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Engineers Newsletter

Tower Water Temperature . . .

Control It How??!

1
"As cold as possible!"
2
"Always run it hot — at design, if possible."
3
"We always use wet bulb plus 5 degrees."

Where **should** you run your tower sump controller? It's an often-asked question that's been answered various ways, as evidenced above. With the advent of new technology, it's time to rethink each of these conclusions.

1 — As Cold As Possible

Half-Truth: "The chiller is the 'largest' power consumer of the HVAC system . . . "

Fallacy: ". . . so, one way to minimize chiller energy consumption is to supply the chiller with the coldest tower water possible."

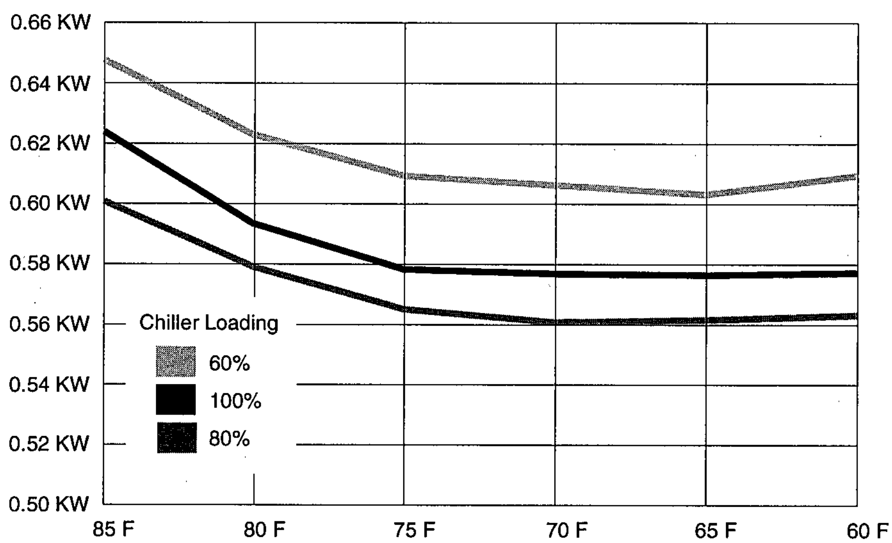
Fact: It's commonly known that lowering condensing temperature increases a chiller's efficiency. As long as the evaporator temperature is constant, a reduced condenser temperature will yield a lower pressure difference between the evaporator and condenser, and ease the burden on the compressor.

However, it's important to recognize that the efficiency improvements initially gained through lower condenser temperatures are limited. From a system perspective, improved chiller efficiency may be offset by increased tower fan and pumping costs. Consider, too, that not every condenser temperature reduction necessarily results in improved chiller efficiency. As Figure 1 illustrates, chiller consumption (kw/ton) eventually "bottoms out" and actually begins to increase as condensing pressure falls.

In short, though chillers are still a significant power consumer within the HVAC system, they are also the most efficient part of that system. Centrifugal chillers, for example, are available at 0.50 kw/ton at ARI rating conditions.

That's performance unheard of just a few years ago. With that in mind, don't overlook the potential energy savings possible in other areas of the system; the air handler may be a good place to start.

Figure 1: Chiller efficiency at various loads and tower leaving water temperatures.



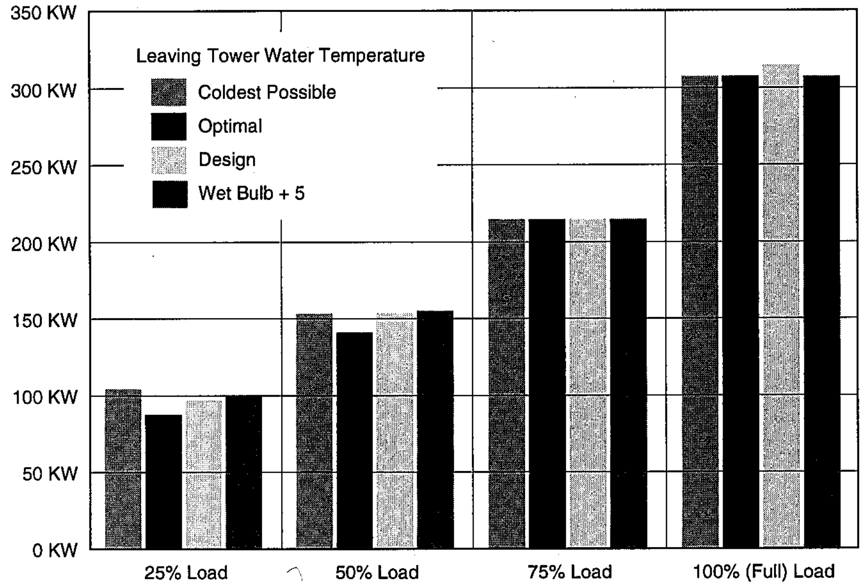
2 — Always Run It Hot... At Design If Possible

Half-Truth: "Fan power is proportional to the airflow rate cubed (Q^3), so when variable-speed drives are used... "

Fallacy: "...it's a good idea to produce the warmest possible tower water if you want to obtain a considerable reduction in tower fan energy consumption."

