Control Your Chilled Water – Save Energy / Increase Capacity

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ABSTRACT

Most large chilled water systems suffer from excess flow and low chilled water delta T. As a result, chilled water systems typically consume 15-45% more energy than required for cooling. This problem, commonly called "low delta T syndrome," also limits the available tonnage that can be delivered by a central plant.

The following two case studies, University of Southern California and Midway Airport, illustrate the performance made possible with proven technology in use at a growing number of prominent facilities nationwide.

This paper demonstrates that control valves set the system delta T. With proper hydronics design, system operators should expect outstanding performance with no less than chilled water design delta T at all load conditions.

Key Words: Hydronics, Heat Transfer, Low Delta T, Energy Waste, Limited Capacity

Note: A quick energy savings calculation form will be distributed at presentation. This form will allow operators to quickly assess the energy conservation potential at their facility if they suffer from low delta T.

CASE STUDY #1
UNIVERSITY OF SOUTHERN CALIFORNIA (USC)
LOS ANGELES, CA

Existing Condition and Problems

In 1999 at the University of Southern California (USC), old and inefficient chillers, installed in each building, served existing facilities on campus. The operating and maintenance cost of all of these individual systems was very expensive and growing. Issues with CFC refrigerants were also a concern.

Engineering Approach

To solve chilled water system problems, USC decided to build two new central plants, install a new chilled water underground piping loop and tie in existing buildings. Before proceeding with the plan, USC had to first address the following key issues:

1) When the buildings are tied together, how will the campus manage the changing hydraulic profile at the cooling coils and control valves?
2) To save energy, what can be done to minimize flow and maintain high chilled water delta T's at all load conditions?
3) How can full system diversity be achieved to maximize the chilled water system investment?

Scot Duncan P.E. of Retrofit Originality Inc., Lake Forest, CA was the mechanical engineering consultant hired for the project.

Implementation

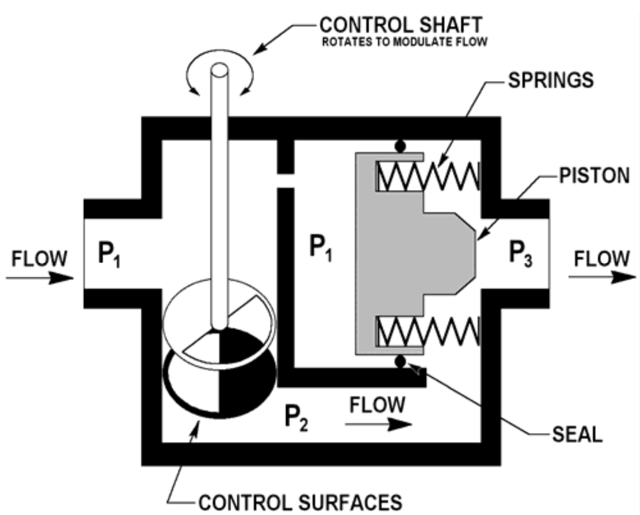
In 2000, USC started tying their buildings into two new central chiller plants (note: a separate system serves the Health Science Campus). New Plant I features 2,000 tons installed capacity with primary variable flow pumping. New Plant II features 800 tons installed capacity with primary/secondary pumping. In addition, a new underground piping system was installed to connect the buildings to the central plants.

Where there is restrictive piping, distribution pumps in the buildings are used to overcome high local pressure drops. To minimize flow, raise delta T, and achieve full diversity, pressure independent modulating control valves were specified. These unique valves are described below.

To date, approximately 30 buildings are currently tied to the new central plants on the loop. Plans call for connecting several more new and existing buildings. In 2004, a chilled water storage tank will be added.

