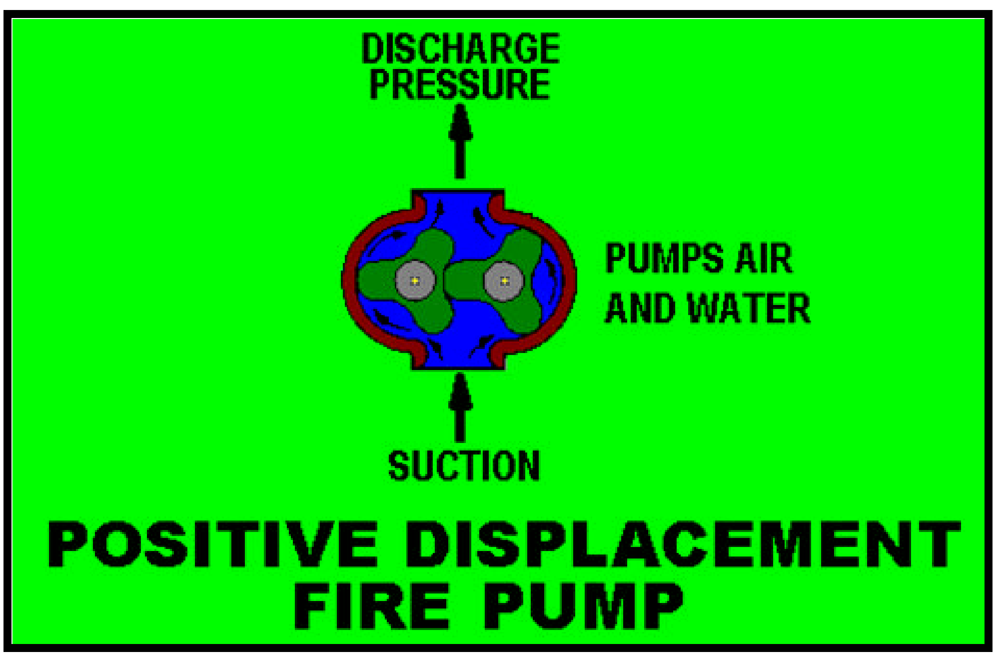
TIME TO PRIME, by Rich Teske

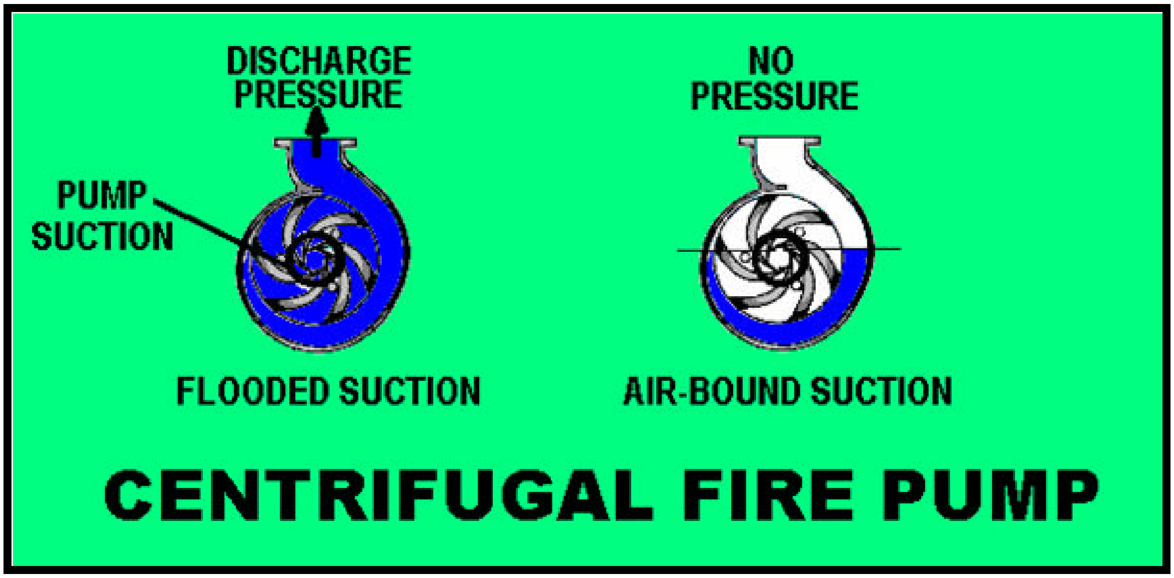
Fire pump design on motorized vehicles experienced a radical change starting as early as 1912. That was when the basic fire pump designs started to change over from the positive displacement type to centrifugal pumps. This was a very gradual transition and typically started with the larger city/municipal departments with pressurized hydrant systems switching over first. Departments in the rural areas where more drafting occurred generally stuck with the positive displacement pumps a little longer, for reasons that will be explained below. The two truck builders that pioneered the use of centrifugal pumps were Seagrave and VanPelt. By the end of World War II, the centrifugal pump dominated the fire service. But, centrifugal fire pumps must have a suction completely flooded with water in order to produce pressure or they must use a PRIMER to completely remove the air from the pump suction by providing enough vacuum to bring water into the suction hoses and inlet of the fire pump.

