defect may usually be determined by connecting the engine to a hydrant and making a pressure test as previously explained.

If the results of the dry test are satisfactory, the process should be repeated with the suction hose connected to the inlet and the inlet cap connected to the end of the hose, if provided. If a rapid loss of vacuum occurs it is obvious that there is a leak in the suction hose, which will usually be found at one of the suction connections.

## POOL AND RESERVOIR CONNECTIONS

Pools and reservoirs are emergency water supply sources. A list of emergency water supplies over 5000 gallons is carried in each chief officer's vehicle. The sources are listed by battalion district. These supplies have either a 3-inch gated connection if under positive pressure, or a 6-inch suction connection if under low or static pressure.

In some cases pressures may be at a very low head pressure and the outlet may be a 3-inch connection. In this situation, it may be necessary to draft by removing the Navarro or Keystone from the apparatus and placing its 3-inch side directly onto the emergency water supply 3-inch outlet. The 6-inch hard suction would then be connected between the pump and valve.

# SECTION 5. STANDARD OPERATING GUIDELINES AT FIRES

It is important that all firefighters become familiar with the procedures in this chapter, as they may be required to assist in the making of supply leads at any time. The standard practices as set forth in this chapter are intended primarily to show how the engine can be used to its best advantage.

When operating from its water tank, an engine is self sufficient for a limited time only. Continued operation beyond the capacity of the water tank will require that the engine be supplied with water from an external source. This requirement of external supply is obvious when the engine is to operate as a hose manifold adjacent to the fire scene.

## SOURCES OF WATER FOR EXTERNAL SUPPLY TO ENGINES

An external water supply will be necessary on all but very small fires. The 500 gallons of water carried on our engines for initial attack is normally depleted in a few minutes, making it mandatory that an external supply be obtained as soon as possible.

An engine may receive its external water supply from any one of several sources. The supply may be obtained by drafting, receiving water from a low or high pressure hydrant to which the engine made a direct connection or laid its own supply lead, or from other engines that are connected to hydrants or drafting. The most important point to be considered is that the supply be adequate to meet the demands of the discharge required.

Locating and using engines to the best advantage at fires is a field operation problem and is the responsibility of the Incident Commander. However, it is the duty of the company officer to place the engine in position for service at a fire. This does not relieve the pump operator from spotting hydrants, knowing where to position the apparatus, or visualizing which hose lead will likely be used.

Once the apparatus has been ordered spotted in a position to go to work, supplying and maintaining an adequate water supply for an engine is mainly the responsibility of the pump operator. Company officers and members of other responding companies should comply with the requests of the pump operator requesting a supply line. Such requests shall be considered as substantiated by the Incident Commander, provided they do not interfere with orders to such companies in making their own leads. Compliance with such requests will normally take the form of leading two hose lines to supply the engine.

## USING GATED INLETS AND BLEEDERS

Gated inlets are provided on engines to permit continuous pump operation beyond the limits of the water tank supply. They provide the pump operator with means to control the flow of water into the pump by means of individual gate valve controls at each inlet. The 6" inlets must have a Navarro Valve, a Keystone Valve or one way on demand valve, attached in order to provide this control.

Each gated inlet is equipped with an individual bleeder on the supply side of the gate. The purpose of this bleeder is to exhaust the air from the incoming supply line when it is first charged. After the air is exhausted through the bleeder , a solid stream of water will be ejected, indicating to the pump operator that they may then open the inlet gate valve. These bleeders are normally left in an open position, but should be closed after the air is exhausted and water is flowing through the bleeder.

When connecting engines to hydrants by use of a soft suction, the soft suction may be connected to any inlet. However, if the soft suction is not pre-connected, the preferred method is to connect the soft suction to the 6 inch gated inlet first. This will provide maximum capacity.

**ANY CONNECTION TO A LOW PRESSURE HYDRANT FOR SUPPLY WILL REQUIRE THE USE OF AN AMES BACKFLOW DEVICE OR ONE-WAY DEMAND VALVE**

## SUPPLY LINES

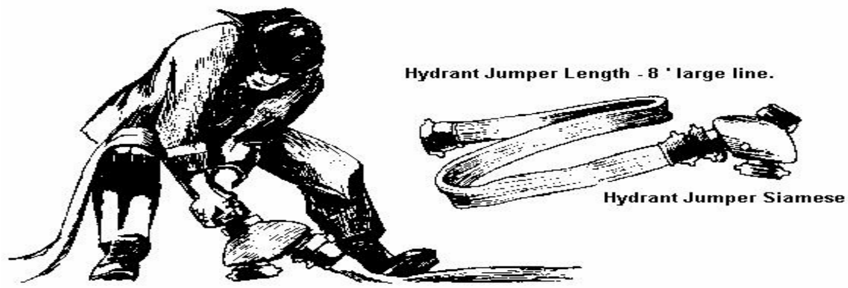
The leading of supply lines for connection to engines may be made by the engine itself, by another engine, or by a hose tender. Only one engine with supply lines led to it would normally be required to operate in front of a fire building. Large buildings with extensive street frontage or fronts on two or more streets are obvious exceptions.

When the term “front of the fire building” is used, the intent is to mean the most advantageous position to immediately attack the fire. Due consideration should always be given to the placement of aerials when positioning engines at fires.

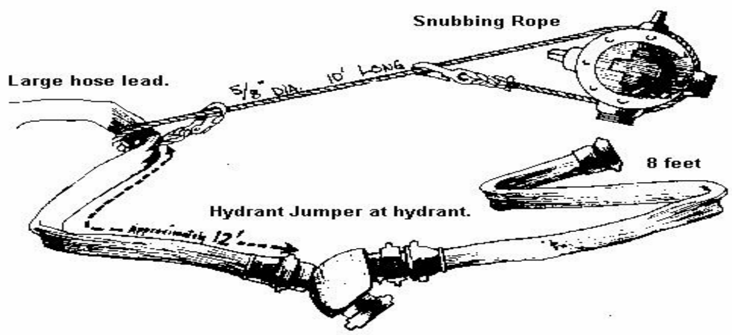
## HYDRANT JUMPER

The hydrant jumper assembly is designed to act as an aid when an engine drops a supply line for its own use, and proceeds to the front of the fire building. It consists of a Siamese with two 3-inch female inlets and one 3-inch male outlet, a bleeder on one of the inlets, an 8-foot length of 3-inch hose, a strap to hold the assembly together, and a large brass spanner.

The male coupling of the 8 foot hose is connected to the Siamese inlet equipped with the bleeder. The female coupling of the 8 foot hose is connected to the hydrant outlet with an Ames backflow device. The open inlet of the Siamese is available for connection by the 2nd engine taking over the hydrant jumper.




Connecting hose lead to hydrant jumper siamese




The hydrant jumper assembly is usually carried on the rear of the apparatus. In most outlying areas the hydrant jumper is carried pre-connected to the hose in the left hand hose bed. In those areas where standpipe work may be frequent, the hydrant jumper is usually not carried preconnected.

## SNUBBING ROPE

Many hose leads will be from a hydrant to the fire, and will require snubbing of the hose lead to the hydrant. In order to facilitate this operation, engines are equipped with a snubbing rope. The snubbing rope is a 5/8-inch rope approximately 10 feet in length, equipped with either large snap hooks or eye splices.

It is standard practice to carry the snubbing rope attached to the hose in the left hand hose bed. Attach the rope to the hose bight closest to the last hose coupling. The loop is formed by passing a snap hook or eye loop around the selected hose bight and fastening it to the rope at the bight. The snubbing rope is attached in this manner, regardless of whether the hydrant jumper is carried preconnected or not. The free end of the snubbing rope should not be looped and should be placed between the folds of the hose on top of the hose bed. This is done in such a manner that it will not fall off and be dragged, but can still be easily removed. This practice is preferable to carrying the free end looped. It eliminates the delay caused when unfastening the loop and makes it easier to apply around a hydrant that may be obstructed by hose lines, soft suctions, or Gleeson valves.

## HYDRANT JUMPER LEADS

The following procedure has been adopted as the standard method used when making a hydrant jumper lead:

1. The engine stops near the hydrant.

2. The snubbing rope and hose bight are taken to the hydrant and the rope is secured to hydrant or other solid object. If the hydrant is a high pressure hydrant, the Gleeson Valves and spanner are left at the hydrant.

3. The hydrant jumper assembly is placed within eight feet of the hydrant.

4. The firefighter at the hydrant connects the hydrant jumper hose to the hydrant. Should the hydrant jumper not be preconnected, first connect the jumper hose to the hydrant while the hose lead is being made, and then connect the hose lead to the outlet of the hydrant jumper Siamese. The firefighter then slowly turns on the water when they visually see the Hebert hose clamp placed on the hose or a signal to charge the line is received. After charging the hydrant jumper supply line, the firefighter should return to their company.

5. When the engine stops at the fire scene, the driver will place the hose clamp on the hose approximately 10 feet from the rear of the apparatus and signals to the firefighter at the hydrant. Firefighter then assists in leading attack line.

6. The driver assists with the hose leads as needed and charges the attack line when in place.

7. The driver connects the hydrant jumper lead to a gated inlet, preferably at the pump panel. The clamp is then removed and placed on the engine. All gated inlet, valve bleeders should be in the open position until all air has been exhausted from the supply line. The driver then throttles down to 60 psi, opens the inlet valve while observing the discharge pressure, then adjusts throttle to the desired pressure.

Note: Hose clamp should be stored in a partially opened position, being open just enough to accommodate an uncharged large hose line.

