Improving Pump Performance To Increase Profitability of Retail Fuel Sales

A White Paper

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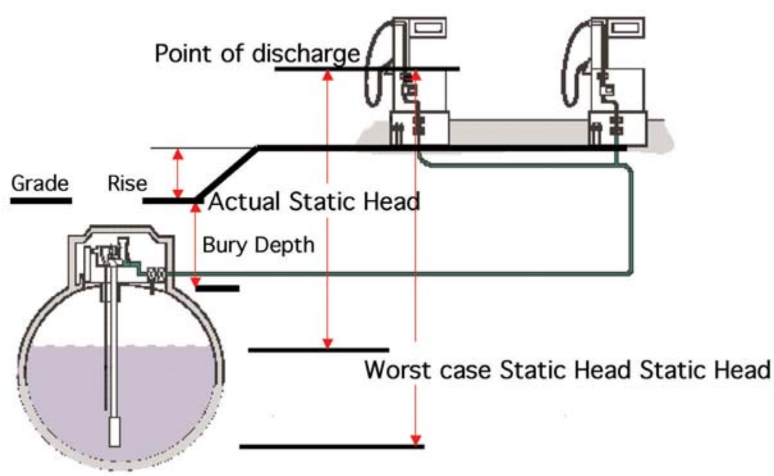
October 2004

Pump performance plays critical role in delivering high profitability in retail gasoline sales. The right pump can maintain flow rates at high levels during peak periods in order to move customers through the station quickly and avoid frustration, which could cause them to cut purchases short. Just as important, pumps that deliver consistent, reliable performance will help to prevent shutdowns that could cost thousands of dollars in revenue per hour at a high volume site. Pumping performance also affects profitability in subtler ways, such as by impacting electrical power consumption. This article will explain the key performance factors involved in pumping gasoline, compare and contrast the different pumps that are available, and provide information that will help you maximize profits by optimizing pump performance.

Challenge of delivering flow

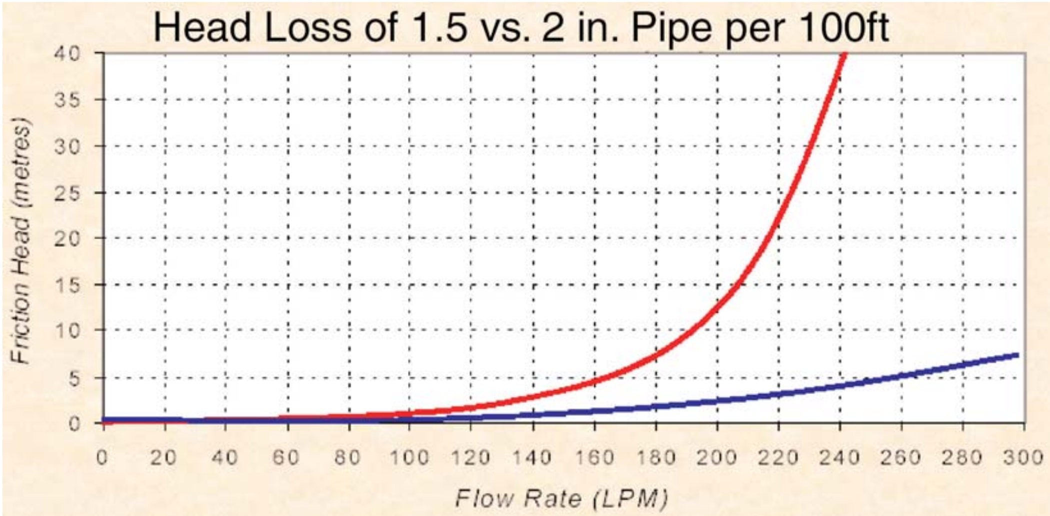
First, let's consider the challenge of providing flow consistently at or near the maximum permitted levels very reliably and at a minimum cost.



Static flow in a retail fueling system

First of all, the pump must overcome the static head loss caused by the height a fluid must be lifted from tank to nozzle. This is the distance from the product in the tank to the point of discharge into a car tank or loading rack. In a submersible pumping system the pump must be able to perform under the worst case scenario of a near empty tank. In bottom loading applications, the highest point in the tanker is taken as the point of discharge. The static head can vary with the tank level, typically resulting in a difference of 7 to 11 feet or about 2 to 3 psi in the pressure of the pump. It's important to note that the effect of the static head does not vary with the flow rate.

