HIGH PERFORMANCE CHILLED WATER SYSTEMS

EarthWise HVAC
Chiller – Tower Systems

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EarthWise Menu

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  – Variable CHW
  – Variable CDW
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• Heat Recovery
• Ice Thermal Storage
• Advanced Air Systems
CHW Plant Efficiency

- Chiller efficiency have seen good improvements
  - Minimum code requirements: MEPS compliant
  - AHRI or Eurovent certified; assurance of performance
- CHW Plant Ancillaries
  - CHW and CDW pumps: low flow, variable flow
  - Cooling Tower performance: CTI certified
- CHW Plant System Efficiency [COP] defined by:

  \[
  \frac{\text{Cooling Capacity [kW]}}{\text{Total Power Input [kW]}}
  \]

  - Total Power Input includes power input of chillers and ancillaries

CHW Plant Efficiency Scale

AVERAGE ANNUAL CHILLER PLANT EFFICIENCY IN KW/TON (C.O.P.)
(Input includes chillers, condenser pumps and tower fans)

Based on electricity driven centrifugal chiller plants in comfort conditioning applications with 42°F (5.6°C) nominal chilled water supply temperature and open cooling towers sized for 95°F (35°C) maximum entering condenser water temperature. Local climate adjustment for North American climates is ± 0.05 kW/ton

Source: Thomas Hartman, 2001
OPTIMIZING HEAT REJECTION
CHILLER – TOWER SYSTEMS

Cooling Towers in HVAC
Preliminaries

• Sizing vs performance
  – Balance cost vs performance
  – Economizing in cooler climates
• Design conditions
  – Design WB and tower water temps
  – What’s the correct approach temperature? 3 to 9K!? 
  – Standard rating conditions 29.5°C with 5.5K range may not be optimal!
• Operational efficiency
  – How do I control to best system efficiency?
**Chiller – Tower**

**Key Parameters**

- Wet-bulb
- Condenser water temperature
- Heat Rejection Load
- Tower Design
- Cooling Load
- Condenser water temperature
- Chiller design – fixed or vary speed

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**Condenser water control**

**At Part Load**

- **Warm or Hot?**
  - 26 to 29°C minimizes tower fan power, increases chiller power
  - Works well with older equipment requiring higher lift

- **Cold?**
  - 15 to 18°C or less minimizes chiller power, increases tower fan power
  - Efficient chiller operation but what about the overall system?

- **Wet-bulb + 3K approach?**
  - Assumption that Load ∝ WB ... Tends to drives to coldest
  - Approach is NOT fixed at part load

- **Optimized?**
  - Dynamic reset based on load & ambient to minimize overall system energy
Tower Control

- On/Off
- Two-speed fan
- VSD/VFD
- Tower performance \( \propto \phi(WB, \text{Load}, \text{Fan speed}, \text{Flow}) \)
- Optimization involves multi-dimensional sub-system that must be integrated with chiller performance as a system
  - Manual / trial and error or,
  - Dynamic monitoring and reset optimization
    - Predictive
    - Dynamic feedback

Tower fan power

<table>
<thead>
<tr>
<th>% FAN kW</th>
<th>FAN SPEED</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

- ON/OFF
- 2-SPEED
- VFD
CT performance: Load & WB

Note: Cooling tower with constant flow and 100% fan speed, 4K design approach

CT performance: WB & Fan Speed

Note: Cooling tower with constant flow and 50% load
Cooling Load & WB

Chiller – Tower Optimization (CTO) Concept

Note: Chiller at part load and low ambient WB
Chiller – Tower Parametric Study

- Chiller matched to cooling tower at fixed design flow rate, 54 L/s/MW
- Cooling tower selected at 4K approach to WB
- Compare chillers with fixed speed and variable speed drive (AFD)
- CT with variable speed fan motor
- Part load analysis (75%, 50% and 25% loads) at varying WB (20 °C, 17 °C, 14 °C, 10 °C)
- Observe equipment temperature limits
  - Min CT temperature to maintain lift
  - Max CT temperature to avoid surge
- Assess overall power input of heat rejection system

