■ The Application

Primary pumps in a primary/secondary pumping system, such as shown in Figure 1, can be used to maintain a constant flow through devices that encounter operation or control difficulties when exposed to variable flow. The primary/secondary pumping technique decouples the “primary” production loop from the “secondary” distribution loop. This allows devices such as chillers to obtain constant design flow and operate properly while allowing the rest of the system to vary in flow.

As the evaporator flow rate decreases in a chiller, the chilled water begins to become over-chilled. As this happens, the chiller attempts to decrease its cooling capacity. If the flow rate drops far enough, or too quickly, the chiller cannot shed its load sufficiently and the chiller’s low evaporator temperature safety trips the chiller requiring a manual reset. This situation is common in large installations especially when two or more chillers in parallel are installed if primary/secondary pumping is not utilized.

■ The Design

In Chilled Water systems, the Primary loop or “production” loop, consists of pumps sized to handle the chillers designed flow rate at a discharge pressure just high enough to circulate the water through the chiller and the rest of the primary piping loop. This loop should be as small as possible, just large enough to allow the secondary system to be attached. This minimizes the resistance of the primary loop and therefore the energy consumption of the non-regulated constant flow pumps.

The primary pump flow is traditionally controlled by throttling valves or balance valves on the discharge of the pumps, figure 1. The pumps are often oversized due to safety margin in the designs. By adding losses to the pumping circuit with the throttling valves, the proper design flow rate can be established, figure 2 (moving from flow 1 to Design flow).

Another method used is to trim the pumps impeller. Once the system is operating, the balancing contractor can determine the actual pressure drop in the primary loop.

Once the actual pressure requirement of the pump is established, the pumps impeller can be removed, trimmed to the proper diameter, rebalanced, and reinstalled in the pump.

Decreasing the diameter of the pumps impeller reduces both the capacity and pressure of the pump as desired, but also has an impact on the pumps efficiency, figure 3.

