Chiller Pump Connections

James B. (Burt) Rishel, PE

July 17, 2006

The Patterson HSC pumps designed for the HVAC industry offer great selections for chillers in the range of 300- to 2500-ton capacity. Their high efficiency and rugged design is seldom equaled by other manufacturers. Typical of this are the following selections made, as we evaluate the correct methods for connecting chilled water and condenser pumps to their chillers.

The advent of variable speed drives and digital control necessitated that we look at the connection of chillers to pumps and ensure that the best piping arrangement and sizes of pumps are utilized for each particular installation. There is no single, best method of connecting chillers to pumps.

Chilled Water Pumps:

Now that variable primary pumping is the accepted method of pumping chilled water, a review should be made of how the pumps are connected to the chillers. They can be arranged in tandem with one pump for each chiller (Figure 1) or they can be headered (Figure 2) so that any pump can be used with each chiller.

Before we can make any suggestions on the pumping arrangement, we must review the chiller sizing and the basic missions of the chillers. The simplest chiller arrangement is chillers of the same size and in parallel as shown in Figures 1 and 2. Another common chiller arrangement is parallel arrangement but with a smaller chiller for off-peak loads as shown in Figure 3. Larger chiller installations may require the chillers to be in tandem/parallel as shown in Figure 4. Also, there are many chiller installations with various sized chillers which require specific and careful design of the pumping installation. The majority of the chiller installations are those of Figures 1, 2, 3, and 4, and we will limit this discussion to them. Manual shut-off and check valves are not shown in the figures.

Chillers in tandem/parallel, Figure 4, will not be discussed in detail since the mission of the chillers can be so variable. On some installations, the differential temperature across the evaporators in tandem is equal; on others it may be different. Other installations will have bypasses around some or all of the chillers. The chilled water pumps are almost always headered due to the standby requirements of the installation.

All of the chillers of Figures 1, 2, and 3 have specific missions that must be fulfilled. Chillers either support the full cooling load of the installation or they are

designed to handle off–peak cooling loads. In the case of the smaller chiller of Figure 3, it is either designed 1) to handle an off-peak load and no other or 2) to handle the off-peak load and be available for supporting the full load in event of failure of another chiller.

The chilled water pumps likewise have missions that must be fulfilled. With primary/secondary pumping, the pumps were selected usually at the design flow of the chiller evaporators, and one pump was provided per chiller. Various standby procedures were utilized. With variable primary pumping, each chiller must be capable of being pumped to at least 120% of design flow to take advantage of the chiller's ability to provide additional chilled water when the condenser water temperature is lower than the design temperature.[1] The actual allowable percent of overflowing the evaporator is the maximum allowable velocity divided by the design velocity. Assume that the maximum allowable velocity is 10 fps and the design velocity is 7.5; the percent of overflowing allowable is then 10 ÷ 7.5 or 133%. In actual practice, it has been found that 120% appears to secure most of the benefit of overflowing when reduced condenser water temperatures are available to the chillers. Overflowing is also a procedure for reducing the problem of low return water temperature.

With these factors under consideration, let us look at a three-chiller installation with each chiller designed for 600 tons cooling and then a second installation with three 600-ton chillers and a 300-ton chiller for off-peak loads. For the second installation, we will consider the small chiller for off-peak loads only and then as a stand-by chiller as well. In all these cases, assume that the design load is 1,800 tons at a differential temperature of 12° F, and a minimum of three chilled water pumps are required. No special chiller or pump capacity will be included for standby since the amount of standby needed varies with the type of building.

Following is the design criteria:

> Chiller evaporator or condenser loss: 300-ton: 10 ft.; 600-ton: 15 ft.
> Chilled water system friction loss at design flow of 3,000 gpm: 50 ft.
> System differential pressure at remote transmitters: 15 ft.
> Pumping system loss (for any pump): 8 ft.
> Total friction losses less evaporator loss at design flow: 73 ft.

First System: three 600-ton chillers with pumps in tandem, Figure 1.

