Minimizing energy losses in control valves

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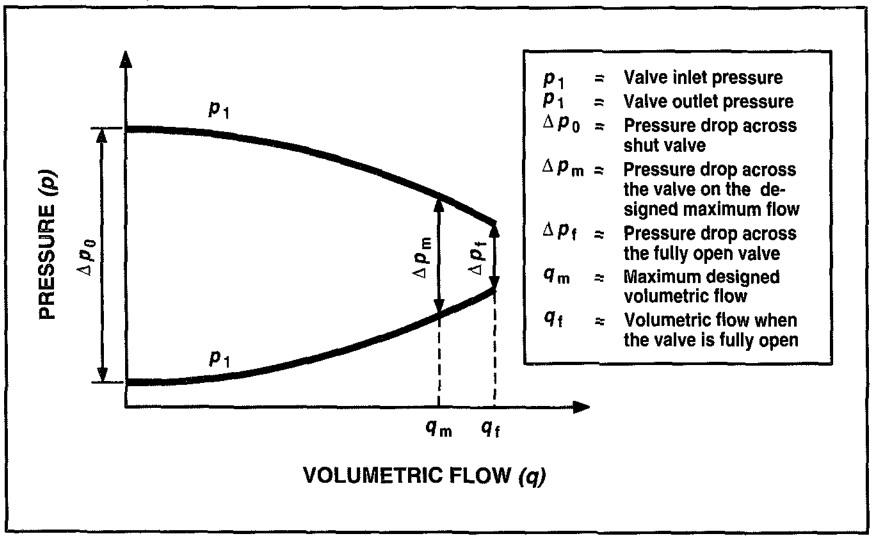
Combining improved control valve flow characteristics with state-of-the-art sizing and simulation programs ensures minimal pressure drop without loss of accurate and reliable control.

The pulp and paper industry uses massive amounts of energy, but it could reduce its electricity consumption by about 2000 MW worldwide by simply optimizing the pumping of process liquids. This change alone would reduce total energy costs at plants by an average of 5%.

Pulp and paper plants have traditionally installed oversized pumping equipment, accepting the accompanying energy waste as an operational necessity. The following considerations, for example, often lead to oversizing:

- A substantial safety margin in pumping power is needed to assure proper functioning of the process in all operating conditions.
- There may be a lack of accurate information on process valves such as pressures and flow quantities.
- Designers anticipate equipment deterioration, increased flow resistance in the piping, and any growth in capacity requirements.
- Accurate and reliable flow control is assured by providing sufficient pressure drop in the valves.

1. The process pressure model



Improving the efficiency of process pumping is not difficult, and the conditions listed above can still be satisfied. The energy consumption of a conventional control valve and pump loop can be reduced by optimizing the pipe size between the pump and the throttling control, reducing unnecessary pressure loss in the control valve. The power P generated by the pump that is lost through pressure drop p in the control valve can be calculated as:

$$P = q\,\Delta p/1714\eta \qquad (1)$$

where

P = power of the pump, hp

q = volumetric flow, gal/min

Δp = pressure loss in the control valve, psi

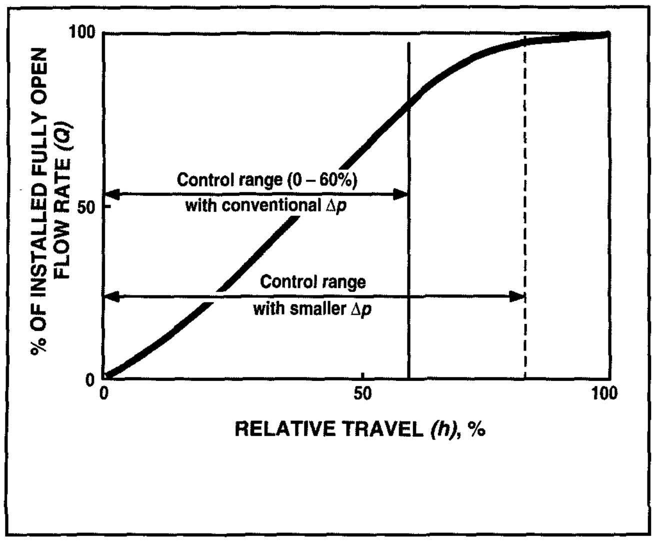
η = efficiency of the pump.

The equation shows that the energy loss in a control valve is linearly dependent on the pressure loss (Δp). Consequently, reducing pressure loss in the control valve reduces the energy required to pump liquids. With more accurate sizing, the pump can run at its optimal efficiency and reduce energy loss.

