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WHAT THE PUMP WAS DESIGNED TO DO AND WHY IT DOESN'T DO IT.

Contrary to popular opinion, a centrifugal pump is not designed to develop one head at a single capacity as requested by the pump purchaser. In fact a pump is designed and produced to supply a whole range of head-capacity conditions as identified on it's performance curve. The pump will operate on that curve if it is driven at the particular speed for which the curve is drawn.

However, the actual conditions on that curve at which the pump will run, will be determined by the system in which it operates. In other words, for all practical purposes, the system controls the pump, and will operate that pump at whatever conditions it sees fit, regardless of the Head and Capacity for which it was bought (and designed) to achieve.

First we need to understand how a pump works!

For this we need to understand the Characteristic Pump Performance Curve. To the uninitiated, this diagram may seem like a mass of lines set up simply to confuse the reader. In fact, it is only a picture of how the pump works. However, we do need to be able to make some sense out of that picture

Pump Capability

Let's start with the relationship between the Capacity (or flow rate) and the Head. The "Head" is simply the concept of "Pressure" identified on a barometric scale with the medium being water instead of mercury. For example, an atmospheric pressure of 14.7 psi can support a 30 inch column of mercury in a Barometric scale.

This is frequently used to identify vacuum conditions in "inches of Mercury".

However, it can also support a 34 feet high column of water and this is used to identify pump pressures in "feet of water".

Such a column of liquid is referred to as the Static Head. Consquently the relationship between Pressure and Head is as shown:

$$\textbf{Head in Feet} = \frac{\textbf{Pressure in P.S.I. x 2.31}}{\textbf{Specific Gravity of Liquid}}$$

To fully appreciate the relationship between Head and Capacity, consider a Centrifugal Pump discharging into a straight vertical pipe.

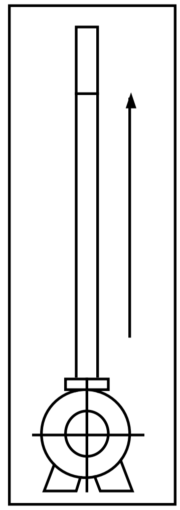

Figure 1

The liquid will eventually reach a level beyond which it is unable to move. This can be considered as the maximum Head the pump can develop. Although the pump will continue to run it will be unable to push the liquid any higher in the pipe.

Under these conditions, liquid is being churned around in the pump casing, but there is no flow passing through the pump, therefore the Capacity at this maximum Head is zero.

Expressing pressure as "Head" in this way makes the pump curve applicable to every liquid regardless of it's Density.

If we cut holes in the discharge pipe at progressively lower levels, the Head is effectively reduced, and the pump will steadily develop an increasing Capacity.

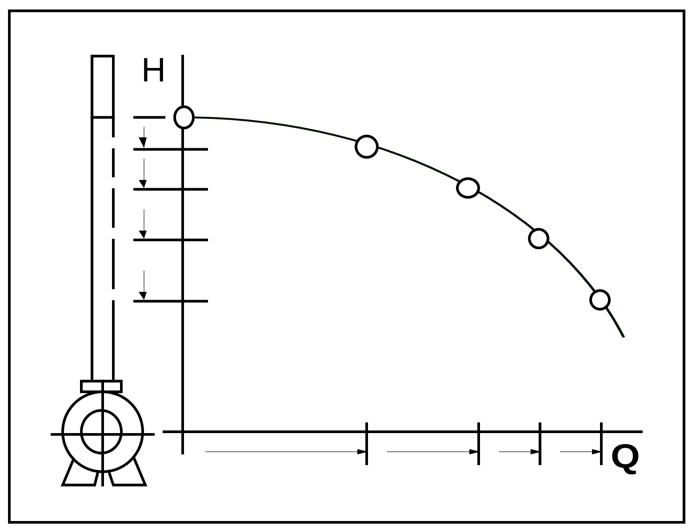

Figure 2

By graphically depicting these results, a characteristic pump performance curve is drawn. You will note that this curve is not completed down to Zero Head, as a centrifugal pump does not operate reliably beyond a certain Capacity, at which point, the curve is usually discontinued.