Dynamic head, on the other hand, is the resistance of fueling system components to movement of product from the tank to the nozzle. The resistance profile of each component causes a decrease in head or pressure as the fluid passes through. Every component that the product passes through decreases the pressure until the pressure is near zero at the point of discharge. As the flow rate rises, the dynamic head resistance increases at an exponential rate. So twice the flow generates four times the resistance and requires four times the pressure to move the gasoline at a given flow rate. The components that create dynamic flow resistance in a retail fueling system include the piping, accessories such as leak detectors and safety values, and the dispenser and hanging hardware such as the nozzles, hoses, fittings and swivels.



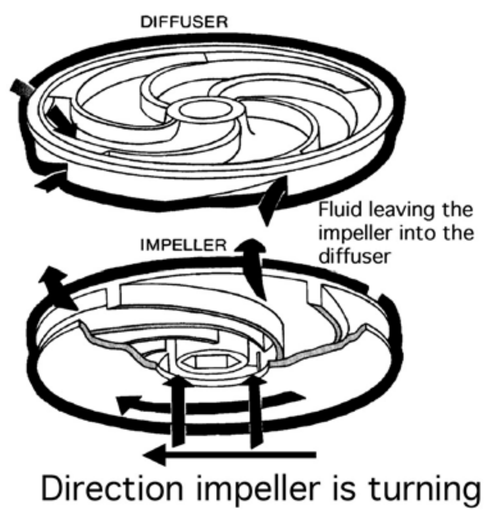
Dynamic head losses of components

Normally, the hanging hardware generates about 2/3 of the pressure drop through the flow system and the dispenser produces about 1/3 of the pressure loss.

Operation of centrifugal pumps

The vast majority of pumps used in retail fueling systems are centrifugal pumps which create pressure to overcome static and dynamic head by accelerating fluid from the center of a spinning impeller to the outer perimeter. They typically have several stages, each of which is primarily made up of three parts. The impeller is spun by the motor while fluid enters its central eye and is accelerated to the perimeter where it then enters the diffuser. The diffuser converts the velocity of the fluid to pressure then directs fluid, into the eye of the next stage's impeller. The diffuser plate, along with the diffuser, enclose the impeller to form each stage. About 14-15 psi is created in each stage in 60 Hz pumps while 50 Hz pumps typically generate 9-10 psi per stage.

The performance of a pump is typically described by performance curves that show pressure in the form of head on the left or Y axis and flow rate on the bottom axis. The Y axis shows the pressure at which the pump can produce the flow on the X axis. When the pump is running it



How a centrifugal pump works

supplies the flow it can against the pressure it experiences in the flow system. Changes in upstream components to reduce frictional pressure will improve overall system flow by reducing the amount of pressure the pump must overcome to deliver flow at the nozzle. As the pressure requirement decreases, the amount of flow a pump can deliver increases. With a lot of pressure against the hose there is very little flow. As the pressure against the hose is relaxed, the flow increases. The flow capacity of a pump can be increased by increasing its speed by using a higher speed motor, increasing its diameter, or increasing the width of its vanes.

