TRANE

Engineering Bulletin

Reducing Condenser Flow Rates for Systems with CenTraVac™ Chillers

—or—

3.0 GPMc/Ton is Too High

March 2004

CTV-PRB015-EN

3.0 GPM_C/Ton is Too High

Run the numbers

The optimum condenser water flow rate for minimum *system power* is less than 3 GPM_C/ton. The optimum flow rate will depend on several variables, including the hydraulic distance from the chiller to the tower, the specific chiller, the cooling tower, and other factors. The only way to determine the optimum flow rate is to do an analysis, and one such way is presented here.

Minor chiller adjustments

The analysis which follows uses the same size chiller/motor/heat exchangers, but the impeller diameter may change. There is no impact on chiller cost.

Chiller replacements

For a chiller replacement where the tower will also be replaced, there are some operating versus first cost choices to be made. When the existing tower will be reused, it is important to make sure that the nozzles are appropriate for the flow rate.

Assumptions

1. The size of the condenser water piping in this analysis will remain unchanged.

However, the building owner can separately examine reducing the condenser water piping size, trading higher condenser pumping costs for lower installed costs.

2. The tower size and tower performance will be held constant.

A customer can use an existing tower for a larger tonnage chiller when using lower GPM_C/ton (as a tower is essentially a GPM_C heat exchanger). The building owner can separately examine using a smaller tower to trade higher system operating costs for a lower tower first cost.

3. The benefit of reduced flow will be taken as lower design entering condenser water temperature (ECWT) to the chiller. Because we are asking it to create colder water, the cooling tower will provide more condenser water temperature relief for the chiller when operating at part load.

To determine the balance entering condenser water temperature (ECWT) at design conditions, the centrifugal chiller selection program and the tower selection program must be run to obtain the same temperatures. For example, at 2 GPM_C/ton, the programs "balanced" at 83.3°F. Figure 1 shows the average ECWT as a function of condenser flow rate. The averages were calculated by maintaining the same cooling tower and running the tower hardest to obtain the lowest return condenser water temperature. This temperature will vary with the specific cooling tower. Figure 1 shows the average ECWT from several cooling tower selections.

Figure 1: ECWT by Flow Rate

GPM_C/ton	Average Design ECWT
3	85
2.8	84.7
2.6	84.4
2.4	84.1
2.2	83.7
2.0	83.3

Related Topics

Chiller-Tower optimization

The optimum *hourly*, not design, tower temperature varies with the chiller, the ambient conditions, the load, and some system criteria. Generally, the optimum temperature for best chiller plant efficiency will vary between 60° - 77°F — it is NOT at 55°F entering condenser water temperature. This topic is addressed separately in an Engineers Newsletter:

Tower Temperature...Control it How?, available from the web at http://www.trane.com/commercial/library/vol241/v24a.asp and in:

CTV-SLB005-EN, Chilled Water System Design and Operation, available on TraneNET.

EarthWise™ System Designs

Not covered in this analysis but of similar value are lower or variable evaporator flow (GPM_E) for reduced evaporator pumping costs and lower leaving evaporator water temperature (perhaps 42 or 40 °F or lower, depending on the specific installation) to reduce the delivered air temperature—thereby reducing the first cost and operating cost of the air handlers. The building owner can separately examine reducing the duct sizes, effectively trading higher air side operating costs for lower installed costs.

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Calculations

Evaporator pump energy requirements[1]

$$EvapPumpkW = \frac{\left(0.000188\frac{kW}{GPM \cdot Ft}\right) x\ (GPM_E\ x\ (PD_{chiller} + PD_{loop}))}{\eta_{pump} \times \eta_{pumpmotor}}$$

$$EvapPumpkW = \frac{\left(0.000188\frac{kW}{GPM \cdot Ft}\right) \times 1000GPM_E \times (24.65Ft + 30Ft)}{0.67} = 15.3kW$$

Condenser pump energy requirements[2]

$$CondPumpkW = \frac{\left(0.000188\frac{kW}{GPM \cdot Ft}\right) \times GPM_c \times (PD_{chiller} + H_{tower} + PD_{chiller...tower})}{\eta_{pump} + \eta_{pumpmotor}}$$

