Chapter 9
Pump Theory

Positive Displacement Pump — Self-priming pump that utilizes a piston or interlocking rotors to move a given amount of fluid through the pump chamber with each stroke of the piston or rotation of the rotors. Used for hydraulic pumps on aerial devices' hydraulic systems and for priming pumps on centrifugal fire pumps.
These pumps are "constant flow machines" in that they produce the same flow at a given speed regardless of discharge pressure.

Positive Displacement Pumps

Although the positive displacement pump has been replaced by the centrifu- gal pump as the main pumping unit on fire apparatus, positive displacement pumps continue to serve a vital role on modern apparatus because of their ability to pump air and foam. In this capacity, they are used as priming de- vices to get water into the centrifugal pump during drafting operations. By removing air trapped in the centrifugal pump, water is forced into the pump by atmospheric pressure.

Piston Pump — Positive- displacement pump using one or more reciprocating pistons to force water from the pump chambers.
These multicylinder, PTO-driven pumps can provide pressures up to 1,000 psi (7 000 kPa) for high-pressure fog lines, or to inject foam concentrate into a water line or manifold at a higher pressure than the water pump is creating.

Rotary Pumps

From the standpoint of design, rotary-type pumps are the simplest of all fire apparatus pumps. In modern apparatus, the use of rotary pumps is confined to small capacity, booster-type pumps; low volume, high-pressure pumps; and priming pumps. Most of the rotary pumps in use today are either rotary- gear or rotary-vane construction. These pumps are driven by either a small electric motor or through a clutch that extends from the apparatus drive shaft.

Rotary Gear Pumps

Rotary gear pumps consist of two gears that rotate in a tightly meshed pat- tern inside a watertight case
The total amount of water that can be pumped by a Air Discharge rotary gear pump depends on the size of the pockets in the gears and the speed of rotation.
. To prevent damage to the casings, most gear pumps feature gears made of bronze or another soft metal, while a strong alloy such as cast iron is used for the pump casing.

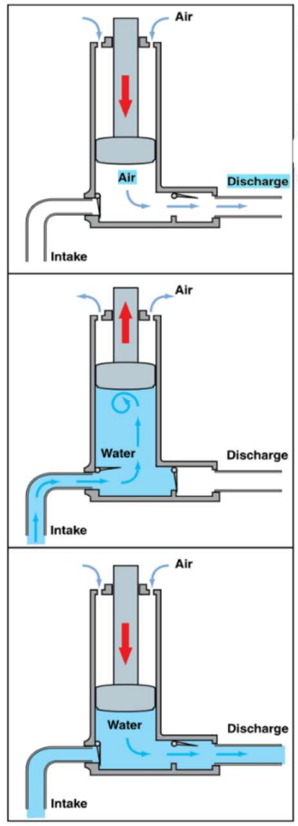

Figure 9.1 A piston pump.

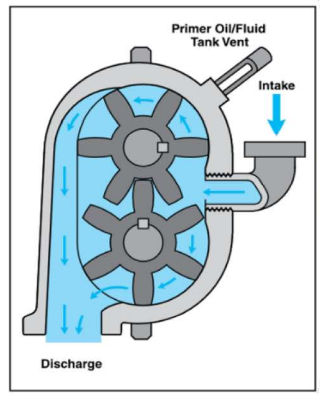

Figure 9.2 A rotary gear pump.

Piston & Rotary Gear pumps

Rotary vane pumps are constructed with moveable elements that automati- cally compensate for wear, maintaining a tighter fit with closer clearances as the pump is used.

As the rotor turns, air is trapped between the rotor and the casing in the pockets formed by adjacent vanes. As the vanes turn, this pocket becomes smaller, which compresses the air and causes pressure to build up. This pocket becomes even smaller as the vanes progress toward the discharge opening. At this point the pressure reaches its maximum level, forc- ing the trapped air out of the pump. The air or water is prevented from returning to the intake by the close spac- ing of the rotor at that point

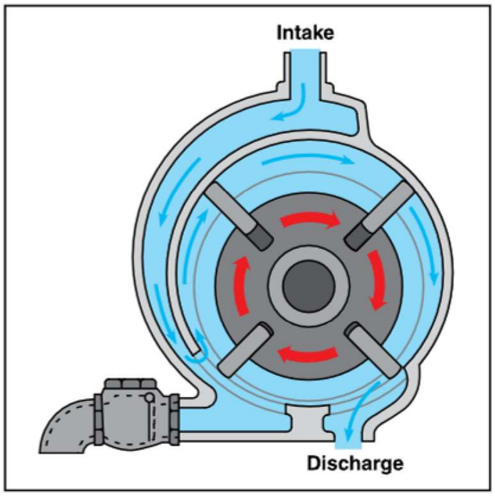

Figure 9.3 A typical rotary vane pump.

Rotary Vane Pump

Centrifugal Pumps

Nearly all modern fire apparatus feature a centrifugal pump as their main pump. This pump is classified as a nonpositive displacement pump as it does not pump a definite amount of water with each revolution. The pump imparts velocity to the water and converts it to pressure within the pump itself.

Centrifugal Pump — Pump with one or more impellers that rotate and utilize centrifugal force to move the water. Most modern fire pumps are of this type.

Principles of Operation and Construction of Centrifugal Pumps

The operation of a centrifugal pump is based on the principle that a rapidly revolving disk tends to throw water introduced at its center toward the outer edges of the disk

Impeller — Vaned, circulating member of the centrifugal pump that transmits motion to the water.

Impeller Eye — Intake orifice at the center of a centrifugal pump impeller.

The height to which the water rises, or the extent to which it overcomes the force of gravity, is based on the speed of the impeller's rotation.

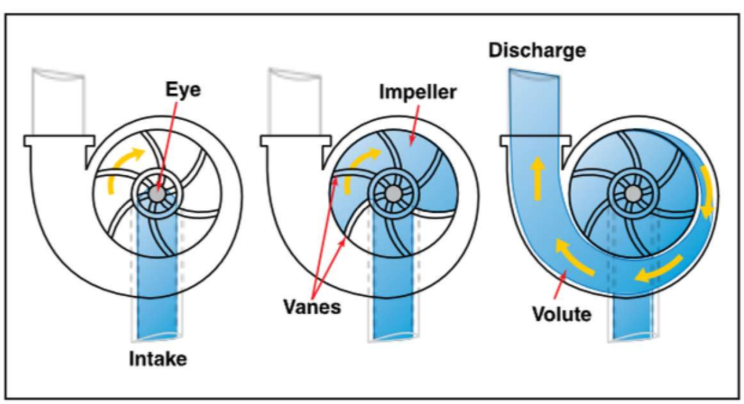

Figure 9.4 A centrifugal pump.

Centrifugal Pump

A centrifugal pump contains an impeller assembly with the impeller, shaft, and seals.
The speed at which the impeller rotates is a ratio based upon the power train configuration.
Volute — Spiral, divergent chamber of a centrifugal pump in which the velocity energy given to water by the impeller blades is converted into pressure.
Three main factors influence a centrifugal fire pump's discharge pressure:

- **Amount of water being discharged** — If the discharge outlet is large enough in diameter to allow the water to escape as it is thrown from the impeller and collected in the volute, the pressure buildup will be very small. If the discharge outlet is closed, a high pressure buildup will result. With all other factors remaining constant, the amount of output pressure that a pump may develop is directly dependent on the volume of water it is discharging. Thus the discharge volume affects both the intake and discharge pressures.
  • **Speed at which the impeller is turning** — Greater pressure is developed with increased impeller speed. The increase in pressure is roughly equal to the square of the change in impeller speed. For example, with all other factors remaining constant, doubling the speed of the impeller will result in four times as much pressure.
  • **Pressure of water when it enters the pump from a pressurized source (hydrant, relay, etc.)** — Water will flow through a centrifugal pump even if the impeller is not turning. When water is supplied to the eye of the impeller under pressure, it moves through the impeller by itself. Any movement of the impeller increases both the velocity and the corresponding pressure buildup of the water in the volute. Because the incoming pressure adds di-rectly to the pressure developed by the pump, incoming pressure changes are reflected in the discharge pressure.

Two basic types of centrifugal pumps are used by the fire service: single stage and multistage. There is a phenomenon of cavitation due to recircula-tion in single-stage pumps, where excess capacity is not allowed to escape the impeller area. This may lead to pump damage.

Single-Stage Centrifugal Fire Pumps

Pumps used in the fire service constructed with a single impeller are referred to as single-stage centrifugal pumps (Figure 9.5). These may consist of front- mount pumps, power take off, auxiliary engine driven, and midship pumps that use a single intake impeller and a simple casing to provide flow capacities up to 2,250 gpm (9 000 L/min
To minimize the lateral thrust of large quantities of water entering the eye of the impeller, a double-suction impeller may be used. The double-suction impeller takes water in from both sides; the reaction of each side being equal and opposite cancels out the lateral thrust. It also provides a larger waterway for movement of water through the impeller. Because the impeller turns at a high rate of speed, a radial thrust is developed as the water is delivered to the discharge outlet. Stripping edges in the opposed discharge volutes divert the water into two streams that are 180 degrees apart. Water being removed at two places and traveling in opposite direc-tions cancels the radial thrust. This design provides a hydraulically balanced

pump that reduces stress on the pump and vehicle chassis, helping to lengthen the service life of the pump and apparatus.

Multistage Centrifugal Fire Pumps

Multistage centrifugal pumps have an impeller for each stage mounted in a single housing. The impellers are usually mounted on a single shaft driven by a single drive train. Generally, the impellers are identical and have the same capacity.

Pumping in the parallel (volume) position. Each of the impellers is capable of delivering its rated pressure while flow- ing 50 percent of its rated capacity; therefore, the total amount of water the pump can deliver is equal to the sum of the stages

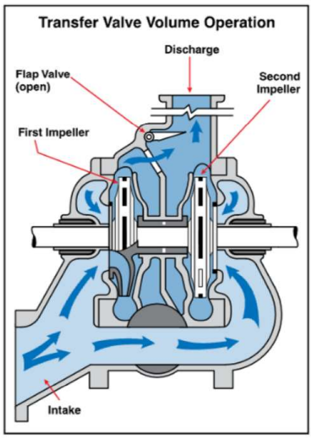

Figure 9.7 Pumping in the parallel (volume) position.

Pumping in series (pressure) position. When the transfer valve is set in the pressure position, all water from the intake manifold is directed into the eye of the first impeller. Depending on the specific pump, the first stage increases the pressure and discharges 50 to 70 percent of the volume capacity through the transfer valve and into the eye of the second impeller.

