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# Don't Touch the Red Button, Part 3

Part 2 followed the stream of water from the intake to discharge, examining the control systems it contacts along the way. Part 3 addresses pump control.

**BY EDWARD COLLET**

Controlling the pump is paramount in getting the proper amount of water to the fireground. This is mainly done by the engine throttle. The more revolutions per minute (rpm) the operator commands the engine to produce, the faster the pump spins, throwing more water out of the discharge. How the operator interacts with the pump has evolved with technology. It is critical that the operator understands how the throttle control system controls the pump discharge. Engines using independent throttle control and a discharge relief valve control the flow and pressure of the water, allowing the operator to be the brains behind the controls. This is the first method of control discussed in the series.

## ANALOG ENGINE CONTROL

After the air bleeder, relief valve, and intake valve, the water will come to the pump. The velocity of the pump impeller controls the flow and pressure developed at the discharges. The speed of the engine controls the speed of the pump. Engine throttle designs have evolved over the years with improvement in technology and changes in regulations. Initially, a cable was connected directly to the engine throttle from the pump panel. This was the tried-and- true Vernier throttle. Twisting the knob to the left tensioned the cable, increasing rpm. Turn the knob to the right, and the rpm went down. In the middle is the red emergency idle button. Many operators use this button as the normal means to bring the engine to an idle at the end of operations.


**1** A Vernier throttle. *(Photos by author.)*


**2** An electronic throttle and relief valve control.

This puts added stress on the engine—it should be slowly brought to idle after working to pump water. It is the equivalent of running a marathon and immediately plopping on the couch with a bag of chips—your body would not appreciate this style of cool down, and neither does your engine.

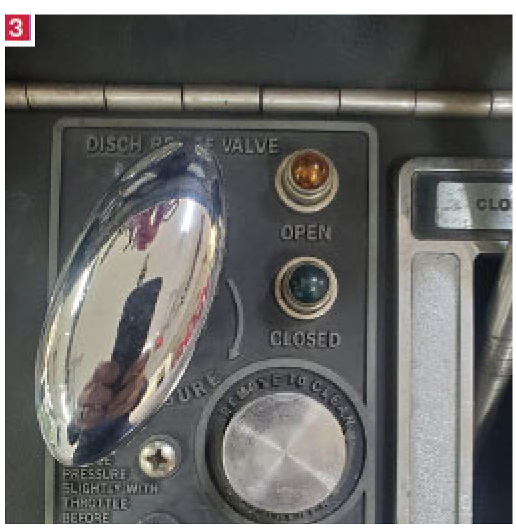
Engines started using fly-by-wire throttle systems in the late 1990s. This technology evolution required fire apparatus manufacturers to adapt and make the throttle control on the pump panel electronic. Electronic throttle controls can have a knob or up and down pushbuttons. Many may say, "I have a rig from the 2000s and still have a Vernier throttle." Open the pump house and see if a cable or several wires are connected to the Vernier dial. It is a good bet it is wires, as many departments want a controller to look and act like what they used for many years. The one thing the electronic throttle and Vernier throttle have in common is the need for an operator to make adjustments to develop and maintain pressure. I refer to this control setup as the analog engine.

## DISCHARGE PRESSURE RELIEF VALVE

Analog engines need a way of controlling spikes in the discharge pressure. Spikes occur when multiple handlines are flowing and one shuts down or when transitioning from tank to a hydrant. NFPA 1900, *Standardfor Aircraft Rescue and Firefighting Vehicles, Automotive Fire Apparatus, Wildland Fire Apparatus, and Automotive Ambulances* (2024 ed.), restricts the increase in discharge pressure to 30 psig. For analog engines, the discharge pressure relief valve manages pressure spikes by venting excess flow into the pump intake. The pressure is set by a handwheel of some style on the pump panel, and the open or closed status of the valve is indicated by one or two lights, depending on the model. Once water is flowing at the desired pressure, the valve is set at the operational pressure. When a handline closes, the pressure increase will open the relief valve to maintain the correct pressure and not increase the flow in the remaining open lines. Unlike the intake relief valve that vents to the atmosphere, it is not possible to tell if the discharge relieve valve opened by seeing water on the ground since it dumps to the intake.