Positive displacement fire pumps were truly “self-priming”. The positive displacement fire pumps initially utilized were typically piston pumps or rotary pumps. A self-priming pump has the ability to pump both air and water, so all that must be done is to attach a suction line to a water source, engage the pump, open a discharge, and wait for the all the air to move through the pump and the water to follow. This was the earliest, least complicated, and most reliable way to apply a fire stream when starting from a non-pressurized water source.



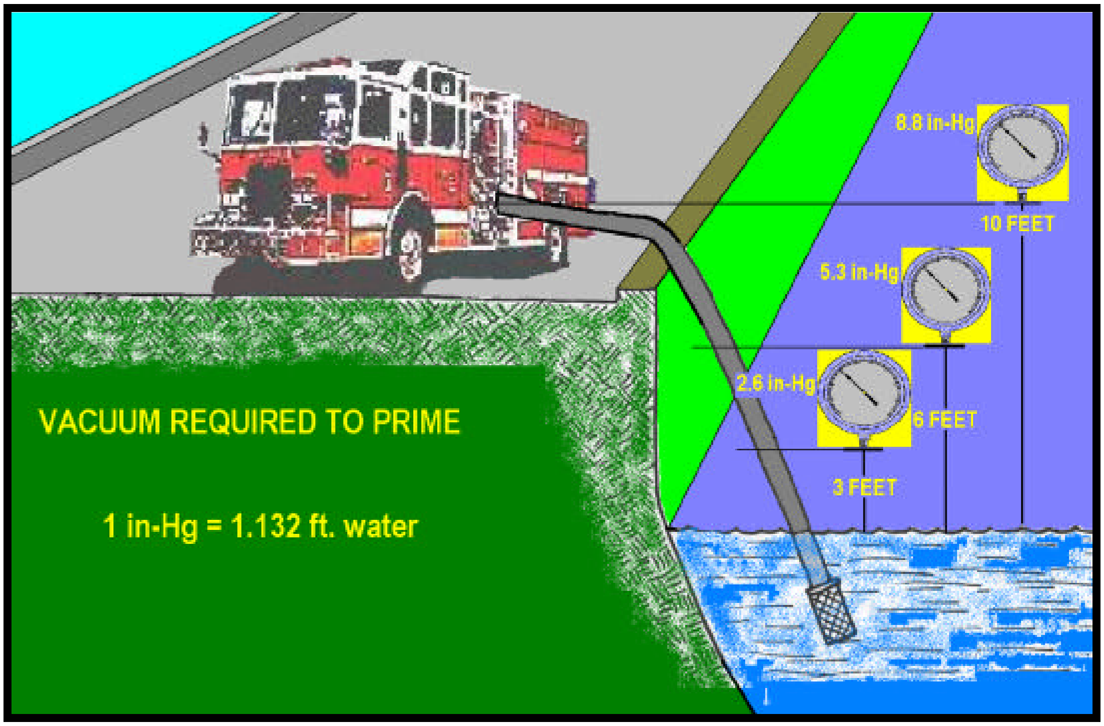
There were however many good reasons for moving away from positive displacement pumps and toward the centrifugal fire pump design. The centrifugal pump is a much simpler design with fewer moving parts. The centrifugal pump is much easier to manufacture and does not require as exacting part tolerances. All these advantages make the centrifugal fire pump easier to maintain and keep in service. But, the most important advantage of centrifugal fire pumps is that they are capable of much higher flows for a given pump size and weight. The biggest rotary or piston pump (and they were huge) could not flow more than about 1300-GPM. Today centrifugal pump ratings average 1500-GPM and can be as high as 3500-GPM on industrial pumpers.

