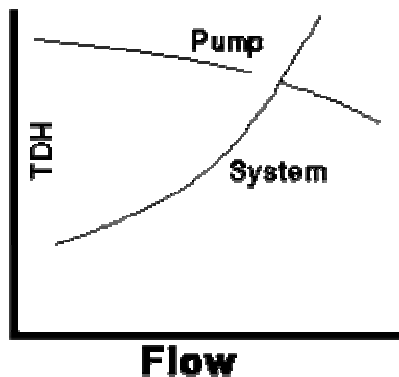


All of us who work with centrifugal pumps have been in situations where a new or existing pump is not performing as expected. Perhaps the process flow rate does not appear to be adequate, or the pump is cavitating. Regardless of the symptoms, one of the first things to establish is where the pump is operating relative to its rated design point. Knowing this helps identify whether a problem is associated with the pump or with the process system. This month we look at using the pump curve along with some field measurements to help make that determination.



Dale B. Andrews – Editor

Each pump in your facility should have a performance curve provided by the pump manufacturer at the time of purchase<sup>1</sup>. Unless otherwise indicated, pump curves show the pump's performance characteristics on water. Curve information usually includes total dynamic head, pump efficiency, driver output power and NPSHR, all plotted as a function of pump flow rate. Provided the pump is mechanically sound, there is sufficient NPSHA<sup>2</sup>, and there is no gas entrainment, the operating point of the installed pump should fall somewhere on the published pump curve<sup>3</sup>.



Not only does the pump have an operational curve, but the system also has an operating characteristic curve where the total dynamic head required to move fluid through the system at any given flow rate increases with the square of the flow rate. This curve depicts the resistance to fluid flow caused by fluid friction, and other mechanical devices such as valves, fittings, orifices and other components. These head values, when plotted for a number of different flow rates, form what is known as a system-head curve, or sometimes just the system curve. The operating point of the pump in the system is where the characteristic curve and the system curve intersect.

<sup>1</sup> If the curve is not readily available, the pump manufacturer can usually provide one when given the pump model and serial number from the name plate.

<sup>2</sup> Net Positive Suction Head Available – The absolute pressure at the impeller eye expressed in feet of head. This number must be greater than the NPSHR (Net Positive Suction Head Required) provided by the pump manufacturer.

<sup>3</sup> Actual test curves are likely to be more accurate than general catalog curves. Catalog curve performance may deviate somewhat between pumps due to casting and manufacturing variances. However, for the purposes of troubleshooting as described herein, a catalog curve should be adequate to provide a general indication as to whether a pump or system problem exists.

This factual concept should be kept in mind when troubleshooting pumps. No matter how poorly a pump may be performing, it is operating at the intersection of the system and pump curves. If that point is not the rated duty point, then something has happened to cause one or both curves to move.

**Every centrifugal pump always operates at the intersection of its head-capacity curve and the system curve.**

For many pumps there is one operating point that can be verified in the absence of a flow measurement device; zero-flow. If allowable<sup>4</sup>, a momentary run at near zero-flow will permit suction and discharge pressure readings to be obtained to determine the TDH generated by the pump at that point<sup>5</sup>. To determine TDH:

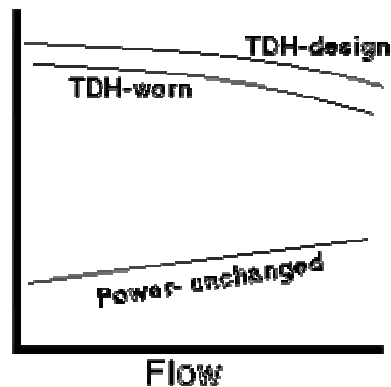
1. Subtract the suction pressure from the discharge pressure. This is the pressure differential ( $\Delta P$ ). Total dynamic head (TDH, in feet) may be calculated as shown below.
2. Adjust the head for any difference in elevation between the suction and discharge gages.
3. Compare the TDH to the pump curve.

$$TDH = \frac{\Delta P \times 2.31}{sp.gr.}$$

A near shut-off TDH reading that is below the published pump curve indicates pump wear. A decrease in the TDH without any change in motor current also indicates pump wear.

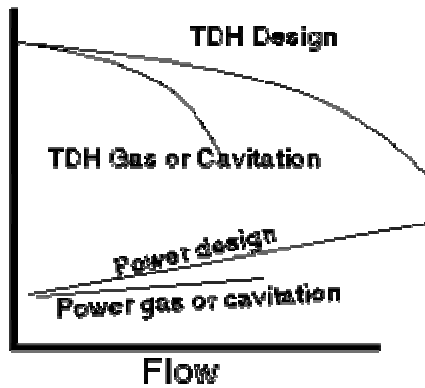
If the pump does not exhibit a wear characteristic, then its operating point should be on the design pump curve. To determine the flow:

1. Return the pump to its normal operating point.
2. Calculate TDH from the suction and discharge pressure.
3. Find the corresponding flow rate for the measured TDH from the published pump curve. Unless there is cavitation or gas entrainment, this should be the flow rate of the pump.



<sup>4</sup> Always check with the pump manufacturer regarding minimum flow. Running small industrial pumps near shut-off is generally not a problem. Running a large pump near shut-off may damage the pump or seals.

<sup>5</sup> Horizontal pumps need some flow maintained through the pump to prevent overheating. For most pumps a near shut-off pressure reading will be sufficient to determine if the pump is capable of developing its rated TDH.



If cavitation or gas entrainment is present, the pump usually will operate on the design curve near shut-off, but its performance will degrade as flow is increased. A low motor power combined with a low TDH reading may indicate gas entrainment or cavitation.

If the TDH is low and motor power does not fall below the design power curve, it is likely the pump is running at a higher than design flow rate. Power delivered by a three phase motor may be estimated from the following equation:

$$Bhp = \frac{Volts \cdot Amps \cdot Efficiency \cdot Powerfactor \cdot 1.73}{746}$$

For KW use 1000 instead of 746

Average the values of voltage and current for each phase. Motor power factor and motor efficiency may be estimated from the published motor data. Generally, this calculation is only an approximation. Motor efficiency and power factor vary depending on load, motor condition, and plant environmental factors. A small error in the actual vs. estimated values for these variables will result in a power calculation error that often represents a significant change in pump flow. A power calculation may be useful as a performance indicator, particularly to determine if a pump is restricted by suction conditions or is operating far out on its curve. However, motor calculations typically are not well suited as a solitary indicator of pump performance.

With knowledge of the pump's approximate performance relative to its rated duty point, one may assess if the pump or a system parameter is the root cause of the problem. If the process or system has undergone changes that adversely affect the pump's performance, the manufacturer should be consulted. In many situations, modifications may be made to an existing pump to compensate for system changes and reduce the operational costs associated a pump that is not performing as expected.