

# Principles of Operation

# Inspection & Troubleshooting

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**WATEROUS**

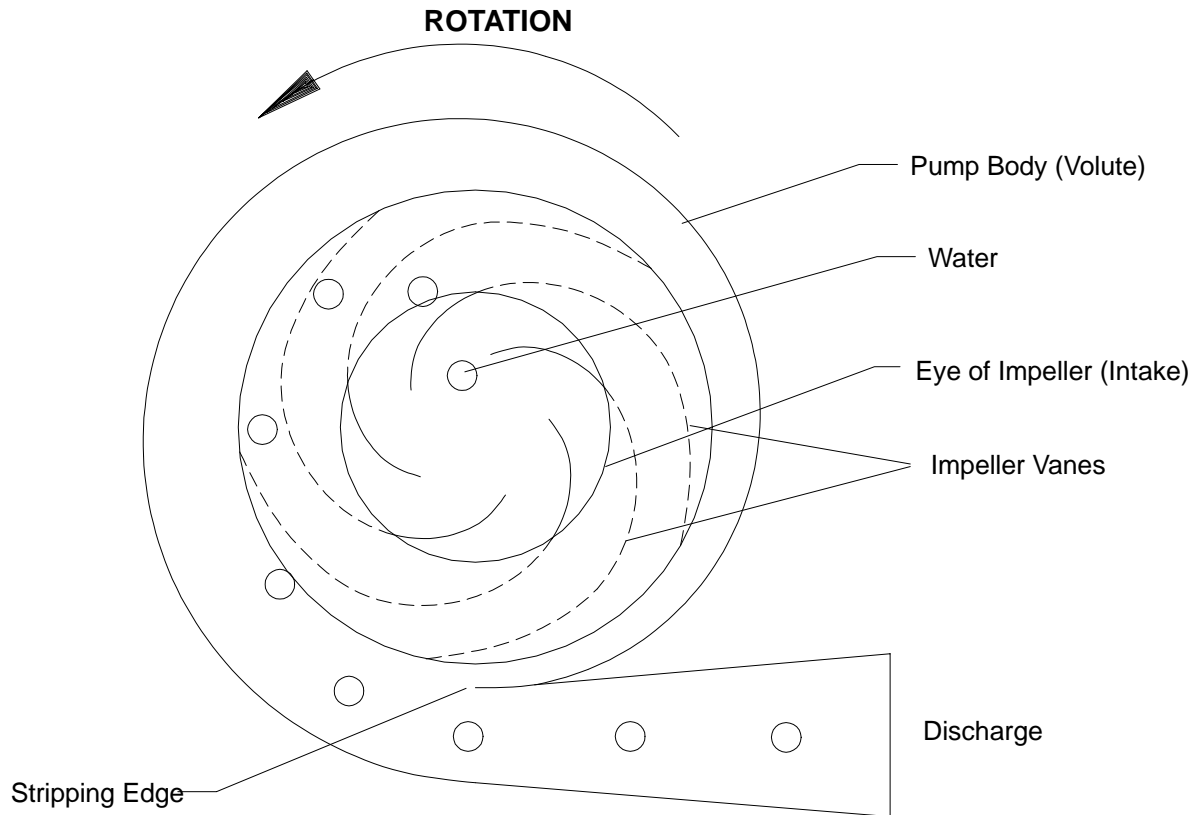
*Fire Pumps – Since 1886*



## Principles of Operation

The two main parts of centrifugal pumps are the impeller(s) and volute(s). The impeller is powered to rotate within the volute, creating centrifugal force which hurls the water from the impeller eye outward through the impeller. The volute is a spiral shaped flow passage surrounding the impeller, which collects the water from the impeller and guides it to pump discharge. In operation, atmospheric or

other pressure continuously forces water through pump intake passages into the eye and the rotating impeller forces it outward into the volute and to the pump discharge. Figure 1 shows the path a single drop of water takes through a centrifugal pump. Pump discharge pressure and capacity can be regulated by adjusting pump speed, transfer valve setting, discharge valve opening and nozzle size.



**Figure 1**

Path water takes through pump body and out discharge passageway.

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## Multi-Stage Pumps

When variations in capacity and pressure are required beyond that which can conveniently be obtained from a single impeller, then multi-stage series/parallel pumps are used. These pumps have two or more impellers, each enclosed in its own volute, which is usually part of a common body. A transfer valve at the outlet of the first stage volute directs the water either to pump discharge or to second stage intake, depending on how the pump is being used.