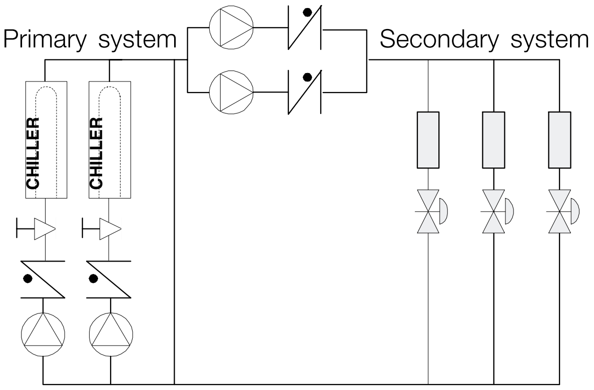

Fig. 1 - Traditional Primary/Secondary design

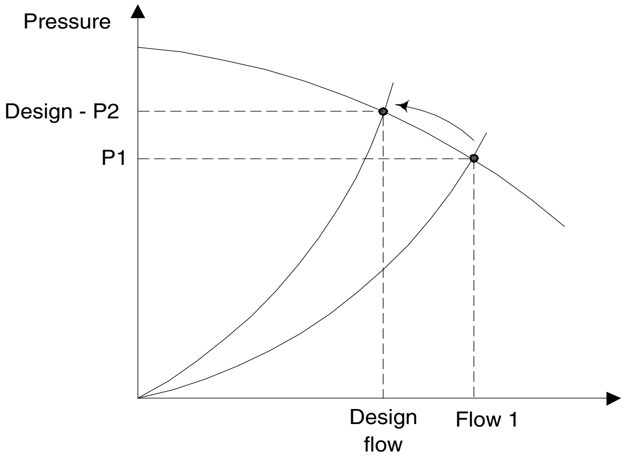

Fig. 2 - Throttling valve

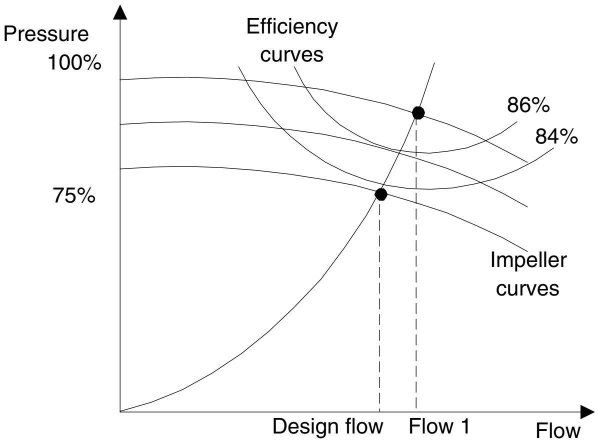

Fig. 3 - Impeller trimming

■ The new standard:

Depending on the size of the system and the size of the primary loop, the energy consumption of the primary loop can become substantial.
A VLT frequency converter can be added to the primary system, to replace the throttling valve and/or trimming of the impellers, leading to reduced operating expenses (fig. 4). Two control methods are common:

The first method uses a flow meter. Because the desired flow rate is known and is constant, a flow meter can be installed at the discharge of each chiller can be used to control the pump directly. Using the built-in PID controller, the VLT frequency converter will always maintain the appropriate flow rate, even compensating for the changing resistance in the primary piping loop as chillers and their pumps are staged on and off.

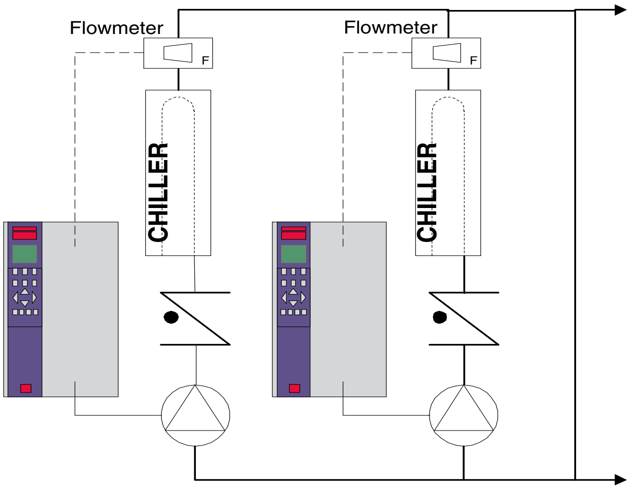

Fig. 4
The VLT frequency converter solution

The other method is local speed determination. The operator simple decreases the output frequency until the design flow rate is achieved.
Using a VLT frequency converter to decrease the pumps speed is very similar to trimming the pumps impeller, except it doesn't require any labor and the pumps efficiency remains higher, figure 5. The balancing contractor simply decreases the speed of the pump until the proper flow rate is achieved and leaves the speed fixed. The pump will operate at this speed any time the chiller is staged on.
Because the primary loop doesn't have control valves or other devices that can cause the system curve to change and the variance due to staging pumps and chillers on and off is usually small, this fixed speed will remain appropriate. In the event the flow rate needs to be increased later in the systems life, the VLT frequency converter can simply increase the pumps speed instead of requiring a new pump impeller.

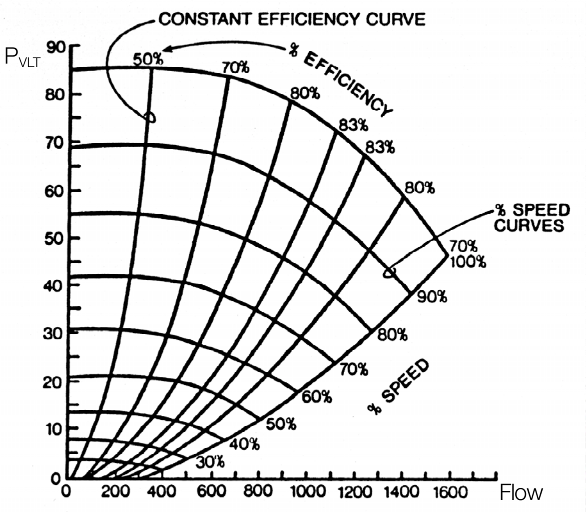

Fig. 5
Pump efficiencies with variable speed
(Figure courtesy of ITT Bell & Gossett)