While the primary indicator is the open and closed lights, we all know lights blow out and might not get replaced right away. What can we do? Depending on where the valve is located in the pump house, it may be possible to hear water flowing through the valve and plumbing when it is open. Gauges will pop up when the pressure increases and quickly drop down as the valve opens. If the operator forgets about the relief valve and keeps increasing the rpm without seeing an increase in pressure, the relief is likely open. Unlike cavitation, which exhibits the same qualities, the needle will move fluidly with the relief valve operating as opposed to the shakiness of cavitation.

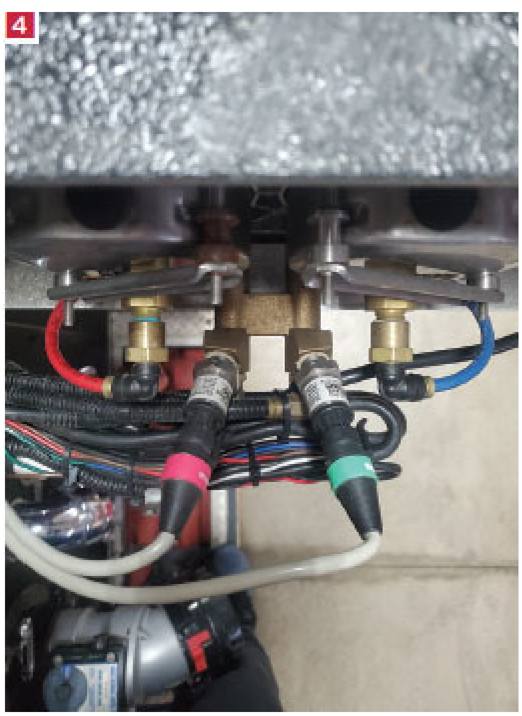
This system has served the fire service well for decades. As electronics started to proliferate the management of our engines, it was only a matter of time until they arrived on our pump panel.




**3** A discharge pressure relief valve with indicator lights.

## PRESSURE GOVERNORS

Pressure governors have been around in one form or another for decades. Early governors used an air pressure balancing system mechanically linked to the engine's throttle to maintain pressure. These early mechanical governors had varied degrees of success. With the engine's throttle managed electronically, it was only a matter of time before engineers married pressure transducers and computer controllers with the throttle to form the electronic pressure governor. The most common style of pressure transducer uses a diaphragm and strain gauges to convert pressure into an electrical signal capable of being read by a computer. At one time, these had low accuracy or were too big to fit neatly in the pump house. Today, small form transducers with high accuracy are common throughout process industries. These transducers fit on the back side of the master discharge and intake gauges. The heart of the pressure governor is basically a small computer, or electronic control unit (ECU). It reads inputs from the engine management computer, most important engine rpm, and discharge pressure to determine how to adjust the engine throttle to maintain the desired discharge pressure.




**4** Intake and discharge pressure transducers.



**5, 6** Electronic pressure governors.

## PRESSURE (PSI) MODE

In psi mode, the ECU looks at the pressure and rpm once every 500 ms (0.5 seconds) and compares it with the last reading. If a change occurred, the ECU will adjust the throttle to keep the pressure at the previous reading. While each of the three major governor manufacturers have slightly different logic and thresholds, the basic functionality and water management goals are similar. When the pressure drops, as when an additional line is opened, the governor increases the engine rpm to maintain pressure. If rpm increases but pressure does not, the governor identifies the discharge demand being higher than the intake capacity, making for potential cavitation, and will stop increasing rpm. The governor will limit or hold the increase in rpm until the pressure increases. When this happens, the operator will receive an audible alarm indicating attention is required. In older governor models, the rpm would drop to idle to protect the pump from cavitation. This may have protected the pump, but it left the attack crew with no water without any warning. Today's governors will either lock in the rpm or cycle several times in an attempt to maintain pressure. An attentive operator must pick up that the pump is on the verge of cavitation and either decrease output flow or increase input flow.

