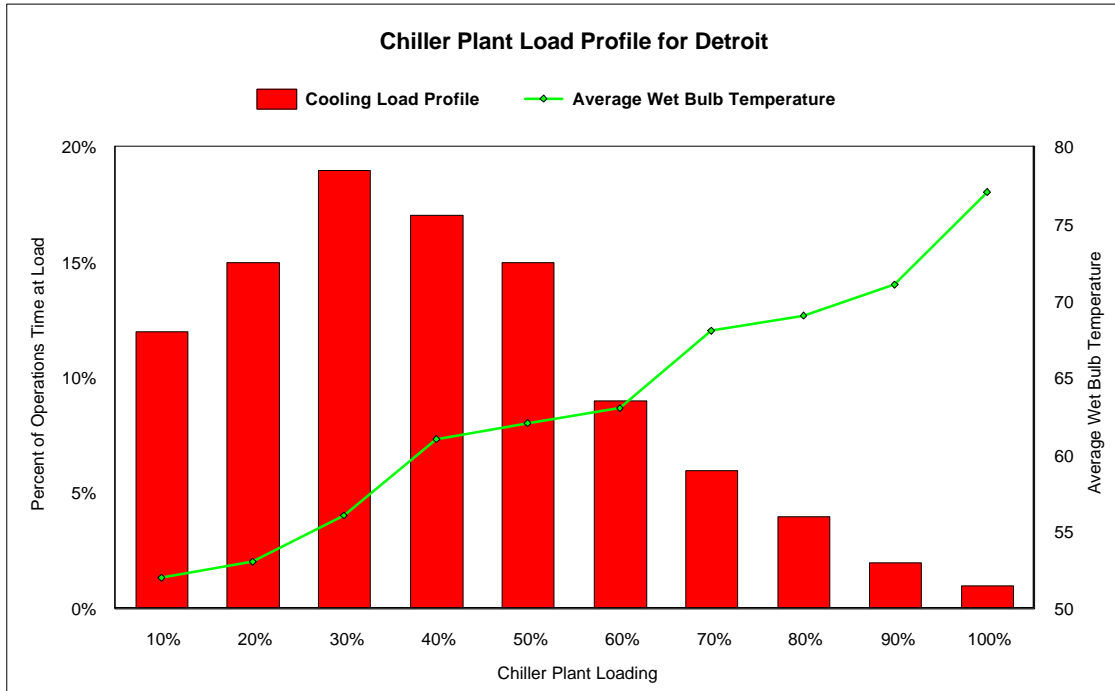# A HARTMAN LOOP EXAMPLE

AN ENERGY COMPARISON OF A LOOP CHILLER PLANT WITH CONVENTIONAL CHILLER PLANTS

by

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NOTE: This document shows a specific example of how a LOOP chiller plant reduces energy use compared to conventional constant speed or variable speed chiller plant configurations. In order to present an example with verifiable numbers, this example uses and identifies specific pieces of equipment. However, any one of a number of different equipment configurations could be employed to achieve nearly identical results. This document is not intended to indicate endorsement or support of one manufacturer's equipment over another.

The purpose of this document is to evaluate chiller plant performance for a typical application at a specific operating point to show how LOOP technologies can reduce energy use compared to conventional chiller plants. This example is for a chiller plant that serves a load that peaks at 1800 tons of cooling. The load is a commercial office building and the chiller plant consists of three 600 ton York centrifugal chillers, each with a nominal 0.6 kW/ton efficiency. Each chiller is connected to a Marley NCB2A1 Tower 600 ton cross flow cooling tower. For simplicity, a constant 42°F chilled water supply temperature is assumed at all loads (though actual LOOP projects employ variable chilled water temperature when possible for additional energy savings). The plant is located in Detroit, and has a load profile shown in the figure below, which is typical for such a facility in the Detroit climate. Detroit is chosen for this specific example because the Detroit load profile is typical of cooling load profiles for chiller plants throughout much of the US. A design tower approach temperature of 8°F establishes an 85°F entering condenser water temperature at the design condition or 77°F wet bulb.

