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Performance Optimization Tips: Field Measurements in Pumping Systems—Practicalities and Pitfalls

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

Pump Head

Head, as a general term, is a measure of the relative hydraulic energy per unit weight of the fluid, and is usually expressed in units of feet in the United States and meters elsewhere. Although other energy components, such as heat, may represent a significant portion of the overall energy possessed by a fluid in a pumping system, the portions of the fluid system energy that are important from a fluid movement standpoint are pressure, elevation, and velocity. The total head associated with these three components, in respective order, is:

$$H_{tot} = \frac{P}{\rho} + z + \frac{V^2}{2g}$$

where H_{tot} is total head, *P* is gauge pressure, p is fluid density, z is elevation, V is Fluid Velocity, and g is gravitational constant.

For incompressible fluids, the useful work per unit weight performed by a pump is simply the difference between the suction and the discharge heads, or:

$$\text{Pump head} = \left[\left(\frac{P_d - P_s}{\rho}\right) + (z_d - z_s) + \left(\frac{V_d^2 - V_s^2}{2g}\right)\right]$$

where the subscripts d and s refer to discharge and suction conditions, respectively.

In order to understand pump performance in the field, you must account for these elements of head.

Some practical considerations involving the pressure component of head were discussed in the May 1999 issue of *Energy Matters*. In this issue, the elevation component will be discussed.

Elevation

The elevation head, in the context of pump measurements, is simply the difference in elevation between the pump suction and discharge reference points, where pressure measurements are made. Elevation is usually a fairly straightforward term to measure, and can be done accurately with nothing more sophisticated than a pocket tape measure; but there are sometimes complicating factors to be considered. To illustrate, let's use the example shown in Figure 1, which shows a pump with pressure gauges connected by short instrument tap stubs to the suction and discharge piping (instrument isolation valves are not shown).

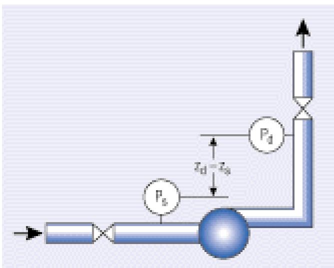

Figure 1. Pump with short pipe stub pressure taps and local gauges.

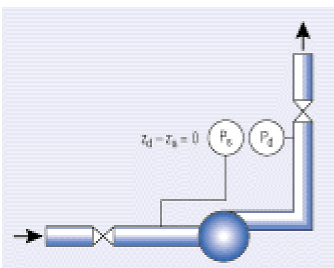

Figure 2. Use of instrument tubing to provide adjacent suction and discharge pressure gauges.

The elevation difference between the discharge and suction reference points—the pressure gauges—is simply zd- zs. From a practical standpoint, the elevation difference is usually determined by reference to some third elevation, such as floor level or pump datum elevation (defined in Reference 1).

But, what if the pressure gauges are configured as shown in Figure 2, where an instrument tube run is used to allow suction and discharge pressure gauges to be conveniently located next to each other (e.g., when the gauges or transducers are located in a common instrument rack)? The same rules are still applicable, and ideally the elevation head difference would be zero—provided the instrument tubing is completely filled with process fluid.

But there is a potential pitfall that did not exist for the arrangement shown in Figure 1. It is associated with an improperly vented instrument line—a situation that can easily creep in unnoticed, particularly when maintenance is performed.

Let's assume the pump develops a problem that requires disassembly to make the repair. A lockout/tagout procedure is performed, the suction and discharge isolation valves are closed, and the pump casing drain plug is opened to drain fluid from the casing and adjacent pipe sections, which incidentally includes the instrument tubing. After the maintenance work is completed, the normal procedure would be for operators to open the suction and discharge valves and complete a system fill and vent process using system high-point vents (not shown). After completing the fill and vent, the system would once again be available for process service.

It is common operator practice to simply ignore instrument tubing when conducting fill and vent procedures (these lines "belong" to instrument technicians). In the case of the system shown in Figure 1, that is not a practical concern, as the instrument stubs are short. However, when the system shown in Figure 2 is filled, the air pocket left in the suction gauge instrument line from the draining process will be compressed (assuming the suction pressure is greater than atmospheric), and the actual liquid level will be different than the gauge elevation.

Figure 3. Elevated Pressure gauge with loop seal. The potential for the instrument line draining problem can be minimized by a loop seal or "pig tail" between the pressure gauge and the pipe connection, as in Figure 3. Pig tails can also buffer the pressure gauge from high process temperatures.

For moderate- and high-pressure connections, this is usually not an important concern because the air pocket will be significantly compressed in volume, and the trapped air will also be more likely to escape around fittings. Over time, the escaping air results in the instrument tubing becoming liquid-filled. Further, an error of a few feet in high-head systems would be a relatively insignificant factor. But for low-pressure systems using low-head pumps, the air will be less likely to be driven from the system, and the error associated with a few feet of compressed air will be much more significant in calculating the pump head. It should be noted that the extent of error attributable to unvented instrument lines depends on the physical layout of the tubing run, and it is generally not practical to adjust for the effect of unvented lines.

In situations where instrument tubing is used to make pressure (or flow, for that matter) measurements, it is helpful to have a permanently installed vent petcock at the gauge to ensure the instrument line is completely filled.

The ASME standard for pressure measurements (2) discusses the importance of ensuring that instrument lines contain what is intended-whether gas or liquid. Although it is a lengthy document that is quite involved in some sections, many portions provide useful, practical guidance for folks involved in field measurements.

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

References

1) ANSI/Hydraulic Institute Standard 1.6-1994, Centrifugal Pump Test.
2) ASME/ANSI PTC 19.2-1987, Pressure Measurement.