When the transfer valve is in VOLUME (parallel) position, the water enters each impeller eye from a common intake and leaves through a common pump discharge. See figure 2. If the transfer valve is turned to PRESSURE (series) position, the first stage pumps its full volume and pressure directly to the second stage intake, instead of to pump discharge. The second stage then pumps this same volume of water to pump discharge, but at twice first stage pressure. With the transfer valve in this position, first stage pressure also closes the flap valves in the intake passageways which prevents water from bypassing back to first stage intake. See figure 3.

## Cavitation

Any liquid, at any temperature, forms a vapor over its surface which produces a certain amount of pressure. This "vapor pressure" increases as the liquid temperature rises. When the vapor pressure is equal to or greater than the pressure surrounding the liquid, the liquid boils. Vapor pressure is important because of the way it affects pump operation.

Each pump is designed to operate within a given speed range, and under a specific set of intake conditions. Operating a pump at excessive speed, too high an intake lift, restricting the intake, or any other factor that causes the pressure on the liquid to fall below its vapor pressure produces a condition called "cavitation". When this condition exists, the liquid vapor released in the low pressure regions of the pump forms bubbles. These bubbles are carried into the high pressure sections of the impeller (underneath each vane) where they collapse with considerable force. This may cause pitting near the impeller vane tips.

## Signs of Cavitation

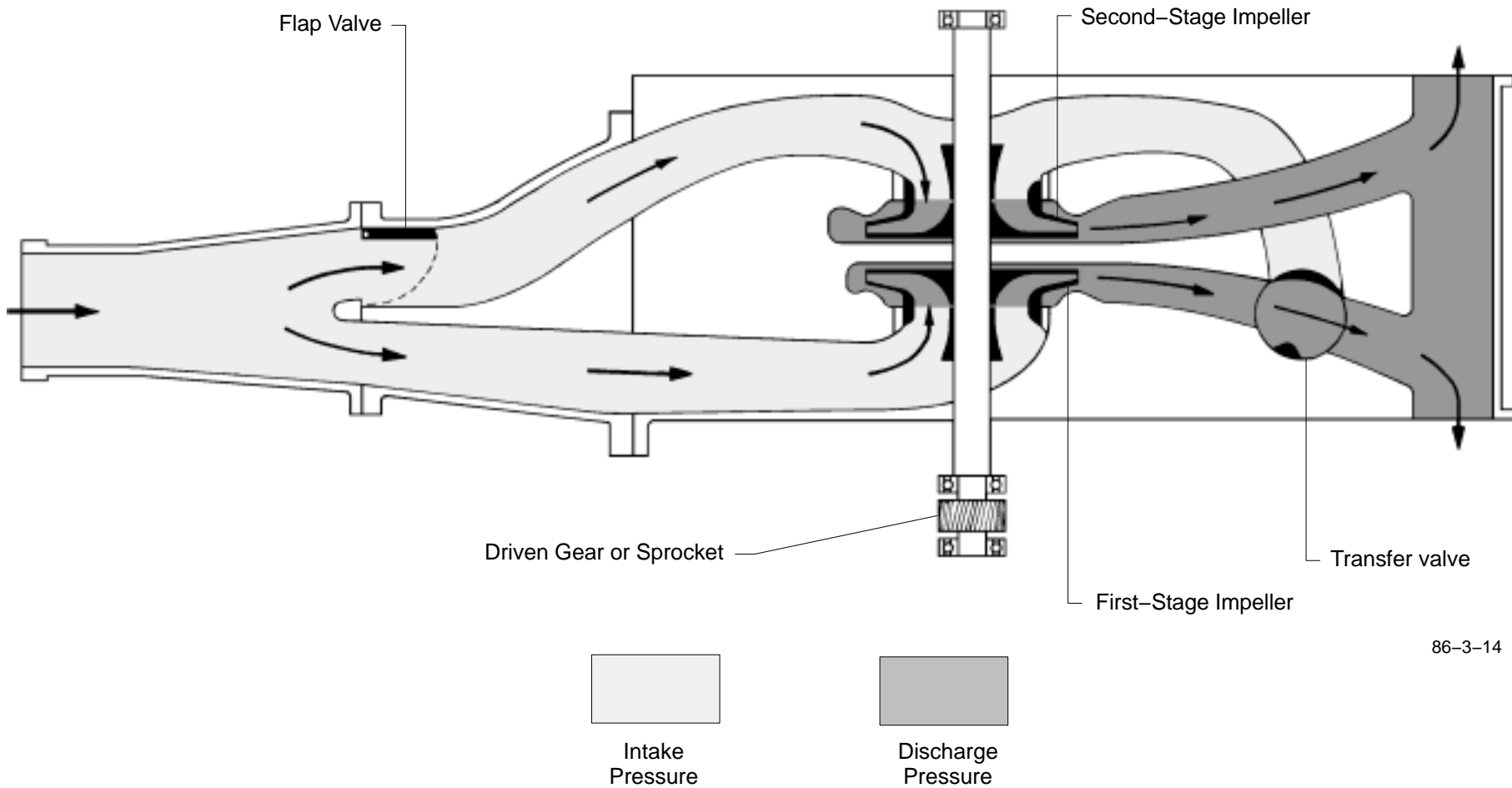
1. Sudden pressure or capacity loss.
2. Increasing pump speed without corresponding increase in volume or pressure.
3. Excessive pump vibration.
4. A rattling sound resembling gravel going through the pump.