So, what are the negatives about centrifugal fire pumps? The first downside, already mentioned is the need for a second pump (the priming pump) that has to be used to create enough vacuum to let atmospheric pressure push the air out of the suction hoses and pump by passing through the primer. In addition, centrifugal pumps have very little tolerance for air when pumping. Centrifugal pumps are so named because they rely on centrifugal force to sling the water from the impeller suction to the impeller outlet; this high velocity water is then turned into pressure in the pump casing. Because air (at sea level) is 784 times lighter than water, the centrifugal pump impeller is not large enough and cannot spin fast enough to give the relatively lightweight air any significant velocity, so the air just remains in the pump suction, and NO pressure can be generated. That is also why you can lose prime if you get a major suction leak when drafting, or have a large air bubble find its way to the eye of the centrifugal impeller under any suction condition. Whenever that happens, the discharge pressure can drop-off completely, and the people at the other end of the hose will be put in harm's way.

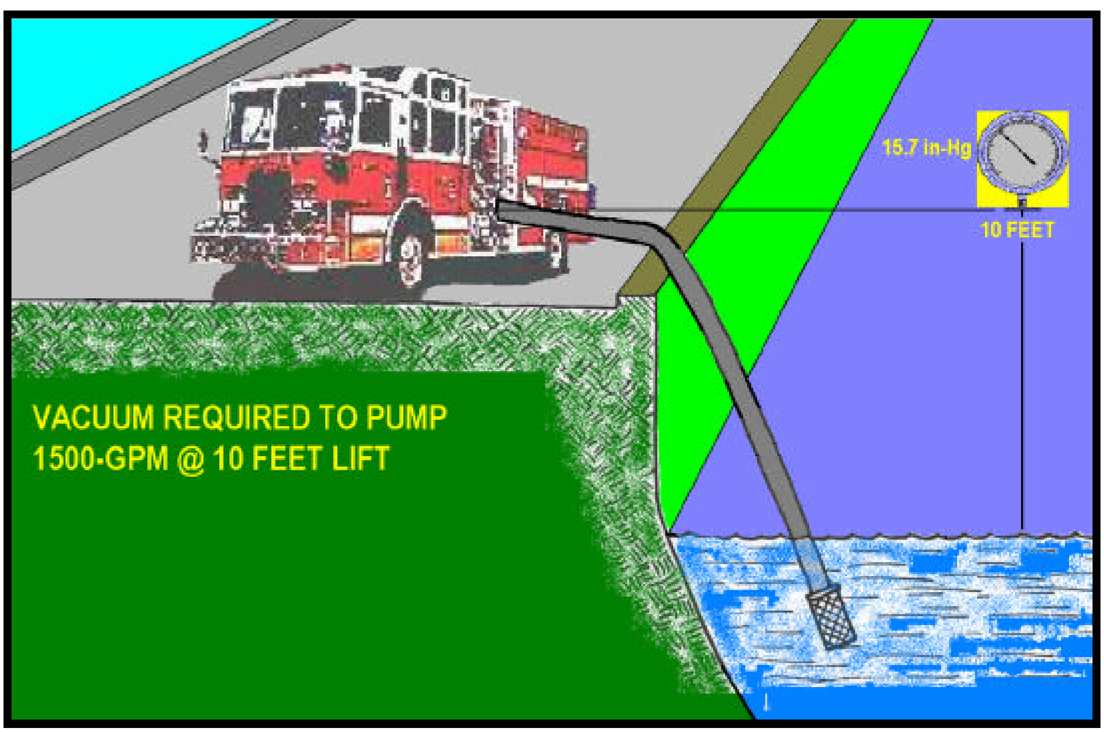


The job that the primer must accomplish is to develop enough vacuum to remove all the air from the pump and suction hose and lift the water to completely fill the suction of the pump when it is at an elevation above of the water source. It must also do this within the times specified in the NFPA 1901 standard. The standard allows 30 seconds to prime a 1250-GPM and smaller pump and 45 seconds for a 1500-GPM or larger pump. An additional 15 seconds is allowed if the pump has additional suction volume such as a front or rear suction connection.