Since the pumps must be able to operate the evaporators at 120% flow, their design flow is 600 x 2 gpm/ton x 1.20 or 1,440 gpm. Their head must be adjusted for this 120% flow, so the evaporator loss is 15 ft. x 1.20 or 22 ft. The individual pump condition is, therefore, 1,440 gpm at 73 + 22 or 95 ft. The Patterson 8x5x12 HSC pump has an efficiency of 86% at this condition and requires 40.1 bhp. (Note that this pump has a peak efficiency of 89% which is unequalled in

the HVAC industry for this size pump.) (Also note that these are variable speed pumps, and the variable speed drive will not allow overloading of the motor beyond its service factor, so it is no longer necessary to equip the pump with a 50 hp motor.)

Second System: three 600-ton chillers with pumps headered, Figure 2.

With this system, two pumps can operate with one chiller when it is running at 120% capacity, so the pumps can be selected at 1,200 gpm at 73 + 15 or 88 ft. The same Patterson 8x5x12 HSC pump has an efficiency of 84% at this condition and requires 31.7 bhp.

Third System: three 600-ton chillers with one 300-ton chiller with the pumps in tandem, Figure 3.

The pumps for the 600-ton chillers are the same as those for the First System.

The pump for the 300 ton chiller needs to serve the chilled water system when 300 tons or fewer cooling loads are existing on the chilled water system. Under these conditions, the friction loss in the system will be 2 ft. and the pump head will be 2 + 10 + 8 + 20 or 40 ft. The pump condition will be 600 gpm at 40 ft. head. The Patterson 6x4x11 pump at 1200 rpm has an efficiency of 86% and requires 7.1 bhp. An alternate pump is a Patterson end suction pump, size 5x4x7.25 at 1,800 rpm and 85.5% efficiency at this condition and requires 7.1 bhp also.

Fourth System: Same as the above excepting that the 300-ton chiller must operate with the 600-ton chillers, Figure 3.

The pumps for the 600-ton chillers are the same.

The pump for the 300-ton chiller must be able to pump the system, so its head must be 73 ft + evaporator loss of 10 for a total of 83 ft. The pump condition will be 600 gpm at 83 ft. The Patterson 6x4x11 HSC pump has an efficiency of 83% at 1,800 rpm and requires 15.2 bhp.

Fifth System: three 600-ton chillers with a 300-ton chiller with the pumps headered, Figure 5.

The pumps can be the same as the Second System. The-300 ton chiller utilizes one of the larger pumps. The brake horsepower will be substantially the same as that for the Second System. A balance valve needs to be installed in the 300-ton chiller circuit to create the same friction in that circuit as that for the 600-ton chillers.

Sixth System: the large chiller pumps headered and the 300-ton pump in series

with its chiller, Figure 6.

The pumps for the 600-ton chillers are the same for the Second System. The pump for the 300-ton chiller will be similar to the one in the Third or Fourth System

Summary of Chilled Water Pumps:

Following is the total brake horsepower for the six chiller/pump installations.

> First System: (3) 40.1 = 120.3 bhp total
> Second System: (3) 31.7 = 95.1 bhp total
> Third System: (3) 40.1 + (1) 7.1 = 127.4 bhp total [Small chiller used on
> 300-ton loads only]
> Fourth System :(3) 40.1 + (1) 15.2 = 135.5 bhp total [Small chiller used on
> all loads]
> Fifth System: (3) 31.7 = 95.1 bhp total
>
> Sixth System: (3) 31.7 + 7.1 or 15.2 = 102.2 or 110.3 bhp

The above listing of brake horsepowers demonstrates that the defined mission for the chillers determines the optimum pumping arrangement. The need to be able to pump any chiller to 120% of its design flow increases the horsepower of tandem arrangements. A thorough review of the chillers' mission needs to be made before a pumping arrangement is selected.

There is a reasonable trend to convert existing constant speed chilled water pumps to variable speed with sizeable savings in energy. Often, existing chillers are equipped with chilled water pumps in tandem with the chillers. A recent evaluation was made of an installation of four 800-ton chillers that had their chilled water pumps installed in tandem. The pumps were adequate at 1,600 gpm with an efficiency of 86%. A problem occurred when it was attempted to operate the chillers at the above 120% overflow. The flow was 1,920 gpm, and the efficiency of the pumps fell to 66%, resulting in an over 30% increase in energy consumption. The solution was to header the four pumps and eliminate this run-out of the pumps through the operation of two pumps with one chiller at the flow of 1,920 gpm.