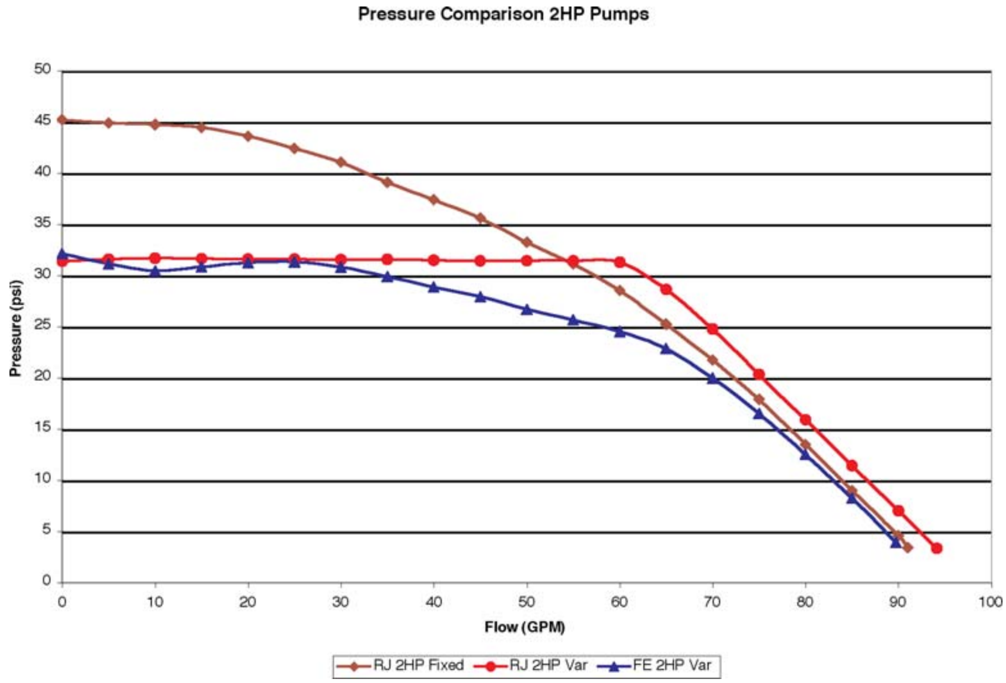
Fixed and variable speed pumps

Fixed speed pumps are the default choice for retail fueling systems. A 2-hp fixed speed pump typically operates at a pressure of about 45 psi when delivering below 20 gpm flow. Some type of flow limiter may be needed to meet Environmental Protection Agency regulations that mandate a 10 gpm flow rate restriction to avoid overtaxing the onboard carbon canisters used to capture vapors. Both mechanical and software based flow limiters are available that control flow at the nozzle. This approach provides maximum flow for every customer. At a typical cost of $1500, fixed speed pumps are economical to purchase. They are economical to install, because they do not require shielded cable, and have proven to be less expensive to maintain.

Variable speed pumps have multiple programmable set points that allow them to maintain a single output pressure over a wide range of flow rates. The motor speeds up or slows down in reaction to the varying system flow requirements. The variable speed pump delivers fuel at a relatively constant pressure until it reaches a point where the load is too great and the pressure begins to drop rapidly just like a fixed speed pump. Variable speed pumps normally do not require flow limiters because they deliver gasoline at a lower pressure at low demand. Controlling flow at the pump is, however, less accurate than at the dispenser because you can only set pressure to provide a given flow at one particular dispenser while other dispensers may deliver higher or lower flow depending on branching and pressure drops within the distribution system. Variable speed pumps typically cost $2200 and the variable speed controller costs around $820 in case it needs to be replaced.

The move towards variable speed pumps raises concerns about electromagnetic interference (EMI), interference by electromagnetic signals that can cause reduced data integrity and increased error rates on transmission channels in wireless equipment. The variable speed motor controller controls the speed of the pump by generating alternating current at the frequency that corresponds to the desired motor speed. The controller rapidly switches current, which can produce both conducted and radiated emissions as an unwanted byproduct. These emissions could potentially interfere with other electrical equipment operating at the station.

While industrial controllers such as variable speed pump controls are not required to obtain FCC certification, Veeder-Root has proactively addressed this concern by designing the Red Jacket variable speed pump to minimize EMI and obtaining FCC certification. Veeder Root engineers carefully designed the unit to keep noise levels substantially below requirements for consumer products. As a result, the pump was awarded FCC Class A certification for radiated emissions in the 30 MHz to 1000 MHz frequency range and conducted emissions in the 150 KHz to 30 MHz range.