## CONNECTING SUPPLY LINES TO ENGINES

All supply line leads to engines will require a hand signal before delivering the water. If it is a known fact (visually seeing or verbally hearing) that the supply line has been attached to an inlet, then this signal need not be made. Once the supply line is attached to an inlet, this supply line can be charged. **Note: Although it is proper for anyone to connect a supply line to an inlet, only the pump operator shall open the inlet gate.**

The problem of sudden pressure increase, and the accompanying hazards to hand held lines, will normally be most severe when associated with the first supply line introduced into the pump. Additional sudden pressure increases may also occur when subsequent supply lines are introduced. The pump operator must be alert to protect the firefighters operating hand held hose lines each time a supply is introduced, or when pressure increases are expected through supply lines already in operation. The discharge pressure of the pump should be reduced to 60 psi whenever water is to be introduced into supply inlets, and then readjusted for proper discharge pressure when the effects of the increased supply are indicated on the pump pressure gauges.

When making supply leads to another engine, the supplying engine's pump operator should think volume rather than pressure. The transfer valve should be in the volume position and the number of supply lines given should be considered. One supply line at a high pressure is a dangerous practice. It is better to supply the engine with multiple supply lines at a safe pressure.

## APPARATUS PLACEMENT

It must be clearly understood that no hard and fast rule can be followed when talking about apparatus placement and/or hose leads. Many variables dictate the actions to be taken. The size and location of the fire, the type of fire, the available water supply, the width of the street, the time of day or night, and the time of arrival of the next arriving engine all will have a bearing on the actions taken.

In most cases the first arriving engine will end up in front of the fire building. This engine will be used extensively by its own crew and later arriving companies. Later arriving companies will often advance lines from this engine. Therefore, it can be seen that not only is the placement of this apparatus of utmost importance, but also the obtaining of an effective water supply. Remember, it is the <u>volume</u> of water supplied to this engine that is important, not the pressure.

The second engine usually is for supplying water to the first-in engine only.

If at all possible, the second arriving engine should make sure that the first engine not only has its initial supply, but also the anticipated volume needed. Two supply lines led to the first engine, with the second engine's crew working off the first engine is often the safest and most effective procedure. The second engine can then work at safe operating pressures with the outlet gates to these supply lines fully open, thus allowing maximum volume. Supply to the first engine should not exceed a maximum of 80 psi.

## 1ST ARRIVING ENGINE

1. Position apparatus just short of or just past the front of the fire building. Normally the apparatus is positioned just past the front of the fire building. Allow room for truck company placement. Circumstances encountered may alter these guidelines.

2. A water supply shall be secured or planned
   - Hydrant jumper
   - Nearby hydrant
   - Second engine

3. If the building is equipped with a dry standpipe system, a hose line shall be connected to the inlet.

4. Direct attack on the fire, depending upon conditions, may require:
   - Attacking with 1¾-inch ready lines.
   - Attacking with large line or a large line wyed to one or two 1¾-inch line(s)
   - Attacking with 1¾-inch bundle off a standpipe
   - Attacking with 2½inch hoseline
   - Attacking with master streams (position the apparatus safely)

## 2ND ARRIVING ENGINE

**When arriving *__before__* the Chief Officer:**

1. Position apparatus in order to take measures dictated by the situation. This engine should be used as a supply engine only and controls the pressure and volume of the water to the attack engine. The supply engine's objective is to maximize the volume of water to the attack engine.

2. Providing a water supply to the first engine shall be the number one priority. Even with the first engine having its own supply, laying two additional supply lines should be considered first. If possible, two supply lines (both hose beds) should be led to the first engine as a primary and backup supply. The left bed (supply side) shall be connected directly to the first engine's inlet. Hose from the right bed with a shutoff control shall be placed for the use of the first engine driver.

3. On narrow streets, alleys, etc. the apparatus shall be backed down, drop hose for leads, bundles, wye. etc., and proceed out to a hydrant. If

conditions permit, consider dragging a hand lead to an engine in an alley for supply to expedite rather than backing down to drop the lead.

4. On wide streets the apparatus may be stopped alongside the first engine, drop the hose lead or leads and proceed to the hydrant. Be aware that it is always safer to back in, rather than risk driving by and getting blocked or boxed in by other arriving companies.

**When arriving *after* the Chief Officer:**

1. Position apparatus and provide water supply to the first engine. Report to the incident commander with required equipment:
   - SCBA
   - Bundles
   - Officer Wye, etc.

2. Actions shall be as directed by the chief officer. Where feasible, chief officers should use the same guidelines outlined above.

## 3RD ARRIVING ENGINE

**When arriving *before* the Chief Officer:**

1. If the second engine has not been able to supply the first engine, the third arriving engine should complete this assignment.

2. If the first- and second-arriving engines are operating according to standard operating guidelines, the third-arriving engine company shall:
   - Consider covering another side of the building
   - Consider covering an exposure building
   - Request an update of conditions or orders from the IC.

3. Third engines should not block a hydrant that the second engine may be leading to.

4. If the third arriving engine enters the intersection on the same side of the unit block as the second engine, the third engine should consider circling the block and entering from the opposite side. This avoids congestion, and is likely to place the third engine on another portion of the water main distribution grid.

**When arriving *after* the Chief Officer**

1. Position apparatus near intersection, with rear of apparatus facing towards the fire building.

2. Officer and crew with required equipment (SCBA, small line bundles, etc.), report to the incident commander.

3. Remain flexible and be prepared to respond to any area the incident commander may direct.

## BUILDINGS EQUIPPED WITH DRY STANDPIPES

### 1ST ARRIVING ENGINE

The first arriving engine company shall make a lead into the dry standpipe inlet.

While the standpipe is being filled, the effect on the pump is as if it were pumping through an open coupling and therefore moving a large volume of water. In moving this large volume, the pump is unable to develop what we normally consider an adequate pressure. In order to eliminate any confusion this situation may cause, the following procedure should be followed when charging the first line into a standpipe.

- The Pump operator connects the first lead into the standpipe from the most convenient discharge outlet.
- Throttle to 100 psi;
- Charge the line at this pressure so that when the standpipe fills, the compound gauge will return to 100 psi.
- At this point, throttle to the desired pressure of 120 psi plus 5 psi per floor to account for back pressure.
- If after an unusually long period of time the discharge gauge does not return to the initial discharge pressure noted, then the possibility of an open outlet or other standpipe malfunction may be the problem.

This procedure is primarily directed to incidents where an engine is positioned near the standpipe (within 150 feet) and taking the initial supply from the tank.

### MONITOR OPERATIONS AT MAJOR FIRES

When first-in at a fire of major proportions, where it is evident that master streams must be quickly setup and you intend to use a monitor, insure yourself an adequate supply of water at sufficient pressure. If possible, the monitor should be set up so it is applying water to the fire on the officer's side of the pumper. This will help to keep the pump operator from continual wetting from overspray.

The decision to remove the pre-plumbed deluge set from the apparatus or remain in front of the fire is a decision of the Company officer or the Incident Commander. Leads made for deluge operations should be from a high pressure hydrant when possible. In any event, two lines shall be led for supply.

Other engines arriving on the alarm will be engaged in setting up their own operations and in covering other sectors of the fire; hence you must make your own provisions for an adequate supply of water.

## FACTORS TO CONSIDER IN ENGINE LEADS

## POSITIONING THE ENGINE

As it is normal practice to place an aerial truck in front of tall (three stories or more) fire buildings, engines shall be positioned short of, or past, the building front. The engine should stop past the front of the building when the aerial is approaching from behind the engine. The engine should stop short of the front of the building when the aerial approaches from the opposite direction. In all cases, the engine shall be placed as close to the curb as possible.

**Visible Fire.** Encountering visible evidence of fire while responding may call for obtaining your own water supply. This is especially true if it will take appreciable time before the next engine arrives.

**Backing In.** When other companies are already on the fire scene, the officer and driver should give due consideration to backing down to the fire front rather than entering head first. The risk of being blocked by apparatus coming from the opposite direction, thus preventing your ability to make a lead, is greatly reduced. When a fire is in an alley, it is imperative to BACK DOWN the alley in order to lead out or be in a position to move apparatus quickly. Consider leading lines by hand down alleys.

**Bed Position.** When positioning an engine at a fire, make an effort to place the engine with the bed facing the fire building. This facilitates the pulling of lines from the engine to the fire.

**Hydrant Jumper.** When an engine has led its own supply line from a low pressure hydrant using a hydrant jumper, another engine connecting to that hydrant must pump into the second inlet of the hydrant jumper. This is required not only to augment the supply line with pump pressure, but also to prevent decreasing the hydrant supply pressure by the use of the second engine.

A hydrant jumper is “taken over” when a pressure higher than the hydrant pressure is pumped into its 2nd inlet. After pumping into this second inlet, it is good practice to shut down the hydrant supply to the hydrant jumper and disconnect the hydrant jumper hose from the hydrant. A second supply for the engine connected to the hydrant should then be taken from this available outlet. The hydrant is then under the control of the engine hooked up to it, and if in the judgment of the pump operator the supply is adequate, additional hose lines may be taken from the outlets of this pump.

If a choice of hydrants exists, pump operators should select the hydrant from which another pump operator has led a hydrant jumper lead. The supply to this hydrant jumper should then be augmented.

**Unused Hose, Equipment and Outlets.** Companies making hose leads should take advantage of unused outlets on engines already hooked up to hydrants or operating in front of the fire. If these engines have an adequate water supply, a great deal of time and effort can be saved by using these outlets.

**Inlets:** Remember that supply lines are connected to inlets, and that it is extremely important that connections are completed before charging these lines. Verbal or visual confirmation should have been received.

**Apparatus.** Remember, because of the higher pumping capacity of the newer apparatus, it is recommended that only one pumper be connected to any low pressure hydrant.

## CHANGING FROM TANK TO EXTERNAL SUPPLY

It is usually the case where the first engine company will charge hose lines from the tank prior to securing a water supply from an external source. In these situations it is imperative that the pump operator secure an external water source (hydrant or another engine company) as soon as possible.

External supply lines bring in water under pressure, and the amount of this pressure may vary considerably. If the pump discharge pressure is not reduced when admitting an external water source, the discharge pressure may become excessive and result in possible injuries. The compound gauge on the suction side of the pump will show the supply line pressure at the inlet, and the gauge on the discharge side will show the combination of the pressure at the inlet and the pressure produced by the pump.