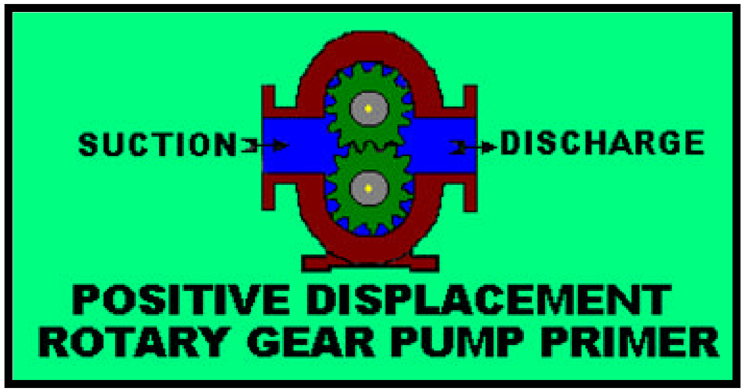
As shown below, the vacuum required to lift the water to a given height (PRIME) can be read on the compound gage. By converting the reading on the compound gage (in inches of mercury) to feet of water, you can tell exactly how far up the hose the water has risen while you are priming. You can also see how high the pump suction is above the water level, by watching the compound gage and reading the vacuum just as water starts to discharge from the primer. So when priming, the maximum vacuum required is equal to only the height that the water must be raised.



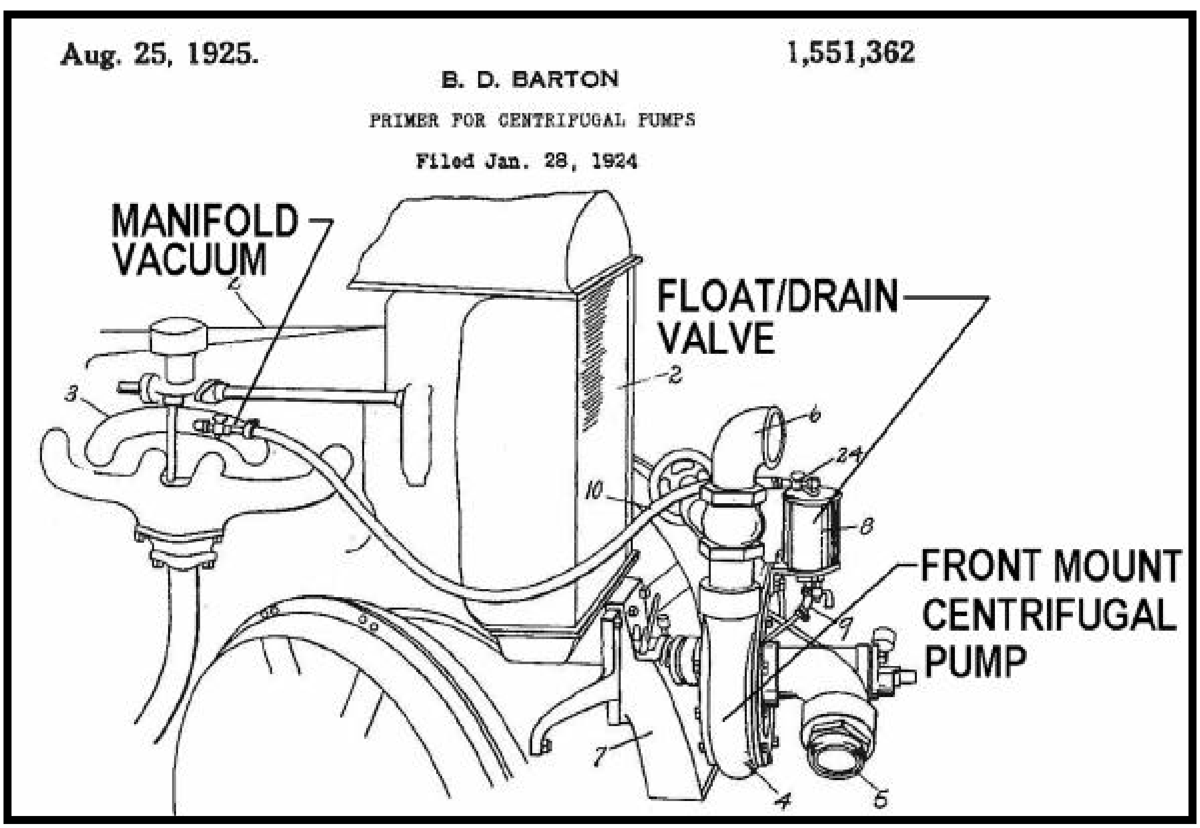
When the priming operation is complete, the centrifugal fire pump will begin to pump water and build discharge pressure. When pumping water, the centrifugal pump becomes an excellent vacuum pump and must now pull a higher vacuum on the suction side of the pump. The higher vacuum is a combination of the height that the water is being lifted, plus the friction losses in the strainer and suction hoses due to the water flow, plus the velocity head-which is the pressure energy required to move the water at any given flow. The friction losses and velocity head increase exponentially as the flow through the pump increases. So the vacuum that the water pump must produce when flowing water is always more than the vacuum the primer must produce to prime.



