High-Head Pumping Knowhow

By Michael Microbi

Improving efficiencies & overcoming friction losses

Reducing energy demands in municipal wastewater infrastructure continues to grow in importance, especially in wastewater collection systems. In high-head pumping applications that result from long force mains or high static heads from hilly terrains, the designer and municipality must evaluate many factors to efficiently overcome friction losses and achieve installation with reasonable capital costs.

Competitive bidding induces quoting the smallest horsepower pump at the highest speed. When the smaller pump is deficient in head, a larger pump is called for closer to shutoff; however, a dramatic reduction in efficiency likely occurs as it moves away from its best efficiency point. In these situations, use of vacuum-primed series pump arrangements helps to obtain higher pumping efficiencies—resulting in lower power costs and potentially smaller force mains.

Series pump arrangements differ from the parallel arrangements seen in a typical duplex lift station, which comprise the duty pump and the stand-by pump. Pumps in series connect two pumps: The outlet of the first pump leads to the inlet of the second pump. Working in concert, the flow rate still remains the same, but the heads produced by the two pumps are added.

Unlike typical submersible pumps, this unique series pump construction can be accomplished because the vertically constructed, non-clog pumps are housed outside the wet well—typically above-grade—and each pump already comes designed with a suction flange. This enables the entire lift station to be positioned above the wet well, thereby eliminating any need for extra valve vaults and the associated confined space concerns.

The bottom-line advantage gained in the series arrangement comes from selecting two smaller and more efficient pumps working in tandem to achieve the higher head. Even by adding the second pump, the total connected horsepower and/or resulting power consumption would still amount to less than what the single pump can achieve at the higher head.

Compare & Contrast

Consider a real-life example of a medium-sized Midwestern town with a large residential area served by septic tanks. Increasing problems with improper drainage and increasing nitrate levels in the groundwater prompted the city to plan sewers. Wastewater must be pumped up and over a gradually rising ridge to the sewage treatment plant in an adjacent valley. The city wanted to minimize capital costs because of limitation in its bonding capacity.

The static head is only 70 ft, but the length of the force main to the top of the hill is 6,200 ft. The flow was 410 gal per minute (gpm) and was not expected to increase much. A 6-in. internal diameter ductile iron force main was selected with 4.65 ft per second (fps) velocity.

This vacuum-primed pump station serves a high-head pumping application in which a series pump arrangement operates at grade level with higher efficiency and less total connected horsepower.

A long-term Williams and Hazen coefficient of friction (C) of 120 was chosen based on the expected relative roughness of the pipe when coated with residual sewage. The resulting hydraulic conditions, including manifold losses, were thus established as 410 gpm at 174 ft total dynamic head (TDH).

Typical parallel arrangement lift station pumps were considered, including a leading submersible pump and a vacuum-primed pump. The designer's submersible selection required an 8-in. pump with 88 hp and a pump speed of 1,770 rpm. With a 6-in. discharge nozzle and manifold pumping, the pump's efficiency measured 37% at the stated design conditions. The resulting brake horsepower draw would be 48.7.

By contrast, the vacuum-primed pump measured 4 in. in size with a similar pump speed of 1,770, but at only 40 hp. Also featuring the 6-in. manifold piping, the pump's efficiency measured 50%. Brake horsepower draw would be 26.9.

The difference between the two pump scenarios would favor the vacuum-primed selection by a differential of roughly 27,500 kWh, which translates to more than $2,000 in annual power savings.

Yet, because of the high head application, a series pump arrangement also was considered. It was determined that smaller vacuum-primed pumps in series would produce higher pump efficiency with lower connected horsepower than the single pump selections. At the same head, two 15-hp vacuum-primed pumps in series with a similar pump speed of 1,760 rpm would best meet the conditions—and at 72% efficiency. The series arrangement dictates two pumps serving in the duty role and two more in standby. Although the total connected horespower was 60 hp, the 72% efficiency yielded a brake horsepower draw of only 25.

When compared with the submersible selection, the series pump configuration measured almost half of the brake horsepower draw (48.7 to 25). Assuming a typical eight hours of running time, 365 days a year, the differential in kilowatt hours favors the series configuration by 51,536 kWh per year. At a typical rate of $0.08 per kWh, that differential translates to $4,122 annually in power savings for just one lift station.

Added Benefits

Other savings can be accomplished as well. Series pump arrangements provide step-starting, which can reduce demand power and thus require smaller standby power generators. In variable-speed applications using the first stage pump connected to a variable-speed device, a smaller and less expensive variable frequency drive may be utilized because the series vacuum-primed pump does not need the higher degree of horsepower required by a single-stage pump.

Therefore, in high-head collection system applications, especially those with lower flows, it is important for designers to review the pump curves for single-state and series-connected lift station pumps. Higher efficiency and less total connected horsepower can be achieved than larger and higher head pumping units would allow. The improved efficiency of the smaller pumping units will largely offset the difference in the operating costs of using smaller diameter force mains. PS

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