Once the supply line is charged, and all air has been bled from this line, conversion to external supply can be made. When discharge lines are not in operation, no immediate problem is present when changing over to external supply. However, when discharge lines are in operation, the procedure for changing to external supply has to be followed. This procedure is:

1. Close inlet bleeder
2. Throttle the pump pressure back to approximately 60 psi. or down to idle if over 60 psi
3. Slowly open the inlet supply gate fully, observe the discharge pressure
4. Re set throttle to desired pump pressure.
5. Observe compound gauge on inlet side of pump to determine that the water supply is adequate (30-40 psi is an adequate residual pressure)

The problem of sudden pressure increase and the accompanying hazards to hand-held lines will normally be most severe when the first supply line is introduced to the pump. Additional sudden pressure increases may also occur on subsequent supply line connections. The pump operator must be alert to protect the firefighters operating hose lines each time a supply line is opened, or when pressure increases are expected through supply lines already in operation. At no time during normal operations should the pump compound gauge exceed 80 psi when large hand lines are in operation. The pump operator should not request additional supply lines as long as 30 to 40 psi can be maintained on the compound gauge.

**Do not allow** the pump compound gauge to fall below 20 psi. If it does, you are starting to exceed the capacity of your water supply and need to obtain additional supply source, providing your tank water level is not lowering. If tank water level is not lowering you have ample supply for the lines in use

**CAUTION**

**If the tank runs out of water before a change-over is made, all pressure will be lost, and the discharge gauge will read "0" psi.**

**However, the engine is still working to produce the pressure that was showing on the discharge gauge before the tank was depleted. Once water enters the pump, the discharge water pressure that was set previously will again show on the pressure gauge and combine with the supply line water pressure.**

**This high pressure can be extremely dangerous to firefighters handling hose lines. Therefore, it is extremely important that the throttle be backed all the way down (turned clockwise) or returned to idle as on the Fire Commander, before introducing an outside water supply.**

## READY LINES—WATER TANK OR HYDRANT SUPPLY

The first lead is usually made from the side of the engine nearest the fire. However, the length of the lead to be made may dictate otherwise. In either case, all of the ready line (other than the amount needed to reach the outlet) must be removed from the engine before being charged. The pump operator must check to see that the ready line is in position before opening the proper ready line gate. The pump pressure for a 1¾" ready line is.120–150 psi

If an engine is connected to a hydrant and ready lines are ordered taken from the engine, the pump operator should open the desired gate and admit hydrant pressure into the lines before increasing the pressure of the pump to the desired level. Outlet gates operate easier with less pressure behind them, and the hose lines have a chance to fill up with water and expel the air while under relatively low pressure.

Operating pump pressures normally are:

**Ready line (depends on length of lead and type of nozzle 120-150 psi)**

## WORKING PRESSURES

All pressure measurements are pump pressures.

| Type of Lead | Initial Pump Pressure |
|---|---|
| 3-inch Large Line Hose Lead | • 80 psi<br>• Add 5 psi per 100 feet of horizontal hose lay.<br>• Add 5 psi per floor of elevation above first flow.<br>• Subtract 5 psi per floor or equivalent below pump level |
| Large Line Supplying Wye | 120 psi |
| 2½-inch Hose Lead 1-1/8-inch tip | 75 psi |
| 1¾-inch preconnected lines (ready lines) | 120 – 150 psi |
| Standpipe lead | • Adjust desired outlet to 100 psi, open outlet, when standpipe fills pressure will return to 100 psi. If it becomes difficult to open desired outlet, reduce pressure, open outlet, monitor pressure and re-adjust when standpipe stabilizes.<br>• Add 5 psi per floor of elevation to the fire floor |
| Forestry line | 80 - 100 psi |

## SUPPLY PRESSURES

150 psi to Combination Standpipes
150 psi to Automatic Sprinkler and Standpipes
150 psi to Automatic Sprinklers

(Note: These shall be charged only on orders of the Incident Commander)

## MASTER STREAM APPLIANCES

<u>Definition of Master Stream</u>: A nozzle capable of supplying more than 300 GPM or a straight tip with a diameter of 1½" or larger.

High Pressure Hydrants regulated by Gleeson Valves shall be the first choice of supply to master stream appliances.

If an engine is supplying a master stream through its pump, that engine shall be used to supply the master stream only.

**Master stream Siamese appliances shall be supplied by at least two lines.**

| Master Stream Appliance | Supply Pressure |
|---|---|
| Ladder Pipe: 75-degree angle; 80-ft. elevation; 85-psi tip pressure with 2” tip | 150 psi at the Siamese |
| Multiversal (Deck Gun/ Monitor) | •100 psi with 1 3/8 inch tip (two lines)<br>•100 psi with 1 ½-inch tip (two lines)<br>•70 psi with 1¾-inch (two lines)<br>•50 psi with 2 inch tip (two lines) |
| Cellar Nozzles/Circulators | 80 psi |
| Attack Hose Tender | 150 psi at hose tender inlet (gauge). |

Situations may arise on the fireground, which may require a change in these recommended pressures in order to maintain adequate flow. Friction loss on the fireground is dependent on flow of water and length and condition of the hose. Pump operators shall maintain a constant vigilance at the pump panel and the radio tactical channel, for instructions directing an increase or decrease in pump pressure. A general rule for supply to hose lines is as follows:

| | |
|---|---|
| Smooth bore nozzles on hand lines (solid stream) | 50 psi nozzle pressure |
| Smooth bore nozzles on Master Stream Appliance | 80 psi nozzle pressure |

# SECTION 6. RELAY PUMPING AND PORTABLE HYDRANTS

## RELAY PUMPING

When involved in relay operations, a Water Supply Officer should be appointed to make maximum use of available resources and equipment. Relay operations are a complex and difficult setup and an Officer should be dedicated to monitoring pressures and insuring proper pumping operation. Use of a dedicated radio channel (not fireground) is recommended for the Water Supply officer for radio communications during relay operations.

Engines are placed in relay operation when the conditions necessary for effective fire streams exceed the performance ability of a single engine. This type operation is used where the distance from supply to nozzle is excessive and would require an unusually long hose lead with resultant high friction loss. Relay may also be employed to overcome back pressure when the point of nozzle discharge is at an elevation considerably higher than the source of supply.

The need for relay operation is not common in the built-up areas of San Francisco where water supply and hydrant spacing is adequate. However, conditions may arise at fires in some areas that would require relay hook ups, such as in the undeveloped sections of Sutro Forest, Twin Peaks, and public parks. Under emergency conditions created by earthquakes and other, mains could be broken and relaying would then be necessary.

It is doubtful that any two relay hook ups necessary to combat actual fires would be the same. Therefore, a definite rigid procedure governing the laying of lines, placement of engines, and setting of pressures is impractical. In this manual only basic information, general requirements and limitations are set forth.

The most important factors that determine the set up of a relay are:

1. The total amount of water (GPM) to be discharged from the nozzles supplied.
2. The size, length and layout of the hose necessary to carry the amount of water required.
3. The capacity of the pumps available.
4. The elevation of the point of discharge above the point of supply.

The maximum allowable working pressure is 200 PSI based on a hose test of 250 PSI less 50 psi for safety. The available pressure for each pump is 180 psi leaving 20 psi necessary for residual pressure at the intake side of the pump. The 180 psi is the pressure available to overcome friction loss and any height gain of the hose lead.

Maximum distance of flow at 180 psi in feet.

| GPM | 3 inch hose | 5 inch hose |
|---|---|---|
| 100 | 18000 | |
| 200 | 4500 | |
| 300 | 2000 | 27000 |
| 400 | 1000 | 16000 |
| 500 | 720 | 10000 |
| 750 | 350 | 48000 |
| 1,000 | 200 | 27000 |

| Head in Feet | Pressure (PSI) To Overcome |
|---|---|
| 10 | 4.33 |
| 50 | 21.65 |
| 100 | 43.30 |

Nozzles that would probably be used in relay operations would range in size from ½ inch to 7/8-inch on 1-3/4-inch lines, 7/8 inch to 1-1/4 inch on large lines, and possibly the 1-1/2 inch on deluge sets. The Table below shows the approximate amount of water necessary to produce effective streams from these size nozzle tips, and the approximate friction loss through the various size hose.

| Nozzle Pressure (PSI) | Tip Size (inches) | Flow (GPM) | 1-3/4-inch hose line | 1 Large Line | 2 Large Lines |
|---|---|---|---|---|---|
| 50 | ½ | 50 | 9 psi | minimal | minimal |
| 50 | ¾ | 120 | 45 psi | 2.5 psi | minimal |
| 50 | 7/8 | 160 | | 4 psi | minimal |
| 50 | 1¼ | 325 | | 15 psi | 4 psi |
| 50 | 1½ | 470 | | 30 psi | 8 psi |

If we assume that inlet pressure at each succeeding pump in a relay should be at least 20 psi residual, and that each pump in the relay line can safely maintain a maximum discharge pressure of 200 psi without danger of bursting hose lines, then we have 180 psi available at each engine to overcome friction loss and back pressure. Certain general requirements can then be set up for use in relay operation.

If we assume that the pumps in relay are working at 200 psi discharge pressure, and with a required discharge of 325 GPM (sufficient to supply one 1-1/4-inch, two 7/8-inch, two ¾-inch, or six 1/2-inch nozzles), then friction loss in one line of large hose laid on the level will use up 180 pounds in approximately 1200 feet.

If two lines are laid between each pump, the distance between engines can be increased from 1200 feet to 4700 feet before the 180 pounds pressure is depleted due to friction loss.

For flows up to 470 GPM (1-½-inch tip) with 180 pounds pump pressure available, a single line between engines would be limited to 600 feet. The use of parallel lines between engines would increase this distance from 600 feet to 2400 feet.

If the pumps in a relay are so placed as to require 200 psi at each pump, then the rated capacity of each pump at that pressure will be ample for the discharge required in the preceding examples. It is apparent that, if available, the use of two lines between pumps in relay provides for greater spacing of engines. Where engines can be more closely spaced and supplied by more than one line, then higher discharge GPM at lower pump pressures would be possible.