Condenser Pumps:

Condenser pumps require a similar evaluation, as they can be installed in tandem or headered like chilled water pumps. The same chiller arrangements will be evaluated, and the condenser losses will be assumed to be the same as the evaporators. The condenser flow will be set at 3 gpm/ton. Assume that the rise over the cooling towers is 10 ft., and the condenser piping loss at design is 15 ft. for a total system loss of 25 ft.

Unlike variable primary pumps, condenser pumps can be constant speed or variable speed. Generally, for chillers of the size that we are evaluating here, there is little need for variable speed since there is not a great amount of friction in the cooling tower piping; also, it is generally recognized that constant flow in the condenser will result in chiller energy savings that may be equal to or greater than the energy saved with variable speed pumps.

First System: three 600-ton chillers with pumps in tandem, Figure 1.

The condenser pumps can be sized for the chillers at design flow, as the differential temperature for the condenser water increases when the evaporators are operating at 120% flow. The condenser loss is 15 ft., and the individual pump condition is 1,800 gpm at 25 + 15 ft or 40 ft. The Patterson 10x8x11 HSC pump has an efficiency of 86% at 1,200 rpm and requires 21.1 bhp.

Second System: three 600-ton chillers with pumps headered.

With this system, one pump must operate with each chiller, so the pumps are the same as those for the First System.

Third System: three 600-ton chillers with 300-ton chiller for small loads only with pumps in tandem with the chillers, Figure 3.

The pumps for the 600 ton-chillers are the same as for the First System.

The condenser pump for the 300 ton chiller needs to deliver only 300 x 3 or 900 gpm regardless of the duty of the chiller on the chilled water system. The pump head is the system head of 25 ft. + the condenser loss of 10 ft. for a total of 35 ft. The pump condition is, therefore, 900 gpm at 35 ft. The Patterson 8x6x12 HSC pump has an efficiency of 86% at 1,200 rpm and requires 9.2 bhp.

Fourth System: Three 600-ton chillers with a 300-ton chiller with three larger pumps headered, Figure 5.

This is not a recommended condenser pump arrangement due to the small brake horsepower of the pump for the 300-ton chiller.

Conclusions:

1. Equal sized chiller installations should always have headered pumps for chilled water. The pump motor horsepower is almost always less, and standby capacity is available in the event of a pump failure. Motorized valves are required on the chillers to isolate them when not called to duty.

2. Condenser pumps for equal sized chillers can be tandem or headered.

Tandem connection requires some type of standby while headered connection needs an automatic isolation valve on each chiller.

3. Unequal sized chillers create pumping questions that must be analyzed carefully. The chilled water pumps for any equal sized chillers should be headered with smaller chillers in tandem with their own pumps, Figure 6.

4. Existing chillers with pumps in tandem should be analyzed carefully to determine whether headering the chilled water pumps is necessary when they are changed to variable primary pumping.

5. Condenser pumps for unequal sized chillers should, in general, be installed in tandem.

Patterson HSC pumps offer excellent construction for chilled and condenser water services. They require less room to service than most other types of pumps in the HVAC industry. The HSC pump has a shorter shaft (Figure 7) than other manufacturers' pumps. This shortened shaft reduces the deflection at the seal faces and lengthens the useful life of the pumps.

[1]Gil Avery, PE, *Operating Chillers in the Max-Cap Range,* Engineered Systems Magazine, June 2003

