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Eliminating Costly Thermal Contamination In Chilled Water Systems

It's no secret that effectively designed variable speed pumping can save money and energy in a wide variety of applications. But many consulting/specifying engineers are surprised to learn that it can also significantly reduce thermal contamination in chilled water systems.

In simple terms, thermal contamination is the addition of unnecessary, unwanted heat to chilled water. Due to basic laws of physics, every time water flows in a pipe, water friction occurs in the form of pipe loss and system head loss, resulting in thermal contamination. This phenomenon occurs every time chilled water is pumped. *See Figure 1*.

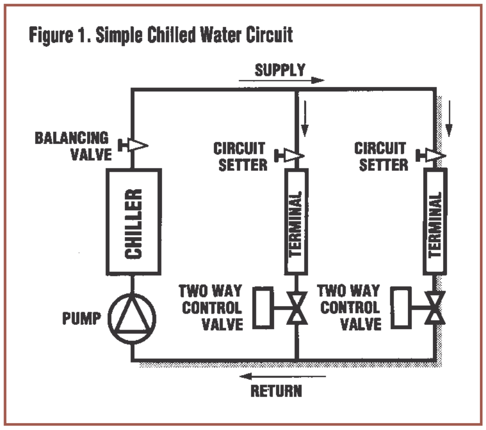

Figure 1. Simple Chilled Water Circuit

Some of the heat is added in the pump itself. More is added through the friction of pipe and system head loss as water droplets collide with each other and with pipe walls as they transit the piping system to and from the pump. Additionally, before water returns to the chiller, it is exposed to even more thermal contamination by the chiller pump.

But by expending less energy, chilled water systems can significantly reduce thermal contamination. Since one pump horsepower equals 2,545.8 BTUs per hour or 42.43 BTUs per minute, and one ton of refrigeration equals 12,000 BTUs per hour, we can relate pump horsepower (or energy) savings to BTU (or thermal) contamination within a system.

See Chilled Water Systems, pg. 2

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PROBLEM SOLVING

Chilled Water Systems

from pg. 1

For instance, if 100 horsepower is saved in pumping, a reduction in total plant heat or thermal load of 21.2 tons of refrigeration can result.

That's more than five percent of a 400-ton chiller or 10 percent of a 200-ton chiller.

With the exception of a small amount of power lost in the pump bearings and the stuffing boxes (termed mechanical losses), the difference between the brake horsepower and hydraulic horsepower represents energy degradation within the pump itself. Most of this is transferred in the form of heat to liquid passing through the pump.

The mechanical losses of a given pump depend on the size of that pump and the relationship of its bearing load and mechanical seal diameter. You can estimate what these mechanical losses are. Figure 2 reflects typical mechanical losses for centrifugal pumps rated from 50 to 10,000 gpm. The mechanical losses are expressed as the percentage of total shaft horsepower.

For instance, on a 1,000-gpm pump, the total mechanical losses on a 50 horsepower rating would amount to only about two percent - or about one horsepower on a typical centrifugal pump. The remaining 49 horsepower will contribute to the thermal load and contamination of the system.

In many cases, the heat per se added by the pump to the fluid stream may not be great and represents the inefficiency of the pump itself. However, the pump imparts greater energy into the chilled water in the form of pressure. Although it is not thermal contamination yet, as the chilled water is transferred throughout the circuits, the rubbing and friction leads to significant thermal contamination.

But much of this wasted energy can be saved through variable speed pumping. In addition, system energy expenditures and flows can be reduced or increased to meet actual needs.

Using a common example, 100 percent of full load design operation is only required 2 percent of the time, whereas 50 percent of the full load is required 30 percent of the time. While the pumping system must be designed for full load operation, the system operates at only half its capacity 15 times longer than at full capacity.

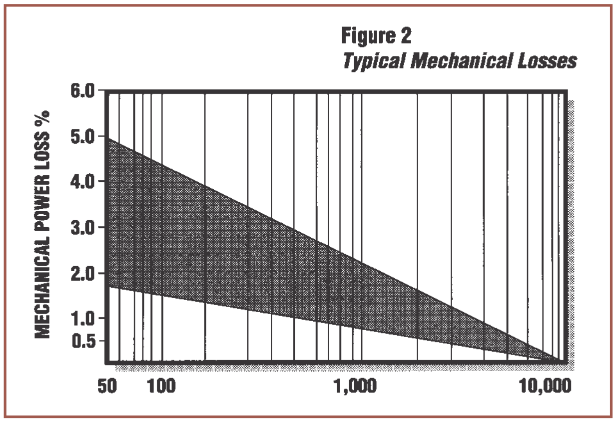

Figure 2 — Typical Mechanical Losses

As system loads decrease, so does the required flow. As flow decreases, so does system resistance or friction.

In a given system, friction head loss varies as the square of flow, or **Head 2 = (Capacity 2 / Capacity 1) 2 x Head 1**

With this formula, a head loss curve can be established. This is shown in Figure 3 as the system head loss curve or variable head loss. The pump control curve is derived from the system head loss plus the addition of the design pressure drop.

The shaded area depicts constant speed pump performance overlaid on the actual system control curve and is wasted pumping energy or direct thermal contamination.

However, variable speed pumping tracks the control curve. Thus, only the flow actually required at any given time is pumped. This action substantially lowers annual operating costs. Since variable speed pumping tracks true demand, the annual savings, when compared to safety factored or overheaded pumps, is even greater.

It's easy to quantify direct savings from using variable speed pumping to reduce thermal contamination. A modern chiller typically will cost approximately $300 in initial capital costs for each ton of refrigeration it produces. So initially reducing refrigeration needs by 10 tons saves $3,000. At .063 average kilowatts per ton and at a 10 cents electrical energy cost, that same 10 tons of refrigeration saved will return over $5,500 per year in energy costs.

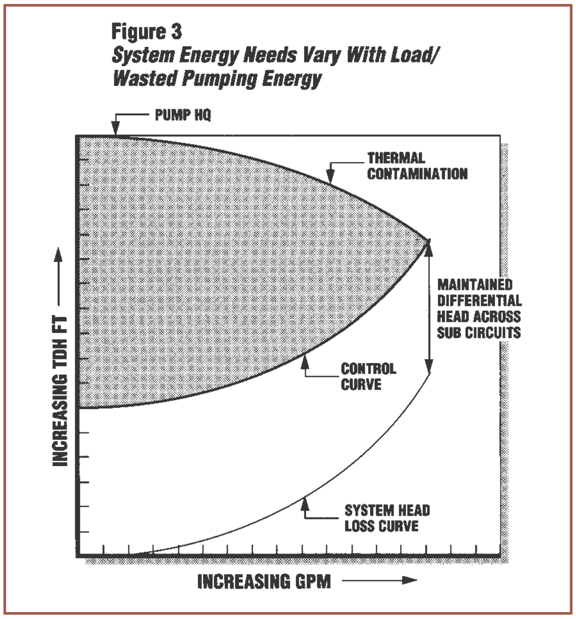

Figure 3 — System Energy Needs Vary With Load/ Wasted Pumping Energy

With numbers like those, it's hard to ignore thermal contamination and the benefits of system responsive variable speed pumping.