Back pressure (head) plays an important part in the engine placement for relay operation. It will reduce the pressure available to overcome friction loss, and could feasibly require placement of engines quite different from that of the same relay on level ground,

There is only one sure method of determining back pressure at any or all of the relay pumps in line: charge the line from hydrant to nozzles, close the nozzles, close the hydrant and disengage all pumps. Back pressure may then be read at the pressure gauge of each pump in the line. The disadvantage of this procedure is that a complete shutdown of the pumps is required.

Another method which is not so accurate but which will give a fairly close approximation is to assume a certain maximum percentage of grade and allow accordingly. When setting up a relay operation uphill, it is suggested that a 10% grade be assumed, which allows a 10-foot rise to each 100 feet of hose laid out. Thus, for 1000 feet of hose laid uphill, assume 45 pounds back pressure.

Back pressure is independent of the amount of flow and will subtract from the pressure available to overcome friction loss. Where it is excessive, the relay set up may require the placement of additional engines in the line, however, it is pointed out that if sufficient hose is available to lay additional lines between engines, friction loss is reduced considerably. Pump pressure may then be adequate to compensate for both friction loss and back pressure.

Since pressures at each pump in a relay line should be held at a 200 pound maximum, it should now be apparent that the spacing of the pumps will be determined by the balancing of three factors: quantity of flow, friction loss, and back pressure.

The accepted relay formula places a second pump at a point near the fire that is equal to one third of the total distance between the source of supply and the fire. This formula will work very well if only two pumps are to be used, and if the hose lead is on level ground. However, if more than two pumps are to be used, or if back pressure is a major consideration, the formula may not apply.

The terrain of San Francisco is extremely hilly, and in many parts of the city back pressure will be a major problem in relay operation. Under fire conditions, particularly those due to disaster, it may not be possible to place relay pumps in accordance with any set formula. This is particularly true in areas where access to undeveloped areas is difficult.

Thus, a more general and flexible procedure for relay operation is suggested. Place one pump at the source of water supply, and one as near the fire area as possible. If the distance between these pumps is over 1000 feet, or if back pressure is a major consideration, place an additional pump or pumps as near equal distance as possible between the first and last pump. If available, lay parallel lines between each pump. This may eliminate the necessity of an additional pump in the layout.

For example, assume that the last pump in a relay line requires 320 GPM (to supply two 7/8 inch tips). This pump is 2000 feet from and 100 feet above the supply pump. The total back pressure to overcome is 45 psi. Inlet pressure of 20 psi is required. If a single line of large hose is used, the total friction loss for 2000 feet will equal approximately 300 psi, making a total pressure requirement at the supply pumper of 365 psi. If one pump were placed between the supply and discharge pump, each pump would then have to pump at only 185 pounds, which is within the maximum suggested limits of 200 psi pump pressure. (NOTE: Do not count the discharge pump as one of the relay pumps).

If two large lines are used between engines, the total friction loss will drop to about 80 psi, for a total pressure requirement of 135 pounds. This lay would not require an additional engine in the line.

The general procedure suggested will, in most cases, prove adequate for relay problems encountered in undeveloped areas. Relay problems due to disaster obviously will be more complex. The water supply officer in charge of the relay operation will have to know definitely that the source of water supply is adequate, and then space the relay pumps by determining a balance of the three factors: quantity of flow, friction loss, and back pressure.

A development in relay operations which proved successful in those cities which were under attack during World War II was one in which the engines in relay discharged into improvised open reservoirs, tanks, dams, or cisterns rather than directly into the suction inlet of each succeeding pump; each intermediate pump taking suction from the improvised reservoir, tank, etc.. In San Francisco, maximum use could be made of our strategically placed street cisterns for this purpose.

This method of relay is commonly called open relay, while the method previously discussed is called closed relay.

There is no major difference between the setting up of an open relay and a closed relay. In either type of relay, source of water supply must be adequate, and spacing of pumps must be determined by the quantity of flow desired, friction loss, and back pressure. There are, however, three distinct advantages of the open relay over the closed relay.

1. The immediate water supply available at each, improvised storage point may enable control of adjacent incipient fires.

2. Fluctuation of the discharge pressure of each relay pump in an open relay is not as serious as it is in a closed relay. In a closed relay pressure fluctuations could result in burst hose lines, damage to pump, or ineffective fire streams. In open relays, such pressure fluctuations merely result in a small change in water levels of intermediate storage facilities.

3. Open relay permits a momentary shutdown of one of the pumps, if necessary, without interruption of the relay as a whole. Burst lengths may be replaced or defective pumps withdrawn and replaced without causing a complete stoppage of water flow.

## Operation Of Pumps In Relay

1. When engines are properly placed in a relay layout, the pump operator of each engine, except the engine at the source of supply, should prepare to receive supply lines to the suction inlets of the pump.

2. Discharge gates on the engine at the source of supply must not be opened until the pump operator is notified that connections to the receiving engine have been completed.

3. Pump operators of each succeeding engine must not charge discharge lines until notified that the next engine in relay is ready. As each intermediate engine receives water, provision should be made by the pump operator to exhaust air trapped in supply lines, by opening an unused discharge outlet and/or bleeders.

4. Unless otherwise ordered, discharge pressure at the first and each intermediate pump should not exceed 200 psi if possible, inlet pressure should be kept at not less than 20 psi residual. Increase pump pressure gradually, open discharge outlet gates slowly.

5. The pump operator of the last engine in the line should consider the supply lines as a hydrant and operate the pump accordingly. The relief valve or governor should be set promptly to protect the pumps, the hose, and the firefighters at the nozzle.

6. An alert pump operator will keep a close watch of the gauges and be prepared to reduce pump pressure in the event of relief valve or governor failure.

7. Pump operators of all engines in a closed relay, except the first engine, should not place too much reliance on the reading of the compound gauge

at low pressure. Indication of an adequate inlet pressure may be more accurately determined by feel of the supply hose.

8. Keep discharge outlet valves fully opened to prevent curtailment of discharge. Check these valves frequently to make certain that they have not partially closed due to pump vibration.

9. Temporary shutdowns, whether from the nozzles or any intermediate pump in the relay line, should be done very slowly to give pump operators time to adjust pump pressures.

10. To shut down relay pumps in a closed relay, shut down the pump nearest the fire first and work back to the source of supply. Lower the operating pressure and disengage the pumps without closing the discharge outlet gates. Discharge gates should not be closed until the engine at the source of supply has been shut down. Then all pumps in the line may shut down in the usual manner.

## HOSE TENDERS AND 5 INCH HOSE

Rear Bed

Portable Hydrants have 4½-inch inlets and outlets, with two gated 3½-inch outlets in the middle. They can be placed anywhere in a 5-inch hose lay.

These hydrants can flow 2,500 gpm through the two 3½-inch outlets. At the end of the lead, always place an in-line shut-off, this allows for extension if needed.

Portable Hydrants make it possible to pump large volumes of water, at high pressures, long distances. The water can be distributed at any point along the relay by means of a Gleeson Valve.

Battalion Chiefs shall arrange for drills according to the Drill Schedule, with Division Chiefs to familiarize personnel with the Hose Tender and equipment.

## HOSE TENDER GUIDELINES

The Incident Commander will determine the source of the water supply (hydrant, lake, cistern, bay) and where the portable hydrants are to be placed.

1. Place the supply pumper or pumpers at each end of the hose line.

2. Lay 5 inch hose between supply pumpers and break connections where hydrants are to be placed. Use the gated 2 way inlet wyes, (two 3 inch inlets, one 4½-inch outlet), for supply to the 5 inch hose.

3. Put two 3 inch lines from a pumper or from a high pressure hydrant into a gated wye. Try to keep supply lines to 50 feet. Full capacity of a pumper can easily be supplied through two 3 inch lines.

NOTE: More than two lines can be put into a two-way inlet gated wye by connecting a small non-gated wye (such as a hydrant jumper wye), to a 3 inch inlet. This allows additional 3 inch hose lines to be used for supply. This should be done when leads are more than 50 feet from a pumper or high pressure hydrant into the gated wye.

## HIGH PRESSURE HYDRANT SUPPLY

When using high pressure hydrants as the supply source, set the Gleeson Valve at **220 psi**. This allows for friction loss at high volume flow through the fittings and the valve and provides 200 psi into 5 inch hose.

When using upper zone hydrants, Twin Peaks must be put in service; when in the lower zone, Ashbury pressure must be in service.

For very long hose lays (or up hill), a supply line should be inserted into the middle of the hose line through one side of a Portable Hydrant. A Portable Hydrant can be supplied by 5 inch hose at each end and through one of the 3½-inch outlets and discharge through the other outlet gate. When taking discharge lines from a Portable Hydrant through gated 3½-inch outlet, a Gleeson valve **must always** be used. This is to control discharge pressure.

## FRICTION LOSS

| Hose Size | GPM | Pressure Loss |
|---|---|---|
| 5-inch hose | 1000 | 4 psi per 100 feet |
| 5-inch hose | 500 | 1.2 psi per 100 feet |
| 3 inch hose Siamesed into wye (two 3 inch lines) | 1000 | 12 psi per 50 feet |
| 3 inch hose Siamesed into wye (two 3 inch lines) | 500 | 3 psi per 50 feet. |

Hose Tenders, can be put to work very easily using the 5-inch hose and Portable Hydrants. Using 5-inch hose works extremely well for high volume flows. The Hose Tender driver will lead the 5-inch hose from the source of water supply to the desired location. Connect a Portable Hydrant to the end of the 5-inch hose; put two Gleeson valves onto the hydrant outlets; and put four 3-inch lines into the inlets. Set Gleeson valves at 140 psi. This will give excellent flow and pressure.. (**NOTE: also refer to Training Bulletin 90-1 for more information on evolutions with Hose Tenders and 5 inch hose)**

## HOSE TENDER MONITOR

Each of the standard hose tenders is equipped with a monitor nozzle mounted permanently behind the driver's compartment. Directional control of the nozzle by one firefighter is accomplished by a bar handle for horizontal movement and by a hand wheel for elevation. The nozzle normally is equipped with a 1-1/2-inch tip. Three additional tips are available to supply 1-3/4-inch, 2 inch, and 2-1/4-inch orifices. The flow of water to the nozzle is controlled by means of a control valve in the riser on the right side of the apparatus and is operated by a hand wheel. Supply pressure to hose tender monitor is 100 psi at the inlet.