Many approaches to priming have been taken over the years, but almost all of them rely on a small positive displacement pump in addition to the centrifugal water pump. The earliest primers were small rotary gear pumps, typically driven from the transfer case or back of the fire pump shaft. These primers utilized a small tank of motor oil, to lubricate and seal the passages of the rotary gear pump when it was running dry and evacuating air. The priming pump would be engaged either through a clutch, or as an alternative in the transfer case shift choices, which had positions for pump, prime, neutral, or road.



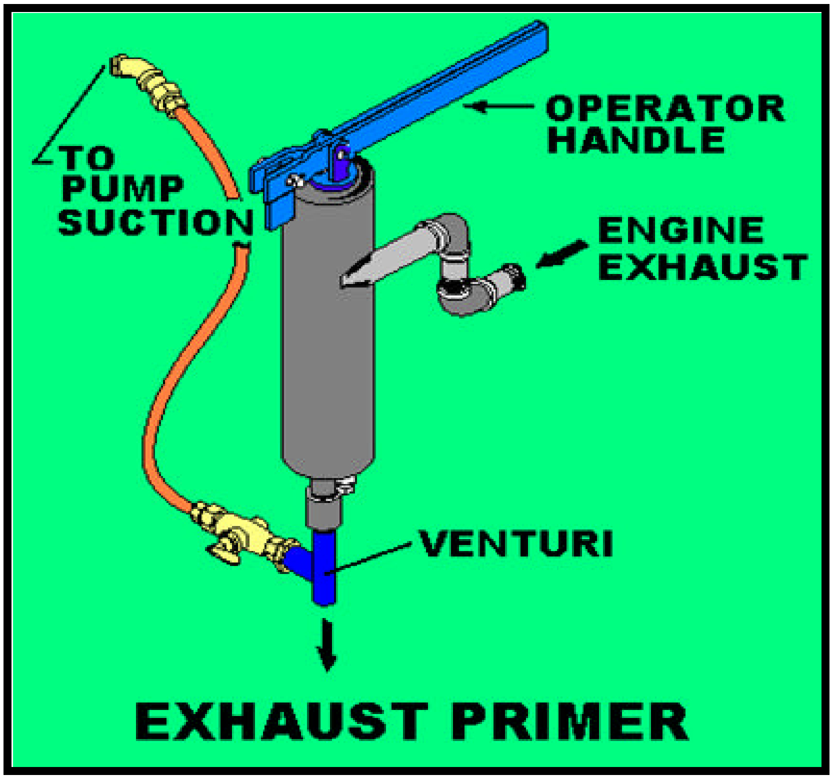
B. D. Barton patented an interesting alternative to the positive displacement primer in 1925. His approach used the gasoline engine manifold vacuum to prime the fire pump. This worked well, and completely eliminated the need for an additional priming pump. It did however require an elaborate float valve and drain system to be sure that water was never pulled into the engine. This system was utilized on trucks with Barton American pumps built by the P.E. VanPelt Company. The diesel engines powering today's vehicles do not have manifold vacuum.



As technology changed, so did the available choices for means to power the primer. In the early 1960s the fire truck electrical systems started to grow and larger alternators became available. This enabled the use of electrically driven primers, which are still popular today. Initially, the primers were the same small rotary gear pumps, now connected to an electric starter motor. The next priming pump design used was an electric motor driven rotary vane type which has sliding vanes spinning on a rotor that is eccentrically mounted in a circular housing. The original rotary vane designs also used oil to lubricate and help seal the spaces between the housing and primer vanes during the dry running portion of the priming cycle. These primer motors can draw currents as high as 250 to 300-amperes, and often create low voltage problems for electronic devices.

Today, most primer manufacturers offer an oil-free primer, due to the environmental concerns of discharging any oil on the ground. The oil-free primer also removes the need for mounting an oil tank, and the need to have an access door for the tank, and saves on the routine maintenance to keep the tank filled. Without the oil to lubricate and seal the inside of the primer, the oil-free primers are a little less efficient and develop maximum vacuums slightly less than their oiled predecessors. As with all "dry-lubricated" devices the friction must be reduced through the use of special materials. For rotary vane primers this means the vanes must be loaded with substances like; carbon, graphite, or Teflon. The lubrication then comes from a small amount of these materials *wearing away* as they rotate around the housing and slide in and out of the slots in the rotor to keep the heat of friction down to a tolerable value. Without the oil lubricant, the eventual result is wear to the vanes and housing. The time between vane and housing replacements will be directly proportional to the primer's usage.