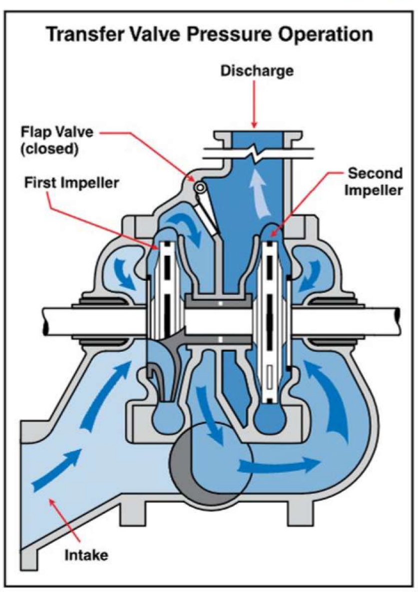

Figure 9.8 Pumping in series (pressure) position.

Figure 9.9 Pump operators use a transfer valve to switch between volume and pressure pumping operations.

The process of switching between pressure and volume is sometimes referred to as "changeover."
If there is any question as to the correct position for the transfer valve, it is best to operate in parallel (volume) rather than series (pressure). In the parallel mode, the pump will be capable of supplying 100 percent of its rated capacity at 150 psi (1 050 kPa) at 10 feet (3 m) of lift with 20 feet (6 m) of suction hose while drafting.
Clapper (check) valves are essential to the operation of a multistage pump (Figure 9.10). Should a valve stick open or closed, or be hampered by debris, the pump will not operate properly in series (pressure).
Clapper Valve — Hinged valve that permits the flow of water in one direction only.
Check Valve — Automatic valve that permits liquid to flow in only one direction. For example, the inline valve that prevents water from flowing into a foam concentrate container when eduction pressure is disrupted.

Pump Wear Rings and Packing

Some amount of sediment and dirt is found in all water supplies. As these impurities pass through the pump, they cause wear on the impeller as it turns at speeds of nearly 4,000 rpm when the pump approaches its capacity
Wear Rings — Replaceable rings that are attached to the impeller and/or the pump casing to allow a small running clearance between the impeller and pump casing without causing wear of the actual impeller or pump casing material.

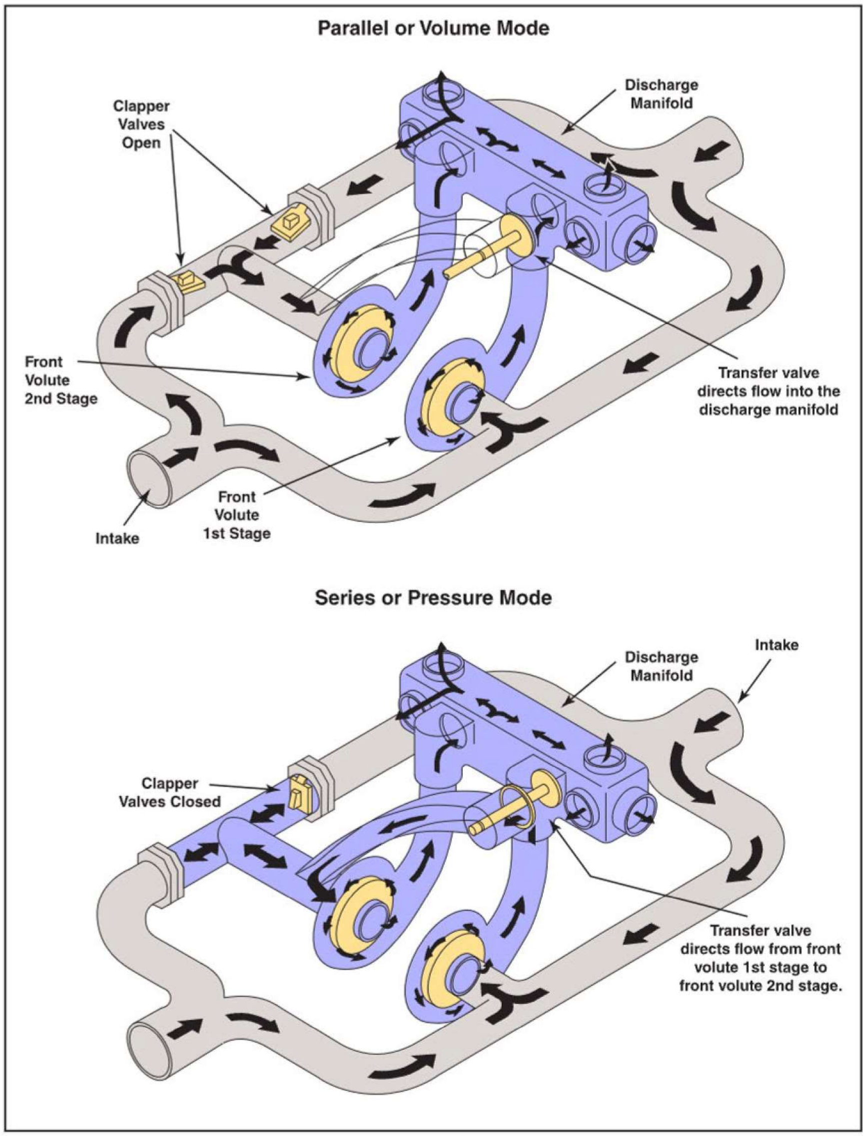

Figure 9.10 Clapper valves are essential to the operation of a multistage pump.

Newer model centrifugal pumps may be equipped with a thermal relief valve that opens to allow overheated water to circulate between the pump and the main water tank or into the atmosphere. When operating a pump not equipped with a thermal relief valve, the best course of action to prevent overheating is to ensure that some water is moving through the pump at all times.

Pump impellers are fastened to a shaft that connects to a transfer case. The transmission transfers the required energy to spin the impellers at a very high rate of speed. At the point where the shaft passes through the pump casing, a semi-tight seal must be maintained to prevent air leaks that may interfere with the pump's ability to conduct a drafting operation. Mechanical seals are the most common type in use today. They form a tight seal without dripping and do not require a periodic adjustment. It is, however, important to operate the pump regularly to lubricate the seals. Mechanical seals should not be allowed to freeze in cold weather. Damage may be incurred, requiring the disassembly of the entire pump and drive assembly in order to replace the seals

The most common type of seal packing material is composed of rope fibers impregnated with graphite or lead.

Heat develops by friction where the packing rings come into contact with the shaft. In order to overcome this, a spacer, known as a lantern or slinger ring is supplied with the packing to provide cooling.

If the packing is too loose, an excessive amount of water may leak from the pump during operation.

The packing only receives water for lubrication if the pump is full and operating under pressure

Pump Mounting and Drive Arrangements

When determining which pump would work best for the needs of a local fire department, factors include the intended use of the pump and its cost, appear- ance, space requirements, and ease of maintenance.

Although used on some structural fire fighting pumpers, the most common applications for auxiliary engine driven pumps are:

- Airport rescue fire fighting (ARFF) vehicles
- Wildland fire apparatus
- Mobile water supply apparatus (Figure 9.11)
- Trailer mounted fire pumps
- Portable fire pumps

With a pumping capacity of generally 500 gpm (2 000 L/min) or less, some jurisdictions mount these assemblies on pickup trucks.

Power Take-Off (PTO) System — Mechanism that allows a vehicle engine to power equipment such as a pump, winch, or portable tool; it is typically attached to the transmission.

Some manufacturers offer a rear-engine PTO design that is driven off the engine's flywheel. This type of system has been used with much success in the construction and refuse industries for many years. In addition to offering the versatility of **pump and roll** capability, the mounting of the pump offers an opportunity for a shorter wheelbase, additional room for compartments, as well as cross lays that are packed lower on the apparatus body where they are more accessible.

Pump and Roll — Ability of an apparatus to pump water while the vehicle is in motion.

the

The PTO unit is powered by an idler gear in the vehicle's transmission. The speed of the shaft is independent of the gear in which the road transmission is operating when the pump is in use but is under the control of the clutch. When the driver/operator disengages the clutch to stop or to change gears, the pump also stops turning. The PTO pump does permit pump and roll operation, but it is not as effective as the separate engine unit.

In the past, conventional PTO units were limited to powering pumps up to approximately 500 gpm (2 000 L/min). However, some manufacturers now provide full torque power take-offs that allow for the installation of pumps as large as 1,250 gpm (5 000 L/min). This type of PTO is commonly used with automatic transmissions where the flywheel of the engine drives the PTO unit.

Front-Mount Pumps

Some fire department pumpers feature an extended front bumper with a pump mounted between the bumper and the grill of the vehicle (Figure 9.13). This unit is typically driven through a gear box and a clutch connected by a drive shaft to the front of the crankshaft. The gear box uses a step up gear ratio, which causes the impeller of the pump to turn faster than the engine. This ratio is set to match the torque of the engine to the rotation speed required

The maximum capacity of the pump depends on the limitations of the engine driving it, typically up to 1,250 gpm (5 000 L/min)

Front-Mount Pump — Fire pump mounted in front of the radiator of a vehicle and powered off the crankshaft.

One major disadvantage of the front-mount pump is the susceptibility of the pump and gauges freezing in cold weather due to their exposed position

During warm weather operations, front-mount pumps may obstruct airflow through the vehicles radiator and may contribute to overheating. In addition to these disadvantages, front-mount pumps must be installed with proper protection against damage from a front-end collision. Their position makes them vulnerable to damage from even a minor impact.

Midship Pumps

Most fire departments operate pumpers that feature the pump mounted later-ally across the frame behind the engine and transmission (Figure 9.14). Power is supplied to the pump through the use of a split shaft gear case (transfer case) located in the drive line between the transmission and the rear axle. By shift-ing a gear and collar arrangement inside the gear box, power can be diverted from the rear axle and transmitted to the fire pump. The pump is then driven by either a series of gears or a drive chain or belt.

The gear ratio is set to match the engine torque curve to the speed of the rotation required for the impeller to deliver the rated capacity of the pump. This ratio is arranged so that the impeller turns faster than the engine, usually one and a half (11⁄2) to two and a half (21⁄2) times as fast

Some pumps can be rated anywhere from 500 to 2,250 gpm (2 000 L/min to 9 000 L/min) with no major changes to the pump itself.

The usual arrangement provides control of the transfer case from inside the apparatus cab by using a mechanical linkage or by electrical, hydraulic, or air-operated controls.

The driver/operator may check to see that the transmission is in the correct gear by observing the speedometer reading after the pump is engaged. With the engine idling and the pump engaged, most speedometers will indicate between 10 to 15 mph (15 to 25 km/h). However, there are some apparatus that are designed so that the speedometer does not register above 0 mph (0 km/h) including all PTO pumps when the pump is engaged

Rear-Mount Pumps

Apparatus with rear-mount pumps are becoming increasingly popular (Figure 9.17). This design offers a number of advantages, including a more even weight distribution on the chassis and more usable compartment space. A disadvantage of the rear-mount pump is that the driver/operator may be more directly exposed to oncoming traffic than in other pump-mounting positions. This situation may be somewhat alleviated by placing the pump controls on one of the rear sides of the apparatus so that the vehicle may be positioned on an angle to protect the driver/operator.

