Pumps are designed for many different purposes. In order to understand the proper application and operation of a pump in a given situation, firefighters must be familiar with the different types of pumps, the use of pump accessory equipment and pump theory.

There are two basic types of pumps used in the fire service today: positive displacement pumps and centrifugal pumps. There are also various devices used to complement and augment pump operations. We will cover relief valves and primers.

**Positive Displacement Pumps**

The theory of positive displacement is based on the principle that water is a non-compressible fluid, and will therefore occupy space in direct proportion to its volume. Theoretically, a positive displacement pump will discharge a quantity of water equal to the quantity of water taken into the pump. Actually, the discharge will be slightly less than the intake, due to "slip". "Slip" is leakage between the internal parts of the pump. The amount of slippage is dependent on the condition of the pump and the operating pressure.

Because of the close fit of its internal working parts, a positive displacement pump will exhibit very little slip. Therefore, air as well as water can be drawn into and expelled by a positive displacement pump. The ability to pump air and water means that these pumps are capable of producing sufficient vacuum to "prime" themselves.

There are two main styles of positive displacement pumps: piston pumps and rotary pumps. There are two types of rotary pumps: rotary gear and rotary vane.
A piston type pump creates a pressure differential by enlarging the cylinder capacity as the piston moves upward. Air or water is drawn into the cylinder due to the negative pressure created. When the piston moves downward, the air or water is expelled. Check valves operate to close off the intake and discharge ports at the appropriate time.

A rotary type pump consists of a casing divided into separate intake and discharge chambers by a rotor device, either gear or vane. The rotor is designed and located so that travel from the intake chamber to the discharge chamber displaces a definite quantity of air or water per revolution.

Centrifugal Pumps
The word "centrifugal" means to proceed away from the center. The operation of a centrifugal pump is based on the principle that a revolving disc will tend to throw water, introduced at the center, toward the outer edge of the disc. In a centrifugal pump, a revolving disc, known as an impeller, rotates very rapidly within a casing. As the impeller revolves, water introduced through a suction tube enters the impeller, and by centrifugal action, is hurled into the open space in the casing. This casing may be one of several designs, with the most common being the volute type.

The cross-sectional area between the outer edge of the impeller and the wall of the casing is constantly increasing as it approaches the discharge, producing a volute or spiral. The action of the volute is to enable the pump to handle this increasing quantity of water, while at the same time, permitting the velocity of the water to remain constant, or to decrease gradually and maintain the required continuity of flow.

Actually, the movement of the impeller simply creates a velocity in the water which is converted into pressure as it approaches the confining space of the discharge pipe. Water under pressure on the discharge side of the casing is prevented from flowing back into the pump by the close fit between the casing and the impeller at the entrance to the suction inlet, by the rapid movement of the impeller and by the unequal pressure in the pump casing. The pump discharge pressure and capacity can be regulated by adjusting the pump speed and the size of the discharge opening.
A centrifugal pump allows for 100 percent slippage - the pump can be operated with the discharge closed. Therefore, a centrifugal pump cannot create a vacuum to draw water into itself; water must be introduced under pressure. In operation, atmospheric or other pressure continuously forces water into the suction eye, the impeller forces water outward and the volute conducts the water out of the pump. For atmospheric pressure to be used to force water into the pump, it is necessary to use a priming device to create a vacuum or negative pressure. We'll cover this in more detail under primers.

**Multistage Centrifugal Pump**

The connecting or coupling of two or more single-stage centrifugal pumps in a series, with the discharge of the first impeller, or stage, connected directly to the inlet of the second impeller, creates what is called a multistage centrifugal pump.

The operation of a series/parallel pump is controlled by a transfer valve and two clapper valves. The transfer valve, located at the outlet of the first stage, directs the water either to the discharge or to the second stage inlet, depending upon how the pump is being used.

When the transfer valve is in the volume (parallel) position, each stage pumps half the total volume at the same discharge pressure. The water enters both inlet eyes at the same time from a common suction and leaves through a common discharge.

When the transfer valve is in the pressure (series) position, the first stage pumps its full volume and pressure directly to the second stage, instead of the discharge. The second stage then pumps this same volume of water to discharge, and doubles the first stage pressure.

**Transfer Valve Operation**

There is no hard-and-fast rule to use when deciding whether to pump in pressure or volume. In general, for long, single lines use pressure; for short lines with big tips use
volume. Another guide is to use whichever setting results in the lowest engine speed (RPM). This will vary from apparatus to apparatus and will also depend on the water source (i.e., hydrant or draft).