With the hose tender in operating position, the problem of obtaining the greatest value from the monitor nozzle is the responsibility of the firefighter operating it. When it is possible, best results are generally obtained by slowly moving the stream in a sweeping motion over and into the involved area. Any firefighters operating in such areas should be withdrawn before using heavy monitor streams. Such streams directed into buildings through doors or windows are limited in their sweep; in fact, they may have to be held steady in one position until ordered to change direction.

In many cases, hose tender streams can be used to good advantage by deflecting the stream off ceilings where it cannot be applied directly to the fire. Those heavy streams may be frequently used to advantage to protect exposures. Water is supplied to standard hose tender monitor nozzles through eight 3-inch female swiveled inlets, four of which are located on each side of the hose tender body. Each inlet is equipped with a clapper valve that permits the use of one to eight supply lines. All inlets are inter-connected to supply the nozzle and each inlet has its own individual bleeder on the supply side of the clapper valve. A pressure gauge is provided which registers pressure being delivered to the nozzle.

A water curtain outlet with a spray head is provided on each side of some hose tender for the purpose of protecting the apparatus and operator of the nozzle from excessive heat. The water curtain outlet is 1-½ inch in size and is controlled with a gate valve, however, there is no pressure control, the pressure being the same as that at the inlet manifold. This fact is important because if it is desired to remove the spray head and connect a 1-½-inch hose line to the water curtain outlet, the outlet pressure will be the same as that at the inlet manifold.

## STANDARD POSITION OF HOSE TENDERS AT FIRES

Width of streets is a determining factor in spotting a hose tender, and when directing a stream at the proper angle of elevation. A good average position for spotting a hose tender is in the center of the street so that the monitor can reach multiple floors.

Where a choice exists, the best vertical angle for the direction of a monitor stream is between thirty and forty-five degrees for second and third floor penetration.

A monitor tip pressure of 90 psi produces a satisfactory stream for any of the tips carried on hose tenders. Nozzle pressure may be estimated by deducting 10 psi (for friction loss and back pressure) from the inlet pressure as indicated on the pressure gauge connected to the inlet manifold riser.

Proper use of hand signals will be of value in controlling pressure and water supply to hose tender nozzle operation.

## HOSE TENDER INVENTORY

| Item | Qty. | Description |
|---|---|---|
| Inlet wyes for supply to five-inch hose | 3 | 2-way, 3-inch inlet to 5-inch outlet gated |
| Gleeson valves | 5 | |
| Portable Hydrants<br>In-Line Shutoff | 4 | 5-inch in-line shutoff |
| Fittings | 2<br>1 | 3-1/2-inch female to 3 inch male<br>3-1/2-inch female to 4-1/2 inch |

| | | |
|---|---|---|
| | 1 | 3½-inch male to 4½ inch |
| Wyes | 2 | 3-inch female inlets (2) to one 3 inch male outlet |
| Fittings | 4<br>2<br>4<br>2 | 3-inch double male-<br>2½-inch to 3-inch increaser<br>3 inch double female<br>3-inch to 2½--inch reducer |
| Spanners: | 4<br>10 | large brass for 3 inch hose<br>large brass for 5 inch hose and 3-inch hose |
| Hose | 9<br>4 | 15-foot length 3 inch hose<br>15-foot length 5-inch hose<br>A total of 4,000 feet of 5-inch hose @100-foot lengths on three Standard Hose Tenders |

**Gated inlet wyes** do not have clappers. They are equipped with a brass cap if only one inlet is used; however, two inlets should always be used to supply five-inch hose.

**Three-inch wyes**, also non-clappered, can be used to connect to gated inlet wyes when more than two lines are to be put into them.

Full capacity of a 1,500 gpm pumper can pump into a two way gated inlet siamese with two 3 inch hose lines, such lines should be kept 100 feet or less in length to reduce friction loss.

3-1/2-inch to 3-inch fitting is used to connect a 3 inch hose line or a 3-1/2- to 4-1/2-inch increaser for use with a 5-inch hose line into gated outlet of Portable Hydrant, this for additional supply into a hydrant.

# SECTION 7. CARE AND MAINTENANCE OF ENGINES

## ENGINE STARTING GUIDELINES

1. Before starting, ensure that headlights and all warning lights are off.
2. Place battery isolator switch on the BOTH position on all makes of pumpers except Spartan. The Spartan's shall be placed on either the "ONE" or the "ON" position.
3. The gear selector should be in the neutral position.
4. DO NOT depress foot throttle.
5. Pull out ignition switch.
6. Press starter(s).

Engines should start if the above procedures are followed. If the engine does not start, suspect the motor shut-off was not re-set. This shut-off must be pushed in after being pulled. This relates to the 5" inch hose tenders only.

Mack and Ward LaFrance engines also have an emergency shutoff control. If this control has been pulled, it will have to be reset in the engine compartment. This will have to be done before the engine will start.

## MASTER ELECTRICAL SWITCH INTERIOR CAB

The master electrical switch is turned on after the motor has been started. Then the individual circuit switches are turned on one at a time. Having all the circuits on draws large amounts of amperage and may cause damage to the alternator. When shutting them off, shut down the individual switches first and then the master switch.

If operating a Spartan or Mack apparatus the master switch must be ON in order for the warning lights and motor operating gauges to function (oil, temperature, and tachometer gauges).

## PROPER TRANSMISSION GEAR SELECTION

1. Apparatus should not be operated in drive gear (D) on city streets. D is too high a gear to provide proper braking control, additionally, the transmission tends to "search" for lower gears.
2. Manually upshifting and downshifting automatic transmissions is recommended.
3. Only use lowest gear (1) on steep hills.
4. Gear 2 or 3 is preferred

## PLACING ENGINE IN PUMP

1. Bring apparatus to a complete stop.

2. Set the parking brake.
3. Place the gear selector into the neutral position.
4. Engage the power take-off control (PTO).
5. Place the transmission into the proper drive gear. "D"
6. If the pump is equipped with a "ready to pump" light, check that it is lit. If not, check the PTO for engagement. If PTO is not the problem, do not pump, contact the Bureau of Equipment.

CAUTION: Some Ward La France 5” inch hose tenders will not pump with their ignition switch pushed in. This is the case even though their motors are operating, the PTO is engaged and they’re in the proper pump gear. Therefore, ensure the ignition switch is pulled out.

## DISENGAGING PUMP

1. Place the gear selector into the neutral position.
2. Wait 5 seconds, allowing motor RPM to slow to idle.
3. Disengage PTO slowly.
4. Immediately after pumping, allow the engine to idle for at least 3 minutes. This will allow the motor to cool down and stabilize oil pressure.

## AT FIRES OR OTHER PUMPING OPERATIONS

The effective and continued operation of a pump in use at a fire hydrant, at draft, or in relay requires that the pump operator give close attention to the readings of the pump and engine gauges. They give the pump operator knowledge of many conditions affecting the pump, the engine , the water supply, and the hose leads. Variations in their readings may indicate many faults which occur while pumping, enabling the attentive pump operator to detect not only a defect which may be developing, but to tell within close limits the cause of the trouble.

To further appreciate the significance of variations in pump gauge readings, the pump operator is referred to the sections of this manual on "Supply Under Pressure, "Supply Under Draft", and "Pump Accessories".

Keep a close watch over the oil and fuel supply of your engine. It is absolutely necessary that the pump operator request replenishment of fuel or oil before the original supply is exhausted. Exercise good judgment and anticipate the need for supply, allowing sufficient time for response of the fuel unit. Request for supply may be made through a Chief Officer, an Incident Support Specialist, or a member of the Bureau of Equipment, if present. The fuel supply of an engine, if full, should last at least several hours under strenuous pumping conditions. It is therefore apparent that if a pump operator calls for a supply of fuel after a relatively short period of pumping, it shows negligence in the care of the apparatus at quarters. Maintain your fuel supply as instructed in the Vehicle Operations Manual.

Any abnormal variation of oil pressure should be investigated and reported to the proper authority. At frequent intervals during pumping operations observe the oil pressure gauge. Every pump operator should know the normal oil pressure gauge reading for his/her particular pump. At any time when the oil pressure gauge shows **NO PRESSURE OR VERY REDUCED PRESSURE, THE ENGINE SHALL BE STOPPED IMMEDIATELY.** Failure to do so may result in irreparable damage to the engine . DO NOT RESTART or ATTEMPT TO RESTART the engine until authorized to do so by personnel of the Central Shops or Bureau of Equipment. Note: On some apparatus the oil level in the crankcase may be checked during prolonged pumping operations with the engine running. This type apparatus has an oil dip stick that is marked on one side with the words "OPER. LEVEL," and two lines about 1-¼" apart. If the oil level is within this range with the engine running, there should be ample oil in the crankcase. (This marking is at a lower level on the dip stick than the normal high and low markings for checking the oil with the engine stopped.)

When the pump is connected to a hydrant, check for leaks that will show up with water under pressure. These leaks will be air leaks at draft and may be the cause for failure of the pump to draw a vacuum. There is usually a small dribble of water from pump glands at all times, but if this leak is excessive, the glands have worn to a point where the pump may not draft.

It cannot be emphasized strongly enough that the care and attention a pump operator gives to the engine when in use at a fire is often the difference between a successful pumping job and one unnecessarily interrupted. This interruption could have been caused by pump failure that may have been avoided by prompt action on the part of the pump operator.