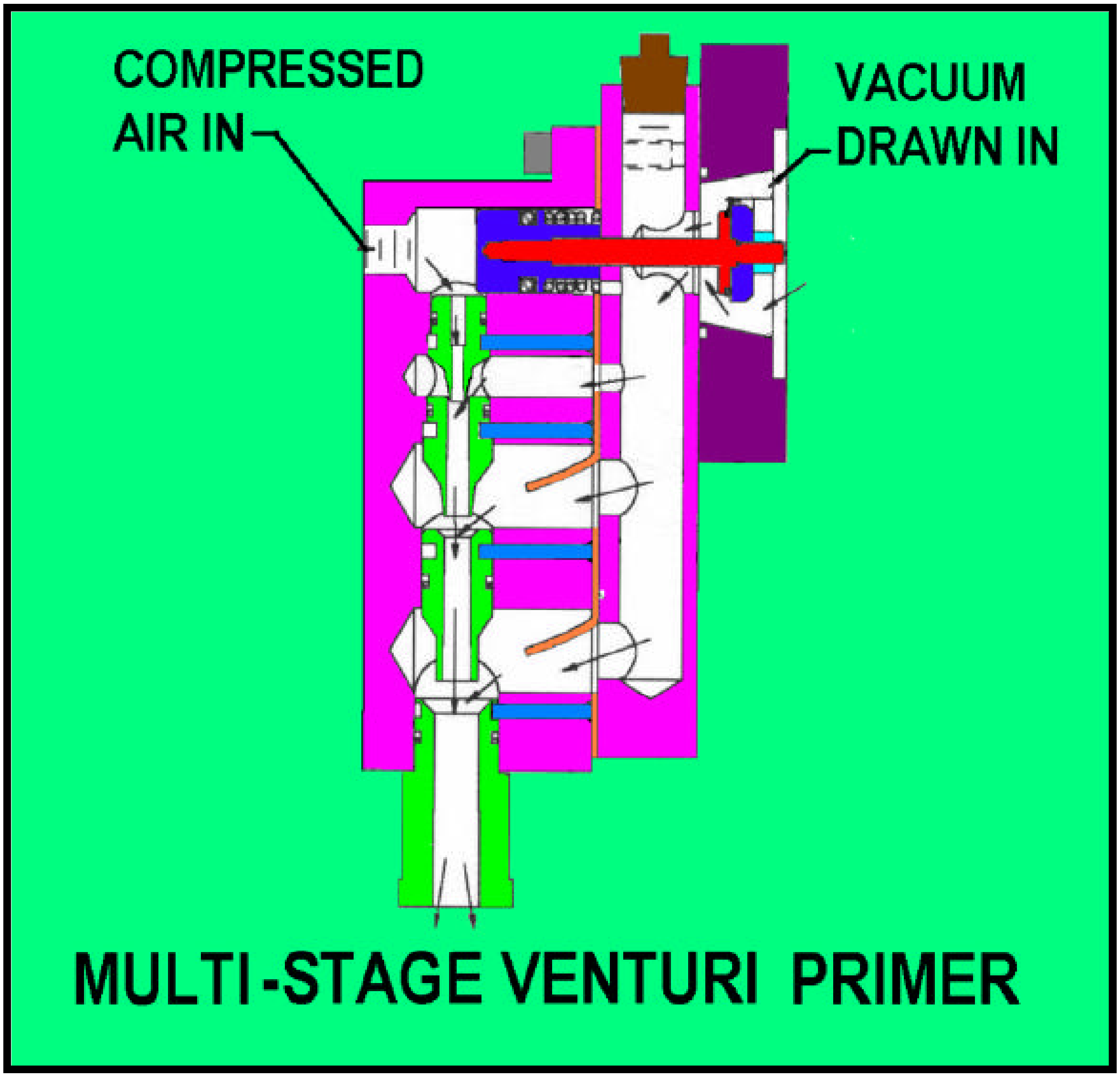
Meanwhile, portable pumps (also centrifugal type) were using the gasoline engine's exhaust, to power a small venturi that would then pull a vacuum on the suction of the pump. The "exhaust" primer is still the standard offering with today's engine driven portables. The design does require that the hot exhaust gases be forced through a heat resistant venturi, and then be switched back to discharging to the atmosphere when the priming cycle is complete. This is generally accomplished with a steel tank that replaces the regular muffler and has the venturi mounted at the bottom. A metal "bottle capper" is located at the top that is manually closed-off to prime and opened again when the priming cycle is completed. The engine usually must be run at maximum speed in order to create enough exhaust backpressure to properly drive the venturi primer. Care must be taken not to touch the hot exhaust components and to close the valve between the pump suction and venturi after the priming is complete.