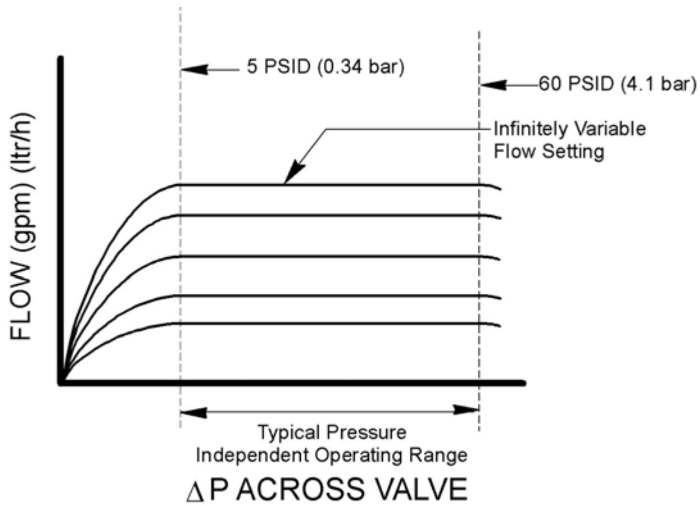
Pressure Independent Modulating Control Valves

With numerous the buildings on the chilled water loop, USC anticipated significant pressure and flow variation, especially at part load. This led to the specification of industrial quality, pressure independent, modulating control valves. A schematic and performance characteristics of pressure independent modulating control valves is illustrated in Figures 1 and 2 below.



Note: Pressure across the control surface (P1-P2) remains constant. Steady flow improves heat transfer, minimizes flow, and raises delta T.

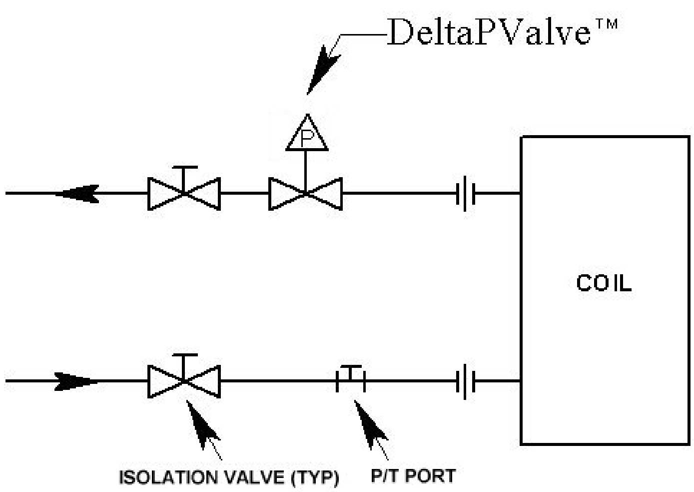
Figure 1 - Schematic of Pressure Independent Modulating Control Valve



Note: Pressure variations do not change the flow rate. Flow rate varies only by adjusting the valve.

Figure 2 - Flow Performance Curve for Pressure Independent Modulating Control Valve

In the retrofit buildings, pressure independent modulating control valves were installed in the chilled water return (see Figure 3) at terminal units.



Note: No balancing or balancing valves are required.

Figure 3 - Typical Cooling Coil with a Pressure Independent Modulating Control Valve

Results

The two new chilled water plants have been running since 2000. So far, control valves have been changed to pressure independent modulating type in about ½ of the buildings hooked to the loop. Figure 4 illustrates theoretical cooling coil performance of a 12°F cooling coil for comparison to measured performance. Note that 50% of the flow addresses 80% of the cooling load.