## SHUTTING DOWN THE PUMP

1. Upon receipt of an order to shutdown, close the throttle slowly until the engine is running at its normal idling speed. Unless in cases of extreme emergency, never decrease (or increase) engine and pump speed suddenly. A sudden change of pressure may seriously endanger or injure the firefighters on the hose line, as well as damage the pump. If the throttle is equipped with a quick action release, it is intended for emergency use only.

2. After the discharge pressure has been reduced, close the discharge gates slowly and open the bleeder valves for the outlets shut down.

3. Reset automatic pressure regulator/governor to normal setting (off on non Fire Commander engines.)

4. Shift automatic transmission to Neutral position. If equipped with separate pump controls, shift the pump control to Road.

5. Top off water tank.

6. Shut down hydrant.

7. Disconnect suction and discharge hoses, replace discharge outlet caps.

8. Pick up all hose and fittings, including suction saddle, chock blocks, suction ropes, etc., Replace hydrant caps, spanner tight.

Your engine should be prepared for any emergency that may be encountered while returning to quarters.

## GENERAL GUIDELINES FOR PUMP OPERATORS

1. Pump operators must remain at their pump and be vigilant during active pump operations. They shall have the apparatus radio on the correct channel, tactical channel while at incidents, (and the volume high enough to ensure receiving communications from the IC or other pump operators.

2. Recommended discharge pressures have been made in this manual. Fire hose that is kinked or clamped in some manner will cause gauges to read higher. The factoring in of friction loss per 100' of hose and head pressure is recommended. Equal consideration needs to be given when pumping to discharge locations below that of the pump.

3. The Incident Commander is to be informed at once if the pump operator cannot resolve a mechanical malfunction that could cause the pump to quit.

4. Corrective instructions by Bureau of Equipment and/or Central Shops personnel shall be followed immediately.

5. Chock blocks shall be used at all times.

6. Pump operators shall wear the proper safety equipment, including turnouts, helmet, and hearing protection.

## RETURNING TO QUARTERS

Immediately upon return to quarters, the apparatus, pump and equipment shall be thoroughly inspected, cleaned, and serviced. Any deficiencies observed on the apparatus or equipment must be corrected or reported for repair or replacement. The fuel, oil and water levels of the engine must be checked and brought up to full level if necessary.

Clear all pump valves of sand and grit, washing and lubricating as required. Examine all washers in the gated suction (female) inlets or suction inlet caps, hose, and appliances for damage that could affect their use.

Check all important lubrication points, paying particular attention to those parts of pumps and primers that require lubricants to act as a seal. If oil is used in the priming pump, the oil reservoir should be checked and filled as necessary. If anti-freeze is used be sure level is correct as well. Be certain that all equipment assigned to the apparatus is in its proper place and in good condition. Immediately report to the company officer any deficiencies that cannot be corrected.

If the pump has been operated at draft, it must be connected to a hydrant and thoroughly flushed with clean, fresh water. This applies equally to the hose, fittings, and appliances used and is especially important if salt or dirty water has been pumped. Proper procedure is as follows:

1. Connect the pump to a low pressure hydrant and engage the pump.

2. Open the discharge outlet gates and bleeders, opening and closing several times until each gate and bleeder is thoroughly washed out. At this point, considerable time will be saved if the used hose lines are connected to the pump discharge outlets and flushed out simultaneously with the operation of the pump. The discharge from open couplings of the hose lines may be used to flush out the suction hose, nozzles, fittings, and appliances used. Check suction strainers to be certain that they are not clogged.

3. During this time the governor or pressure relief valve should also be flushed.

4. Run the primer for a short time to assure that the priming system is cleared of contaminated water.

5. At some point during the washout period, the change over valve should be operated four times to assure a complete washout and to prevent corrosion which could cause the internal valves to stick if left in one position for too long a period.

6. Lubricate all required parts of the pump.

7. Insure the apparatus water tank is full

## NORMAL CARE IN QUARTERS

The Vehicles Operations Manual sets forth a daily procedure for inspection and maintenance of all Departmental apparatus. These provisions are designed to maintain the apparatus in top operating condition at all times. They set forth a daily program of apparatus inspection and delegate responsibility for compliance directly to the driver.

In addition, the pump operator is also responsible for the cleanliness of the apparatus and for the care and condition of the pump and the equipment carried. The pump operator is directed by Department rules to report immediately to the Company Officer any apparatus defect requiring adjustment, repair, or replacement. Responsibility for adjustment repair or replacement of apparatus or equipment is delegated to the Bureau of Equipment and is not a function of normal fire station maintenance. However, responsibility for these deficiencies remains with the driver who fails a prompt report to the Company Officer.

In addition to the daily inspection and maintenance procedure set forth in the Vehicle Operations Manual, attention must be given to the examination of the pump. Discharge outlet valves and levers should work easily and smoothly; clean and lubricate them as required. Caps on the discharge outlets and suction inlets should not stick or bind. The threads should be cleaned with a brush and lubricated. Replace worn, cracked, or grooved washers. Check the pressure relief or governor valve, as well as the cooling valves, and change over valves for proper setting. Give attention to all lubricating points, particularly to pumps and primers.

# SECTION 8. APPENDICES

## APPENDIX A - GLOSSARY

**Ammeter.** Gauge that indicates either the amount of electrical current being drawn from or provided to the vehicle's battery. 13.8-14.3 volts

**Atmospheric Pressure**. The Weight of the atmosphere at a given location. (Atmospheric Pressure at sea level is 14.7 pounds per square inch).

**Automatic Relief Valve**. A valve used on centrifugal pumps, which permits the circulation of water from the discharge side to the intake side of the pump. It is used for the mechanical control of pump pressure and when set, operates automatically. 40 –60 psi differential is needed between incoming and outgoing to operate properly.

**Auxiliary Cooling System**. A manually controlled system designed to be used either independently of the main cooling system or interconnected with it. Its purpose is to control the temperature of the cooling water in the motor during pumping operations.

**Auxiliary Cooling Valve**. A valve that controls the supply of water to the auxiliary cooler.

**Auxiliary Throttle**. A hand throttle located on the ground control panel and used to control engine rpm.

**Bleeder Valve**. A valve located on the incoming or discharge side of the valve. This valve removes air on the incoming side and water on the discharge side.

**Back Pressure**. Pounds pressure per square inch due to the weight of a column of water above the pump, generally taken as 0.434 psi per foot of elevation. For quick mental calculation, 5 psi may be taken for each 12 feet of elevation above the pump.

**Tank.** A water storage tank carried on the apparatus and used as a source of supply for the pump*.* SFFD pumpers have at least a 500 gallon tank.

**Cavitation**. A condition in which air forms in the pump and may cause vibrations, loss of efficiency, and possible damage.

**Change-Over-Valve (Transfer Valve)**. A valve on a parallel-series centrifugal pump which permits changing from parallel to series or from series to parallel operation.

**Clapper Valves. (Check Valve)**. A hinged valve that permits the flow of water in only one direction.

**Cistern**. A water storage container below street grade for emergency fire protection use.

**Compound gauge**. A gauge connected to the intake side of the pump that is capable of measuring positive or negative intake pressures.

**Dead End**. Refers to that section of a water main supplied only from one end.

**Discharge Gate Valve.** A valve which controls the flow of water into hose lines. This valve is located at the discharge outlet of the pump.

**Drain Valve**. A valve located at the bottom of the pump and used for draining water from the pump. This is done by members of the BOE and Central Shops only.

**Drafting**. An operation involving the removal of air from the pump thereby creating a vacuum and allowing the pressure exerted by the outside atmosphere to force water up the suction line and into the pump.

**Friction Loss**. Loss of pressure in hose, fittings, standpipes, etc., due to the resistance between the moving water and the inside surface of the hose, fittings, standpipes, etc. The greater the flow the higher the friction loss.

**Gallon**. A quantity of water occupying 231 cubic inches and weighing approximately 8.35 pounds.

**GPM**. Gallons Per Minute.

**Gate Valve**. A valve equipped with a sliding gate that permits a full unobstructed flow of water.

**Gauge (Pressure)**. A gauge used to register water pressure in pounds per square inch.

**Gauge (Vacuum)**. A gauge used to register vacuum in inches of mercury.

**Gauge (Compound)**. A single gauge designed to register both pressure and vacuum.

**Governor**. A device used to maintain constant pre-determined pump pressure by regulating the speed of the engine..

**Ground Control Panel**. A panel located on the outer body of the apparatus and upon which are mounted the gauges as well as operating and controlling devices necessary for control of the pump. The devices complement the controls located within the driver's compartment.

**Hard Suction.** A flexible smooth bore rubber hose reinforced with a spiral steel core designed to prevent collapse under partial vacuum and to withstand static interior pressures up to 30 psi.

**Hook-Up**. Connecting an engine to a source of water supply, and hose to the discharge outlets of the pump.

**Hose Bumper**. A device used to permit automotive traffic to pass over fire hose lines.

**Hydrant**. An upright metal casting connected to a water supply system and equipped with one or more valved outlets to which an engine or hose lines may be connected.

**Hydraulics**. The science of the use and movement of water, especially as it pertains to the extinguishment and control of fires.

**Impeller**. The veined, circulating member of the centrifugal pump that transmits motion to the water.

**Inlet Eye** (Impeller). The opening through which water enters the impeller of a centrifugal pump.

**Inlet (Suction)**. An intake water supply connection on an engine to which the suction or supply hose is connected.

**Lift**. Distance in feet of elevation between the surface of a static source of water and the center of the pump inlet when drafting.

**Parallel Operation**. Operation of a centrifugal pump with each impeller discharging into a common outlet, thereby providing volume rather than increased pressure.

**Pressure (Static)** Pressure created by water at rest.

**Pressure (Flowing)** Pressure exerted by water at the point of discharge.

**Pressure (Residual)** As it pertains to pump operation, the pressure remaining at the inlet side of a pump, supplied under pressure, while water is being discharged from the outlets of the pump.