Reducing pump speed or improving intake conditions will usually eliminate cavitation.

## Overheating

If the pump runs even for a few minutes completely closed it may heat the water enough to scald someone when the valve is opened. When operating the pump, at least one discharge valve should be open slightly to prevent the pump from overheating. Overheating can damage the packing, seals and other pump parts. If the apparatus builder has installed a bypass system or other provision designed to prevent overheating, opening a discharge valve may be unnecessary.

## PARALLEL (VOLUME) OPERATION

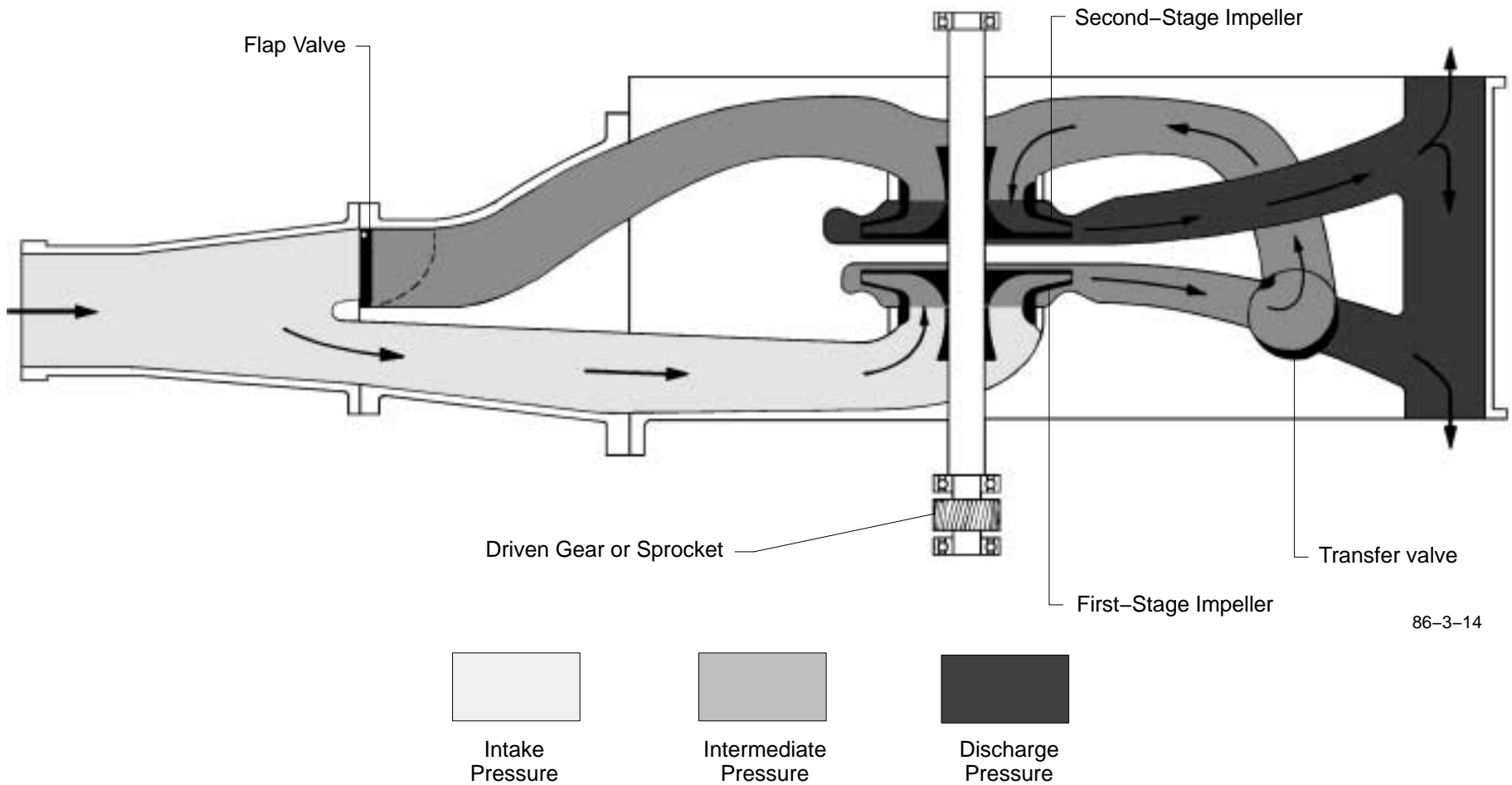


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**Figure 2**

Each impeller pumps half the total volume being delivered, at full discharge pressure. The transfer valve routes water from first stage impeller directly to pump discharge.

# SERIES (PRESSURE) OPERATION



**Figure 3**

Each impeller pumps all of the volume being delivered. Each impeller develops half the total pump pressure. The transfer valve routes water from the first stage impeller to second stage intake. First stage pressure also closes the flap valve.

# Inspection Tests

A regular testing program offers the best means of determining the actual condition of a pump and its accessories, and permits locating problems before they cause trouble. At a fire, it is usually difficult for the pump operator to observe the pump closely enough to determine its true condition.

Conduct these tests either every month or annually, as outlined below:

## Monthly Tests

### I. Vacuum Test

Remove all caps except openings without valves. Close all discharge, intake, drain valves and other similar openings. Operate priming device to create a vacuum of about 22 in. Hg/.735 atmospheres in pump, then stop primer and engine.

Watch pressure gage; if vacuum drops more than 10 in. Hg/.334 atmospheres in 5 minutes, listen for air leaks around packing glands, gaskets, valves, etc.

Replace gaskets, repack or otherwise repair source of trouble.

### II. Pressure Test (Hydrostatic)

Connect pump to a hydrant or other pressurized water source. Remove all caps except openings without valves. Close all discharge, intake, drain valves and other similar openings. Turn on inlet valve and “crack” highest discharge valve on pump to expel air from pump. Close discharge valve. Carefully examine pump and accessories for leaks. Replace gaskets, tighten joints, repair valves or repack as necessary to eliminate leaks. (See “Packing” under running tests below.)