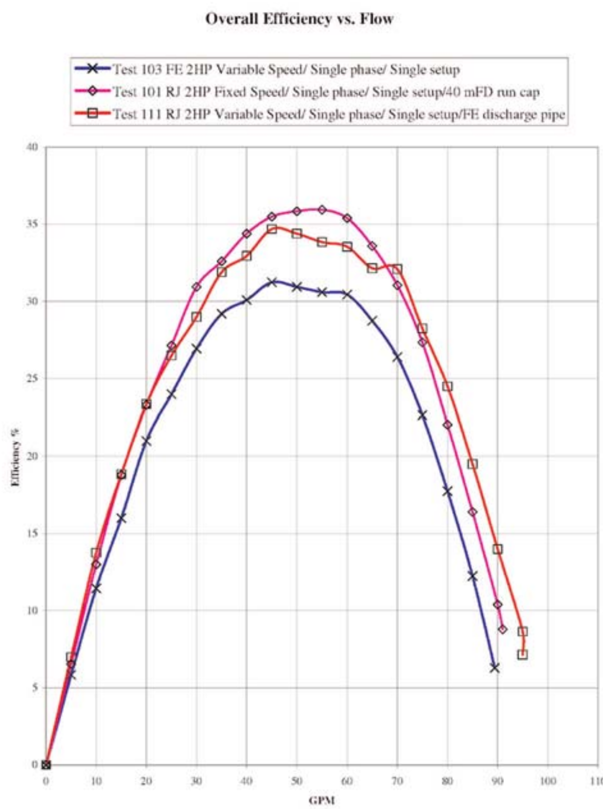


Pressure curves for 2 hp pumps

Flow and electrical efficiency comparisons

While all variable speed pumps follow these basic principles there are some important differences between the different models that are available. The Veeder-Root Red Jacket P200U20-2 variable speed 2 hp pump and Veeder-Root Red Jacket fixed speed 2-hp pump were tested along with the FE Petro IST MagVFC 2 hp variable speed pump by Jairus D. Flora, Ph.D., consulting statistician. Both variable speed pumps were set to an operating pressure of 30 psi. The graph above shows the pressure achieved by all three 2 hp pumps as flow rate increases. The fixed speed pump operates a higher pressures in the lower flow range and behaves in a similar way to the variable speed pumps as flow rate increases. The two variable speed pumps provide a similar pressure of just over 30 psi in the flow range from 0 to 30 gpm. But the Red Jacket pump maintains pressure better as the flow increases. The difference becomes particularly noticeable in the range between 30 to 70 gpm. The Red Jacket maintains the set pressure up to 60 gpm while the FE Petro pump pressure dropped below the set pressure when the flow reached 30 gpm. This substantial difference in performance can have a major impact on fuel delivery. For example, the 2 hp Red Jacket pump will supply about 10 cars fueling simultaneously at an average of 7 gpm while the FE Petro pump can supply only 8 cars at the same rate.

The testing also demonstrated that both the Red Jacket fixed speed and variable speed pumps are relatively equal and superior to the FE Petro. 2 hp variable speed pumps in energy efficiency. When the pumps were set at 25 psi in the test setup, the 2 hp fixed speed pump delivered 65.4 gpm or 28.4 gpm per watt. The Red Jacket variable speed pump delivered 26.8 gpm per watt while the FE Petro variable speed pump delivered 25.6 gpm per watt.