Figure 5 shows that the pumps efficiency remains constant as the speed is reduced to obtain the design flow. This differs from the results of the trimming the impeller where the efficiency decreases (fig. 3).

■ Annual operation load profile

Since primary pumps by definition are constant flow, the flow rate is always at 100%. What the profile doesn't show is the discharge pressure required.

■ Energy saving calculation example

In the following calculation example, a 30 kW primary pump´s operation cost with a VLT frequency converter is compared to the same pumps operation cost with a throttling valve.
For the purposes of a comparison, the pumps original design discharge pressure is assumed to be 15% overheaded.

It is normal for pumps to be overheaded by 15% or more to compensate for possible installation variations and other safety calculations. For constant flow applications, this overpressurization causes a proportional waste of energy. Using a VLT frequency converter to balance the system instead of throttling valves allows for the elimination of the otherwise wasted energy.

Example:

A 30 kW primary pump is operating by a constant flow at 100% for 24 hours every day.

Total annual operating hours is:	24h x 365 days	= 8760 hours.
Energy consumption per year:	30 kW x 8760h	= 262800 kWh
Energy saved by using a VLT:	15% of 262800 kWh	= 39420 kWh
Annual money saved by using a VLT:	39420 kWh x US$ 0,10	= US$ 3942
Simple payback:	$\frac{\text{Drive price}}{\text{Energy savings}}$	≈ 1.5-2.5 years

■ Sensor Type And Placement

For Primary Pumping systems, the sensor location is not as critical since a flowmeter is not really required, but when used, proper location will avoid any operational difiiculties. The proper location for a flow meter is at the discharge or inlet of each chiller, assuming each chiller has a dedicated pump and VLT frequency converter.
This allows the VLT frequency converter system to guarantee the design flow rate through each chiller and take advantage of the decreased resistance in the piping network as parallel chillers are destaged.
An example schematic showing the sensor placement is shown in Fig 4.

Differential pressure sensors can also be located across each chiller because differential pressure across a non modulating load also measures flow. Since flow is the critical parameter however, it is recommended that a flow meter be utilized.

■ Comparison of installation and maintenance costs

Aside from the potential energy savings,the cost of using a VLT frequency converter can be partially paid for by the savings on installation and maintenance costs. The traditional system not only requires the throttling valves and balancing valves, but also needs at a minimum: 6-wire motor cable, a softstarter, and power factor correction capacitors (PFCC´s). When opting to trim the pumps' impeller, system down-time and a considerable amount of labor is also saved.

Utilizing the Danfoss VLT frequency converter makes the valves, soft-starters, power factor corrections, and extensive cablework unnecessary. Manual speed adjustment or a simple voltage (0...10V) or current (0/4...20 mA) control signal and flow meter is sufficient to vary the flow.

Maintenance is limited to a minimum, and installation costs and space can be saved. The VLT frequency converters IP 54 enclosure allows it to be mounted in the mechanical equipement room close to the pumps on the wall.

A smart design combined with the falling costs of electronic equipment and increasing costs in labor have brought the investments for most regulation methods to a similar level. The comparison of the energy consumption, installation costs, and decreased maintenance costs show why the utilization of VLT frequency converters are the best choice.

■ True pay-back calculation:

$$\frac{\text{Cost of drive + flow meter - (throttling valves + starter + wiring + PFCC´s) - saving in commissioning time}}{\text{Energy savings + annual maintenance savings}} \approx \text{0 year} \pm \text{0.5 year}$$