### III. Running Test

Run pump for at least 15 minutes from draft, if possible. Drafting is best because the pump is then more sensitive to defects than when connected to a pressurized water source. Check the following:

1. Priming Ability – If pump does not prime readily (30 seconds for 1250 GPM (4731 L/min) or less and 45 seconds for 1500 to 2000 GPM (5678 to 7570 L/min) pumps) stop pump and determine cause. (An additional 15 seconds may be required if the pump is equipped with a 4 inch or larger front or rear intake.)
2. Shaft Seal  
**Packing** – Packing should leak a small amount to keep it cool and lubricated. Refer to MAINTENANCE INSTRUCTIONS for the particular pump involved for specific leakage rate and packing adjustment.

**Mechanical Seals** – Mechanical seals should not leak. Refer to MAINTENANCE INSTRUCTIONS for the particular pump involved for mechanical seal maintenance.

3. Transfer Valve (series/parallel pumps only) – With the pump running at idle speed, switch valve from one position to the other several times to make sure it operates properly. If the transfer valve is equipped with a grease fitting, lubricate it in accordance with MAINTENANCE INSTRUCTIONS for the pump involved.
4. Shift – Check shift mechanism to make sure it is working properly.
5. Performance – Check pump speed at rated pressure and capacity.
6. Accessories – Operate all discharge and intake valves, relief valve, drain valve and similar accessories to make sure that they all function correctly. If any power accessories are installed, be sure to operate the overrides (if connected) to make sure they operate properly.
7. Indicating Lights – Check to make sure they are working properly.

## Annual Tests

1. At least once a year, test the pumper to determine if it is capable of meeting the requirements outlined in NFPA 1911, Tests of Pumps on F.D. Apparatus. Compare the pump and engine speeds observed in these tests with those in the acceptance and other previous tests. If the speeds observed in the latest tests are much higher, the pump probably requires some repairs.
2. Tank to Pump Check Valve – Remove the tank to pump valve and associated piping and inspect check valve for excessive wear and replace if necessary.