**Priming Devices**

The purpose of a priming device is to remove air from the centrifugal (main) pump. The removal of air is necessary in drafting operations and is also sometimes required if the main pump develops an "air lock."

As previously stated, centrifugal pumps allow 100 percent slippage, and are therefore incapable of expelling any air which may be in them. For this reason, some type of auxiliary pump or device must be used as a primer.

There are several styles of priming devices, including those driven by the exhaust manifold, the intake manifold or the clutch. All of the EFD apparatus use positive displacement rotary pumps for primers. While some of these may be rotary-vane and others may be rotary-gear, and some may be electrically driven and others may be mechanically driven, the purpose is the same - to remove air from the main pump.

It is worth noting here, the idea that the priming pump actually "lifts" water during drafting is untrue. The priming pump simply decreases the atmospheric pressure inside the main pump by creating a partial vacuum. The atmospheric pressure exerted on the surface of the water source then forces water into the pump.

As shown, the priming pump is lubricated by oil stored in a reservoir. When the vacuum is created in the priming pump, the oil is drawn in along with the air and/or water. In addition to lubrication, the oil is necessary to help seal the close-fitting parts of the priming pump. There is a vent hole at the highest point in the oil tubing line which allows the oil flow to cease when the primer is disengaged.
The primary purpose of a pressure control device is to protect firefighters at the nozzle from a sudden, dangerous increase in pressure. A secondary purpose is to protect the hose and pumps.

When pumping to multiple lines, if one line is shut down, there is an increase in pressure to the remaining lines. This is due to the increase in pump speed resulting from the decrease in load. A similar situation occurs when you are driving a vehicle up a hill with the accelerator depressed 3/4 of the way - when you reach level ground, your speed will increase.

To maintain the desired discharge pressure, it is necessary to install some type of automatic pressure control mechanism. This may be accomplished by one of three devices:

- An automatic relief valve that opens a bypass between the discharge and suction sides of the pump.
- A pressure operated governor to control the speed setting of the throttle on the engine.
- Pressure reducing valves on each discharge gate.

Priming Pump Motor
Manual Relief Valves

A relief valve is merely a piston in a cylinder. One end of the piston normally closes a passageway between the pump discharge and the pump suction. The other end of the piston is subjected to water pressure, which is automatically regulated by a pilot valve.

The pilot valve incorporates a spring-loaded needle valve that moves to allow the passage of water in response to changes in pump discharge pressure. The piston is set by adjusting the compression on a coil spring that opposes the pump discharge pressure. At any discharge pressure below the setting, the piston will be closed. At any pressure higher than the setting, the piston will be open, allowing the excess pressure to bypass.
PUMP BOSS PRESSURE GOVERNOR PBA200

The Pump Boss model PBA200 is a governor operated pressure relief device utilized on some of our engines.

Overview

The Fire Research pressure governor operates in one of two modes, pressure or RPM. It maintains a steady pump discharge pressure within system capabilities by controlling the engine speed or holds a selected engine RPM.

The PBA200 models have one 300 psi pressure sensor pressure sensor mounted on the pump discharge.

In pressure mode the governor maintains a constant pump discharge pressure. The discharge pressure is monitored and compared to the selected pressure setting, the engine RPM is varied to keep the discharge pressure at the selected setting.

In RPM mode the governor maintains a constant engine RPM. The pump discharge pressure is monitored, it can vary but is limited to an increase of 30 PSI. If the discharge pressure increases 30 PSI, the pressure governor automatically lowers the engine RPM to reduce the discharge pressure.

All controls and indicators are located on the front of the control module.

Change overs with the Pump Boss 200 is possible without causing an increase of 30 PSI.

Escondido Specific Information:

— Defaults to PSI mode – hit pre-set button and pump goes to 115 PSI (pre-connect 95 GPM)

— When doing a changeover PSI mode gives protection. You still need to open and close valves slowly

— Use RPM mode for drafting – hit pre-set button and engine goes to 1000 RPM

— RPM mode has 30 PSI protection feature

— To increase PSI or RPM, rotate knob to the RIGHT
LED Bar Graphs

Oil Pressure: 10 - 100 PSI
Temperature: (Engine Coolant): 130 - 240 °F
Transmission Temperature: 140 300 °F
Battery Voltage: 11.5 to 15.5 VDC (12 V)

Controls and Indicators

All controls and indicators are located on the front of the control module.