Depending on the manufacturer or fire department preference, rear-mount pumps may be powered by either a split-shaft transmission or by a power take- off. In either case, a driveshaft of appropriate length and size is connected between the transmission and the pump. Other than the location at the rear of the apparatus, the operation is the same as previously described for PTO and split shaft (mid ship transfer) drive pumps.

Pump Piping and Valves

The piping and valves attached to a pump are integral components of the fire pump system. The primary parts of the piping system are intake and discharge piping as well as pump drains and valves. NFPA® 1901 requires all components of the piping system be of corrosion resistant material. Most pipes are constructed of cast iron, brass, stainless steel, or galvanized steel and may include rubber hoses in certain applications.

The piping system and the fire pump itself must be capable of withstanding a hydrostatic test of 500 psi (3 500 kPa) before being placed into service.

Intaking Piping

According to NFPA® 1901 pumpers with a capacity of 500 gpm (2 000 L/min) or less should have piping capable of flowing 250 gpm (1 000 L/min). Pumpers with a capacity greater than 500 gpm (2 000 L/min) should be able to flow at least 500 gpm (2 000 L/min).

Many pumpers are equipped with tank-to-pump piping as large as 4 inches (100 mm) in diameter

Modern pumps are equipped with check valves that prevent damage to the tank if the tank-to-pump valve opens inadvertently while water is being supplied to the pump under pressure, such as during a relay operation.

Fire apparatus pumps must be capable of being supplied from external pressurized and static sources. When using a static source, prime the pump by removing all or most of the air from the pump, lowering the atmospheric pressure within the pump casing. The primer is tapped into the pump at a high point on the suction side or the impeller eye and use a priming valve. Air trapped in the pump can prevent a successful drafting operation. Therefore, all intake lines in a centrifugal pump are normally located below the eye of the impeller and no part of the piping is above this point. The rare exception to this may be the tank-to-pump line where water is moving under the natural pressure of gravity.

Midship pumps usually have a large intake connection on either side of the apparatus, whereas on front-mounted pumps the connection and piping extend from the lower portion of the pump.

Pumps rated greater than 1,500 gpm (6 000 L/min) capacity may require more than one large intake connection at each location.
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Additional intake lines, usually gated, are provided for use in relay opera-tions, or when water is received through small diameter supply hose. Many of these intakes have 21⁄2 inch (65 mm) hose couplings.

Discharge Piping

Pumps rated less than 750 gpm (3 000 L/min) are required to have only one 21⁄2-inch (65 mm) discharge. Discharges greater than 21⁄2-inches (65 mm) in diameter may not be located on the pump operator's panel.
A minimum of 2-inch (50 mm) piping, valves, and elbows must be used to supply discharges where 11⁄2-, 13⁄4-, or 2-inch (38 mm, 45 mm, or 50 mm) handlines are attached
When multiple attack lines that require different pressures are being operated, the driver/operator must set the engine discharge pressure to the highest level needed. Then each line requiring less pressure should have the valve partially closed and locked in position until the reduced flow through the valve is sufficient to provide the correct pressure for the hoseline.
According to NFPA® 1901, apparatus equipped with tanks of less than 1,000 gallons (4 000 liters) must have a tank fill line of at least 1-inch
Tanks greater than 1,000 gallons (4 000 liters) must be provided with at least a 2-inch (50 mm) tank fill line.

Valves

The most common type of valve is the ball-type valve that permits the full flow of water through a line with a minimum friction loss.
The quarter-turn handle has a simpler mechanical linkage with the handle mounted directly on the valve stem. The valve is opened or closed by a 90-de- gree movement of the handle.
Butterfly valves are most commonly operated by quarter-turn handles.
NFPA® 1901 requires that all intakes or discharges that are 3 inches (77 mm) or greater be equipped with slow acting valve controls. This feature prevents the valve movement from open to closed (or vice versa) in less than 3 seconds. This will minimize the risk of damage caused by water hammer when large volumes of water are being moved.

Pump Drains

Pump drains are useful when the hoseline has not been bled off by opening the nozzle. By using the drain valve, the line may be drained and the hose disconnected.
The bleeder valve on a gated intake serves another purpose. If a supply line is connected to the gated intake of a pump while the attack lines are be- ing supplied from the tank, the changeover to the supply line can be made without interrupting the fire streams.

Automatic Pressure Control Devices

NFPA® 1901 requires some type of pressure control device to be part of any fire apparatus pumping system. This device must operate within three to ten seconds after the discharge pressure rises and restricts the pressure

Relief Valves

The main feature of a relief valve is its sensitivity to pressure change and its ability to relieve excessive pressure within the pump discharge

There are two basic concepts for pressure relief valves:

- Those that relieve excess pressure on the discharge side of the pump. This valve controls the pressure that is delivered to the hoseline nozzle from the pump.
- Those that relieve excess pressure on the intake side of the pump. An adjustable spring-loaded pilot valve bypasses water from the discharge to the intake chamber of the pump. Although only a small quantity of water is re-routed, this re-routing permits the pump to continue operation when pressure rises above the working, or set, pressure. Although

Although there are several types available, the **most common** relief valve uses a spring-controlled pilot valve

When the pump discharge pressure rises higher than allowed by the pilot- valve setting, the spring in the pilot valve compresses.

A second type of relief valve, although equipped with a pilot valve, operates in a slightly different manner. When the pressure rises above the set pressure, the pilot valve moves, compressing its spring until the opening in the pilot valve housing is uncovered.

The two basic types of intake pressure relief valves include:

• One that is supplied by the pump manufacturer and an integral part of the pump intake manifold.

• The second type is an add-on device that is screwed onto the pump intake connection

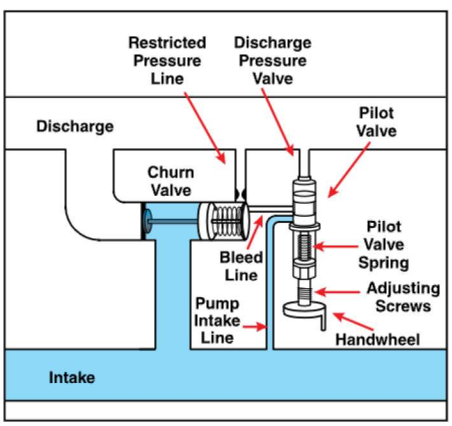

Figure 9.27 A relief valve relieves excessive water pressure.

Figure 9.28 An intake pressure relief valve.

Pressure Governor

Pressure in a centrifugal pump may also be regulated by a mechanical or electronic governor that is pressure activated to adjust the engine throttle. The pressure governor is designed to regulate the engine speed to match the pump discharge requirements. When the pressure in the discharge piping of the pump exceeds the pressure necessary to maintain safe fire streams, the excessive pressure must be reduced. Because the speed of the impellers determines the pressure, and the engine speed determines the speed of the impellers, it is only necessary to reduce engine speed to reduce pressure.

Pressure Governor — Pressure control device that controls engine speed, eliminating hazardous conditions that result from excessive pressures.

Cavitation — Condition in which vacuum pockets form due to localized regions of low pressure at the vanes in the impeller of a centrifugal pump, causing vibrations, loss of efficiency, and possibly damage to the impeller.

The electronic governor also features cavitation protection by returning the engine to idle when intake pressure drops below 30 psi (210 kPa). These governors are accurate and quick to respond, eliminating the need for a discharge pressure relief valve.

Priming Methods & Devices

Priming Device — Any device, usually a positive-displacement pump, used to exhaust the air from inside a centrifugal pump and the attached hard suction; this creates a partial vacuum, allowing atmospheric pressure to force water from a static source through the suction hose into the centrifugal pump.

Primers fall into several categories including positive displacement, exhaust, vacuum, and air primers.

Positive Displacement Primers Most modern pumpers use positive displacement primers. Small versions of both the rotary vane and rotary gear type positive displacement pumps are commonly in use. The theory behind these devices was outlined earlier in this chapter. Rotary vane primers require relatively high rpms as compared to rotary gear primers and can be driven by either mechanical means from the pump transfer gear case or by an electric motor. Although some apparatus feature primers that are driven off the transfer case of the transmission, an electric motor is the most popular means of powering rotary vane priming pumps, as they may be operated efficiently regardless of engine speed.

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Many conventional primers use an oil supply or other type of fluid (Figure 9.29). The oil/fluid serves the following purposes:

- As the pump wears, the clearance between the gears and the pump case increases and the pump loses efficiency. A thin film of oil/fluid is drawn into the pump and seals the gaps between the gears and the case.
- The oil/fluid also fills any irregularities in the housing caused by sediment or debris.
- A coating of oil on the metal parts of the pump created by periodic operation of the primer will aid in the preservation of the pump.

Because the oil reservoir for the priming pump is often mounted higher than the pump itself, a vent hole is provided to break the siphon action as the tank drains. This vent must be checked frequently to ensure it is free of dirt and debris.

The ideal engine rpm for the transfer case, rear-driven primer operation depends on the construction of the primer, the gear ratio of the transfer case, and other features unique to a particular apparatus. The operator manual supplied by the fire pump manufacturer should specify the preferred engine speed (rpm) for priming but, **in general, the range is between 1,000 to 1,200 rpm**. Activate the primers with the engine at idle speed and then increase the throttle to the specified rpms. This will minimize wear on the mechanical clutch.

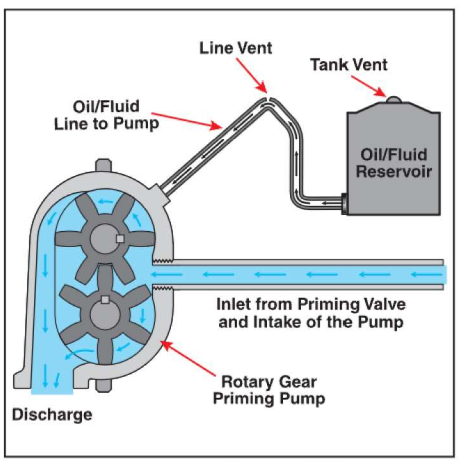

Figure 9.29 A primer uses oil/fluid to assist in drafting operations.

Oil-Less Primers- Most new pumpers are equipped with oil-less primers. These devices are constructed of materials that do not require lubrication; therefore, oil is not required in the priming process. Oil-less primers may also be installed into an older apparatus as an environmentally friendly initiative.