Pressure governors work to prevent pressure spikes along with maintaining pressure. Figure 1 shows the response of the pressure governor to opening and closing different size handlines in psi mode. Some have the misconception that if different size lines are being operated, psi mode will not manage the discharge pressure. It is important to remember the pressure governor operates based on the master discharge pressure. The discharge pressure of a gated discharge depends on the pressure on the inlet side of the valve, the pump master discharge pressure, to produce the proper flow. By managing the master discharge pressure, the governor maintains the proper pressure on fully opened and gated discharges. The data in the figure was taken using a high-speed data acquisition system with a sampling frequency of once every quarter second—this is twice the sample rate of the pressure governor. The green line is the master discharge pressure. The orange line is the pressure at the nozzle of a 2^-inch line with a Pi-inch tip flowing 265 gallons per minute (gpm). The blue line is a 1%-inch line flowing 150 gpm from a 100- psig combination nozzle. When both lines are closed, the pressure at the nozzle equals the master discharge pressure. Notice the spike above the master discharge pressure occurring with each nozzle closure; this is water hammer. When the lines are opened, the master discharge drops with the increased flow until the governor can increase the rpm to restore the pressure. An important point to observe is the pressurespike in the flowing line: This is the spike the governor is working to minimize to protect the crew. When the 2% is shut, there is a bigger spike in the 1% inch because of the high volume of water being controlled. The spike is still less than 20 psig and does not last longer than a few seconds. Closing the 1%-inch line produces only small blips in the pressure of the 2%-inch line because of the smaller ratio of water being shut down. While the details are cool to dig into, the main takeaway of this figure is that the pressure governor in psi mode will effectively manage pressure on different size lines with different flows.

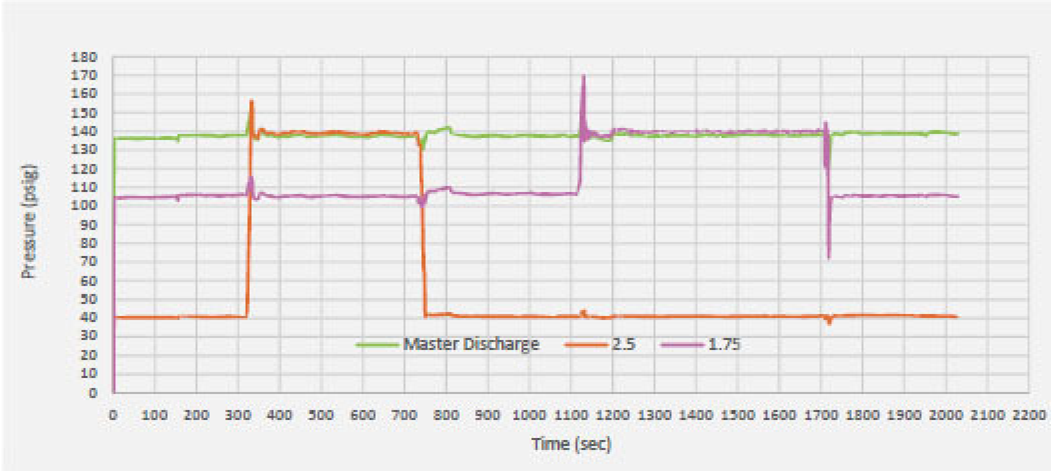



Figure 1: A pressure governor function test (FRC Pump Boss 400).