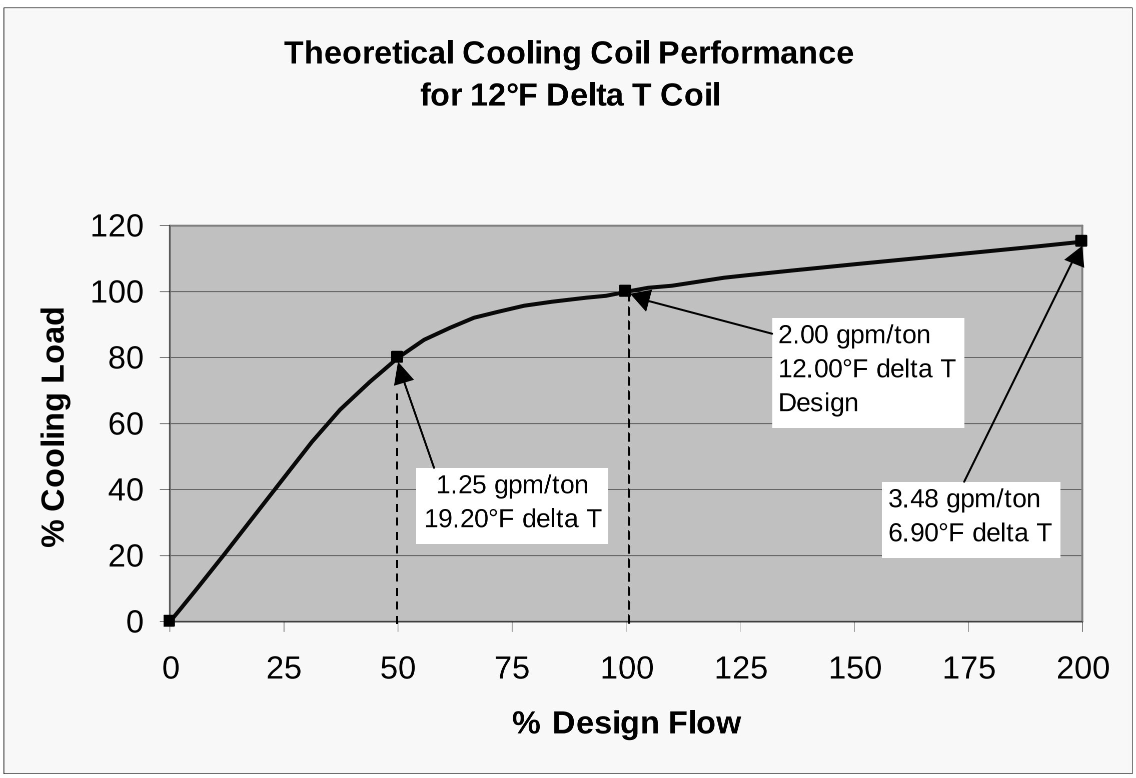


Figure 4 - Theoretical Coil Performance Curve (% Flow vs. % Cooling Load)

The buildings that have pressure independent modulating control valves always return chilled water at higher than design delta T. Figure 5 shows actual building performance with industrial quality pressure independent modulating control valves.

Delta T exceeds design by 25 to 50% at part load, minimizing flow and demonstrating that theoretical performance is achieved.

In contrast, in buildings where standard control valves are still installed, excess water flows and delta T is below design. This demonstrates that control valves set the system delta T.

