Pump ED 101

Understanding the Impact of Velocity Head

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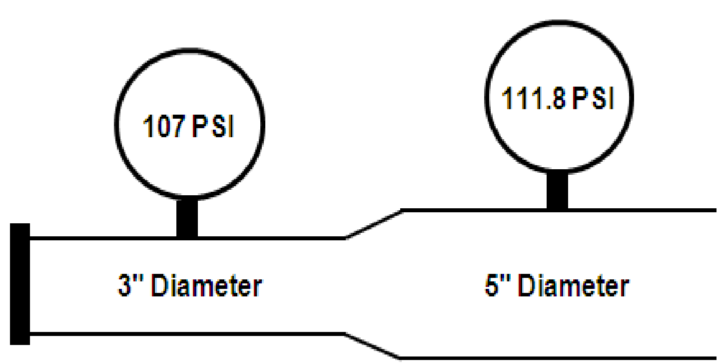
My February 2011 P&S article, "Testing Centrifugal Pumps in the Field", featured an Excel spread sheet that was designed to simplify the field test procedure. The equation for TDH (total dynamic head) showed the various components that lead to its calculation. One of those components is velocity head and I have received several requests to revisit its effect upon a pump's TDH when tested in the field. I believe that this month is perfect timing since we spent the last two months discussing the achievements of the man who defined it – Daniel Bernoulli.

Velocity head can be a very important component when measuring the discharge pressure of a pump in the field. After all the bourdon tube pressure gauge measures pressure just like a piezometer and measures the static pressure only. In some instances velocity head can contribute significantly to the total dynamic head (TDH) and if it is not taken into account, comparing the field test data to the manufacturer's test curve will not be accurate.

Where a gauge reading is taken can have a significant effect upon the actual pressure reading. It is not unusual for a centrifugal pump to be connected to a pipeline, sized for low friction losses, via a short length of pipe that is the same size as the pump discharge. If the discharge pressure is measured in that section, it can be very different than a measurement taken on the larger diameter pipe. For example, many pumps with 3" discharges can produce flows over 700 gpm and 4" models can exceed 1100 gpm. In fact, almost all pump sizes are capable of flows that exhibit extremely high discharge velocities. When this occurs, velocity head becomes an important component when measuring TDH.

Let's take a look a couple of real examples. A 3X4X9 end suction pump operating at 3500 RPM is connected to the flanged discharge line shown in Figure 1. The gauge located on the short section of 3" diameter pipe reads 107 PSI (247'). A flow meter, installed downstream



in the 5" diameter section, measures a flow of 650 GPM. When we compare these measurements to the manufacturer's H/Q curve we find that this pump should be producing 650 GPM at 260' (112.5 PSI). Our initial thought would be that this pump does not meet the manufacturer's test conditions. Now, suppose we do not have a flow meter and we use the pressure measurement to find the flow point on the H/Q curve. A head of 247' would show a flow of 740 GPM. Neither of these methods would provide the actual performance of the pump.

The manufacturer's test curves include velocity head as calculated or measured during testing. Our tests did not. When 650 GPM flows through a 3" diameter, schedule 40 steel pipe its velocity is 28.2 feet per second. If you compute the velocity head ($v^2/2g$) you end up with and additional 12.4 feet (5.4 PSI) that was not accounted for by the pressure gauge measurement. If the pressure had been measured in the 5" diameter pipe it would be far more accurate. The gauge shows a pressure of 111.8 PSI (258.25'). There the velocity is only 10.4 feet per second and the velocity head is just 1.69 feet (0.7 PSI).

The pressure measurement in this example is off by 4.7% and the error will always be smaller for higher head pumps. When lower head pumps are involved that error percentage can increase substantially. A good example of lower head applications is wastewater pump down. Many lift stations that pump into a gravity main require relatively low heads that can range from 15 to 30 feet. Wet wells that use submersible pumps will often use discharge piping that is the same diameter as the pump discharge and base elbow since the piping runs are relatively short. This can lead to relatively high velocities and inaccurate pressure measurements. Since many of these stations are not equipped with a flow meter a combination of pump down time and discharge pressure is used to determine pump performance. Below is an example of the effect of high velocity in low head applications.

A lift station has 4" submersible pumps that are designed to provide a flow of 650 GPM at a TDH of 20' (8.6 PSI) at the beginning of the pump down cycle. The pumps are connected to individual 4", schedule 40 steel discharge pipes. The gauge used to measure discharge pressure is mounted on the discharge pipe at an elevation that is 10 feet above the surface of the water in the wet well. When the pump starts the gauge reads 2.5 PSI (5.8'). Correcting for the gauge elevation (10') we obtain a corrected measurement of 15.8' (6.8 PSI). Based upon the performance curve flow would be 800 GPM at this pressure. At 650 GPM flow velocity is 16.4 ft/sec and the calculated velocity head is 4.2' (1.8 PSI). In this example, ignoring velocity head results in a TDH error of 21%.

Velocity head can be an important factor when testing pumps in the field. At a flow velocity of 8 ft/sec, velocity head is just 1 foot but it increases exponentially with any increase in flow velocity.

Joe Evans is responsible for customer and employee education at PumpTech Inc, a pump & packaged systems manufacturer & distributor with branches throughout the Pacific Northwest. He can be reached via his website www.PumpEd101.com. If there are topics that you would like to see discussed in future columns, drop him an email.