One issue with psi mode is it manages discharge pressure by manipulating the engine rpm. Most of the time this works great, but there is a circumstance where the governor is rendered useless and will not protect the hoselines. If you connect to a good hydrant with flow and pressure sufficient to flow two handlines with the engine at idle, the governor has no room to move engine rpm to protect the lines. Today the use of large-diameter hose (LDH) along with low-pressure nozzles connected to low- friction-loss hose means even moderately good hydrants could keep the engine at idle. What can be done about this? Some departments with extremely good hydrant systems opt to stick with an electronic throttle and pressure relief valve. This option is only a solution in the design phase of the engine. When confronted with this scenario with a pressure governor, several actions can be taken and the best one is based on your particular environment and operating procedures.

One option is to bleed off pressure by opening a free discharge. This might be an option in warmer climates, but in the North it would create an ice rink around the engine during the winter months. Even in warm areas, this option wastes water andadds potential hazards to the working environment. It is possible to open the tank-to- pump valve, but this only works until the tank is full. Then the same issues arise as opening a discharge to bleed pressure.

This one might be a little controversial and relies on the engineer and officer having a good read on the fire and knowing the hydrants in the area. If the fire is a two-line (1% inch) or even a three-line job, it might be possible to use 3-inch supply on the hydrant as opposed to LDH. This will provide more system resistance between the hydrant and intake, reducing the intake pressure, necessitating the governor to bring the engine off idle. Three-inch line can easily flow 500 gpm for 50 feet from the hydrant. Two 1%-inch handlines flow 150 to 186 gpm, making the flow from two lines 300 to 372 gpm, well within the capability of 3-inch supply line. Adding a third line puts the flow in the range of450 to 558 gpm but is still manageable.

If the fire gets ahead of the flow a 3-inch can handle, it should be relatively easy to add a second line to the hydrant if a gate valve is on the unused 2%-inch outlet. Preferably this would be LDH. Even connected to the other 2%-inch outlet, it will still flow a significant amount of additionalwater. Remember, the restriction of the 2%-inch outlet is only for a couple of inches; then the LDH does the long distance moving. This option is highly dependent on officer and engineer experience and SOPs. There are departments that will always use LDH no matter what; then there are others without supply line options. The simplest and less controversial method of getting the engine off idle is to simply gate the discharges until the engine is 300 to 400 rpm over idle. This should give the governor enough room to modulate the pressure for line protection. If more flow is needed and intake pressure drops off, the gated valves can be opened to reduce the pressure needed to produce the desired flow.

Governors are on the lookout for loss-of- water events. Generally, when the particular algorithm in the ECU determines water supply is low, it will increase rpm a certain amount for a set period of time before going to idle and cycling between the rpm setpoint and idle. A no-water event triggers different algorithms and responses. The general reaction to this condition is for the rpm to go to idle for a set period of time. If water supply is not reestablished in this time, psi mode is canceled, and the controller goes to rpm mode. These algorithms are triggered between 45- and 15-psig discharge pressure. Everyone knows Murphy will show up at a fire, and the pressure governor is a good backup. But, a proficient operator will have started interventions for insufficient water supply before the governor starts to do its job. If it has started to act, the operator knows what it will do and is not surprised how the engine reacts.

