inch (or kilograms per square centimeter, in the metric system). The pump manufacturer denotes pressure in feet of head (or meters of head). The pump operator needs a pump that generates 20 psi. The manufacturer offers a model that generates 46 ft of head.

To understand pumps and analyze their problems, its necessary to dominate the formula that changes feet of head (H) into psi. This is explained in Chapter 2, but here is a brief review:

The formula is:

$$\textbf{Pressure in psi} = \frac{\textbf{H (Head in feet)} \times \textbf{sp. gr.}}{\textbf{2.31}}$$

And in the other direction:

$$\textbf{Head in Feet} = \frac{\textbf{psi} \times \textbf{2.31}}{\textbf{sp. gr.}}$$

If the liquid is water, the specific gravity is 1.00. We see that two factors separate 'psi' from 'head in feet'. First is the 2.31 conversion factor, and second, the specific gravity.

The pump companies develop their curves using head in feet (H), because when they make a new pump, they don't know the ultimate service of the pump (they don't know the liquid that the pump will be pumping), but they do know how many feet of elevation the pump can raise that liquid. This is why it's necessary to specify pumps in feet of head and not in psi. Let's begin by exploring the H-Q curve of the pump, using feet of head.

H-Q

The matrix of the pump curve graph is the same as the mathematical 'x-y' graph. On the horizontal line, the flow is shown normally in gallons per minute or cubic meters per second. The vertical line shows the head in feet or meters. See Figure 7–1.

By definition, the pump is a machine designed to add energy to a liquid with the purpose of elevating it or moving it through a pipe. The pump can elevate a liquid in a vertical tube up to a point where the weight of the liquid and gravity will permit no more elevation. The energy contained in the liquid's weight is the same as the energy produced by the pump. This point on the pump curve would be the 'shut-off head'. Shut-off head is the point of maximum elevation at zero flow. It's seen in Figure 7–2.

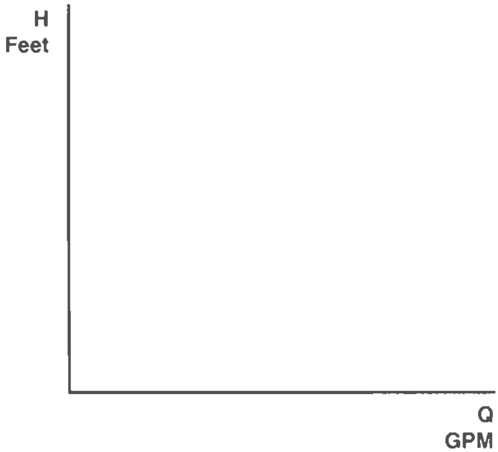

Figure 7-1

Once again, imagine starting a pump and raising the fluid in a vertical tube to the point of maximum elevation. On the curve this would be maximum head at zero flow. Now, rotate the running pump on its centerline 90°, until the vertical tube is now in a horizontal position. The very action of rotating the running pump on its centerline would trace the pump's curve. Any elevation in feet would coincide with a flow in gallons per minute. Consider the graph show in Figure 7–3.

On the graph, if point 'A' represents 10 ft of head at 0-gpm, and if point 'F' represents 10 gpm at 0 ft of head, then point 'C' on the curve represents 8 ft of head at 6-gpm. Here we see that the pump is always on its curve. The pump can operate at any point on this curve from point 'A' to point 'F'. At any specific head, this pump will pump a specific flow, or gpm corresponding to the head.

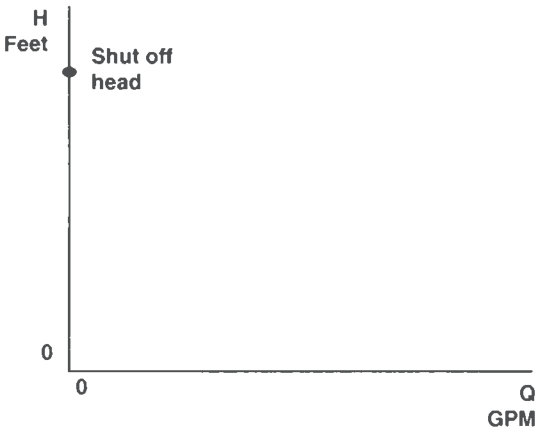

Figure 7-2

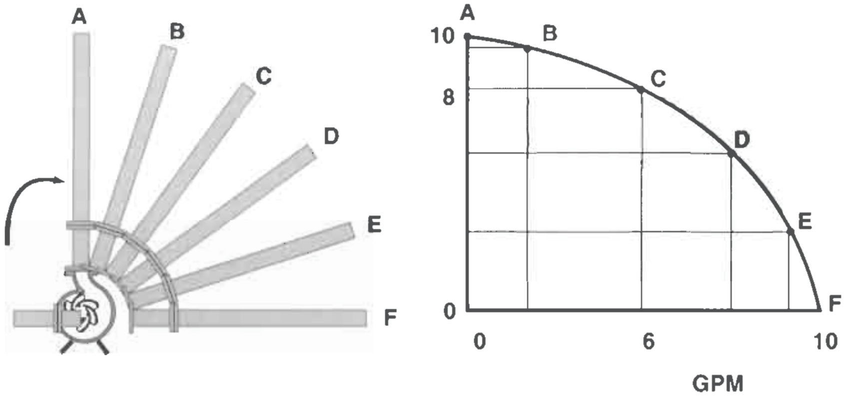

Figure 7-3

AUTHOR'S NOTE

Sometimes you hear people say that the pump is operating off its curve. If the velocity, the impeller diameter and design are correct, if the pump has all its parts installed and functioning correctly, including the mechanical seal and coupling, it is impossible to operate off the curve. The pump will be somewhere on its curve between shut-off head and maximum flow a zero elevation.

The pump can be too far to the right, or too far to the left of its best efficiency point (BEP) but it cannot be off the curve. Conceivably, the pump can be operating off the graph, and even off the page, but it cannot be off the curve. If the pump is off the curve, something else is out of control, like the velocity, or impeller diameter, assembled parts and tolerances. Now, the 'lack of control' is the real problem, and not the pump.

Pump efficiency

Let's talk about the pump efficiency. Imagine a small pump connected to a garden hose squirting a stream of water across the lawn. You could direct the flow from the hose up into the air at about a 45-degree angle, and the stream would arc upward and attain its best distance of reach from the nozzle or launch point. The stream of water would attain a specific height into the air and a specific distance. The efficiency curve of a pump is seen as the trajectory or arc of a stream of water. When squirted from a hose, the elevation that attains the best distance, when plotted onto the pump curve, is called the best efficiency point (BEP). On the pump curve, it is seen as in Figure 7–4.