Improved vehicle technology continues to evolve and today an extremely simple and highly reliable power source for a primer is available on fire trucks, AIR PRESSURE. The use of air brakes on fire trucks began in the 1940s, and in the 1980s gained increased popularity and reliability, due in part to the deregulation of the trucking industry, which allowed heavier trucks on Federal highways. Today air brakes are standard on 99% of all over the road trucks produced. The air brake system uses an engine driven compressor, a pressure governor, and series of air tanks to keep the air pressure between 90 and 125-psig at all times. The air compressors are sized to meet the FMVSS-121 (Federal Motor Vehicle Safety Standards) braking requirements. These requirements generally translate to a minimum compressor size of 13.2 –CFM on a fire truck chassis. When the truck is parked at a fire scene, there is no air required for braking. So, using the air power that is readily available from the engine compressor to drive other devices is as easy as running an air line, and simply makes good sense.

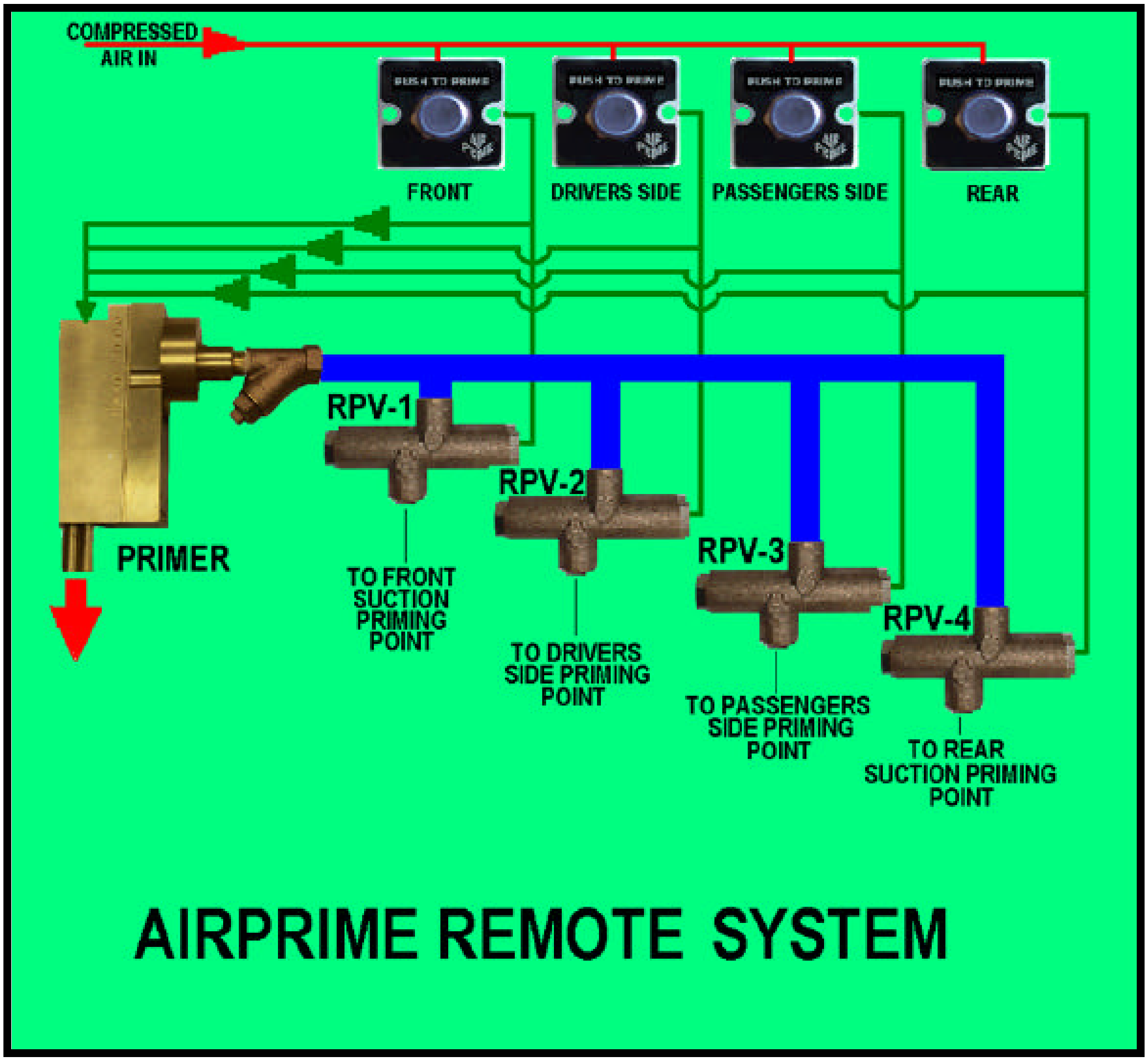
The AirPrime™ is a new primer design that uses air from the truck's compressor to power a multi-stage venturi to prime the fire pump. The highly efficient venturi primer has been carefully designed to exactly match the air pressure and flows available from the standard size vehicle air compressors. Trident Emergency Products, LLC, developed this primer in 2001. The patent-pending AirPrime, solves many of the problems associated with the prior primer designs discussed in this article. It is lightweight and compact, has no moving parts to wear, uses no lubricants (only water and air are discharged), consumes no electrical power, and is self-draining. Today these primers are proving themselves in service on fire trucks across the country.