Exhaust Primers- Exhaust primers are generally found on skid-mounted pumps or older fire apparatus. This type of primer uses the same principle as a foam eductor. Exhaust gases from the vehicle's engine are prevented from escaping to the atmosphere by an exhaust deflector. These gases are diverted to a chamber where their passing velocity creates a vacuum. This chamber is connected through a line and a priming valve to the intake of the pump. There the air is evacuated into the venturi chamber and then discharged along with the exhaust gas into the atmosphere. In order to create this vacuum, high engine rpms are required. Additionally, the exhaust primer requires a great deal of maintenance in order to remove the carbon deposits accumulated in the primer.

Vacuum Primers- The vacuum primer is a simple device that makes use of the vacuum al-ready present in the intake manifold of any gasoline-driven engine. With gasoline-powered apparatus now a rarity in most fire departments, many driver/operators may not have the opportunity to work with or become familiar with this system. In order to prime the pump, a line is connected from the intake manifold of the engine to the intake of the fire pump with a valve connected in the line to control it. A float valve must be installed to prevent water from a primed pump from being drawn into the engine manifold. Because engine vacuum is greatest at near idle speed, the primer works best at low engine rpm.
Chapter
Air Primers- Air primers are becoming an increasingly more popular method of priming pumps on modern fire apparatus. Virtually all pumpers are equipped with an air brake system using a compressor that is not needed for braking while the vehicle is parked and pumping. An air priming system uses the compressor to supply an airline to a jet pump that creates a Venturi Effect that primes the pump using no moving parts or lubricants (Figure 9.30).
Pump
Venturi Effect — Physical law stating that when a fluid, such as water or air, is forced under pressure through a restricted orifice, there is an increase in the velocity of the fluid passing through the orifice and a corresponding decrease in the pressure exerted against the sides of the constriction. Because the surrounding fluid is under greater (atmospheric) pressure, it is forced into the area of lower pressure.
Air
Pump Panel Instrumentation
NFPA® 1901 requires that all controls and instruments necessary to operate the pump are located on the pump operator's panel (Figure 9.31). These include:

- Master pump intake pressure indicating device
- Master pump discharge indicating device
- Pumping engine tachometer
- Pumping engine coolant temperature indicator
- Voltmeter
- Pump pressure controls (discharge valves)
- Pumping engine throttle
- Primer control
- Water tank to pump valve
- Tank-fill valve
- Water tank level indicator

Although not specifically required by NFPA® 1901, a pumping engine fuel gauge is recommended and generally found on the pump operator's panel

Master Intake and Discharge Gauges- The master intake and discharge gauges are the two primary gauges used by the driver/operator to determine the water pressure entering and leaving the pump. The master intake gauge (vacuum or compound gauge) is connected to the intake side of the pump and measures either positive pressure or a vacuum. This gauge is usually calibrated from 0 to 600 psi (0 to 4 200 kPa) of positive pressure and from 0 to 30 inches of mercury (vacuum) (0 to -100 kPa) on the negative side. This gauge provides a reading of the vacuum present at the in-take of the pump during priming or when the pump is operating from draft. As the flow from the pump increases, the vacuum reading increases because more negative pressure is required to overcome the friction loss in the suction hose. When the vacuum reading approaches 20 inches (-70 kPa), the pump is nearing its capacity and is not able to supply additional lines.
Tachometer- The tachometer displays the engine speed in revolutions per minute.
Pumping Engine Coolant Temperature Indicator -The pumping engine coolant temperature indicator displays the temperature of the coolant in the engine that powers the fire pump. This may be the main vehicle engine, or in some cases, an auxiliary engine.
Pumping Engine Oil Pressure Indicator- The pumping engine oil pressure indicator shows if an adequate supply of oil is being delivered to the critical areas of the engine that power the fire pump. This indicator does not measure the amount of oil in the crankcase; however, if this level is too low, the oil pump will be unable to maintain the proper amount of pressure.
Pump Overheat Indicator- The pump operator's panel may be equipped with an audible or visual indicator that warns the driver/operator when the pump will overheat
Voltmeters and Ammeters- Voltmeters and Ammeters The voltmeter provides a relative indication of battery condition, and the ammeter indicates the status of the vehicle's alternator and charging system.
Voltmeter — Device used for measuring existing voltage in an electrical system.
Ammeter — Gauge that indicates both the amount of electrical current being drawn from and provided to the vehicle's battery.
Pump Pressure Indicators (Discharge Gauges)- Pump pressure indicators, commonly called discharge gauges, may be con-nected to the individual discharge outlets of the fire pump. These gauges must be connected to the outlet side of the discharge valve so that the pressure be-ing reported is the pressure actually supplied to the hoselines after the valve. Pressure may be adjusted down for the overall pump discharge pressure as necessary. The gate valve must be adjusted each time the flow at the nozzle is changed. This readjustment is necessary because the pressure loss in the valve is determined by the amount of water flowing through it. If the nozzle is shut down on the hoseline being supplied, the individual pressure gauge for that discharge reads the same as the master pressure gauge because there is no flow through the valve to reduce the pressure. The gate valve should not be readjusted until water is flowing again.
Pumping Engine Throttle- A pumping engine throttle must be contained on the pump operator's panel (Figure 9.33). This device is used to increase or decrease the speed of the

engine that powers the fire pump. An increase or decrease in engine speed will allow the driver/operator to control the amount of pressure that the fire pump supplies to the discharge.
Primer Control- The primer control is used to operate the priming device when the pump will draft from a static water supply (Figure 9.34). This control is generally in the form of a push button, toggle switch, or pull lever.
Water Tank Level Indicator- This device displays the quantity of water held in the onboard water tank, allowing the driver/operator to anticipate the length of time attack hoselines may be operated until an external water source is needed
Auxiliary Cooling Devices- The primary function of an auxiliary cooling system is to control the tempera-ture of coolant in the apparatus engine during pumping operations. Older apparatus usually contain one of two auxiliary coolers: either the marine or immersion type.
The **marine cooler** is inserted into one of the hoses used in the engine cooling system so that the engine coolant must travel through it as it circulates through the system. The cooler features a number of small tubes surrounded by a water jacket that is connected to the discharge of the fire pump.
The **immersion type** auxiliary cooler is mounted in a similar manner as the marine type, with the radiator coolant passing through the body of the cooler. In the immersion system, the water supplied by the fire pump passes through a coil or tubing mounted inside the cooler so that it is immersed in the cool- ant.

Chapter 10
Operating Fire Pumps

Driver/operators should maintain a residual pressure of at least 20 psi (140 kPa) on their master intake gauge at all times during pumping operations
Typically the least desirable hydrants are those located on “dead end mains” that are served by smaller mains from only one direction. These hydrants generally have higher amounts of sediment and deterioration, which further reduce their capacity
Making a Forward Lay One of the most common ways for a pumper to be supplied with water from a hydrant is by making a forward hose lay. A forward lay consists of stopping at the hydrant, dropping the end of one or more supply hoselines at the hydrant, and then proceeding to the fire location (Figure 10.9, p. 341). One potential problem of the forward lay depends on the distance from the hydrant to the fire. In a long lay with large flow demands, a pumper may need to be placed at the hydrant to make use of all available pressure. Another consideration is the amount of supply hose carried on the pumper. If the water supply pumper runs out of hose before it reaches the fire scene, it will be necessary to either bring in more hose and continue the forward lay or have the next arriving pumper lay from the first pumper to the fire and set up a relay pumping operation.

In some cases, the second pumper is necessary due to flow requirements, elevation, or length of the hose lay.

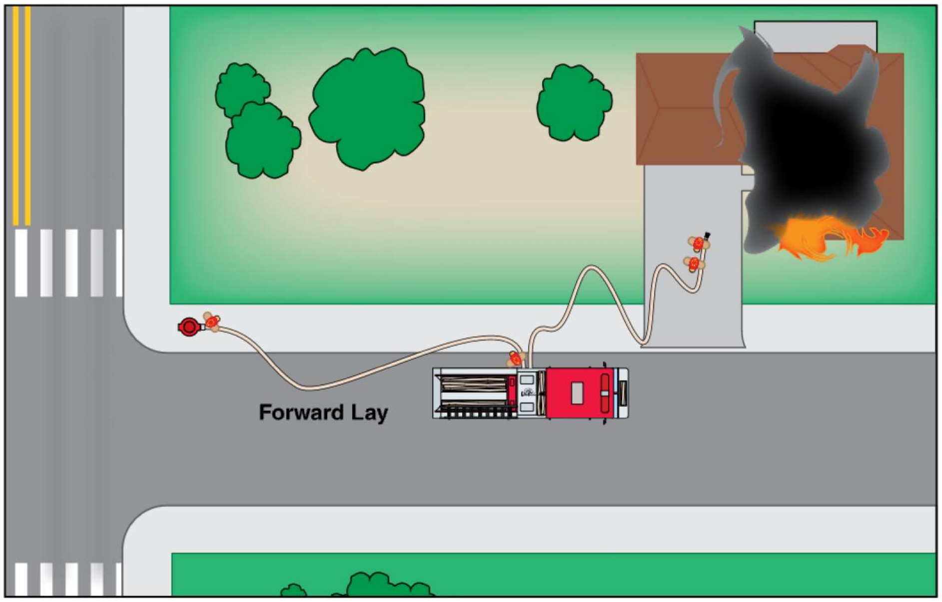

Figure 10.9 A forward lay is one of the most common ways for a pumper to be supplied with water from a hydrant.

Some departments use a four-way hydrant valve to aid the process of mak-ing a forward lay. This valve allows the original supply line that was laid by the first pumper to be immediately charged using hydrant pressure. The valve has a second discharge, usually 41⁄2 or 5 inches (115 or 125 mm) in diameter, equipped with a shutoff valve. This allows a second arriving pumper, located at the hydrant, to be connected without interrupting the flow of water to the original supply line. The second pumper is then able to boost the pressure to the supply line using a second intake connection on the valve (Figure 10.10, p. 343).