Chiller Plant Load Profile for Detroit

Cooling Load Profile　　◆ Average Wet Bulb Temperature

Percent of Operations Time at Load (left axis, 0%–20%)

Average Wet Bulb Temperature (right axis, 50–80)

Chiller Plant Loading (x-axis, 10%–100%)

Using this chiller plant load profile, this example considers a specific part load operating point of 1/3 total plant capacity. Note from the chart above that this chiller plant spends most of its time operating at and around this point. We will compare operating energy consumption at this point for:

1. a constant speed centrifugal chiller plant
2. a conventional variable speed centrifugal chiller plant
3. a "LOOP" all-variable speed centrifugal chiller plant

First, consider a constant speed plant. At 1/3 plant capacity, one chiller, one tower, and one condenser pump are operated. Assume a 3 gpm/ton condenser water flow, and a constant speed tower fan with an optimization strategy aimed at minimizing condenser water temperature. The Marley tower head requirement is 12 ft, the chiller condenser head requirement is 16 ft, and our assumed piping loss is 32 ft. for a total pump head of 60 ft. A B&G 1531, 6BC pump yields an operating power requirement of 34 hp at these conditions. The Marley NCB2A1 Tower achieves an 8°F approach for an 85°F entering water temperature at design conditions. This tower employs a 25 hp fan. The Marley performance data shows that at a 600 ton load and the 56°F Wet Bulb temperature shown on the chart above for 1/3 plant capacity, the tower will deliver 69.9°F leaving Tower Water temperature with the fan in constant operation. From York constant speed chiller

power curves, the chiller power requirement is 84% of the power at design entering condenser water conditions. So, power requirements for the entire plant are as follows:

Chiller - constant speed	600 tons x 0.6 kW/ton x .84 Demand	= 302 kW
Condenser pump	34 hp x 0.746 kW/hp / .92 efficiency	= 28 kW
Tower Fan	25 hp x 0.746 kW/hp / .92 efficiency	= 20 kW

TOTAL	350 kW

Now assume a plant with variable speed chillers of the same nominal efficiency. A conventional variable speed plant still operates only a single chiller at this operating point. Making allowance for the VFD losses, the York power curves show that the power requirements from the York variable speed chiller curves reduces the power from 84% to 75%. Thus the power requirements for this operating point with a variable speed chiller are:

Chiller - variable speed	600 tons x 0.6 kW/ton x .75 Demand	= 270 kW
Condenser pump	34 hp x 0.746 kW/hp / .92 efficiency	= 28 kW
Tower Fan	25 hp x 0.746 kW/hp / .92 efficiency	= 20 kW

TOTAL	318 kW

Now lets look at an all-variable speed LOOP chiller plant in operation. In a LOOP chiller plant, all chillers, pumps and tower fans are variable speed. The operations calculator in the DDC controller that operates the plant calculates that two chillers is optimum for this operating point, and sequences the operation as follows:

Chiller Capacity (each for two chillers)	= 50% (300 tons)
Effective entering condenser water temperature	= 64ºF

Because each tower is only loaded to 300 tons, this optimized lower leaving tower water temperature is obtained with the following operating parameters for each cooling tower:

Condenser Pump Flow (Gpm)	= 1440 gpm
Condenser Pump Head (feet)	= 42 ft.
Condenser Pump speed (RPM)	= 1470 rpm
Condenser Pump motor hp	= 19.2 hp
Tower Fan speed (RPM)	= 1440 rpm
Tower Fan motor hp	= 13 hp
Actual tower leaving temperature	= 62.9ºF