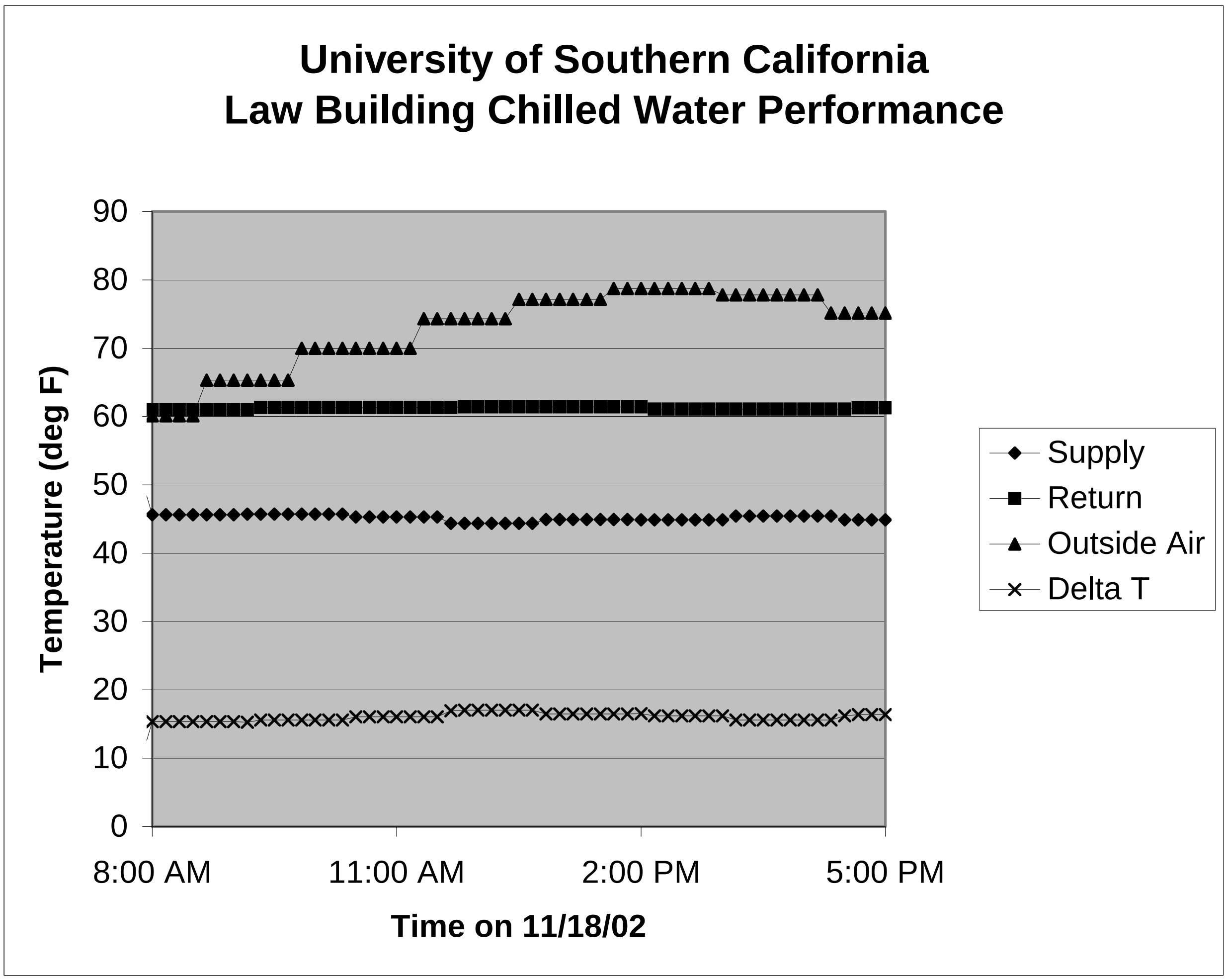


Figure 5 – Typical Performance with Industrial Quality Pressure Independent Modulating Control Valves Installed

Note: The coils in the Law Building were selected at 10 and 12 degrees delta T. This building is over 20 years old. The original cooling coils are still installed. You can see from the above data that the design delta T is exceeded at all loads even with old (but clean) coils.

USC Conclusions

Campuses can successfully tie existing buildings with individual chilled water systems into a campus loop easily and avoid many pitfalls with the proper use of pressure independent modulating control valves. With their newly looped chilled water system, USC achieves the following:

1. No hydraulic or differential pressure problems.
2. Minimum flow and high delta T at all loads.
3. Full system diversity – system dynamically balanced at all loads.

CASE STUDY #2
MIDWAY AIRPORT
CHICAGO, IL

Project

Midway Airport in Chicago, Illinois decided to expand and remodel their existing facilities. The City of Chicago Port Authority put the energy plant out for bid, outsourcing the chilled and hot water for the facility in the year 2000. Northwind Midway, a division of Exelon Thermal Technologies won the energy contract.

Figure 6 – Midway Airport

Potential Problem – Stiff Chilled Water System Requirements

The chilled water plant was designed for an 18°F delta T on the chilled water. To achieve the best possible performance, reaching 18°F delta T at all load conditions was a prime consideration in system configuration and design.