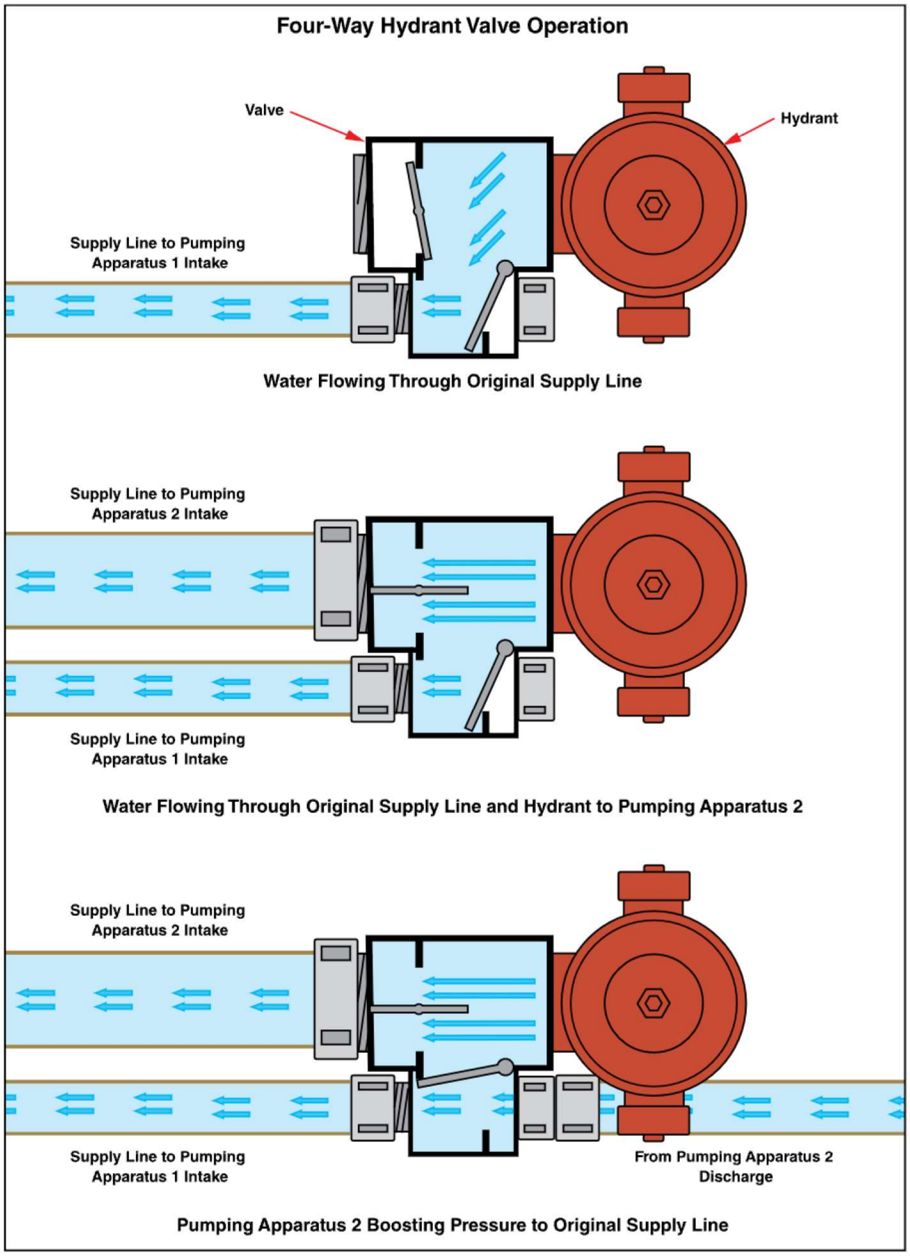

Figure 10.10 A four-way hydrant valve operation.

Making a Reverse Lay- With the reverse lay, hose is laid from the fire to the water source. This method is used when a driver/operator first reports to the incident location to size up the scene before laying a supply line. Water supply must be established in cases where the apparatus that lays the hose must remain at the water source, as in drafting operations, or when an increase in hydrant pressure is needed. Load the hose with a male coupling to come out of the bed first when using hose with threaded couplings for a reverse lay. Use double female adapters at the hydrant and double male adapters at the pump panel to execute a reverse lay using hose with threaded couplings if the hose bed has been set up for a forward lay.

Executing a reverse lay is a common method for setting up a water supply operation using medium diameter hose as a supply line. With medium diam-eter hose, it is necessary to position a pumper at the hydrant to supplement the pressure to the supply hose. The reverse lay is the most direct method of supplementing hydrant pressure or performing drafting operations.

Medium Diameter Hose (MDH) — 21⁄2-(65 mm) or 3-inch (77 mm) hose used for both fire fighting attack and relay-supply purposes.

A common two-pumper operation provides for an **attack pumper** and a water supply pumper. The first pumper (attack pumper) reports directly to the incident scene to begin initial operations using water from its onboard water tank. The second arriving **(water supply) pumper** lays a supply line from the attack pumper back to the water source. This operation is relatively quick and simple, as the second pumper needs only to connect the supply line to a discharge outlet, connect a hose to the water supply and begin pumping.

Attack Pumper — (1) Pumper that is positioned at the fire scene and is directly supplying attack lines. (2) Light truck equipped with a small pump and water tank. Also known as Midi-pumper or Mini-pumper.

Water Supply Pumper — Pumper that takes water from a source and sends it to attack pumpers operating at the fire scene.

When completing a reverse lay, it is *not necessary to use a four-way hydrant valve*. One can be used, however, if it is expected that the pumper may dis-connect from the supply hose and leave the hose connected to be supplied by hydrant pressure alone.

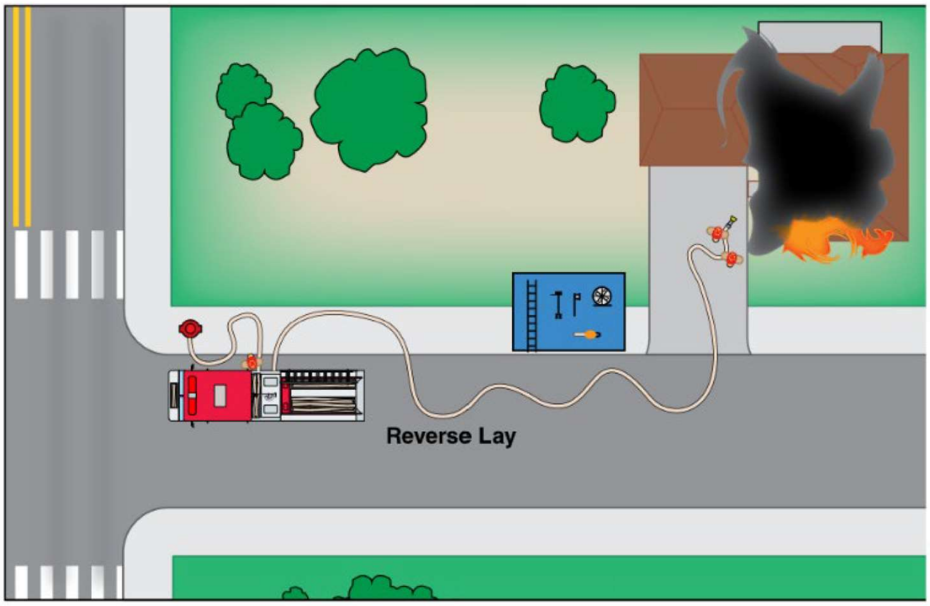

Figure 10.11 A reverse lay with equipment left at the scene as apparatus drive to the hydrant.

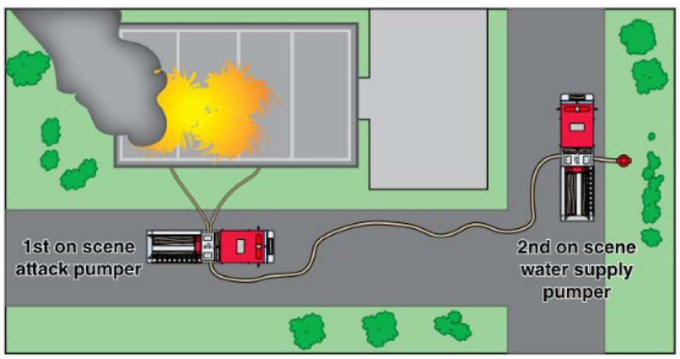

Figure 10.12 A two-pumper reverse lay operation.

Getting Water into the Pump After connections to the hydrant are made, conduct several checks before opening the hydrant. Close the tank-to-pump valve if the intake is not equipped with a shutoff valve. Newer model pumpers have a check valve in the tank-to-pump line. These valves prevent water from entering the tank under pressure

Putting the Pump in Service- Running a pump without water for a significant amount of time may cause the components to overheat and wear out faster, but the driver/operator may engage the pump before leaving the cab if it appears that water will be introduced within a few minutes. If the hydrant is inoperable, the pump drive system will need to be disengaged before the apparatus can be relocated. With the pump engaged and the apparatus wheels chocked, the driver/operator is ready to operate the pump panel.

A driver/operator at the hydrant or in the middle of a relay operation may be located some distance from the fireground. At a distance, it may be difficult to determine how much water is being used or even if any lines are flowing. Several methods for preventing overheating are as follows:

- Establish a continuous minimum flow during intermittent use of water in fireground operations to keep the pump from overheating.
- Pull a length of the booster line or other small diameter line off the reel and fasten it to a sturdy object.
- Open the valve that supplies the booster reel and discharge water in a di-rection that will not interfere with the operation or damage other property. The booster line may also be directed back into the tank to circulate water continuously. NOTE: During prolonged pumping operations, a bypass circulator may not provide sufficient cooling under some conditions and additional measures will be required to avoid overheating.
- Open a discharge drain valve (Figure 10.14). Some may feature threaded outlets that allow a hose to be connected and routed away from the apparatus to a safe discharge point. This feature is especially important when attempting to prevent an accumulation of water during operations affected by freezing weather or on unstable ground. Open some drain valves before the valve is under pressure to avoid potential damage. Consult manufacturers' guidelines before operation.
- Partially open the tank-fill valve or tank-to-pump line. Even if the water tank becomes full and overflows through the tank vent, this result is preferable to the pump overheating. The driver/operator should create a flow sufficient to cool the pump without significantly diminishing the amount of water available for fire suppression.

Additional Water Available from a Hydrant

*When a pumper is connected to a hydrant and is not discharging water, the pressure shown on the intake gauge is **static pressure**. When the pumper is discharging water, the intake gauge displays the **residual pressure**.* The **difference between the two pressures** is used to determine how much more water the hydrant can supply. Several methods are available for making this determination:

- Percentage Method
- First-Digit Method
- Squaring-the-Lines Method

Percent Drop = (Static – Residual)(100) /Static

Table 10.1 Additional Water Available at a Hydrant	
Percent Decrease of Pumper Intake Pressure	**Additional Water Available**
0-10	3 times amount being delivered
11-15	2 times amount being delivered
16-25	Same amount as being available
25 +	More water might be available, but not as much as is being delivered.