This curve identifies the Capacity which this pump can develop, and the Total Head it can add to a system, when it is run at a particular speed with a specified impeller diameter.

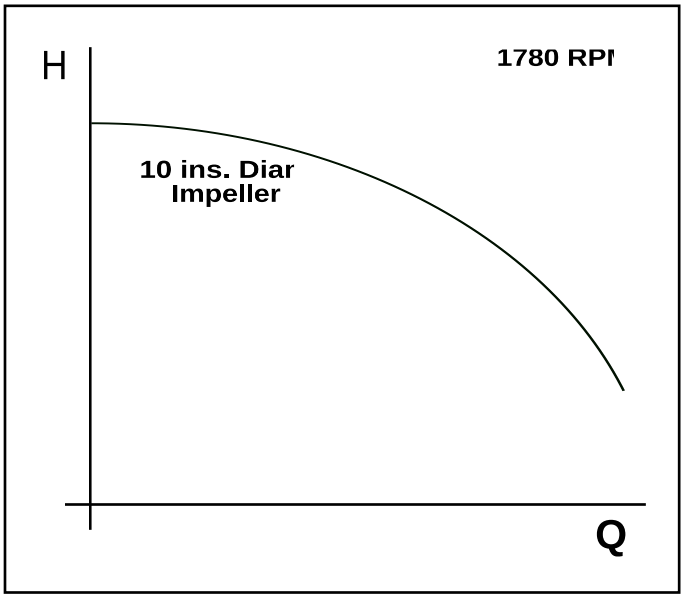

Figure 3

Consequently, the only practical way you can change what the pump is capable of doing is by physically adjusting how fast the pump is rotating, or by changing the impeller diameter.

That's what it's designed to do... so why doesn't it do it?

System Considerations

If the Centrifugal Pump is controlled by the System, we should now understand some aspects of a Pumping System. For this we look at the System Curve.

The System Curve is created by the combination of factors that resist the flow of liquid from one end of a System to the other. The common factors in all systems are Gravity and Friction.

To overcome Gravity in a typical system as shown in Figure 4, the liquid must be raised through the vertical distance represented by the change in elevation between the originating source to the final destination.

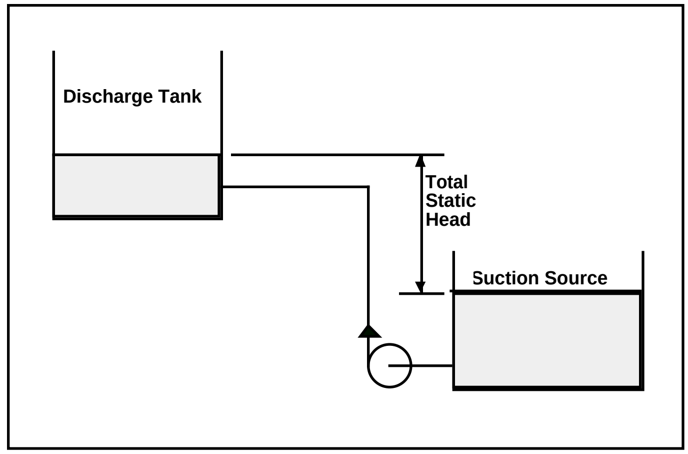

Figure 4

Referred to as the Total Static Head, this distance is measured in one of two ways, depending on the layout of the system.

In the arrangement shown in Figure 4, it would be measured between the free surface of the liquid in the suction source and the free surface of the liquid in the discharge tank.

Where the pump discharge line entered the Discharge Tank from above, the Static Head would be measured between the free surface of the liquid in the suction source and the highest point of the discharge line.