Fact: It's possible to have too much of a good thing. Although the chiller may still perform efficiently, operating at elevated tower water temperatures may cause adverse effects over time. The "higher-than-normal " pressure differential between the evaporator and condenser, for example, places a greater burden on the compressor. Put simply, while reducing fan consumption is a worthy goal, achieving it is not without cost.

Figure 2: Chiller + tower energy consumption at various loads and condenser water temperatures.



3 — We Always Use Wet Bulb Plus 5 Degrees

Half-Truth: "Maintaining the tower sump design temperature means excess chiller energy consumption, but lowering the temperature makes the fans work too hard... "

Fallacy: "... therefore, since the leaving water temperature the tower can produce is a function of ambient wet bulb temperature, the tower control setpoint should be reduced as the wet bulb temperature falls."

Fact: Tower performance is a function of ambient wet bulb temperature, but it's also influenced by the amount of heat being rejected, i.e. the cooling load.

So How *Should* Tower Water Temperature Be Controlled?

(Editor's note: *The following discussion assumes that the only variable system design condition is the tower leaving water temperature setpoint; all other parameters are constant. Given that scenario, only the power consumption of the chiller and tower fan(s) changes.)*

Fact: At some point in the tower control band, between design and "as cold as possible," the total power consumption of the chiller plus the tower is minimized.

Fact: Chillers are rated in accordance with Air-Conditioning & Refrigeration Institute (ARI) standards; similarly, cooling towers are rated in accordance with Cooling Tower Institute (CTI) standards. This practice assures dependable, repeatable performance for both types of equipment.

Fact: The **optimum** tower water temperature needed to minimize the total energy consumption of the cooling tower and chiller can be calculated using rated tower and chiller performance data.

Fact: Tracer Summit™ will soon provide the control algorithm needed to optimize tower water temperature for minimum tower/chiller energy consumption.

How Much Does Tower Water Control Optimization Save?

Obviously, this depends on the loads served. But here's an example.

Chiller

- 500-ton (1758-kw) capacity
- 0.58 kw/ton (6.06 COP)
- 85-95 F (29.4-35 C) condenser water temperature
- 78 F (25.6 C) design wet bulb
- 1500 gpm (94.62 lps) condenser water flow

Tower

- One 25 hp (18.6 kw) fan

Economics

- $0.08 / kwh
- $12.00 / kw
- 1300 equivalent full-load hours

ARI Unloading

- 17% of time at full load
- 39% of time at 75% load
- 33% of time at 50% load
- 11% of time at 25% load

Figures 2, 3 and 4 show the energy consumption of each control option and the savings possible when optimized control is used instead. (As a basis for comparison, the estimated cost of operating the preceding system is about $48,000, so savings range between four and five percent.)

While these **savings** aren't astronomical, they **are easily obtainable** with a soon-to-be-available Tracer Summit control algorithm.

Let's Go A Little Further

Suppose the cooling tower isn't just controlled to provide the coldest water possible, but is actually **designed** to do so. Such a strategy isn't unheard of. Some utilities even offer incentives to encourage this practice, but is it advantageous for either the building owner or utility? The story you are about to read is true.

Using an incentive program, a utility encouraged building designers to achieve low cooling tower approach temperatures with the following results.

Chiller

- 450-ton (1582-kw) capacity
- 0.52 kw/ton (6.76 COP) @ ARI conditions
- 75-85 F (23.9-29.4 C) condenser water temperature
- 71 F (25.6 C) design wet bulb
- 1295 gpm (81.7 lps) condenser water flow

Tower

- Two 25 hp (18.6 kw) fans

Economics

- $0.08 / kwh
- $12.00 / kw
- 1300 equivalent full-load hours

Figure 3: Excess energy purchased at various loads when compared to an optimal tower leaving water temperature.