First-Digit Method= The first-digit method is a quick and easy way to calculate available water using psi and gpm. However, this method cannot be used with metrics.
Step 1: Find the difference in psi between static and residual pressures.
Step 2: Multiply the first digit of the static pressure by 1, 2, or 3 to determine how many additional lines of equal flow may be added. An explanation of how each number affects the outcome is detailed in the following list:

- If the psi drop is equal to or less than the first digit of the static pressure multiplied by one, three additional lines of equal flow may be added.
- If the psi drop is equal to or less than the first digit of the static pressure multiplied by two, then two additional lines of equal pressure may be added.
- If the psi drop is equal to or less than the first digit of the static pressure multiplied by three, then one additional line of equal flow may be added.

Example: A pumper is supplying one line flowing 250 gpm. The static pressure was 65 psi, and the residual pressure reading is 58 psi. Determine how many lines may be added.

Difference in psi = Static Pressure — Residual Pressure
Difference in psi = 65 – 58 = 7 psi

First Digit of Static Pressure x 1
6 x 1= 6

Seven is not less than six, but is less than 12 (2 x 6), so two more lines of at 250 gpm each may be added.

Squaring-the-Lines Method: When using the squaring-the-lines method, the driver/operator must note the static pressure of the water system before any pump discharges are open or know the usual static pressure in the water supply system under normal circumstances. Obtain this information from preplan documents or from previous experience. You must also have a close idea of the volume of water initially flowed by the pumper. After establishing these figures, determine the additional amount of water available and square the number of lines currently flowing and multiply this by the original pressure drop. The following example illustrates this method.

Example 10.3 (Customary) A pumper connects to a hydrant that has a static pressure of 60 psi. When a 250 gpm handline is opened, the intake pressure drops to 52 psi. Determine how many more handlines flowing 250 gpm may be operated without lowing the residual pressure below 20 psi.

Difference in psi = Static Pressure — Residual Pressure
Difference in psi = 60 – 52 = 8 psi

If a second 250 gpm line were added, the pressure drop would be as follows:

Multiplication Factor = (Number of Lines)2
Multiplication Factor = 22= 4

Resultant Pressure Drop in System at the New Flow Rate = (Multiplication Factor) x (Original Pressure Drop)

Resultant Pressure Drop in System at the New Flow Rate = 4 x 8 = 32 psi

If the pressure drop is 32 psi, the residual pressure in the system will be 28 psi. It would not be advisable to add a third hoseline under these conditions. **<u>Each time the flow rate is doubled, the pressure drop in the system is quadrupled</u>**. This is a simple and valuable fact for a driver/operator to use when performing quick mental calculations on the fireground.

Table 10.2
Assumed Flow Rates for Squaring-the-Lines Method

Hose Size in inches (mm)	Flow Rate in gpm (L/min)
1½ (38)	125 (500)
1¾ (45)	175 (700)
2 (50)	200 (800)
2½ (65)	250 (1 000)

Operating from a Static Water Supply Source

All fire department pumpers should be capable of pumping water from a static water supply source. In most cases, this source is located some distance below the level of the fire pump. It is not possible to pull water into the pump. However, it is possible to evacuate some of the air inside the pump creating a pressure differential (partial vacuum), which allows atmospheric pres-sure acting on the surface of the water to force the water into the fire pump. In order to create this condition, an airtight, non-collapsible waterway (hard intake hose) must be used between the fire pump and the static water source.

Pressure Differential — Effect of altering the atmospheric pressure within a confined space by mechanical means. When air is exhausted from within the space, a low-pressure environment is created and replacement air will be drawn in; when air is blown into the space, a high-pressure environment is created and air within will move to the outside.

Drafting Operations In Figure 10.15, the pressure has been reduced inside the pump and intake hose to reduce the atmospheric pressure inside the pump and intake hose to 12.7 psi (86 kPa). With an atmospheric pressure at sea level of 14.7 psi (100 kPa), a partial vacuum of -2 psi (-14 kPa) is measured on the intake (compound) pressure gauge as 4 inches of mercury (Hg) (-13.6 kPa). This vacuum causes the water to rise 4.6 feet (1.4 m) into the intake hose from the surface of the water. The weight of water combined with the reduced air pressure acting on its surface creates a balance.

As the water begins to move through the pump, additional pressure losses are encountered. Any hose or appliance creates a certain amount of friction loss. The amount of friction loss is proportional to the velocity of water moving through it. The inertia of water is an additional factor in friction loss. As water begins to move through a pump, a certain amount of energy is consumed in getting the water at rest to begin to move and increase its velocity sufficiently to supply the amount of water needed. The amount of friction loss in the intake hose depends on the diameter and length of the hose as well as the intake strainer and any adapters in use. A hose with smaller diameter and greater length has higher friction loss, which al-lows less water at the pump (Figure 10.16). Taking this into consideration, the diameter of intake hose may be increased for pumps with larger capacities. It is possible to increase the flow of a pump by using a larger diameter intake hose or adding additional intake hose. For example, a pumper rated at 750 gpm (3 000 L/min) is normally supplied with 41⁄2 inch (115 mm) intake hose to attain the rated capacity. By equipping the pumper with 5-inch (125 mm) hose, the capacity of the pump can be increased to 820 gpm (3 300 L/min), if all other factors remain the same.

Atmospheric Pressure During Drafting Operations -The ability to overcome losses in pressure is limited to atmospheric pressure at sea level (14.7 psi [100 kPa] or 30 inches Hg). The inches of mercury measure-ment is used in drafting since the changes of pressure are so minute. This pressure decreases approximately 0.5 psi (3.5 kPa) or 1 inch of Hg for each 1,000 feet (300 m) of altitude gain. In a city located 5,000 feet (1 500 m) above sea level, the atmospheric pressure is 12.2 psi (85 kPa). Because the same atmospheric pressure of 14.7 (100 kPa) psi must overcome elevation pressure as well as any friction loss. Increasing the height of the lift will decrease total pump capacity. A lift increased from 10 to 16 feet (3 m to 5 m) would require the vacuum to increase from 9 to 14 inches of mercury (Hg) (-30 to -50 kPa), which leaves 5 inches (-20 kPa) less to overcome any friction loss encountered. Consider-ing the same 750 gpm (3 000 L/min) pumper used in the previous example, increasing lift to 16 feet (5 m) with 41⁄2-inch (115 mm) intake hose would reduce the capacity of the pump to 585 gpm (2 350 L/min). Atmospheric

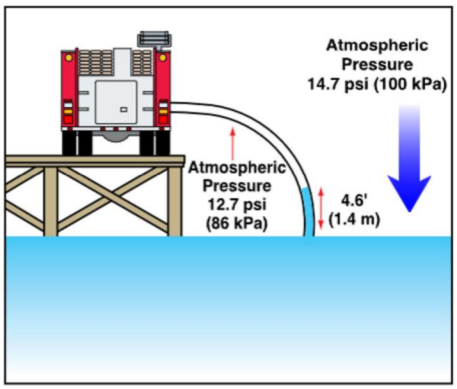

Figure 10.15 During drafting operations, creating a vacuum will cause the water to rise into the intake hose.

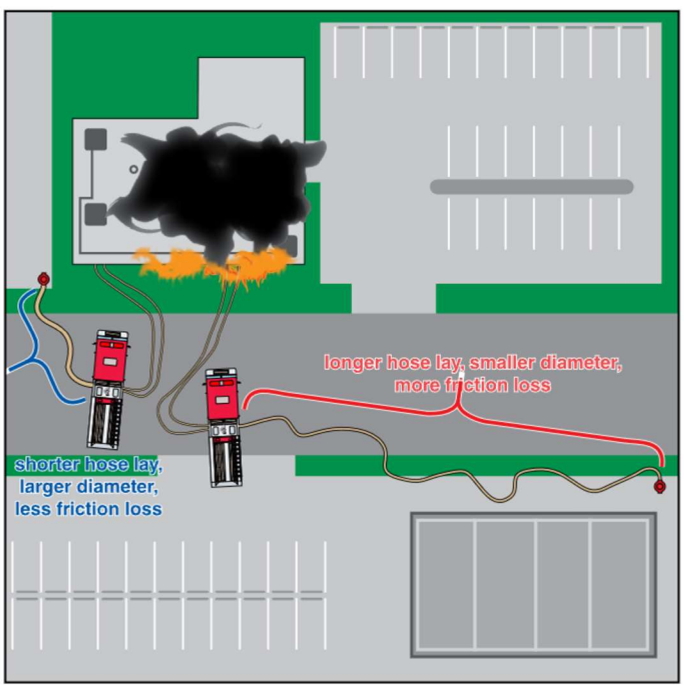

Figure 10.16 Hose lays will have less friction loss if they consist of hose with a large diameter and cover a short length.

With the pump moving water, the vacuum reading on the master intake gauge will provide an indication of the remaining capacity of the pump. Most pumps are able to develop a vacuum capacity of approximately 22 inches of mercury (Hg) (-75 kPa). Because compound gauges may not provide a completely ac-curate reading on the vacuum side, the driver/operator must acknowledge that any reading close to this point indicates that the pump is nearing the limits of its ability to supply water. An attempt to increase the discharge beyond this point may result in cavitation.

Cavitation During Drafting Operations- In theory, cavitation can be described as water being discharged faster than it is coming into the pump. This condition occurs when air cavities are created in the pump or bubbles pass through the pump. They move from the point of highest vacuum into the pressurized section where they collapse or fill with water.
The high velocity of the water filling these cavities causes a severe shock
to the pump. In some cases of prolonged operation, damage to the pump may occur. During cavitation, the pressure drops below atmospheric and the boiling point of water drops to the point that the water changes to a vapor and creates a void composed of water vapor, or steam. As the vapor passes through the impeller of the pump, the pressure increases, the vapor condenses, and water rushes to fill the void. The temperature of the water, the height of the lift, and the amount of water being discharged affect the point at which cavitation begins.
There are a number of indicators that a pump is cavitating. The pressure
gauge on the pump will fluctuate and hose streams may pulsate creating a distinctive popping or sputtering sound as the water leaves the nozzle. In cases of severe cavitation, the pump itself may make noises described as sounding like gravel is passing through the pump. The surest indication of cavitation may be a lack of reaction on the pressure gauge to increases in the throttle.
When a pump reaches the point of cavitation it is discharging all of the
water that the atmospheric pressure or pressurized source can force into the intake. When attempting to discharge water from the pump faster than it can be taken in, increasing the pump rpm will not increase the discharge pressure. Cavitation may result when a pump has been equipped with inadequate
piping from the water tank. In some departments, a pump is most often op-erated from its onboard water supply. Damage to the pump may occur from repeated attempts to pump more water from the tank than the piping allows to flow into the pump. This damage may be severe when the pump is oper-ating at high pressures to supply long attack lines. Although cavitation can occur when operating from a hydrant system, it often occurs during drafting operations. The driver/operator must always be careful to keep discharge rates lower than intake.