As shown below, the AirPrime™ operates when compressed air flows in. This is accomplished by depressing a simple push-button on the operator's panel. The air pressure both opens the inlet valve and powers the multi-stage venturi to create a vacuum at the inlet. The primer is mounted vertically and discharges out of the bottom.



There have been some fairly recent changes in fire truck plumbing and fire scene operation that can have an effect on how best to Prime. The most significant change is the increased use of Large Diameter Hose (LDH) that can be connected to gated side, gated front or gated rear suctions. A typical rural scenario would be arriving at a fire scene, and immediately running an 1-1/2 " cross-lay, while pumping from the onboard water tank. As the fire develops, a tanker arrives, a folding-tank is set up and filled with the first load of water. A suction hose from the passenger side gated LDH inlet is dropped into the folding-tank. But how do you prime the line to the folding-tank? If you just open the gated suction on the passenger side, you will surely lose prime and pressure at the nozzle end of the cross-lay. If the truck is equipped with a primer selector valve (a 3-way valve is often used) that has a prime location on the UP-stream side of the passenger side suction valve, you are in business, just move the selector valve and start the primer. But what if the truck has multiple suction locations; like front, rear, or either side, where the most convenient one could be used for any given fire scene? You could have a series of primer selector valves for each location, but that gets confusing. You could have multiple primers (one for each location) but that gets expensive. Until now there has not been a straightforward way or product to handle this problem.

The AirPrime™ system has an optional *Remote Priming Valve* (RPV) that is a simple air operated shuttle. When air pressure is applied the shuttle valve opens, and when air pressure is removed, the valve closes. This allows for one primer operating on multiple priming locations. There is one pushbutton on the operator's panel, marked for each priming location. Air line connections, and vacuum lines are required as depicted in the system schematic below.



Many departments have Standard Operating Procedures on when to prime the pump and when not to prime the pump. Given the problems that can arise if all the air is NOT completely removed from the suction hoses and pump passages, it is very simple to ALWAYS engage the primer before charging any hose. In addition, when switching between water sources, there is never any harm in engaging the primer until a steady flow of water is apparent. Most gated intake valves have a bleeder valve to let all the air out of a positive pressure suction hose, before the valve is opened when pumping from a hydrant or in a relay operation. In long LDH hose lays there can be a huge amount of air to evacuate. Venting all the air through the bleeder valve is critical and will help to keep the discharge pressure from falling-off due to air in the impeller when the intake valve is opened. For pumps equipped to prime from multiple locations, engaging the primer for each gated intake point used is another way to vent the air. So, if in doubt about the right *time to prime* the proper answer is EVERYTIME.

About the Author:

Rich Teske is a registered Professional Engineer. Teske formerly worked for ITT Domestic Pump Division as an R&D Engineer, and worked seventeen years for Hale Fire Pump Company where he held the positions of Manager of R&D and Vice-President of Engineering. He has served on the NFPA 1901 Fire Apparatus committee, and continues to serve on various NFPA task teams. He is currently the Vice-President of Sales and Administration for Trident Emergency Products LLC. Teske is named as inventor/co inventor on seven US patents for fire-fighting related products.