## WHEN TO USE PSI MODE

When handlines are in service, psi mode must be used to protect the lines from pressure spikes. The next one is not clear cut; there are many opinions on it, and it depends on the controls of the attack engine, the operator, and the source engine. The source engine of a relay can effectively operate in psi mode with the correct conditions. If both engines have pressure governors, they will both make the required adjustments to keep the proper system pressure. The original fear was the two controllers would start to fight each other. In the experiments I have done, this is not the case. The supply engine sets its discharge pressure to supply 20 psig at the attack engine inlet. As the demand for water goes up on the attack engine, the supply engine discharge will drop, and the governor picks up pressure and flow. Now the pressure at the intake will be lower than original (only slightly with LDH) because the higher flow produces greater friction loss, and the supply engine is maintaining the same discharge pressure. The attack engine governor will make the required adjustment to the pressure on the attack lines. When the attack engine requires less water, the supply engine will throttle down as the back pressure increases. There may be some issues with both engines in psi mode when initiating water supply to the attack engine. The potential for a water hammer exists when opening the intake valve on the attack engine. The surge of water causes the supply engine to throttle up because of the increased flow dropping the pressure down. When the water fills the pump, the increase in pressure will cause the supply engine to back down. The hammer will cause the attack engine to throttle up as the water hits the impeller, slows it, and reduces the discharge pressure. Keeping the supply engine in rpm until after the intake is opened on the attack engine will help to smooth the transition. If all the air is not bled from the supply lines, the slug of air will cause a momentary drop in discharge pressure, potentially forcing the governor into a low/ no water mode until the air passes. If the attack engine is analog, and the supply has the pressure governor, it is best to be in rpm at the source. The operator of the analog engine will have to make an extra adjustment after the supply engine makes its adjustment. Keeping the discharge pressure constant to the attack engine minimizes the work effort to maintain flow to the handlines.

Finally, psi mode is a great tool for mobile water supply apparatus (MWSA) fill sites. Even operating from draft, psi can be used once draft is obtained. After securing a water supply, set the pressure governor at 80 to 90 psig to be below the 100-psig limit on polytank fill rates, and let the operator help with filling MWSAs.

## TANK-TO-PUMP IMPLICATIONS

Whether to leave the tank-to-pump valve open or closed after securing a water supply has become a topic of great discussion. The best answer is, "It depends." Is the engine analog or digital? If the tank-to- pump is left open and there is a failure in the supply system, the inlet pressure will become the head pressure of the tank, in turn dropping the discharge pressure by the amount of the original supply pressure. Tank water will take the path of least resistance and flow out the severed intake hose, if that is the failure point-all because the throttle cannot react to the change in the system. With analog engines, it is best to keep the tank-to-pump closed once a water supply is secured. When the same failure happens with a pressure governor in psi mode, the ECU will sense the drop in discharge pressure. The rpm increases to maintain pressure. Not only does this keep water flowing to the hoselines, the sustained flow helps keep a lower pressure at the pump eye to prevent more of the water from taking the path of least resistance. The rise in the rpm should get the attention of the operator, if not at the pump panel, and signal the need for his immediate return. The operator can then notify command of the situation and take actions to rectify the issue.

## USING RPM MODE

This mode acts like a traditional analog throttle requiring operator interaction. This mode overrides the automatic interlocks and algorithms of psi mode with one exception: pressure spike control. Many people do not know the governor will prevent a significant pressure spike while in rpm mode. NFPA 1900 does not differentiate between rpm and psi mode in section 13.10.4.1, requiring the discharge pressure control to limit spikes in discharge pressure to 30 psig. Figure 2 is set up like Figure 1, but this time the governor is in rpm mode. Notice pressure spikes are limited but do not automatically return the rpm to develop the original discharge pressure; the operator must intervene.