Note that the 64ºF "effective" entering condenser water temperature is based on 1800 gpm flow. To adjust for heat transfer changes due to flow reduction and the decrease in log mean
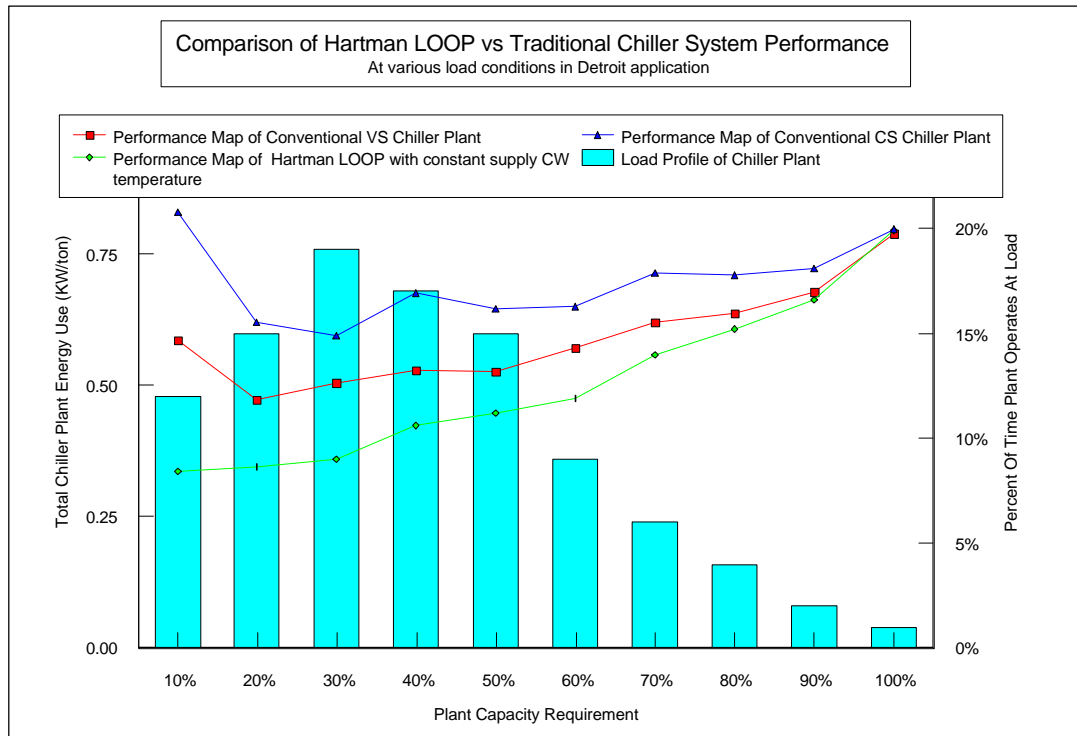
temperature in the bundle, the calculator shows a true tower leaving temperature requirement of 62.9°F is equivalent to the 64°F entering water temperature at full flow.

Using these operating parameters, the power requirements are obtained from York, Marley and B&G performance curves and data and adjusted for variable speed drive losses. The total power consumed is as follows:

Chillers - variable speed   300 tons x 0.6 kW/ton x .51 Demand   x 2 = 184 kW
Condenser pumps (variable speed) 19.2 hp x 0.746 kW/hp / .88 efficiency x 2 =   33 kW
Tower Fans (variable speed)   13.0 hp x 0.746 kW/hp / .88 efficiency x 2 =   22 kW

TOTAL   239 kW

The constant speed plant uses 46% more power and the conventionally operated variable speed plant approach uses 33% more energy than the all-variable speed LOOP chiller plant at this operating point. By making the same calculation for each of the intervals shown in the above chart, we find that in this application on an annual basis, the LOOP plant offers more than double the energy reduction of a conventional variable speed chiller plant compared to a constant speed plant. These results are shown in the chart below:

Comparison of Hartman LOOP vs Traditional Chiller System Performance
At various load conditions in Detroit application

This improved energy savings coupled with a simpler plant configuration and other features make LOOP chiller plants cost about the same, or in some cases less than conventional plants to construct. Also, in many climates, LOOP technologies makes changing out chillers that employ phased out refrigerants a very attractive investment. While it may appear that the patented control sequences that constitute LOOP chiller plant technologies result in a more complex plant, they do not. In fact, the sequence of operations for a LOOP plant is actually simpler than a conventional optimized chiller plant because LOOP technologies include a new simple set of parameters that provide much more straightforward control of all plant equipment.

Please review this example to see if the concepts employed hold true for the plant you are considering constructing or upgrading. If you have any questions or comments please call, write or e-mail us, and we will be happy to respond promptly with whatever information is required to complete your analysis of this exciting new technology for your facility!

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