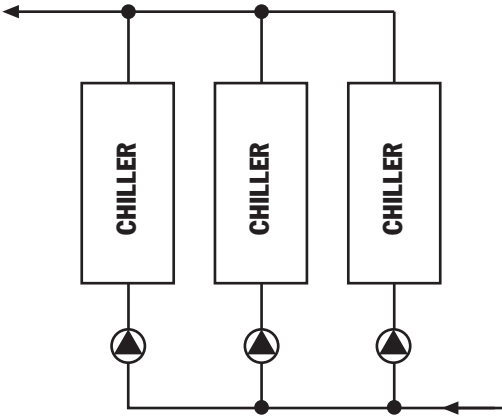# Technical Data
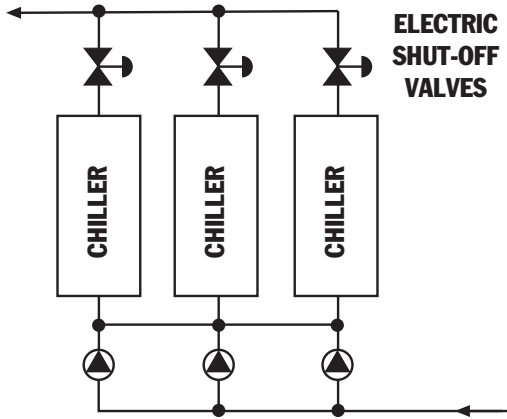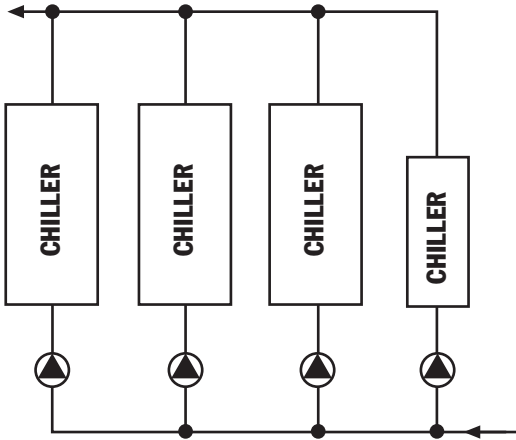## HEADERED OR TANDEM CHILLER PUMP CONNECTIONS

FIGURE 1
TANDEM PUMPS

ELECTRIC SHUT-OFF VALVES

FIGURE 2
HEADERED PUMPS

FIGURE 3
UNEQUAL CHILLERS
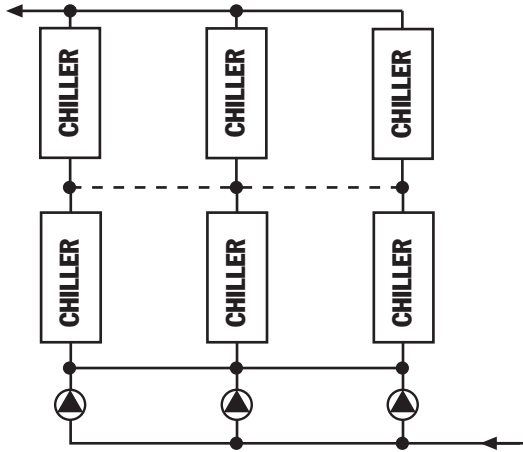
FIGURE 4
TANDEM/PARALLEL PUMPS

ELECTRIC SHUT-OFF VALVES

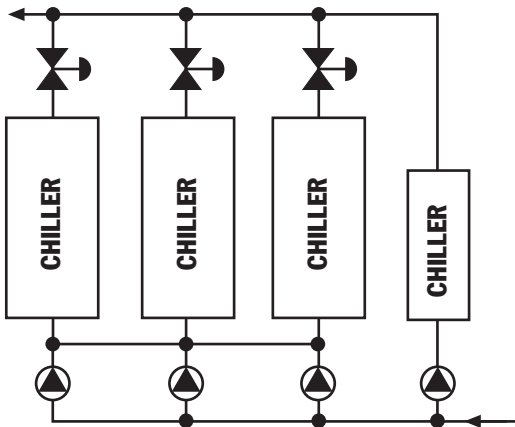BALANCE VALVE
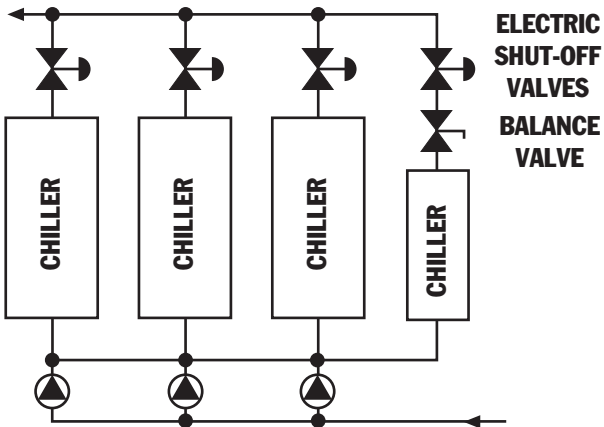
FIGURE 5
ALL PUMPS HEADERED

FIGURE 6
EQUAL CHILLERS HEADERED

FIGURE 7
HSC CUTAWAY