**Pressure (Pump)**. Pressure as indicated on the discharge pressure gauge (corrected for gauge error if necessary).

**PSI.** Pounds Per Square Inch.

**Pull A Vacuum**. A term used in reference to the condition of partial vacuum that prevails when the pump is exceeding the capacity or yield of the hydrant.

**Prime**. To remove all air from the pump

**Priming Pump (Primer**). A small positive displacement pump used to evacuate air from a centrifugal pump housing Evacuating air allows the centrifugal pump to receive water from a static water supply source.

**Pump**. A mechanical device for developing pressure in hose lines.

**Pump (Centrifugal**). A pump which discharges water by centrifugal force created by one or more impellers.

**Pump (Positive Displacement**). A pump that moves a given amount of water through the pump chamber with each stroke or rotation. These pumps are self priming.

**Pump Drain Valve.** A valve located at the bottom of the pump and used to drain water from the pump.

**Pump Packing Glands.** An arrangement used to seal the pump drive shaft where it enters the pump casing.

**Pump Shift Lock**. A device used to hold the pump shift lever in a set position during pumping operations.(5 " Hose Tenders)

**Pump Strainer.** A device placed in each inlet of the pump and used to prevent foreign matter from entering the pump.

**Re-Circulator Valve (Pump Cooler) (Booster Line Cooling Valve)** All are the same thing. A devise in a pump that routes water from the pump back to the water tank. It keeps the pump cool when hose lines are shut down and the pump is continuing to work.

**Relay.** The use of two or more engines to maintain adequate pressure or to move water to a distance or height that, in either case, is beyond the ability of a single engine.

**Relief Valve.** This valve maintains pump pressure by dumping the pump discharge flow into the pump suction.

**RPM**. Revolutions Per Minute. Used in reference to the speed of engines driving fire department pumps.

**Siamese**. A hose appliance used to combine two or more hose lines into one.

**Soft suction.** A length of rubber hose used to connect a suction inlet of an engine to a hydrant or any other source of water supplied under pressure. A soft suction cannot be used for drafting because it will collapse under pressure below atmospheric.

**Stage**. That part of a centrifugal pump in which the pressure developing action of the impeller takes place.

**Suction Hose.** Refer to Hard Suction; and Soft Suction.

**Suction Hose Strainer.** A metal unit, either a basket or flat design attached to the inlet of the hard suction and provided with perforations small enough to exclude foreign matter and yet permit a free flow of water

**Suction Lift**. Refer to Lift.

**Suction Saddle.** An adjustable leather saddle placed on a hard suction hose to prevent chafing and abrasion.

**Tachometer**. An instrument used to record the revolutions per minute of an engine.

**Transfer Valve (Change-Over-Valve).**
A two position valve that changes the pump from parallel (volume) to series (pressure) operation and vice versa.

**Vacuum.** A space from which the air has been exhausted.

**Velocity.** Speed of flow due to pressure energy exerted in a given direction.

**Volume Position (Capacity) (Parallel)**
The operation of a two or more stage centrifugal pump in which each impeller discharges into a common outlet, thereby providing the maximum flow at the rated pressure.

**Volute**. The spiral, divergent chamber of a centrifugal pump in which the velocity energy given to the water by the impeller blades is converted to pressure.

**Water Hammer.** Impact energy due to sudden closing down of nozzles or valves.

**Wye.** A hose appliance that divides one hose line into two hose lines of equal or smaller size.

## APPENDIX B - ELEMENTARY HYDRAULICS

The science of hydraulics is the study of the laws governing fluids at rest and in motion, For firefighting the fluid is water, and it is the intent of this chapter to give, in as simple a way possible, the elementary hydraulic principles and formulas with which every firefighter should be acquainted. All factors and formulas given are revised for direct use with 3 inch hose.

## PROPERTIES OF WATER

When pure, water is a colorless, odorless liquid that is almost incompressible. A pressure of 15 tons per square inch is required to reduce a volume of water approximately one percent. As a fluid, water has a volume but is incapable of resisting change in shape. When poured into a container it will adjust itself to the shape of the container and come to rest with a level surface. This is possible because there is very little friction, or cohesive attraction, between water molecules.

## SYMBOLS, SIGNS, AND THEIR DEFINITIONS

The following is a list of symbols, signs, and their definitions that should prove helpful in the study of elementary hydraulics.

| | |
|---|---|
| $\sqrt{\ }$ | The radical sign. When placed before a value without index, it indicates that the square root of the value is to be extracted. |
| **A** | Area, the extent of any plane surface |
| **BP** | Denotes back pressure, the pressure exerted by a column of water above the point being considered. |
| **D** | Diameter of any circle or nozzle. |
| **EP** | Engine pressure, which is the pressure of the water as it emerges from the pump. |
| **F/S** | Feet per second. |
| **FF** | Friction factor. A factor used in changing a hose layout to an equivalent length of a single line of 3 inch hose flowing the same quantity of water. |
| **FL** | Friction loss in PSI |
| **Gal** | Gallon, a standard measurement of liquid. |
| **GPM** | Gallons per minute,. |
| **H** | Head, the height in feet to the surface of a body of water above the point being considered. |
| **Hg** | Mercury, measured in inches. |
| **IP** | Inlet pressure |
| **K** | A factor which varies with the diameter of the hose and the diameter of the nozzle, Used in the Underwriter's Formula when solving a problem for engine pressure or nozzle pressure. |

| | |
|---|---|
| **L** | The number of 50-foot lengths of 3 inch hose in the hose lay |
| **LL's** | Number of 100-foot lengths of 3 inch hose in the hose layout or the total length of hose divided by 100. |
| **NP** | Nozzle pressure, which is the pressure of the water as it emerges from the nozzle. |
| **P** | Pressure, the measurement of the energy in water; usually expressed in pounds per square inch. |
| **PSI** | Pounds pressure per square inch. |
| **Q** | GPM divided by 100, or the flow expressed in hundreds of gallons per minute. |
| **SP** | Static pressure, pressure produced by water at rest. |
| **V** | Velocity, usually measured in feet per second |

## WEIGHTS, MEASURES, MATHEMATICS

The following additional information is offered to help firefighters in the solution of practical problems commonly encountered in the fire service.

## WEIGHTS AND MEASURES

| | |
|---|---|
| One square foot | 144 square inches (12 inch x 12 inch) |
| One cubic foot | 1728 cubic inches (12 inch x 12 inch x 12 inch) |
| One gallon of water | 231 cubic inches |
| One cubic foot of water weights | 62.5 pounds |
| One cubic foot of water contains | 7.4 gallons (1728 divided by 231) |
| One gallon of water | 8.35 pounds (62.5 divided by 7.481) |

Density of Hg (mercury) is 13.546
Atmospheric pressure at sea level is 14.7 psi
Mercury weights 13.546 times as much as water

## MATHEMATICS

### Area

| | |
|---|---|
| To find the area of a square or rectangular surface, multiply the length by the width. | **Area = Length x Width** |
| To find the area of a circle, multiply the square of the diameter by .7854 | **$A = D^2 \times 0.7854$** |

**Cubic Content**

| | |
|---|---|
| To find the cubic content of a square or rectangular container, multiply the length by the width by the height. (All measurement must be of the same denomination) | **Cubic content = L x W x H.** |
| To find the cubic content of a flat end cylindrical container such as a tank, hose, cistern, etc., square the diameter, multiply the product 0.7854, then multiply this result by the length or height. ALL measurement must be of the same denomination . | **Cubic content = $D^2$ x 0.7854 x H** |

**Gallon Content**

| | |
|---|---|
| To find the number of gallons in a container when the cubic content is given in inches, divide the cubic inches by 231. | **Gallons = Cubic inches divided by 231** |
| When the cubic content is given in feet, multiply the cubic feet by 7.481. | **Gallons = Cubic feet. x 7.481** |

## PRINCIPLES OF PRESSURES IN FLUIDS

There are six rules that cover the principal characteristics of pressure in fluids.

1. Fluid pressure is perpendicular to any surface on which it acts.
2. Fluid pressure at a point in a fluid at rest is of the same intensity in all directions.
3. Pressure applied to a confined fluid from without is transmitted in all directions without diminution.
4. The downward pressure of a liquid in an open vessel is proportional to its depth.
5. The downward pressure of a liquid in an open vessel is proportional to the liquid density.
6. The downward pressure of a liquid on the bottom of a vessel is independent of the shape of the vessel itself.

## HEAD AND PRESSURE

### To Determine Pressure When Head Is Known

| | |
|---|---|
| A cubic foot of water weighs 62.5 pounds and consists of 144 columns of water 1 square inch in area and 1 foot high, each producing a pressure of 0.434 pounds per square inch. | **62.5 divided 144 = 0.434** |
| Since water pressure is proportional to its depth, it follows that the total pressure produced by a known head of water will be equal to the head in feet times 0.434. | **P = 0.434 H** |
| Back pressure is the pressure that a head of water exerts against an engine or hydrant supplying water to a higher elevation. | **BP = 0.434 H** |
| Static pressure is the pressure produced by a column or head of water at rest. | **SP = 0.434 H** |

### To Determine Head When Pressure is Known

To produce 1 pound of pressure, a head of water 2.304 feet in height is necessary. One pound divided by 0.434 (the number of pounds produced by 1 foot head) is equal to 2.304 feet.

To find head (in feet) when the pressure per square inch is known, use the following formula. H = 2.304 P

## DRAFTING

The compound gauge on the suction side of a pump is calibrated above the "0" in psi and below the "0" in inches of mercury (from 0 to 30 Hg). Each inch of mercury reading is equivalent to drafting a 1.13 feet head of water and the pump is doing .49 psi of work.

| Example: | Formula: |
|---|---|
| How high will water rise toward the pump through a suction hose if the vacuum gauge reads 20 inch of mercury? | Height = 1.13 x inches Hg<br>= 1.13 x 20<br>= 22.6<br><br>The height will be 22.6 feet. |

Note: This is the theoretical height to which water will be raised. This does not take into account any friction loss incurred.