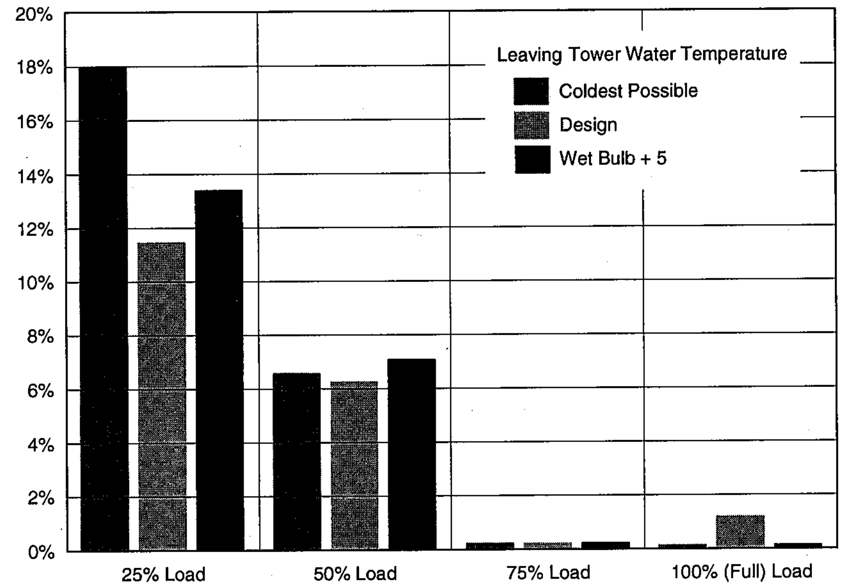
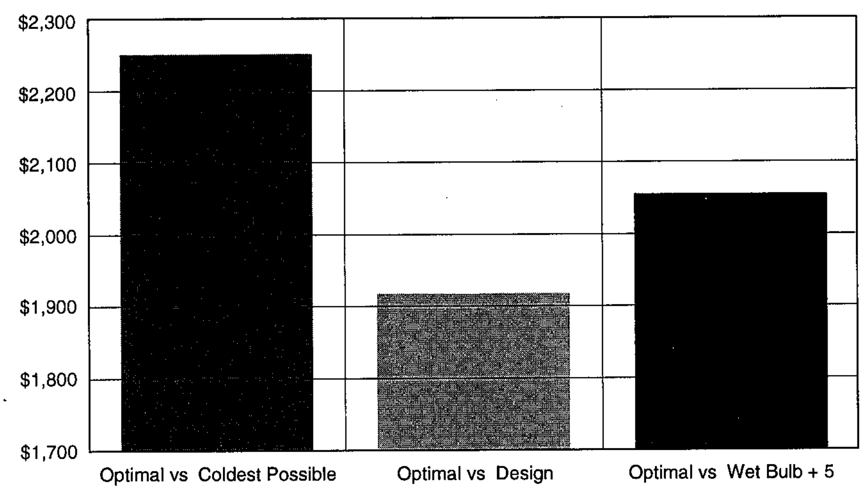


Figure 4: Energy savings comparison of tower leaving water control strategies.



ARI Unloading

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As Figures 5, 6 and 7 indicate, a potential operating cost savings of 14 percent can be obtained by optimizing the tower water control instead of making the coldest water possible. More intriguing is this: Even at full-load design conditions, power can be saved by resetting the tower water control temperature upward! At full load, the tower can produce 75 F water and the tower and chiller, together, consume 254 kw. If, instead, the tower control temperature is 81 F, the tower and chiller consume only 240 kw! (While this begs the question, "Should the system be designed at this higher temperature?" . . . we won't attempt to answer it here.)

Caveats
It's important to remember that the **optimal tower control temperatures** shown here **are application-specific** and are not meant for general use. Load, ambient conditions and the part-load operating characteristics of the chiller and tower ultimately determine the optimum tower control temperatures for a given installation.

Note, too, that helical-rotary (screw) compressor energy consumption drops quickly with reduced head pressure (condenser water temperature), so the optimal tower water setpoint control for these compressors may be lower than for centrifugal compressors.

Figure 5: Chiller + tower energy consumption at various loads and condenser water temperatures.