In either case, the Total Static Head is not a variable of the flow rate, and a graph comparing the two would show up as a straight line as shown in Figure 5

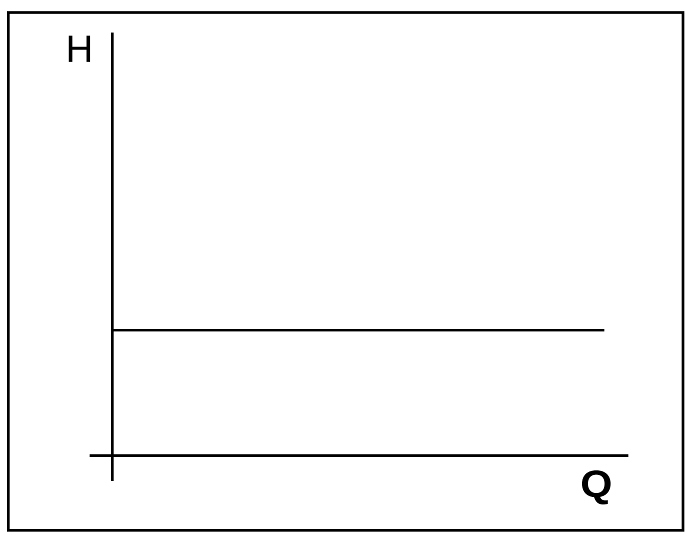

Figure 5

Friction is the resistance to flow in the system and must be considered for three separate areas individually.

The Piping,
the Valves and Fittings, and
Other Equipment, such as filters, heat exchangers, etc.

The Friction Losses in piping can either be calculated from scratch, or from the Friction Loss Tables available from a variety of sources such as the Standards of the Hydraulic Institute. Tables are also available to identify the losses through the more common pipe fittings and valve types.

Losses in Filters, Heat Exchangers, etc., can be obtained from the original equipment manufacturer, or from measuring the inlet and outlet pressures on site.

As the flow increases, so too does the Friction Loss, but at a far higher rate as shown in Figure 6.

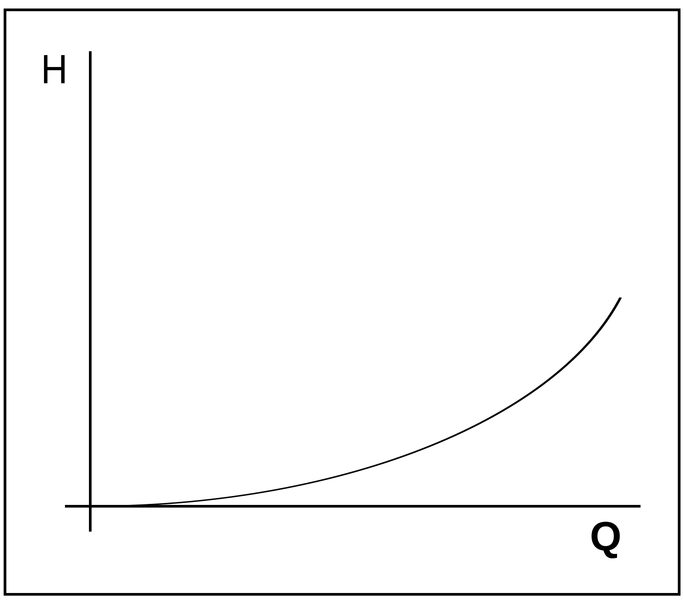

Figure 6

In every pumping system, it is also necessary to accelerate the liquid through the pump. The Velocity Head (Hv) is identified by the difference in values of the velocity energy ($V^2/2g$) between the Suction and Discharge Nozzles of the pump. As the linear velocity of the liquid in most systems is maintained at less than 10 ft./sec. (3 m/sec.), the Velocity Head is usually insignificant except in low head applications.

The only other condition we need to take into account are the pressures at the Suction Source and in the Discharge Tank. If they are both open to atmospheric pressure, then we can ignore them. If however, they are closed vesseles under different pressures, the difference in pressure has to be added to the Total Head required from the pump.

A combination of that Differential Pressure, the Total Static Head, the Friction Loss, and the Velocity Head is referred to as the Total Head. When plotted against the Capacity, the resultant curve shown on Figure 7 is known as the System Curve.