### WARNING

**Equipment Hazard. May cause severe injury to hands or arms.**

Make sure all equipment is turned off prior to reaching into the intake fitting to inspect the intake adapter flap valve.

3. Intake Adapter Flap Valves (Side Intakes only) – Reach inside intake fitting and check the movement of the flap valve. Flap valves should sit securely in the machined slots of the fitting and open and close smoothly.

# Troubleshooting

CONDITION	POSSIBLE CAUSE	SUGGESTED REMEDY
Pump fails to prime or loses prime	Air leaks	<p>Clean and tighten all intake connections. Make sure intake hoses and gaskets are in good condition.</p> <p>Use the following procedure to locate air leaks:</p> <ol style="list-style-type: none"> <li>1. Connect intake hose to pump and attach intake cap to end of hose.</li> <li>2. Close all pump openings.</li> <li>3. Operate primer until vacuum gage indicates 22 in. Hg/.735 atmospheres. (If primer fails to draw specified vacuum, it may be defective, or leaks are too large for primer to handle.)</li> <li>4. Shut off primer. If vacuum drops more than 10 in. Hg/.334 atmospheres in 5 minutes, serious air leaks are indicated. With engine stopped, air leaks are frequently audible. If leaks cannot be heard, apply engine oil to suspected points and watch for break in film or oil being drawn into pump.</li> </ol> <p>Completely fill water tank (if so equipped). Connect intake hose to hydrant or auxiliary pump. Open one discharge valve and run in water until pump is completely filled and all air is expelled. Close discharge valve, apply pressure to system and watch for leaks or overflowing water tank. A pressure of 100 psi is sufficient. <b>DO NOT EXCEED RECOMMENDED PRESSURE.</b></p> <p>If pump has not been operated for several weeks, packing may be dried out. Close discharge and drain valves and cap intake openings. Operate primer to build up a strong vacuum in pump. Run pump slowly and apply oil to impeller shaft near packing gland. Make sure packing is adjusted properly.</p>
	Dirt on intake strainer	<p>Remove all leaves, dirt and other foreign material from intake strainer.</p> <p>When drafting from shallow water source with mud, sand or gravel bottom, protect intake strainer in one of the following ways:</p> <ol style="list-style-type: none"> <li>1. Suspend intake strainer from a log or other floating object to keep it off the bottom. Anchor float to prevent it from drifting into shallow water.</li> <li>2. Remove top from a clean barrel. Sink barrel so open end is below water surface. Place intake strainer inside barrel.</li> <li>3. Make an intake box, using fine mesh screen. Suspend intake strainer inside box.</li> </ol>
	No lubricant in priming tank	With some rotary primers, lubricant is required to maintain a tight rotor seal. Check priming tank oil supply and replenish, if necessary.
	Lubricant tubing/check valve	If there is lubricant in the tank, but lubricant does not enter (exit) the primer, the check valve may be stuck (replace) or installed backwards (arrow points towards primer) or the tubing may be clogged, especially if using a biodegradable lubricant and primer is not operated on a regular basis. Clear clog or replace tubing per Priming System Installation Instructions.
	Defective priming valve	A worn or damaged priming valve may leak and cause pump to lose prime. Consult primer instructions for priming valve repair.
	Improper clearance in rotary gear or vane primer	After prolonged service, wear may increase primer clearance and reduce efficiency. Refer to primer instructions for adjusting primer clearance.
	Engine speed too low	Refer to instructions supplied with primer for correct priming speeds. Speeds much higher than those recommended do not accelerate priming, and may actually damage priming pump.
	Bypass line open	If a bypass line is installed between the pump discharge and water tank to prevent pump from overheating with all discharge valves closed, look for a check valve in the line. If valve is stuck open, clean it, replace it or temporarily block off line until a new valve can be obtained.
	Lift too high	Do not attempt lifts exceeding 22 feet (6.7m) except at low altitudes and with equipment in new condition.
	End of intake hose not submerged deep enough	Although intake hose might be immersed enough for priming, pumping large volumes of water may produce whirlpools, which will allow air to be drawn into intake hose. Whenever possible, place end of intake hose at least two feet below water source.
	High point in intake line	If possible, avoid placing any part of intake hose higher than pump inlet. If high point cannot be prevented, close discharge valve as soon as pressure drops, and prime again. This procedure will usually eliminate air pockets in intake line, but it may have to be repeated several times.
	Primer not operated long enough	Refer to operation instructions supplied with primer for required priming time.
	Insufficient capacity A. Engine and pump speed too low at full throttle	Insufficient engine power
Discharge relief valve set improperly		If relief valve is set to relieve below desired operating pressure, water will bypass and reduce capacity. Adjust relief valve in accordance with instructions supplied with valve.

