Smart Devices for Today’s Chilled Water Systems
Chiller Plants Overall Energy Efficiency

Why Focus on Chiller Plants?

<table>
<thead>
<tr>
<th>Plant</th>
<th>Manufacturer Chiller Plant Efficiency Coefficient*</th>
<th>Average Chiller Plant Efficiency Coefficient*</th>
<th>Actual Delta T [F]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Office)</td>
<td>4.26</td>
<td>2.02</td>
<td>2.4</td>
</tr>
<tr>
<td>B (Museum)</td>
<td>4.78</td>
<td>2.87</td>
<td>2.8</td>
</tr>
<tr>
<td>C (Bank)</td>
<td>3.15</td>
<td>2.14</td>
<td>3.6</td>
</tr>
<tr>
<td>D (Office)</td>
<td>3.87</td>
<td>0.84</td>
<td>0.7</td>
</tr>
</tbody>
</table>

♦ Higher Efficiency Coefficient (COP) reflects higher plant efficiency

“The main finding is that there is a wide gap between theoretical EER values and real-life performances of chiller systems and that the results were nearly the same in all cities”

Source: Chiller systems’ overall energy efficiency / A comparative study of Paris, Helsinki and Gothenburg

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Euroheat & Power, Cimespace, Göteborg Energi / Capital Cooling, Helsinki Energy
Chiller Plants Overall Electric Consumption

<table>
<thead>
<tr>
<th>Plant A (Office)</th>
<th>Plant B (Museum)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chillers</strong></td>
<td><strong>Chillers</strong></td>
</tr>
<tr>
<td>60%</td>
<td>41%</td>
</tr>
<tr>
<td><strong>Pumps</strong></td>
<td></td>
</tr>
<tr>
<td>Avg 25.5%</td>
<td></td>
</tr>
<tr>
<td>Condenser pumps 9%</td>
<td>Condenser pumps 9%</td>
</tr>
<tr>
<td>Evaporator primary pumps 18%</td>
<td>Evaporator primary pumps 24%</td>
</tr>
<tr>
<td>Cooling towers 5%</td>
<td>Cooling towers 12%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plant C (Bank)</th>
<th>Plant D (Office)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chillers</strong></td>
<td><strong>Chillers</strong></td>
</tr>
<tr>
<td>59%</td>
<td>44%</td>
</tr>
<tr>
<td><strong>Pumps</strong></td>
<td></td>
</tr>
<tr>
<td>Other 8%</td>
<td>Other 6%</td>
</tr>
<tr>
<td>Condenser pumps 6%</td>
<td>Condenser pumps 7%</td>
</tr>
<tr>
<td>Evaporator primary pumps 16%</td>
<td>Evaporator primary pumps 15%</td>
</tr>
<tr>
<td>Cooling towers 11%</td>
<td>Dry cooler 28%</td>
</tr>
</tbody>
</table>
# Hydronic Coil Design & Performance

<table>
<thead>
<tr>
<th>Chilled Water Coil</th>
<th>Component: 5</th>
<th>Length: 32 in</th>
<th>Shipping Section: 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coil Model</strong></td>
<td><strong>Total Capacity</strong></td>
<td><strong>Sensible Capacity</strong></td>
<td><strong>Number of Coils</strong></td>
</tr>
<tr>
<td>5WM1008B</td>
<td>1257424 Btu/hr</td>
<td>859478 Btu/hr</td>
<td>2</td>
</tr>
<tr>
<td><strong>Air Volume</strong></td>
<td><strong>Air Temperature</strong></td>
<td><strong>Coil Air Pressure Drop</strong></td>
<td><strong>Finned Height</strong></td>
</tr>
<tr>
<td>Entering</td>
<td>Dry Bulb</td>
<td>Wet Bulb</td>
<td>Entering</td>
</tr>
<tr>
<td>25000 cfm</td>
<td>79.4 °F</td>
<td>65.4 °F</td>
<td>48.0 °F</td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td><strong>Flow Rate</strong></td>
<td><strong>Pressure Drop</strong></td>
<td><strong>Velocity</strong></td>
</tr>
<tr>
<td>Entering</td>
<td>42.0 °F</td>
<td>56.0 °F</td>
<td>180.00 gpm</td>
</tr>
<tr>
<td><strong>Connection</strong></td>
<td><strong>Type</strong></td>
<td><strong>Quantity</strong></td>
<td><strong>Size</strong></td>
</tr>
<tr>
<td>Threaded</td>
<td>2</td>
<td>2.50 in</td>
<td>Opp drive side</td>
</tr>
<tr>
<td><strong>Material</strong></td>
<td><strong>Fin</strong></td>
<td><strong>Tube</strong></td>
<td><strong>Header</strong></td>
</tr>
<tr>
<td>Aluminum .0075 in</td>
<td>Copper .035 in</td>
<td>Copper</td>
<td>Stainless steel</td>
</tr>
</tbody>
</table>
Btu/h Calculation

- $Q(\text{Btu/h}) = 500 \times 180 \text{GPM} \times 14^\circ \text{F}$
  = 1,260,000 Btu/h
- Btu/h 1,260,000 – 1,257,424 = 2576 Btu/h
- .2% discrepancy
Symptom: Low Delta T Syndrome