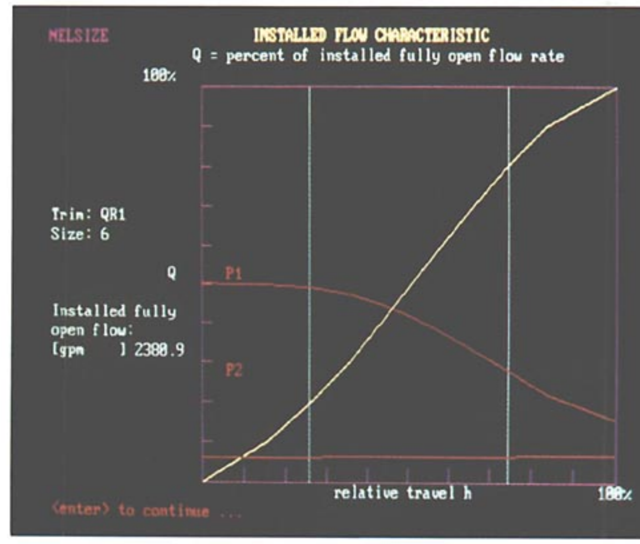
Current sizing principles

When selecting a pump, one general guideline is that the pressure loss in the control valve should account for 30% of the total dynamic pressure loss in the piping at maximum volumetric flow (i.e., $P_m/P_o = 0.3$). If the pressure loss in the piping

2. Installed flow characteristic of a conventional control valve design



3. Representative installed flow characteristic results as seen on-screen



is proportional to the square of the flow (**Fig. 1**), then the installed flow characteristic of a conventional control valve is sufficiently linear to allow good control. The safety margin is also sufficient to allow some increase in capacity and maximum flow rate.

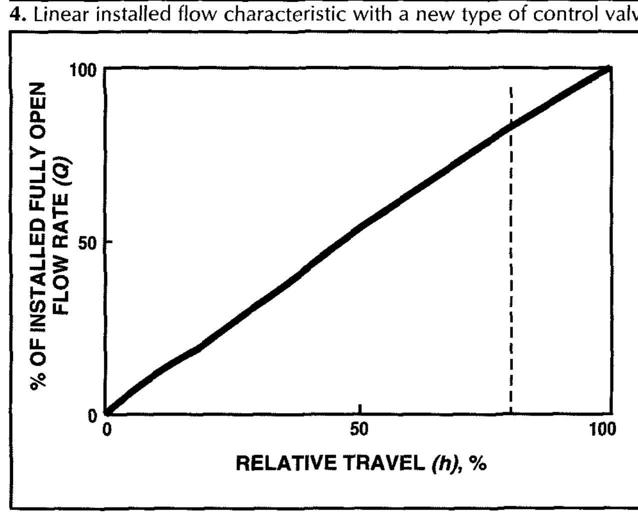
Oversizing can lead to a situation where the control valve must handle up to 50% of the required total dynamic pressure loss in the piping. Valves are oversized to match the pump, narrowing the control range and lowering control accuracy. In addition to any significant energy loss caused by excessive pressure drop in the control valve, cavitation, and thus noise, vibration, and erosion, may also result.

As an example, consider a water flow rate of 2000 gal/min that is controlled with a 10-psi pressure difference. The pressure difference represents 30% of the total dynamic pressure loss in the piping. **Figures 2 and 3** show the installed flow characteristic curve of a conventional control valve under the given conditions. The installed flow characteristic curve in Fig. 2 is produced by the NELSIZE™ control valve sizing program developed by Neles-Jamesbury. In addition to the installed flow characteristic, the program also provides a gain curve of an installed control valve. As the figure shows, the installed flow characteristic in the control range (0-60% of the valve's capacity) is close to linear. Therefore, the controllability in this range is very good.

Trying a new approach

Significant pumping energy can be saved in the throttle control of a pump by reducing the pressure loss in the control valve to 10—15% of the total dynamic pressure loss in the piping. However, reducing the pressure loss in the control valve requires more accurate pumping equipment sizing programs and an improved control valve design to guarantee reliable and accurate controllability.

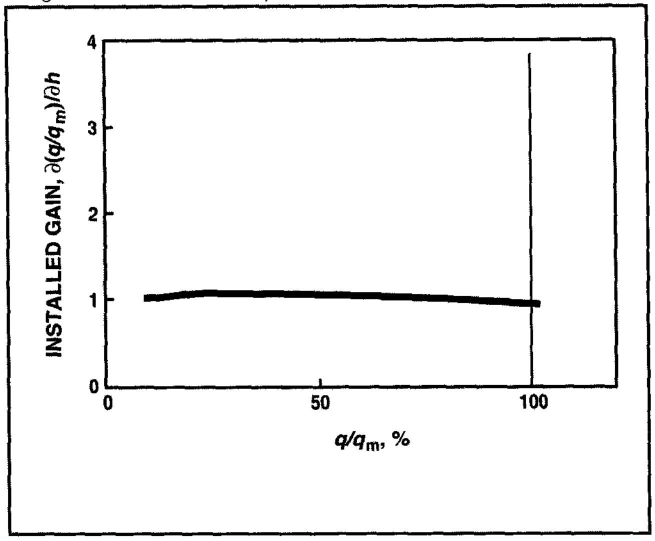
4. Linear installed flow characteristic with a new type of control valve