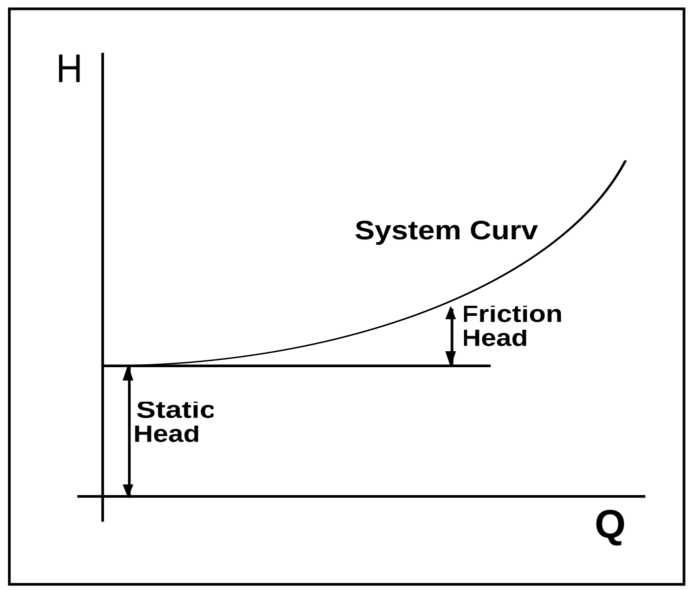

Figure 7

Therefore, when a specific Flow Rate is selected for a system, the System Curve will identify the Total Head that must be overcome.

The Flow Rate through a system can only be supplied by a pump, and is therefore the Capacity required from the pump.

When the pump is properly selected, its Characteristic Performance Curve will intersect the System Curve at the point at which the pump will operate. See Figure 8.

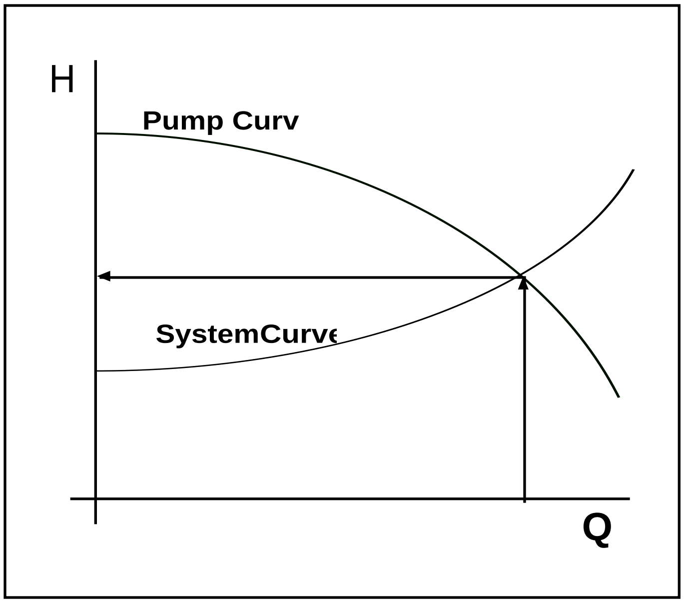

Figure 8

An increase in Static Head can be caused by reducing the liquid level in the tank, and will move the System Curve straight up on the graph, thus reducing the Capacity required.

An increase in Friction Loss can be caused by a variety of conditions such as automated controls opening and closing a different valving system. This will result in the System Curve adopting a steeper slope and again reducing the Capacity required.

Therefore, without physically changing the pump speed or impeller diameter, if any change in Head or Capacity is noted at the pump, it usually means that the system has been changed either purposely, or accidentally.

Remember, the System controls the Pump. So don't be surprised if the Pump doesn't do what you expected it to do. Look at the System and find out what has changed.

Ross Mackay specializes in helping companies reduce pump operating and maintenance costs by conducting training courses in person, and through a self-directed video program.

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