Selecting the Drafting Site
A site may be selected by:

- Amount of water
- Type or quality of water
- Accessibility of water

Amount of Water Available The most important factor in choosing the draft site is the amount of water available. If the location features a static body of water such as a pool or lake, the size of the body becomes significant (Figure 10.17). A backyard swimming pool containing 12,000 gallons (48 000 L) of water will not support a fire attack using master steams for any length of time. A small pond may not have a large standing capacity, but a rapid rate of replenishment may make it an effective source. A small stream may also prove a good source if the flow of water is moving rapidly.

In order for a pumper to approach its rated capacity using a traditional strainer, there must be at least 24 inches (600 mm) of water over the strainer (Figure 10.18). It is also helpful to have at least 24 inches (600 mm) of water all around the strainer in order to avoid drawing foreign objects such as sand or gravel into the pump. In drafting operations with less than 24 inches (600 mm) of water above the strainer, it is more likely that floating debris such as branches or leaves may clog the strainer. Even a very high concentration of algae may prevent effective use of the strainer. In addition to clogging the strainer, small debris that enters the intake hose may collect on the pump intake screen. The rapid intake of water into the strainer may also cause a whirlpool that can result in allowing air into the intake hose, causing the pump to lose its prime. A floating object placed above the strainer, even something as simple as a beach ball or capped plastic jug, may lessen the chances of a whirlpool.

In order to draft from a swiftly moving shallow stream, a dam can be constructed using available material to raise the water level, or the bottom may be dug out to achieve greater depth. A floating strainer may also be used (Figure 10.19). In using this device, the end of the intake hose floats on the surface, and water is drawn into the intake hose through a series of holes on the bottom of the strainer. Because water enters from the bottom, whirlpools are not a problem. In order for a floating strainer to work properly, it must float freely, unconstrained by the rigidity of the intake hose. Because the floating strainer takes in water only from one side, the pumper may not receive enough water to achieve its rated discharge capacity.

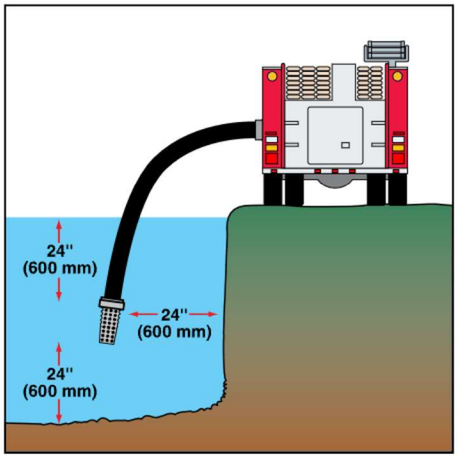

Figure 10.18 For a pumper to approach its rated capacity using a traditional strainer, there must be at least 24 inches (600 mm) of water around the strainer.

Figure 10.19 A floating strainer.

When using a portable tank or swimming pool for drafting operations, a low-level strainer is the appliance of choice. These strainers are designed to sit directly on the bottom of a tank or pool and allow water to be effectively drafted down to a depth of approximately 2 inches (50 mm) (Figure 10.20). However, they may not be able to draft quantities to allow the pump to operate at its rated capacity.

Figure 10.20 Use a low-level strainer when drafting from a portable tank or swimming pool.

Figure 10.21 Dirty water at a drafting site may potentially damage the apparatus pump.

Water temperature will also affect drafting operations. Water below 35°F (1.7°C) or above 90°F (32°C) may adversely impact the ability of the pump to reach capacity.

Dirty or sandy water may potentially cause serious problems (Figure 10.21).
Particles of sand and dirt too small to be blocked by the strainer may enter the pump where they can cause deterioration. As water passes through the eye of the impeller, the sand acts as an abrasive in the area between the clearance rings and the hub of the impeller. This abrasive effect increases the spacing, causing slippage from the discharge back into the intake and reducing the capacity of the pump.

Accessibility- Accessibility to a water source is an important factor in selecting a drafting site. Because drafting is accomplished by evacuating air from the pump and allowing atmospheric pressure to push the water into it, a maximum of 14.7 psi (100 kPa) is available. Elevation pressure and friction loss in the intake hose must be overcome by this 14.7 psi (100 kPa). As the amount of lift required to reach the pump increases, the following effects occur:

- Elevation pressure increases
- Less friction loss can be overcome
- Capacity of the pump is decreased

All fire pumps meeting NFPA® and Underwriter's Laboratories Inc. requirements are rated to pump their capacity at 10 feet (3 m) of lift. If the lift is less, the capacity of the pump is higher; if the lift is greater, the capacity decreases. A pumper in good working order can lift water a maximum of 25 feet (7.5 m). However, all available atmospheric pressure is required to overcome this lift. As a result, the remaining capacity of the pump is of little value for fire suppression. To create an effective fire stream, a lift of no greater than 20 feet (6 m) is recommended. Working with this lift, the pump operates at about 60 percent of its rated capacity. When selecting a site for drafting, the lift must be kept as low as possible. It is more desirable to lay out an extra 100 feet (30 m) of supply line to set up at a draft location where the lift will be lower and more water can be supplied.

- Connecting to the Pump and Preliminary Actions Once a suitable drafting site has been chosen, the driver/operator should move the apparatus toward that position. Use the following steps for connecting to the pump:
- Place the apparatus directly at the location from which the intake hose may be deployed.
- Set the parking brake and chock the wheels when the final position has been achieved.
- Follow local policies regarding the placement of traffic control devices or use of warning lights if the draft site is close to a roadway.
- Do not engage the pump until all connections are made, and it is ready to be put into operation.
- Park the vehicle short of the final drafting spot if the area around the actual drafting spot is limited as the intake hose and strainer are connected to the apparatus. Once they are connected, the driver/operator may slowly posi-tion the pumper at the final

drafting point while other firefighters carry the hose and strainer, placing them in the desired position.

- Inspect the gaskets to be sure that they are in place and no dirt or gravel has accumulated inside the coupling. The strainer and the required lengths of intake hose must then be coupled and made airtight.
- Place each section of hose in line with the other before the coupling is turned. If the gaskets are in good condition and the coupling is connected properly, it should be possible to achieve an airtight connection with the couplings hand tight.
- Use, if necessary, a rubber mallet to make the connections tighter. Enough personnel must be available to connect the intake hose without placing it on the ground, as dirt may lodge in the couplings.
- Fasten a rope to the end of the strainer to aid in the handling of the hose and proper positioning of the strainer (Figure 10.22).

Priming the Pump and Beginning Operation

If the primer is a positive displacement pump that is driven by a transfer case, set the engine rpm according to the manufacturer's instructions. Most priming pumps are intended to work most effectively when the engine is set at a rate between 1,000 and 1,200 rpm. If the priming pump is driven by an electric motor the exact rpm is not critical; however, the rate should be sufficient to keep the alternator charging and prevent the loss of prime once the pump fills with water. If the apparatus features a vacuum-type primer, the engine rpm should be kept as low as possible without causing the engine to stall.

The entire priming action typically requires 10 to 15 seconds from start to finish. However, when up to 20 feet (6 m) of intake hose lifting a maximum of 10 vertical feet (3 m), it may take as long as 30 seconds (45 seconds in pumps larger than 1250 gpm [5 000 L/min]) to accomplish this. If a prime has not been achieved in this time period, the priming attempt should be stopped and the problem traced. The most common failure to prime is an air leak that prevents the primer from developing enough vacuum to successfully draft water.

The most common cause of an air leak is an open drain or valve.

If the previous measures are taken and priming is still not possible, the following list of potential problems may be reviewed:

- Insufficient fluid in the priming reservoir
- Engine speed (rpm) is too low
- Lift is too high
- A high point in the intake hose is creating an air pocket

Several types of problems may occur during drafting operations. They fall into the following general categories:

- Air leak on the intake side of the pump — The most common source of problems while operating at draft. If the discharge pressure gauge begins to fluctuate with a corresponding loss of vacuum on the intake gauge, air is most likely coming into the pump along with the water. The intake hose 360
- Whirlpool allowing air to enter the pump — If there is not enough water above the drafting strainer, a whirlpool may be allowing air to enter the pump. This may be corrected by placing a beach ball or other floating object above the strainer. A floating dock strainer may also be used in areas of shallow water where whirlpooling may be a problem.
- Air leakage due to defective pump packing — If the onboard water tank is empty, the tank-to-pump line may be a source of leakage. Additionally, all drains and intake openings should be re-checked for leakage.

Defective pump packing may also cause air leakage. If there is an excessive amount of water leaking from the packing, in a steady stream instead of dripping, the packing may be the cause. If this is the case, nothing can be done to remedy the situation while the pump is operating.

While the pump is operating, a gradual increase in the vacuum may be noted with no change in the flow rate. This is an indication that a blockage is developing. A blockage often occurs after a pump has been operating at a high rate of discharge, which creates a maximum velocity of water entering the strainer. In extreme cases, the pump may go into cavitation, resulting in a fluctuation and gradual decrease of the discharge pressure. An immediate solution is to decrease the engine rpm until the pressure drops. A drop in pressure indicates that the flow has decreased below the point of cavitation.

Because operating at this reduced pressure may not be sufficient to maintain the desired flow, the driver/operator should attempt to clear the blockage and return to normal operation. The most common place for a blockage to occur is in the strainer. If the strainer can be reached easily, leaves or other debris may be removed by hand or by using a booster line to spray the debris out of the way. If these methods are unsuccessful, the pump may be back-flushed in an attempt to clear the debris.

Attempting to exceed the capacity of the pump will also lead to cavitation accompanied by a high reading on the vacuum gauge. Cavitation may oc-cur well below the rated capacity of the pump if a high lift is involved in the drafting operation.

Shutting Down the Operation (drafting)

When preparing to shut down a drafting operation, slowly decrease the engine speed to idle, take the pump out of gear, and allow the pump to drain. After the pump has been drained and the connections removed, operate the positive displacement primer for several seconds until primer oil or fluid comes out of the discharge from the priming pump. This action will aid in lubrication of the priming pump. The fire pump should then be thoroughly flushed when a supply of fresh water is available, unless the pumping operation was conducted using a very clean static water supply.

Sprinkler and Standpipe Support

The fire department connection may consist of a Siamese with at least two 2 1⁄2-inch (65 mm) female connections connected to a clappered inlet, or one large diameter sexless connection. As water flows into the system, it first passes through a check valve that prevents water flow from the sprinkler system back into the FDC. However, it does allow water from the FDC into the sprinkler system as long as it is supplied at a pressure greater than that holding the check valve closed.