Flow and electrical efficiency

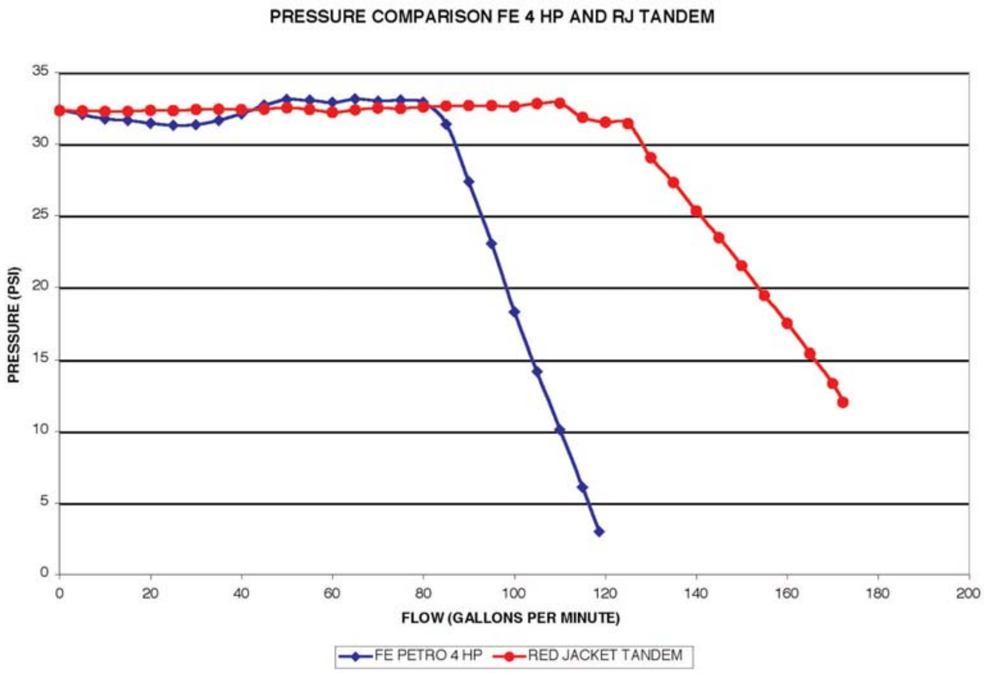
Providing high volume fuel delivery

Sometimes 2 hp motors are not sufficient to provide consistent fuel delivery performance for some very high volume stations. At a flow of 60 gpm with either 2 hp variable or fixed speed pumps, pressure drops below 30 psi, which means that customers will see substantially slower fuel flow. Customers are usually unhappy when they see the meter running slowly because it means they have to spend more time at the pump. Station owners and managers also prefer high throughput because it means higher revenues.

The three options to provide fast fuel delivery to more than 10 dispensers are 1) using a 4 horsepower variable speed pump or 2) combining two 2 hp fixed speed pumps in tandem or 3) combining two 2 hp variable speed pumps in tandem. Two tandem 2 hp pumps are typically configured in a slave and master configuration so that only one pump runs until the demand becomes so large that it cannot maintain the set pressure. Then the second pump is activated and maintains the pressure until the maximum for the tandem configuration is reached. The two pumps can be used in a single tank or in two separate tanks.

The 4 hp variable speed pump, on the other hand, is configured much like the 2 hp pump but with a larger motor. While you might expect performance to be similar for these two alternatives, actually either of the two tandem configurations provide a substantially higher flow rate. The reason is that nearly all gasoline tanks have a four-inch diameter opening into which the pump is inserted. Designing the pump within a four-inch diameter packaging constraint creates a constriction where the product comes up the inlet and passes between the motor and outer shell of the pump. This constriction point means that doubling the motor's power produces considerably less than twice the flow rate.

Let's look at the test results. The figure below shows the pressure delivered by the FE Petro 4 hp variable speed pump and the Red Jacket tandem configuration. Note that the tandem configuration maintains operating pressure at a considerably higher flow rate than the single 4 hp pump. The Red Jacket tandem configuration produced a flow of 141 gpm at 25 psi compared to the FE Petro flow of 93 gpm at 25 psi. When both pumps were



Pressure curves for 4 hp pump vs. 2 hp tandem

compared at a flow rate of 90 gpm, the Red Jacket tandem configuration also used less power than the FE Petro 4 hp pump. The tandem configuration also offers the advantage that if a maintenance problem stops one pump from operating, the other is automatically programmed to take over and run by itself. The tandem configuration costs about $1000 more, however, this extra cost is miniscule considering the ability of the pump to handle 7 additional customers simultaneously means that it can easily pay back its extra cost.

The fuel delivery and power consumption improvements provided by tandem variable speed pumps relative to 4 horsepower pumps were demonstrated recently at two high-volume stations in which each pump delivers in the neighborhood of 300,000 gallons per month. When the Red Jacket tandem 2 hp variable speed pumps were temporarily replaced with single 4 hp variable speed pumps, average flow rates decreased from 9 gpm to 7 gpm, reducing flow by over 20% and increasing filling time for the average customer by 22%. During rush hours, when the station was typically gridlocked, revenues were lowered by about 15%. The stations also saw 5% greater energy costs. Needless to say, the station owner was anxious to return to the tandem pumping configuration. These improvements demonstrate how paying close attention to pump performance can increase retail fueling profitability.