CONDITION	POSSIBLE CAUSE	SUGGESTED REMEDY
Insufficient capacity A. Engine and pump speed too low at full throttle (continued)	Transfer valve set improperly (Does not apply to single stage pumps.)	Place transfer valve in VOLUME (parallel) position when pumping more than two thirds rated capacity. When shifting transfer valve, make sure it travels all the way into new position. Failure of transfer valve to move completely into new position will seriously impair pump efficiency.
	Truck transmission in too high a gear	Consult vehicle instructions for correct pump gear. Pump usually works best with transmission in direct drive. If truck is equipped with an automatic transmission, be sure transmission is in pumping gear.
Insufficient capacity B. Engine and pump speed higher than specified for desired pressure and volume	Transfer valve set improperly (Does not apply to single stage pumps.)	Place transfer valve in VOLUME (parallel) position when pumping more than two thirds rated capacity. When shifting transfer valve, make sure it travels all the way into new position. Failure of transfer valve to move completely into new position will seriously impair pump efficiency.
	Pump impeller(s) or wear rings badly worn	Install undersize wear rings if impeller to wear ring clearance is within limits indicated in MAINTENANCE INSTRUCTIONS. If not, install new impeller(s) and wear rings.
	Intake strainer, intake screens or impeller vanes fouled with debris	Remove intake strainer and hose, and clear away all debris. Pressure backwash (preferably in parallel or "volume" position) will usually clear impeller vanes when pump is stopped.
	Intake hose defective	On old intake hoses, the inner liner sometimes becomes so rough it causes enough friction loss to prevent pump from drawing capacity. Sometimes, the liner will separate from the outer wall and collapse when drafting. It is usually impossible to detect liner collapse, even with a light. Try drafting with a new intake hose; if pump then delivers capacity, it may be assumed that previous hose was defective.
	Intake hose too small	When pumping at higher than normal lifts, or at high altitudes, use a larger or additional intake hoses.
Insufficient capacity C. Engine speed higher than specified for desired pressure and volume	Truck transmission in too low a gear	Consult vehicle instructions for correct pumping gear. Pump usually works best with transmission in direct drive. (Check both engine and pump speed, if possible, to be sure transmission is in "direct".)
Insufficient pressure	Pump speed too low	In general, the above causes and remedies for low pump capacity will also apply to low pump pressure.
		Check pump speed with a tachometer. If pump speed is too low, refer to engine manufacturer's instructions for method of adjusting engine speed governor.
Insufficient pressure (continued)	Pump capacity limits pump pressure	Do not attempt to pump greater volume of water at the desired pressure than the pump is designed to handle. Exceeding pump capacity may cause a reduction in pressure. Exceeding maximum recommended pump speed will produce cavitation, and will seriously impair pump efficiency.
	Flap valve stuck open	When pump is in PRESSURE (series), discharge will bypass to first stage intake. Operate pump at 75 psi/5.2 bar, and rapidly switch transfer valve back and forth between positions. If this fails, try to reach valve with a stick or wire and work it free.
Relief Valve Malfunction A. Pressure not relieved when discharge valves are closed	Sticky pilot valve	Disassemble and clean. Replace noticeably worn parts.
	Plugged tube lines	Disconnect lines and inspect.
Relief Valve Malfunction B. Pressure will not return to original setting after discharge valves are reopened	Sticky pilot valve	Disassemble and clean. Replace noticeably worn parts.
	Sticky main valve	Disassemble and clean. Replace noticeably worn parts.
	Incorrect installation	Check all lines to be sure installation instructions have been followed.
Relief Valve Malfunction C. Fluctuating pressure	Sticky pilot valve	Disassemble and clean. Replace noticeably worn parts.
	Water surges (relief valve)	Pressure fluctuation can result from a combination of intake and discharge conditions involving the pump, relief valve and engine. When the elasticity of the intake and discharge system and the response rate (reaction time) of the engine, pilot valve and relief valve are such that the system never stabilizes, fluctuation results. With the proper combination of circumstances, fluctuation can occur regardless of the make or type of equipment involved. Changing one or more of these factors enough to disrupt this timing should eliminate fluctuation.
Relief Valve Malfunction D. Slow response	Plugged filter or line	Clean lines and filter.