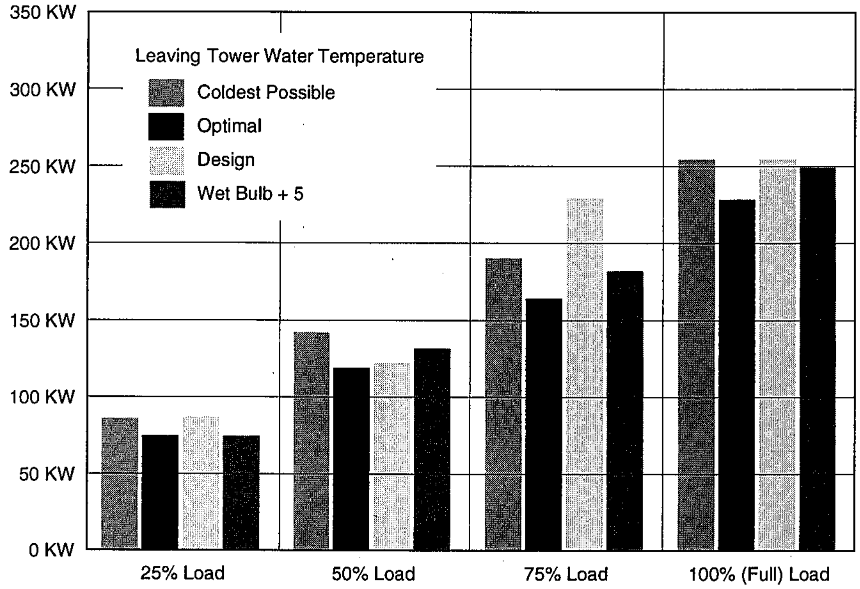


Figure 6: Excess energy purchased at various loads when compared to an optimal tower leaving water temperature.

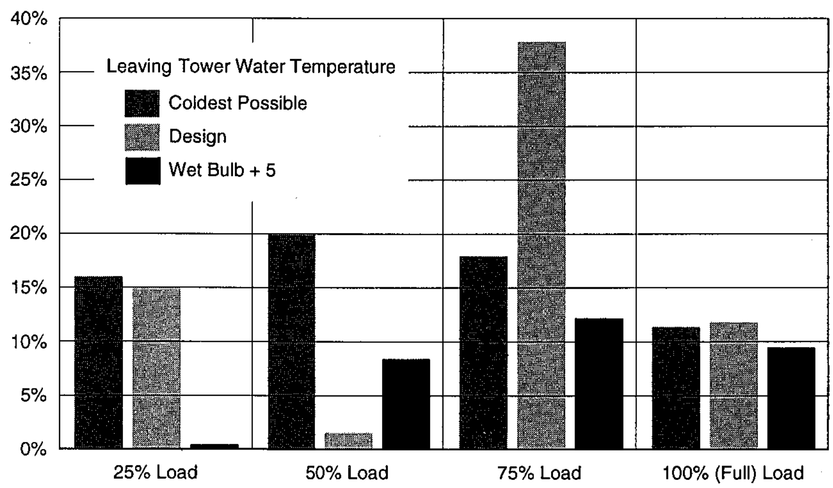
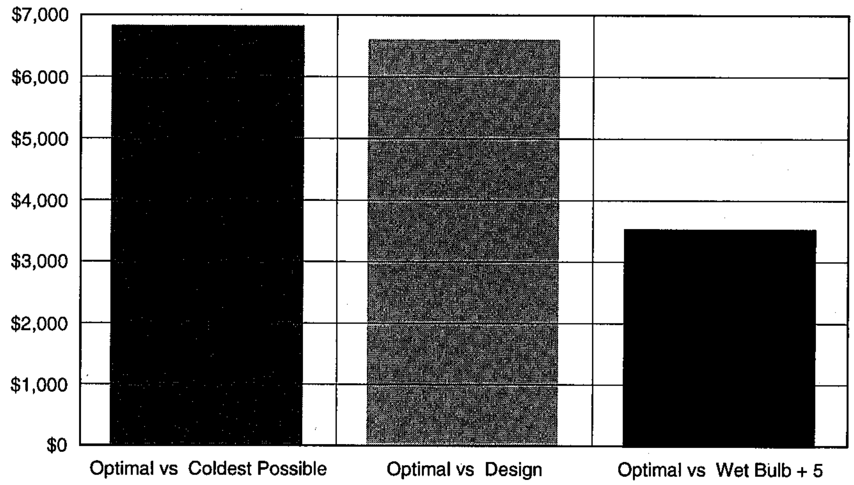


Figure 7: Energy savings comparison of tower leaving water control strategies.



So . . .

. . . to obtain the greatest possible energy cost savings through HVAC system optimization, each subsystem . . . not just the chiller . . . must be operated in the most efficient manner possible while continuing to satisfy the current building load. Key to successful optimization are information-sharing controls capable of monitoring and governing all areas of the HVAC system. Equally important, however, is an awareness . . . and periodic re-examination . . . of our design paradigms if we're to provide building owners with added value. ●

By Mick Schwedler, applications engineer, and Brenda Bradley, information designer, The Trane Company.