If the sprinkler system is to be supplied at the FDC, the driver/operator should slowly develop the amount of pressure required to supply the system, after the need to supply the system has been confirmed. Multistage pumps should be operated in parallel (volume) position. Depending on the policies of a jurisdiction, the suggested discharge pressure may be printed on a plate at the FDC, or contained in pre-incident planning information. If no specific information is available, the general guideline is to discharge 150 psi (1 050 kPa) into the FDC

Supporting Standpipe Systems

Standpipe systems allow for quicker access to water supply for attack hose-lines in multi-floor or single floor buildings with large floor areas. Fire attack teams may connect to the 21⁄2 inch (65 mm) or 11⁄2 inch (38 mm) connections located at strategic points on each floor.

Standpipe systems may be wet or dry, depending on the fire code require-ments for a particular occupancy. Some wet pipe systems contain water under pressure and may be used as soon as a hoseline is stretched and the valve is opened. A dry pipe system must be charged with water from the occupancy's water supply, stationary fire pump, a fire department pumper, or a combina-tion of the sources. The fire department should always support the FDC to ensure adequate flow and pressure is provided for fire fighting operations.

Pump discharge pressure will depend on the following variables:

- Pressure loss (25 psi [175 kPa]) for flows exceeding 350 gpm (L/min) in the standpipe
- Friction loss in the hose lay from the pumper to the fire department connection
- Friction loss in the hose on the fire floor
- Nozzle pressure for the type of nozzle in use
- Elevation pressure due to the height of the building

Generally, the friction loss in the standpipe is small unless the flow is very large, such as when two 21⁄2 inch (65 mm) lines are being supplied from the same riser.

Add approximately 5 psi (35 kPa) for each floor above the fire department connection that will have operating fire streams. Consider friction loss for the attack line(s), standpipe piping, and layout from the pumper to the standpipe connection.

CAUTION
Do not use pump discharge pressures in excess of 185 psi (1 300 kPa) unless the standpipe system, hose, and appliances have been designed to function under high pressures.

When a standpipe system is known to be equipped with pressure-reducing valves, the elevation pressure used must be based on the total height of the standpipe or zone being used. If the pressure at a particular valve is less than that for which the valve was adjusted, the result will be inadequate pressure for attack hoselines.

Pressure-Reducing Valve — Valve installed at standpipe connection that is designed to reduce the amount of water pressure at that discharge to a specific pressure, usually 100 psi (700 kPa).

NOTE: Many manual standpipe systems are designed to be pumped at a pressure of 150 psi (1 050 kPa) at the FDC.

Chapter 11

Static Water Supply Sources

Principles of Lift

Raising water from a static source, or drafting, requires the driver/operator to understand basic principles of lift. Lift is the difference in elevation between the surface of the static water supply and the center of the pump intake. order to establish a draft, air must be exhausted from the intake hose and fire pump. During the process of drafting, the priming device exhausts the air from the intake hose and fire pump creating a pressure difference between the inside of the pump, the intake hose, and the atmosphere

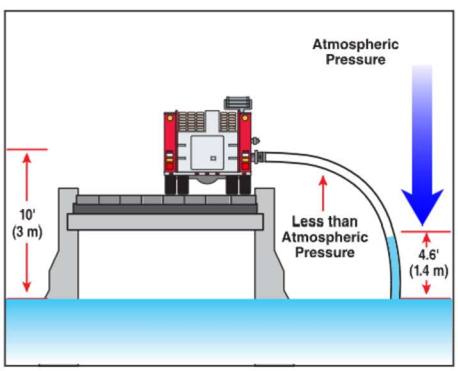

Figure 11.1 Pressure in the intake hose is less than atmospheric pressure, which forces water to rise inside the hose.

The pressure in the intake hose and in the pump drops lower than the atmospheric pressure. This results in water being forced into the hose and pump because of the partial vacuum created in the pump. A total vacuum is impossible to create using fire service equipment.

Because the pressure outside the intake hose is higher than the pressure in the hose, water is forced in and continues to rise until the pump is full of water or the pressure within the pump and intake hose equals atmospheric pressure. The maximum height of the lift is affected by the length of the intake hose, by the amount of negative pressure (vacuum) that the priming device can produce, and the existing atmospheric pressure. If the water does not rise to the level of the pump intake, drafting will not be possible.

Theoretical Lift — Theoretical, scientific height that a column of water may be lifted by atmospheric pressure in a true vacuum; at sea level, this height is 33.9 feet (10 m). The height will decrease as elevation increases.

For every 1,000 feet (300 m) of altitude, the atmospheric pressure decreases by approximately 0.5 psi (3.5 kPa). Because a total vacuum is not attainable using a fire department pumper, the maximum lift at a given altitude will be less than the theoretical lift.

Theoretical lift can be calculated by determining the atmospheric pressure of an area and multiplying that number by the water's pressure per square inch (kPa) while it is in the intake hose.

A total vacuum is not attainable using a fire department pumper, meaning that pumpers cannot be expected to draft water that is located 33.9 feet (10 m) below the level of the pump. Concepts of lift as they relate to fire fighting operations are detailed in the following sections.

Maximum Lift — Maximum height to which any amount of water may be raised through a hard suction hose to a pump; determined by the ability of the pump to create a vacuum.

Variables affecting maximum lift include the atmospheric pressure, the condition of the fire pump and primer, and the intake hose, gaskets, and all valves. In most circumstances, maximum lift is approximately 25 feet (7.5 m)

Dependable Lift — Height a column of water may be lifted in sufficient quantity to provide a reliable fire flow. Lift may be raised through a hard suction hose to a pump, taking into consideration the atmospheric pressure and friction loss within the hard suction hose; dependable lift is usually considered to be 14.7 feet (4.5 m).

After factoring in the surrounding atmospheric pressure and friction loss in the intake hose, every fire pump that is operating properly should have a dependable lift of at least 14.7 feet (4.5 m). Tables 11.1 a and b list minimum discharges that can be expected from a pumper operating at draft with various lifts. All fire department pumping apparatus are rated when drafting with a
minimum lift of 10 feet (3 m) from the center of a pump intake to the surface of water through 20 feet (6 m) of hard intake hose. A strainer is submerged at least 2 feet (600 mm) in a water depth of at least 4 feet

The pump may only deliver about 70 percent of its capacity if lift is increased by 5 feet (1.5 m), to a 15-foot lift (4.5 m), and 60 percent at a 20 foot (6 m) lift.

When at draft, net pump discharge pressure is the sum of the pump discharge pressure and the intake pressure correction that takes into account the friction loss in the intake hose and the height of the lift.

Natural Static Water Supply Sources

Driver/operators must realize that smaller natural sources may be more susceptible to fluctuations in adequacy during periods of drought than larger bodies of water.

Driver/operators must be able to evaluate conditions that affect water source accessibility. Many different problems may impede access including:

- Inability to position the pumper close enough to the water
- Wet/soft ground approaches
- Inadequate depth of the water source
- Silt or debris laden water
- Freezing weather
- Swift water

Inability to Position the Pumper

Pumpers may not be able to reach the water in all areas. These environments may include:

- Bridges too high above the surface of the water
- Bridges unable to support the weight of apparatus
- Very high banks around a water source
- Terrain surrounding a water source that will not permit apparatus to reach the water with intake hoses
- Physical barriers such as walls or concrete highway lane separators

In certain locations, where fire apparatus cannot make the required approach, it may be necessary to position portable pumps at the supply source if it is the only site available. These pumps may supply a fire department pumper that can then supply a relay or water shuttle operation. Floating pumps placed in an adequate water source can develop and maintain a flow of up to 500 gpm (2 000 L/min). Fire boats are also used to supply land based pumpers from fresh or salt water sources.

some jurisdictions employ a water eductor that allows the utilization of static water supplies that are located a modest distance from a fire apparatus. By using a hoseline to create a Venturi effect, water from a static supply is forced to the pumper.

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Inadequate Depth for Drafting

Static water sources must be of sufficient depth in order to be useful for draft-ing operations. Although lesser depths may be suitable, 2 feet (600 mm) of water all around a barrel-type strainer is generally considered the minimum for that type of equipment. Floating strainers may be used for water as shal-low as 1 foot (300 mm). Low-level strainers are most commonly used to draft from portable water tanks. These devices may draw water as shallow as 1 to 2 inches (25 to 50 mm), but generally will not provide the flow required to reach the capacity of the pumping apparatus.

When drafting from a natural water supply source, it is especially important that all intake hoses have a strainer attached and supported so that it does not rest on or near the bottom of the supply source. A ladder may be used to achieve this position (Figure 11.4). Bring the intake hose and strainer through rungs of the ladder near the bottom, based on the steepness of the bank. A piece of rope or webbing pre-attached can also help secure and position the strainer. This procedure should ensure that the strainer is positioned horizontally to the bottom of the supply source. If an adequate draft cannot be established due to clogging at the strainer, back flushing with tank water may help to dislodge the debris.

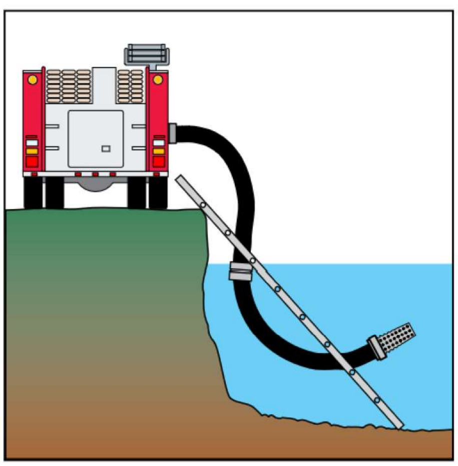

Figure 11.4 Driver/operators should take precautions so that intake strainers do not come in contact with the bottom of the water source.

Cistern — Water storage receptacle that is usually underground and may be supplied by a well or rainwater runoff.

cisterns typically range from 10,000 to 100,000 gallons (40 000 to 400 000 L).

Private Water Storage Tanks Large residential, industrial, or agricultural locations may feature private water storage tanks. These tanks may range in size from several hundred to tens of thousands of gallons of water. These tanks may be stored at ground level or elevated (technically an elevated tank is not a static source as it has elevation pressure at the outlet).

Swimming pools may provide a ready source of water for drafting operations. However, access to some pools may be difficult due to their backyard location and the presence of fences

Square/ Rectangular Pools

(Customary): Square/Rectangular Pool Capacity C = 7.5 x L x W x D

C = Capacity in gallons

7.5 = Number of gallons per cubic foot

L = Length in feet (ft)

W = Width in feet (ft)

D = Average depth in feet (ft)

Round Pools

Formula 11.5 (Customary): Round Pool Capacity C = 7.5 x π x r2
x D

7.5 = Number of gallons per cubic foot

π = Pi, 3.14

r = Radius (1⁄2 the diameter) in feet (ft)

D = Average Depth in feet (ft)

For more information, refer to TANK2PUMP.COM