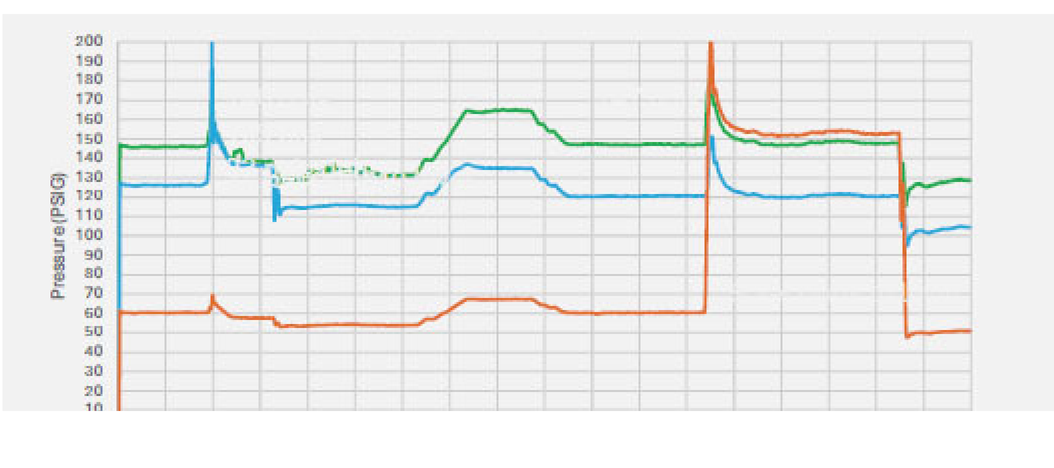



Figure 2: An rpm pressure response (FRC Pump Boss 400).

## WHEN TO USE RPM

When pulling prime for draft, a pressure governor should be in rpm mode. This allows the throttle to be increased with zero pressure on the pump discharge. In psi mode, the throttle will not increase with zero pressure on the discharge, as the governor thinks there is no water available. During the initial stages of drafting, it is normal to get some large pressure swings as pockets of air move through the pump. Being in rpm mode allows the entrained air to work its way through the system without the engine rpm going up and down, which increases the risk of losing prime or the engine going to idle. Once a solid draft is established with water flowing, it is possible to switch to psi mode. This is normally done by pressing the psimode button from 1 to 3 seconds, depending on the governor model. Operating in psi mode from draft requires having a recirculation line going back into the source to maintain prime and provide a flow for the governor to manage. Of course, there are exceptions to every rule. If prime is established before increasing the throttle, it is possible to draft in psi mode from the beginning. The key is producing discharge pressure over 45 psig before increasing the throttle.

When constructing a long or complex relay system, the engines in the middle of the system should be in rpm once all the pressures are set. The supply engine pressure increases and decreases based on the needed fire flow, and the other engines add their set amount of pressure to the system. As the source engine pressure goes up and down, the discharge pressure of subsequent engines will do the same. Relays with analog engines are set the same way: The engines in the middle do not vary their throttle unless necessary, and the source engine sets the pace. Now the engines in the middle will increase pressure if the source engine is tapped out, with water still available at the source, and the attack engine needs more pressure. The engine closest to the source will increase first until it is maxed, then it is the next engine. When using complex relays, it is a good practice to put a water supply officer in place and have engines operate on a separate channel.

Supplying standpipes is the operator’s choice, depending on SOGs and the ability to communicate with the control firefighter. Normally, standpipe operations have a gate valve with a gauge on the discharge with a firefighter controlling the pressure. The engine pumps the

FDC at 150 psig, or the stated SOG pressure. When the attack crew opens the line, the control firefighter adjusts the gate valve to obtain the needed pressure at the discharge. With the engine in rpm, it has no response to these actions, and the pump discharge pressure will drop. If the operator decides to maintain the master discharge at 150 psig, the increase in discharge pressure will cause a matching increase in the pressure at the standpipe control point. The control firefighter will then have to make the appropriate adjustments to prevent overpumping the attack line. It is possible for the operator to do nothing and run with the lower discharge pressure as long as it does not negatively impact operations. In psi mode, when the line is opened and the pressure set atthe standpipe, the engine rpm increase to maintain the master discharge pressure at 150 psig. As the control firefighter adjusts the standpipe outlet to the appropriate standpipe discharge pressure, the governor will make adjustments as well. While there may be a little back and forth with the governor, it adjusts faster than the standpipe discharge is changed, and the variation in control is only slightly noticed.

The pressure governor is only a tool. It can make a good pump operator even more proficient and productive on the fireground, or a mediocre operator can cover deficiency in understanding operations by hitting the preset and letting the governor do the work. The key with a pressure governor is not letting it enable mediocrity for pump operators. Even with the preset button, we must ensure our operators understand hydraulics and the how and why of pump operation. This is a big reason many seasoned pump operators did not receive governors with open arms: the potential for the erosion of the craft. Again, the governor is just a tool. We are responsible for holding ourselves and other operators to the high standards the position has traditionally had.

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