## VELOCITY OF FLOW

The term "velocity" as used in fire department hydraulics, refers to the movement of water through hose lines and nozzles, and is usually expressed in feet per second.

**To Determine Velocity When Head Is Known:**

The amount of head available at an opening will determine the velocity of the stream as it passes from the opening.

| | |
|---|---|
| Where the amount of head in feet is known, the velocity of flow in feet per second may be easily determined by the use of the following formula: | $V = 8\sqrt{H}$ |

**To Determine Velocity When Pressure Is Known:**

The amount of pressure available at an opening will determine the velocity of the stream as it passes from such opening.

| | |
|---|---|
| Where pressure (in pounds per square inch) is known, the velocity of flow in feet per second may be easily determined by the use of the formula. | $V = 12.14\sqrt{P}$ |

## WATER HAMMER

The phenomenon known as “water hammer” is caused by the sudden stopping of water flowing through hose lines or water mains. Instant closing of valves or shutoff type nozzle converts the kinetic energy possessed by the moving water into pressure energy. The extent of shock and the amount of pressure developed depends upon the velocity of the water and the suddenness with which the flow is stopped. The shock and pressure waves that develop are largely absorbed by the hose lines and water mains. However, in many instances, water hammer may cause burst hose lines, damaged pumps, or ruptured water mains. Therefore, too much emphasis cannot be made on the necessity for closing all shutoff nozzles and valves slowly,

## DISCHARGE

**To Determine Discharge When Nozzle Size and Pressure Are Known**

| | |
|---|---|
| For smooth-bore nozzles | $GPM = 29.7\, D^2 \sqrt{P}$ |
| For an open coupling or hydrant outlet | $GPM = 29.7\, D^2 \sqrt{P} \times .9$ |

GPM - Gallons per minute discharge
29.7 - Constant
D - Diameter of nozzle or other opening in inches
P - Pressure in pounds per square inch at discharge opening

| | |
|---|---|
| If a specific GPM is desired, this formula can be transposed to determine the needed tip diameter at a certain pressure. The formula would read: | $D = \sqrt{\dfrac{GPM}{29.7\sqrt{P}}}$ |
| If a specific GPM is desired, this formula can be transposed to determine the needed pressure when using a certain tip size. The formula would read: | $P = \left(\dfrac{GPM}{29.7\, D^2}\right)^2$ |

In both of the above transpositions any problem involving an open coupling or hydrant outlet, the factor (multiplier) .9 must be inserted under the line and after the last item.

**Discharge From Sprinklers**

The standard automatic sprinkler head has a 1/2 inch discharge orifice or a 7/16 inch tapered orifice. The discharge from either can be found by the following formula:

$$GPM = 1/2P + 15$$

If a specific GPM is desired, this formula can be transposed to determine the needed pressure. The formula would read:

$$P = 2(GPM - 15)$$

## FRICTION LOSS

The resistance to the flow of water over the interior surface of fire hose, water mains, valves, couplings, and fittings is a cause of energy or pressure loss and is commonly referred to as "friction loss". This loss increases with the roughness of the interior of the hose or main; the immediate result of Friction Loss in the hose is to cut down the available pressure at the nozzle.

$$FL = CQ^2$$

FL = pressure loss in psi per 100 feet of 3 inch rubber lined hose.
L = Hose length in 100 feet ($^{FEET}/_{100}$)
C = friction loss co-efficient (see table)
Q = Flow rate in hundreds of GPM ($^{GPM}/_{100}$)

## FRICTION LOSS COEFFICIENTS - SINGLE LINE

| Hose Diameter and Type (inches) | Coefficient (c) |
|---|---|
| ½" booster | 1,100 |
| 1" booster | 150 |
| 1-3/4" booster | 80 |
| 1/2" rubber line | 24 |
| 1-3/4" with 1/2" couplings | 15.5 |
| 2" rubber lined with 1/2" couplings | 8 |
| 2-1/2" rubber lined | 5 |
| 2-3/4" with 3 inch couplings | 1.5 |
| 3" with 2-1/2" couplings | 0.8 |
| 3" with 3" couplings | 0.677 |
| 3-1/2" | 0.34 |
| 4" | 0.2 |
| 4-1/2" | 0.1 |
| 5" | 0.08 |
| 6" | 0.05 |

| Standpipes | Coefficient (c) |
|---|---|
| 4" | 0.374 |
| 5" | 0.126 |
| 6" | 0.052 |

**Pump Discharge Pressure**
PDP = NP + TPL
PDP is pump discharge pressure in PSI
NP is nozzle pressure in PSI
TPL total pressure loss in PSI

**Total Pressure Loss**
TPL = FL+EP+AFL
FL is hose line friction loss in psi
EP is elevation pressure
AFL is appliance friction loss in psi

**Elevation Pressure (back pressure)**
EP = 0.5H
0.5 = constant

H = height in feet

## NOZZLE EQUIVALENTS

During certain fire fighting operations it is sometimes necessary to determine the number of smaller sized nozzles required to deliver approximately the same volume as a larger sized nozzle.

When wyed lines are used and a problem is to be solved involving a number of nozzles, it is necessary to combine the nozzles before the problem can be successfully solved.

Certain tables aid in the solution of these problems; however, when the tables are not available, the approximate nozzle comparisons can be solved in the following manner:

| | |
|---|---|
| Diameter of the **larger** nozzle squared | ($D^2$) = 1.25 x 1.25 = 1.56 |
| Diameter of the **smaller** nozzle squared | ($d^2$) = .625 x .625 = .39 |

Number = $D^2/d^2$

Number = 1.56/.39

Number = 4

## ENGINE PRESSURE AND NOZZLE PRESSURE

Where a hose line is laid horizontally, that is, when the engine and nozzle are at the same elevation, then the engine pressure is equal to the nozzle pressure plus the friction loss in the line, and nozzle pressure is equal to the engine pressure minus the friction loss in the line. In such cases when only the engine pressure or the nozzle pressure is known, then a formula must be used to determine the unknown pressure desired.

When the engine and nozzle are not at the same elevation, the difference in elevation becomes a primary consideration.

Where the nozzle is at an elevation greater than that of the engine, and nozzle pressure is known, actual engine pressure required is determined by first finding engine pressure by formula and then adding the pressure necessary to overcome difference in elevation. If engine pressure is known, nozzle pressure is determined by first deducting the pressure necessary to overcome difference in elevation from the known engine pressure, the nozzle pressure then being found by formula.

## STANDPIPE CALCULATIONS

In solving for engine or nozzle pressure where standpipes are involved, engine pressure must be sufficient to overcome friction loss in the hose, back pressure due to elevation of the nozzle, friction loss in the riser and connection, and provide nozzle pressure.

## FRICTION LOSS AND BACK PRESSURE

In solving for nozzle pressure, these involved figures must therefore first be subtracted from engine pressure.

In solving for engine pressure, the figure must be added to the engine pressure found by engine pressure formula. In problems involving standpipes or ladder nozzles, back pressure must of course be likewise handled.

## TO DETERMINE ENGINE PRESSURE WHEN NOZZLE PRESSURE IS KNOWN:

**Formula: EP = NP x (1.1 + KL)**

EP = Engine Pressure
NP = Nozzle Pressure
1.1 = A correction "constant"
K = A factor which varies with the diameter of the hose and diameter of the nozzle.
L = The number of 50-foot lengths of 3-inch hose in the hose layout.

The formula commonly used to determine engine pressure when nozzle pressure is known is the following Underwriter's Formula.

## TO DETERMINE NOZZLE PRESSURE WHEN ENGINE PRESSURE IS KNOWN

**Formula: NP = EP/1.1 + KL**

To change a given hose layout to the equivalent length of a single 3- inch line for use in the above EP and NP formulas, the friction factor table may be used.

The values of "K" for EP and NP formulas (3 inch hose) are:

| Nozzle size in Inches | Single length of 3-inch Hose |
|---|---|
| ½ | .003 |
| 5/8 | .006 |
| ¾ | .013 |
| 7/8 | .023 |
| 1 | .038 |
| 1-l/8 | .062 |
| 1¼ | .092 |
| 1-3/8 | .137 |
| 1½ | .192 |
| 1-5/8 | .266 |
| 1¾ | .351 |
| 2 | .605 |

To determine an approximate "K" factor for any other size nozzle on 3 inch hose not listed above:

$$K = \frac{(D^4 \times .4)}{10}$$

The American LaFrance type circulator is equivalent to a 1½ -inch nozzle.

The Gorter Circulator is equivalent to a 2-inch nozzle.

## RANGE OF STREAMS

An effective solid fire stream is one that at its breaking point will pass nine-tenths of the whole water mass through a 15-inch circle and three-fourths of it through a 10-inch circle at the same point. Such streams must be stiff enough to maintain their continuity to the height or distances named and not produce excessive showers or spray.

The range of an effective fire stream is a combination of two directions, horizontal and vertical. Effective fire streams can only be produced where there is sufficient velocity of the stream to overcome the force of gravity and the friction of the air. The best angle for maximum horizontal range is 32 degrees. There are several different methods used in determining the range of fire streams, both vertical and horizontal; but the following formulas produce results with sufficient accuracy for fire department purposes:

- Horizontal Range = 1/2 NP + 26 for ¾-inch nozzle
  (Add 5 feet to the 26 for each 1/8 inch increase in nozzle diameter.)

- Vertical Range = 5/8 NP + 26 for ¾-inch nozzle

(Add 5 feet to the 26 for each 1/8-inch increase in nozzle diameter.)

## NOZZLE REACTION

Nozzle reaction is based on the principle, "for every action there is an equal and opposite reaction”. As water leaves the nozzle under force, it causes a force in the opposite direction. The amount of force depends upon the size of the nozzle and the nozzle pressure. Nozzle reaction is measured in total pounds force and not in pounds per square inch.  An increase in nozzle tip size could increase nozzle reaction force.

Nozzle reaction formula is: $NR = 1.5\ D^2\ P$