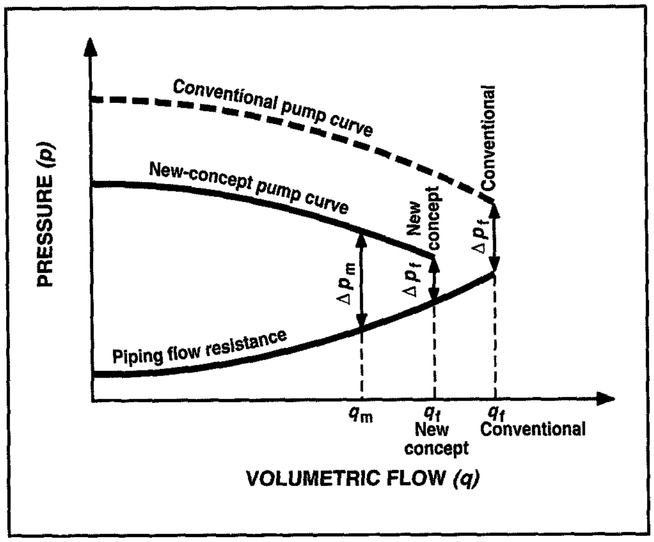
If the 2000-gal/min water flow rate in the previous example were controlled with a 3-psi pressure difference, the pressure difference would represent only 10% of the total dynamic pressure loss in the piping. This would result in significant changes in the installed flow characteristic. A smaller pressure difference (Δp) results in a larger opening and a wider control range (Fig. 2). When operating close to the maximum designed flow, the change in the control signal and valve opening would result in only a minor change in the flow through the valve. The gain of the valve at these conditions would approach zero and would result in very low controllability.

A smaller pressure difference across the valve requires a new type of construction to guarantee good controllability over the entire control range, i.e., a design which produces a flow characteristic that enables control of the process at smaller pressure drops than those conventionally used. In practice, this requires a new design of the valve's inherent flow characteristic.

5. Ideal installed gain with a new type of control valve. q_m = max. designed flow rate = 600 m³/h.



6. New concept of pump throttle control



The safety margin ensures that there is a sufficient margin between the maximum designed flow rate of the process and that of the fully opened valve. An adequate maximum flow capacity ensures the necessary safety margin. The valve's maximum flow capacity is represented by the term C_v of the fully open valve.

A new valve control structure providing the necessary standard of controllability with small pressure drops can be developed based on existing theories of flow characteristic curves and on laboratory tests. The new type of control valve results in a linear installed flow characteristic (**Fig.** 4) and optimum installed gain (**Fig.** 5) with a pressure difference across the valve representing only 10% of the total dynamic pressure loss in the piping. The new concept of pump throttle control is demonstrated in **Fig. 6**. Reducing the pump's pressure below the rated level results in a smaller pressure drop for the valve. If the pressure level is reduced, the valve must have a larger capacity to secure a sufficient margin between the maximum designed flow and the flow when the valve is fully open.

When sizing liquid flow piping systems, a suitable expert system should be used to select and size the control valves. The system helps the designer define and select appropriate pressure drops, valve types, and nominal valve sizes. Valve selection using the expert system is based on the valve's linear installed flow characteristic and on the smallest possible controllable pressure drop. The valve must be measured and tested in a laboratory to obtain reliable and accurate information on its flow characteristics for the expert system.

Final process functioning and controllability with the selected control valve can be modeled with a control valve simulation program. With this program, the entire pump loop and its control loops can be evaluated beforehand.

Conclusions

Wasted pumping power can be significantly reduced by sizing pumps and control valves more accurately, and by using new methods of pump and valve selection. Combining the improved control valve's installed flow characteristic with state-of-the-art sizing and simulation programs ensures minimal pressure drop across the control valve without loss of accurate and reliable control in all process conditions. If accurate process condition information is available at the planning stage, even more significant pumping energy savings can be achieved. Moreover, reduced pressure drop across the control valve reduces the likelihood of valve cavitation. This, in turn, reduces the need for noise attenuation, preventing cavitation erosion, and repairing damage.

To make the most of the advantages gained by using highly developed control valve sizing and selection programs, closer cooperation between process licensees, process users, and valve manufacturers is also required.

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