MENU Button
— Used to access stored data and program features.

Oil Pressure LED Display
— Shows engine oil pressure. The LEDs are green when the pressure is within normal limits and red when it is not.

Check Engine Led, Stop Engine Led
— Repeats the warnings from the cab.

Engine Temperature LED Display
— Shows engine coolant temperature. The LEDs are green when the temperature is within normal limits and red when it is not.

Transmission Temperature LED Display
— Shows transmission temperature. The LEDs are green when the temperature is within normal limits and red when it is not.

RPM Display
— Shows the current engine RPM in bright red digits. It also shows error codes, stored data, and program features.

Battery Voltage LED Display
— Shows battery voltage. The LEDs are green when the voltage is within normal limits and red when it is not.
Day/Night Sensor
  — Adjusts the brightness of the displays for day or night operations.

SILENCE Button
  — Press to suppress audio alarms.

Message Display
  — The message display shows the pressure or RPM setting during normal operations and warning alarms as they occur. It shows the time and date when the throttle ready LED is off. It also shows stored data and program features.

THROTTLE READY LED
  — This LED will be on when the required interlock conditions are met to begin pump operations.

PRESET Button
  Press to change/select a pre-programmed value for pressure or RPM setting.

IDLE Button
  — When pressed immediately sets the engine RPM to idle.

Control Knob
The control knob is used to adjust pressure and RPM settings. The governor senses how fast and in what direction the control knob is rotated and sends a signal to the ECM to increase or decrease the engine RPM proportionally.
  — If the control knob is rotated quickly; the engine RPM changes quickly.
  — If the control knob is rotated slowly; the engine RPM changes slowly.
  — Rotate the control knob clockwise* to increase engine RPM.
  — Rotate the control knob counterclockwise* to decrease engine RPM.

RPM Button
  — Press to select RPM mode. The LED is on to indicate operation in the RPM mode.
PRESSURE Button

— Press to select pressure mode. The LED is on to indicate operation in the pressure mode.

Pressure Mode Operation

In the pressure mode of operation the PRESSURE LED is on. The governor maintains a constant discharge pressure within system capabilities. It adjusts the engine RPM automatically to compensate for variations in pressure.

There is a maximum engine RPM programmed in the governor for pressure mode. If the engine reaches the programmed maximum RPM the message display flashes MAX RPM / OPERATOR and the engine RPM is not allowed to go higher. (The maximum engine RPM is normally set at 2100 and is programmable.)

Note: When changing from RPM to pressure mode during operations, hold the PRESSURE button for 3 seconds. The pressure setting is the pressure that the pump was operating at in RPM mode.

1. Press PRESSURE button to select the pressure mode.
   Result: PRESSURE LED goes on.

2. Press PRESET and/or rotate control knob to select pressure setting.
   Result: Message display shows pressure setting, engine RPM changes.

3. Press IDLE button after operations to set engine to idle RPM. Result:
   Message display shows IDLE ENGINE, engine at idle RPM.

Opening/Closing Discharge Valves

In pressure mode the governor maintains the pressure setting regardless of the number of discharge lines that are opened or closed providing there is sufficient water supplied. As lines are opened the discharge pressure starts to drop and the governor raises the engine RPM to maintain the required pressure. As lines are closed and the discharge pressure starts to rise, the governor lowers the engine RPM to maintain the required pressure.

Operating From a Pressurized Supply

When operating from a pressurized water source (hydrant, in-relay, etc.), the intake supply should be routed through a valve. If the pressurized source fails, the pump operator can close the valve. This eliminates the chance of sharp pressure spikes at the pump intake if the supply is resumed suddenly. The operator must open this valve slowly when the supply is resumed to help prevent pressure spikes.
Running Away From Water, Low Water, or No Supply Water

There are situations during pump operations when there may be low or no supply water. This can be due to an empty water tank, a problem on the intake line, air in the pump, changing the water source, or an insufficient water supply.

The governor constantly monitors discharge pressure and compares it to engine RPM. It is programmed to limit RPM increases when conditions arise that fall outside of normal operating parameters.

Running Away From Water

If the discharge pressure starts dropping while operating in pressure mode, the governor increases the engine RPM and attempts to maintain the selected pressure setting. If pressure drops and an increase in RPM does not bring the pressure back up, the governor recognizes this as a running away from water condition. When this condition occurs the governor switches to the RPM limit mode and controls the engine RPM accordingly.