Unique Solution

The mechanical engineering consultant on the Midway Airport expansion and remodel project was Martin Lunkes P.E. of Environmental Systems Design Inc., Chicago, IL.

To guarantee design delta T, pressure independent modulating control valves were installed on all of the air-handling units. The pumping is supplied by the energy center (see Figure 7). There are no additional chilled water pumps in this large facility. This was a very simple and unique solution to a tough chilled water system requirement.

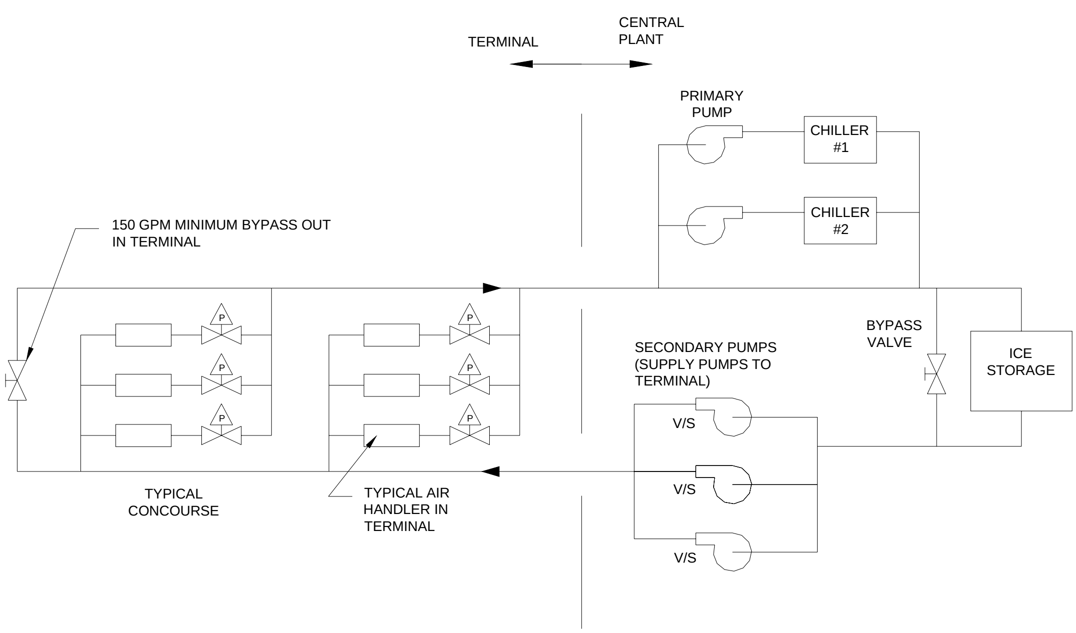


Figure 7 - Chilled Water Diagram – Energy Plant (Northwind, Midway)

Note: There is 150 gpm bypass at all times.

