U.S. Department of Energy - Energy Efficiency and Renewable Energy

Energy Matters

Performance Optimization Tips: Field Measurements in Pumping Systems

From the September/October 1999 issue of Energy Matters

By Don Casada, BestPractices Motor Systems, Oak Ridge National Laboratory

This article is the 3rd in a series dealing with practical considerations and pitfalls of field measurements needed to understand pumping systems.

Pump Head

In the May and July issues, we discussed pressure and elevation components of pump head. We'll finish here with the last head element of that trio—velocity.

Velocity

Velocity head equals the velocity squared divided by two times the gravitational constant ($V^2/2g$). For many centrifugal pumps, the suction flange is one pipe size larger than the discharge flange.[1] When suction and discharge pressure measurements are made in different line sizes, an accounting for the different velocity heads must be made. But, in some applications, use of expanders results in identical size suction and discharge measurement points, meaning that the velocity heads in the suction and discharge are equal. Be sure to note the pipe dimensions where the suction and discharge pressure measurements are made, and adjust the head as necessary.[2]

Of course, the velocity is normally calculated from the pipe size and volumetric flow rate. Using common U.S. units,

V (ft/sec) = $gpm/2.45d^2$ (d is the inside pipe diameter in inches).

Which leads us to the next important energy element in pumping systems—flow rate.

Pump Flow Rate

Flow rate is usually the single most important parameter to grasp in assessing pumping system operation. Frequently, it is also the most difficult to accurately acquire.

In many systems, no permanently installed flow instrumentation exists. In such cases, either temporary flow instrumentation or alternative methods of estimating flow rate must be deployed. This column focuses on considerations where flow instrumentation exists.

Just because permanently installed flow instrumentation exists does not mean it is dependable. Many factors can affect the accuracy of indicated flow rate. We'll touch on just three: installation layout; degraded or uncalibrated instruments; and unrecognized flow paths.

Installation layout

The most commonly used flow-measuring instruments depend on a fully developed, undisturbed flow profile. This means several pipe diameters of straight pipe, without fittings, upstream of the measuring device. For example, an ASME standard for flow measurement requires from 6 to 35 pipe diameters of straight length upstream of the measuring device to keep associated errors below 0.5%, depending on the type of flow disturbance and meter design.[3]

Figure 1 (omitted here) shows an extreme example of nonconformance. Based on other indications (primarily pump head), the indicated flow rate from this meter is in error by around 25%. Furthermore, the extent of error is influenced by the distribution of main and bypass flow.

A quick review of the physical geometry of a flow meter whose output is used in system analysis is time well spent, whether it provides some "warm fuzzies" or raises the flag of uncertainty, as in this case.

Degraded or uncalibrated instruments

Many common types of flow meters involve a reduced flow area (e.g., orifices) or an inserted, movable part (e.g., turbine meters). The flow-measuring device is thus a likely point for foreign materials, which find their way into even "clean" fluid systems. If the meter totally fails, a problem will be quickly obvious. But not all degradation results in total failure. Simple service wear from erosion and scale buildup can, over time, degrade performance.

One of the most challenging, practical aspects of any flow instrumentation is true, comprehensive field calibration. While pressure instruments can be readily removed and/or tested in service with calibrated pressure sources, flow meters normally cannot. As a result, plugging and wear or other primary device problems would not be discovered during calibration.[4]

However, the fact that an instrument is periodically calibrated suggests that someone really does depend on it, and problems in actual service are more likely to be noticed. Determining whether a flow meter is periodically calibrated, finding out who uses the indication, and then asking questions of the user can give at least a qualitative sense of data dependability.

Unrecognized flow paths

When getting flow data from an instrument, always ask: "Exactly what is this thing measuring?"

Consider the simple flow diagram in Figure 2, with four parallel pumps drawing suction from a common tank and delivering the flow to the "Target." The flow meter installed in a common header may be accurately reporting the flow rate going through it, assuming it is the same flow rate as Pump 2, the only running pump, we may be in error. For example, the recirculation valve at the top, shown as closed might actually be open, or one or more of the discharge check valves on pumps 1, 3, and 4 may be leaking. Pump 2 may be pumping considerably greater flow than the meter indicates. One could conclude that Pump 2 is performing below expectation, when it is really a valve(s) problem. This could lead to unnecessary corrective maintenance actions.

But I Don't Have a Flow Meter!

Some industrial systems have no flow instrumentation. What are we to do in that case? Tune in next time, same channel.

Comments/questions welcome by e-mail: a85@ornl.gov

1 In many applications there is no suction pressure measurement connection. An obvious example is in vertical turbine pump applications where the pump draws suction from a tank, river, or other body of water.

2 In actual applications, components between the pump and the measurement points will result in indicated pump head that is less than in a pump test facility because of losses across these components. Head losses across the intervening components can be estimated and added to the measured head to provide a more accurate comparison with manufacturer test results.

3 The latest edition of the ASME standard notes the data used to establish the lengths were acquired in 1927 and analyzed in the 1930s. More recent measurements indicate even those lengths may not be enough.

4 Usually, it is also impractical to even visually verify the condition of the primary sensing element.

References:

1. Measurement of Fluid Flow in Pipes Using Orifice, Nozzle, and Venturi, ASME MFC-3M-1989.

Correction: In July's Performance Optimization Tips, the term specific weight (weight/unit volume) should have been used in the expressions involving head instead of density (mass/unit volume). Normally the symbols g and r are used for specific weight and density, respectively. The author apologizes for his mistake.