RPM Limit Mode

When the RPM limit mode is in effect the PRESSURE LED stays on. To alert the operator the RPM LED and the RPM display flash, and the message display flashes OPERATOR / RPM LIMIT. In this mode the pressure setting does not change and the PRESET button is disabled. When the pressure comes back up to the selected pressure setting, the RPM limit mode is canceled and the governor switches to normal operation in pressure mode at the selected pressure.

In some cases the pressure may not come back up but remains at a level above 45 PSI. In the RPM limit mode, the governor behaves like a manual throttle and the operator can raise or lower the engine RPM by rotating the control knob. If the RPM is manually lowered to a point where the pump is not running away from water and pressure is stable, the RPM limit mode is canceled. The governor switches to normal operation in pressure mode with the current discharge pressure as the new pressure setting.

If the engine is set to idle using the IDLE button, the governor comes out of RPM Limit Mode and cancels the pressure setting.

Low Water Cycle

If the discharge pressure is below 45 PSI, but stays above 15 PSI, the governor enters a low water cycle and the message display flashes LO WATER. It sets the engine at 1100 RPM. If the pressure does not rise above 45 PSI in 7 seconds, the governor sets the engine RPM at idle. The governor repeats the low water cycle as long as the discharge pressure is between 15 and 45 PSI. When the pressure rises above 45 PSI the governor
resumes normal operation. (The values for RPM and PSI in the low water cycle are programmable and may vary for some engine/pump combinations.

**No Supply Water**

If the discharge pressure is below 15 PSI, the engine RPM is set at idle and the message display flashes NO WATER. If, within 3 minutes, the discharge pressure rises above 15 PSI the governor enters the low water cycle. If the discharge pressure does not rise above 15 PSI within 3 minutes, the governor switches to idle mode and cancels the pressure setting. To restart pump operations, the operator must take action (press PRESET and/or rotate control knob to select pressure setting).

**RPM Mode Operation**

In the RPM mode of operation the RPM LED is on. The governor maintains a constant engine RPM.

The pump discharge pressure can vary but, as a safety feature, the governor limits the increase in pressure to 30 PSI over the last established PSI value. As the discharge pressure approaches this limit the governor automatically lowers the RPM to prevent a high pressure surge. The RPM LED blinks as the governor sets a lower RPM. This lower RPM will be the new operating RPM setting.

**Note:** When changing from pressure to RPM mode during operations, hold the RPM button for 3 seconds. The RPM setting is the RPM that the pump was operating at in pressure mode.

1. Press RPM button to select RPM mode.
   Result: RPM LED goes on.
2. Press PRESET and/or rotate control knob to select RPM setting.
   Result: Message display shows RPM setting, engine RPM changes.
3. Press IDLE button after operations to bring engine to idle RPM.
   Result: Message display shows IDLE ENGINE

**Switching Between Operating Modes**

— No variation in discharge pressure or RPM occurs when changing between pressure and RPM modes.

— When changing to RPM mode, the RPM setting is the RPM that the pump was
operating at in pressure mode.

— When changing to pressure mode the pressure setting is the pressure that the pump was operating at in RPM mode.

When the engine is at idle RPM:

Press the mode button and the governor changes modes immediately.

When the engine RPM is above idle:

Press and hold the mode button for 3 seconds and the governor changes modes. (This is to avoid an accidental change over if the buttons get bumped.)

**Pump Discharge Pressure is high at Engine Idle**

Once the governor has set the engine RPM at idle, it can do no more to reduce discharge pressures. To reduce discharge pressure the pump operator can gate incoming water, reduce pressure at the intake relief valve, gate discharges, or disable the pump.

**RPM Limit with Discharge Pressure Less than 100 PSI**

The level II programming code P221 sets the maximum RPM when the pump is operating with a discharge pressure less than 100 PSI. The factory set default is for code P221 is 1500. Access to level II programming required a password. Contact FRC if this default limit needs to be changed.

**High-Idle**

The governor programming includes a high-idle function. To activate the high-idle set all interlocks as called for by local SOP (normally this would include the transmission in neutral and the parking brake on). Set the High-Idle switch to ON.

**Note:** The pump must NOT be engaged when using the high-idle function and the THROTTLE READY LED will be off.