Low ΔT syndrome is the result of the inefficient use of chilled water at the point of consumption.
Symptom: Low Delta T Syndrome

• Delta T: Typically Measured/Trended at Central Plant

• Low dT Usually Caused Outside of Central Plant

• Typically Identified as:
  - Loss of CHW Capacity
  - Farthest Zones Cannot Satisfy DAT Setpoint (Occupant Discomfort)
  - Control Valves Opening to 100% on Non-Degree Days
  - Dehumidification Issues (High Humidity Alarms)
  - Secondary/Back-up Chillers Operating on Non-Degree Days

Low ΔT syndrome is the result of the inefficient use of chilled water at the point of consumption
Symptom: Low Delta T Syndrome

Treating the Symptom – Not the Cause

• Adding Chillers
• Increasing Pump/s Size
• Adding Choke/Deny Valves
• Chiller Optimization
• Replacing 3 way valves with 2 way valves
• Adding VFD’s
Causes of Low $\Delta T$

- Equipment designed for different $\Delta T$’s
- Three way valves allow chilled water to bypass coils at part load
- Resetting the supply air temperature set point above design can lead to unstable control and low return water temperature
- Coils that are not piped with water flow counter to air flow reduce the heat transfer efficiency of the coil compromising return water temperature
- Mixing flow from chilled water supply to chilled water return through the de-coupler or bypass adversely effects the return chilled water temperature
Causes of Low $\Delta T$

- Oversized chillers, pumps, coils, control valves and piping
- Controlling the chilled water valve using only the air sensor is insufficient
- Manual balancing only addresses one flow condition
- Systems rarely run at full load causing overflow at part load
- Hydronic systems are changed but not rebalanced
Causes of Low $\Delta T$
Pressure Dependent Valve Sizing (Static Balancing)

• Typical valve sizing and selection tools use 3 – 5 PSID across control valves for modulating applications.

\[ Cv = \frac{\text{gpm}}{\sqrt{\Delta P}} \]

• Pressure dependent valves are selected for a fixed flow rate & pressure drop. As pressure increases flow will increase as pressure decreases flow will decrease for a given valve position.
• Requires Static Balancing Procedures
Low Delta T at the Coil

Operating in the Waste Zone
1. Pumping more Water
2. Reduced Delta T
3. No additional BTUs

Power Output: \( Q(\text{Btu/h}) = 500 \times GPM \times \Delta T \)

For a given load, Flow and \( \Delta T \) are inversely proportional.
As GPM increases, \( \Delta T \) drops.
Cost of Overflowing the Coil

- 325 kBTU/hr
- 320 kBTU/hr

55 gpm
65 gpm
Cost of Overflowing the Coil

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTUh</td>
<td>320,000</td>
<td>325,000</td>
<td>1.6%</td>
</tr>
<tr>
<td>GPM</td>
<td>55 GPM</td>
<td>65 GPM</td>
<td>18%</td>
</tr>
<tr>
<td>Pump hp</td>
<td>Hp increase = (65/55)^3</td>
<td>65%</td>
<td></td>
</tr>
</tbody>
</table>

\[
\frac{HP_2}{HP_1} = \frac{GPM_2}{GPM_1}
\]
Cost of Overflow at the Plant

Plant Efficiency

- **Chillers**
  - Plant is more efficient at Design $\Delta T$ than at low $\Delta T$
  - Low $\Delta T$ (high flows) can cause improper staging

\[
GPM = \frac{Tons \times 24}{\Delta T}
\]

\[
GPM = \frac{500 \times 24}{12} = 1,000
\]

\[
GPM = \frac{500 \times 24}{8} = 1,500
\]
Consequences of Over Pumping

- Additional chillers and associated equipment are utilized
  - Chillers run at part load and are operated at a higher energy rate per ton of cooling
- Diminished equipment life and increased maintenance needs
- Unstable control
- Compromised occupant comfort
Symptom: Low Delta T Syndrome

If Low dT Is Usually Caused Outside of Central Plant,

- Typically Identified as:
  - Loss of CHW Capacity
  - Farthest Zones Cannot Satisfy DAT (Occupant Discomfort)
  - Control Valves Opening to 100% on Non-Degree Days
  - Dehumidification Issues (Humidity Sensor Alarms)
  - Secondary/Back-up Chillers Operating on Non-Degree Days

Why Is Delta T Rarely Measured/Trended at PoU

When:
Low ΔT syndrome is the result of the inefficient use of chilled water at the point of consumption
Controlling $\Delta T$ Using Smart Control Valves

Smart control valves:

- Measure & report flow, $\Delta T$, BTU/hr & glycol %
- Dynamically adjusts flow & $\Delta T$ in real time to maximize the efficiency of hydronic coils
- Prove their performance & that of the coil
Case Study – 1 year
Southeast Michigan High School

- 5 Cooling Coils serving gymnasium
- 1 new, 4 existing

Results

- Avg dT of 19.2 degF
- Projected Flow = 1,520,364 gallons
- Actual Flow = 1,002,494 gallons
- Savings of 517,870 gallons or 34%!