PUMPS THAT EXPERTS SELECT.

Tackle Tough Services for Centrifugal Pump With Care

By Andrew Sloley

Centrifugal pumps serve as workhorses in the chemical industry. However, highly variable flow rates and low net positive suction head (NPSH) operation can be tough on such pumps. Combining variable flow rate and low NPSH makes for extremely severe services. Common solutions to the problem may involve either higher operating costs through the use of recirculation loops, or greater capital costs for variable speed pumps. An alternative solution presented here minimizes these tradeoffs. At a refrigerant manufacturing plant, it has solved a difficult case with a vaporizing feed, while providing flow control over a wide range of rates.

Every centrifugal pump has a best efficiency point (BEP) on its operating curve. Running significantly below the BEP increases the risk of internal recirculation. Internal recirculation markedly reduces the pressure at the impeller entrance. Inlet recirculation creates noise, vibration and possible cavitation. Vibration and, especially, cavitation can damage the pump and its seals.

Suction-specific speed, *S*, is used to quantify the flexibility of pump operation:

$$S=N(Q)^{0.5}/NPSH_R^{\ 0.75}$$

where *N* is the rotational speed of the pump impeller in rpm, *Q* is the pump flow in gpm, and $NPSH_R$ is the NPSH required in feet. *S* is determined based on operation at the pump BEP with maximum impeller speed. In general, the higher the suction-specific speed, the higher the rate required for stable pump operation. The Hydraulic Institute recommends that *S* be less than 8,500 when evaluated at minimum flow conditions. Many users push the suction-specific speed to 11,000 at the low flow limit. However, it is critical to make sure that higher *S* values are acceptable. Pump energy, pump hydraulic design, fluid pumped and NPSH margin ($NPSH_A$- $NPSH_R$, where $NPSH_A$ is the available NPSH) all affect the lowest stable operating rate for the pump. In most cases, values exceeding 11,000 at low flow should be avoided.

Low $NPSH_R$ increases *S*. Lowering $NPSH_R$ requires enlarging the pump inlet and impeller inlet eye to reduce frictional losses before the liquid pressure starts to increase. Larger flow passages decrease velocity (reducing pressure drop) and boost the possibility of recirculation at low flow. Design standards that require high NPSH margins and overly conservative engineers that demand very low $NPSH_R$ pumps create many low-flow problems.

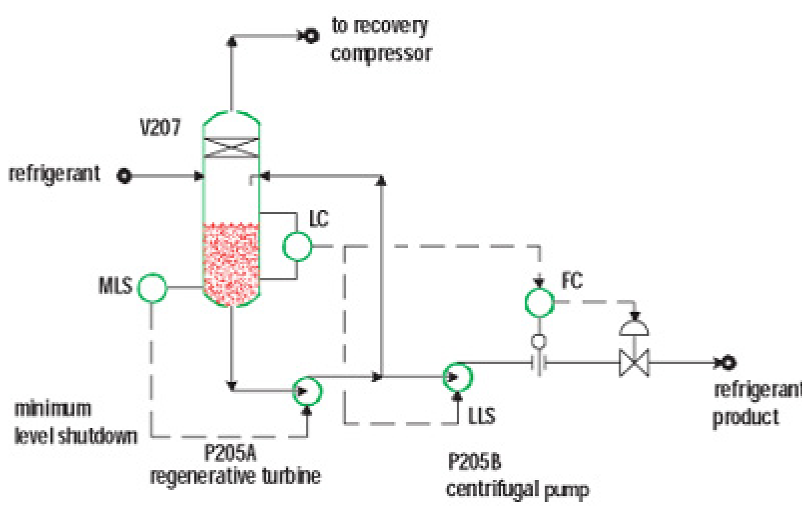

Figure 1: *The control scheme uses low-liquid-level shutdown (LLS) to turn the centrifugal pump off when it is not needed, and minimum-liquid-level shutdown (MLS) to protect the turbine.*

Dealing with the problem

The most common solutions to suction-specific speed problems include using recirculation loops (which allow the pump to stay at higher-flow operation) or variable frequency drivers (reducing *N*) for flow control, when possible. Recirculation loops tend to require less capital, but variable frequency drives use less energy. Selection depends upon plant economics and pressure balance requirements. Variable-speed centrifugal pump operation affects discharge pressures. Many operating systems cannot tolerate broad changes in discharge pressure.

At a refrigerant plant, the original designers had not factored in heat absorbed by the system during operation. The effective $NPSH_A$ was very low after allowing for heat leakage. Under some conditions, the pump's suction contained vapor. Repeated attempts to make centrifugal pumps work in this service failed. All attempts to solve the problem led to pump cavitation -- either because of insufficient $NPSH_A$ or due to inlet recirculation.

In very low head services that may contain vapor, a regenerative turbine pump is often the best choice. However, a regenerative turbine has a very steep head-flow curve. Regenerative turbines are more like positive-displacement rather than dynamic pumps. This service had a 10:1 flow-rate-range requirement that the regenerative turbine could not handle.

After giving up on the direct use of a centrifugal pump, the plant considered reciprocating (piston) pumps with variable speed drivers, pump suction chillers and vertical canned pumps. However, all of these presented formidable technical challenges and were very expensive.

Finally, an alternative was devised and the configuration shown in the figure was implemented. A regenerative turbine designed to operate at low head was used to recirculate refrigerant to the drum. A second pump, a centrifugal, took liquid at higher suction head from the discharge of the regenerative turbine and sent it downstream.

The liquid level in the drum is controlled by cascading the flow controller to the drum level controller. A stepped low-level alarm and shut-off system switches off the centrifugal pump, followed by the regenerative turbine pump upon loss of liquid level. The new system works well, and incurred minimal additional capital and operating costs in commissioning the system.

By Andrew Sloley, contributing editor