2.0 GPMc/ton:

$$CondPumpkW = \frac{\left(0.000188\frac{kW}{GPM \cdot Ft}\right) \times 1000GPM_c \times (12.09Ft + 12Ft + 8.9Ft)}{0.67} = 9.3kW$$

2.2 GPMc/ton:

$$CondPumpkW = \frac{\left(0.000188\frac{kW}{GPM \cdot Ft}\right) \times 1100GPM_c \times (14.38Ft + 12Ft + 10.8Ft)}{0.67} = 11.5kW$$

2.4 GPMc/ton:

$$CondPumpkW = \frac{\left(0.000188\frac{kW}{GPM \cdot Ft}\right) \times 1200GPM_c \times (16.88Ft + 12Ft + 12.8Ft)}{0.67} = 14.0kW$$

2.6 GPMc/ton:

$$CondPumpkW = \frac{\left(0.000188\frac{kW}{GPM \cdot Ft}\right) \times 1300GPM_c \times (19.60Ft + 12Ft + 15Ft)}{0.67} = 17.0kW$$

2.8 GPMc/ton:

$$CondPumpkW = \frac{\left(0.000188\frac{kW}{GPM \cdot Ft}\right) \times 1400GPM_c \times (22.55Ft + 12Ft + 17.4Ft)}{0.67} = 20.4kW$$

3.0 GPMc/ton:

$$CondPumpkW = \frac{\left(0.000188\frac{kW}{GPM \cdot Ft}\right) \times 1500GPM_c \times (25.73Ft + 12Ft + 20Ft)}{0.67} = 24.3kW$$

PD = pressure drop (ft)   H = tower height (ft)

1.Pump efficiency used for all calculations is the assumed combined efficiency of the pump and pump motor efficiencies: 71% pump efficiency and 94.5% pump motor efficiency (obtained from a water pump manufacturer). GPM_E assumes a 12°F water temperature change in the evaporator.

2.Condenser pump calculations assume 20 feet of water pressure drop between the chiller and tower. This pressure drop varies with the square of the flow rate (GPM^2).

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Figure 2: Analysis for 500 ton chiller plant

		Percent Load			
Condenser GPM_C/ton	***kW***	***100***	***75***	***50***	***25***
2.0	chiller	302	195.8	124.5	79.8
	evap. pump	15.3	15.3	15.3	15.3
	cond. pump	9.3	9.3	9.3	9.3
	tower fan	21	21	21	21
totals		347.6	241.4	170.1	125.4
2.2	chiller	297.4	192.8	122.1	78.5
	evap. pump	15.3	15.3	15.3	15.3
	cond. pump	11.5	11.5	11.5	11.5
	tower fan	21	21	21	21
totals		345.2	240.6	169.9	126.3
2.4	chiller	293.6	189.8	120.3	77.7
	evap. pump	15.3	15.3	15.3	15.3
	cond. pump	14.0	14.0	14.0	14.0
	tower fan	21	21	21	21
totals		343.9	240.1	170.6	128
2.6	chiller	291	188.6	119.7	77.5
	evap. pump	15.3	15.3	15.3	15.3
	cond. pump	17.0	17.0	17.0	17.0
	tower fan	21	21	21	21
totals		344.3	241.9	173.0	130.8
2.8	chiller	288.8	186.6	118.2	76.8
	evap. pump	15.3	15.3	15.3	15.3
	cond. pump	20.4	20.4	20.4	20.4
	tower fan	21	21	21	21
totals		345.5	243.3	174.9	133.5
3.0	chiller	287.3	185.9	117.8	76.6
	evap. pump	15.3	15.3	15.3	15.3
	cond. pump	24.3	24.3	24.3	24.3
	tower fan	21	21	21	21
totals		347.9	246.5	178.4	137.2

Conclusions

Figure 2 shows the breakdown of power usage when varying condenser flow from 3.0 down to 2.0 GPM_C/ton. The optimum condenser flow rate is in the 2.0 to 2.5 GPM_C/ton range to minimize overall chiller plant power. As the tower is located further from the chiller, the condenser water pressure drop increases and the optimum condenser flow rate decreases.

In this particular analysis, system power consumption is minimized between 2.2 and 2.4 GPM_C/ton.

Literature Order Number	CTV-PRB015-EN
Date	March 2004
Supersedes	CTV-PRB015-EN 1/04
Stocking Location	Electronic

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www.trane.com

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