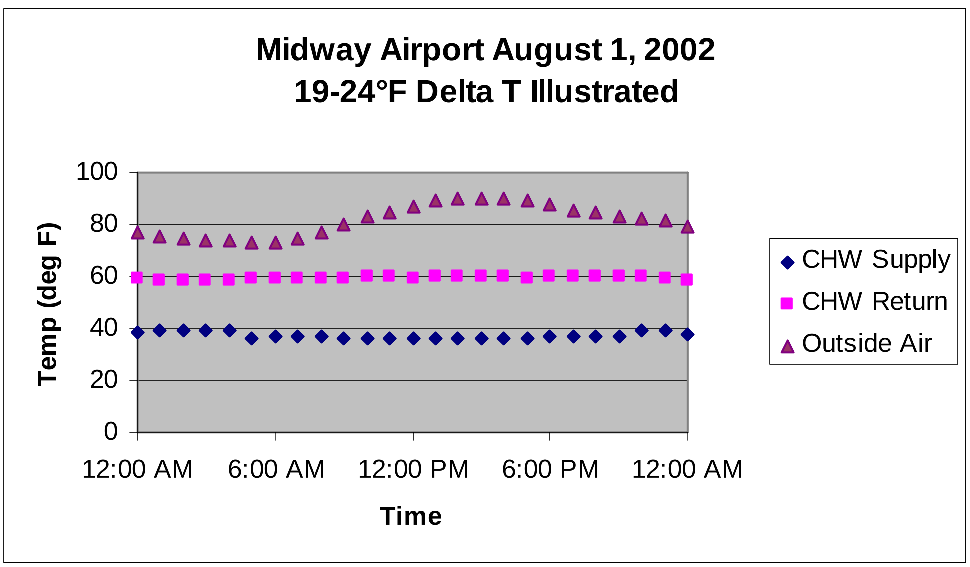
System Specifics

Midway Airport chilled water system specifics (at 75% installed capacity) are listed below:

1. Chillers – 2 each York 1655 Ton Electric Centrifugal
2. Ice Machines – 2 each FES 1200 Ton Screw Compressors
3. Ice Storage – 14,000 ton-hours
4. Chilled Water Design Flow – 4,900 gpm
5. Chilled Water Pumps – 3 each @ 2500 gpm and 140' head
6. Chilled Water Control Valves – DeltaPValves™
7. Cooling Coils - Designed for 37 Degrees Supply and 55 Degrees Return

Results

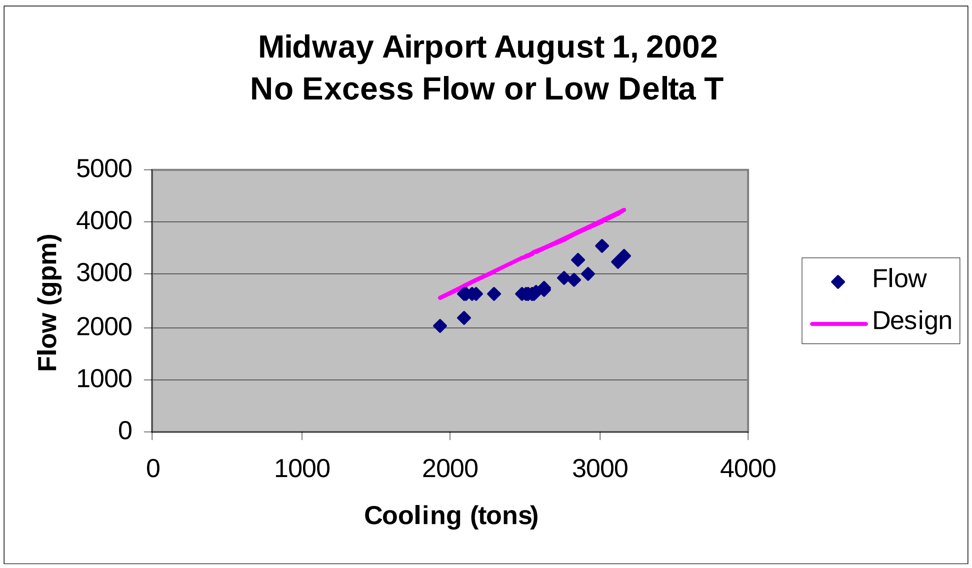
As shown in Figure 8, the chilled water achieves 18 to 26 degrees delta T at all load conditions. Delta T always exceeds design.



Note: 18°F delta T is always met. Shown is a typical day with high and low cooling loads.

Figure 8 - Typical Chilled Water System Performance

Figure 9 illustrates that in August 2002, with a design flow of 4900 gpm, the actual flow never exceeded 3500 gpm. System performance exceeds design.



Note: Midway Airport performance exceeds design. At 18°F delta T, design flow is 1.33 gpm/ton.

Figure 9 – Illustration of Flow per Ton with High Delta T

Midway Airport Conclusions

1. High delta T's are achieved with very simple design.
2. Distributed pumping is not required on new installations.
3. Minimizing flow with high delta T reduces operating costs.
4. High delta T's can be specified and achieved on large chilled water systems.
5. Design delta T's are always met or exceeded, so the system will always be able to deliver its installed tonnage.