High Load, High WB
75% Load, 20 °CWB
High Load, Low WB
75% Load, 14°CWB

Low Load, High WB
25% Load, 20°CWB
Low Load, Low WB
25% Load, 14°CWB

CT Cold Basin, °C

Power Input, kW

14 16 18 20 22 24

CT kW
CH AFD kW
Total
CH non-AFD kW
Total

Low Load, Low WB
25% Load, 10°CWB

CT Cold Basin, °C

Power Input, kW

10 12 14 16 18 20 22 24

CT kW
CH AFD kW
Total
CH non-AFD kW
Total
Chiller – Tower Optimization (CTO)

- At part load neither the coldest or warmest tower water is best for overall efficiency
- “Near optimal point” a moving target
- Fixed flows and single system
  - Trend towards colder water when loads are high and warmer water when loads are low
  - Plant configuration and climatic condition dependent
- Need to consider chiller equipment
  - Constant or vari-speed
  - Equipment limits

CTO - Necessities

- System Level Controls
  - Knowledge of chiller performance at various loads and ambient; know chiller limits
  - Tower fan power characteristics
  - Pump motor power characteristics if variable flow
  - Drives tower fans to “near optimal CT set point”
- VFD on tower fan motors
- Good quality ambient RH sensor
- Commissioning M&V
System Options and Analysis

- No one size fits all
  - There is a trend of lower operating costs with chiller-tower optimization
- Need comprehensive analysis, not spreadsheet

CTO comparisons

Sydney Commercial Office Application; BCA Class 5 schedules
2,200 kW cooling, water-cooled screw chillers, VAV, Econ cycle.
Chiller – Tower Optimization

- TRACER SYSTEM LEVEL CONTROLS
- RH T

HVAC Systems Heat-Cool

- COOLING CALL
- MECHANICAL COOLING
- EVAP COOLING
- E-A HEAT REC
- • Minimize active cooling & heating
  • Heat Recovery
  • Free Cooling

- F F
- E E-A HEAT REC
- CHILLER HEAT REC
- GAS HEAT
- AIRSIDE ECON
- CT PL HX
- FC CHLR

05 15 25 35
Ambient Temperature ºC
Waterside Free Cooling

- Waterside free cooling is the cooling of supply air indirectly with water which is itself cooled by the environmental heat sink without mechanical cooling
- When CT water temperature is cool enough, it can be used to minimize or switch OFF mechanical cooling
  - Strainer Cycle
  - Air-cooled free cooling chiller
  - Plate and Frame HX with CT
  - Water-cooled free cooling chiller (refrigerant migration)

Waterside Plate and Frame

- Sizing of CT to design WB
  - Close approach at low loads and low WB
- Piping options
  - “Side car” on the distribution side of CHW loop to supplement cooling; sees warmest return water
  - Parallel on distribution or production side; “all or nothing”
- HX sized 2 to 3K approach to tower water
- Maintenance
Free Cooling WC Chiller

- Refrigerant migration cycle
  - Operates when CT water is cool enough; e.g. less than 13°C
  - 45 to 60% design capacity with CHW reset
  - Minimizes reheat
- No change in CHW pipe work
- No additional maintenance
- Available with centrifugal chillers > 700kW

Free Cooling Chiller

Free Cooling valves
**Free-cooling Chiller**

1 MW chiller (FC mode)

<table>
<thead>
<tr>
<th>Capacity [kW]</th>
<th>1.7°C</th>
<th>4.4°C</th>
<th>7.2°C</th>
<th>10°C</th>
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<tr>
<td>545</td>
<td>6.3/10.1</td>
<td>9.0/12.8</td>
<td>11.7/15.5</td>
<td>14.4/18.2</td>
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<tr>
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<td>5.3/8.1</td>
<td>8.0/10.8</td>
<td>10.7/13.6</td>
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<td>4.2/6.1</td>
<td>7.0/8.9</td>
<td>9.7/11.6</td>
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<tr>
<td>134</td>
<td>3.1/4.0</td>
<td>5.9/6.8</td>
<td>8.6/9.6</td>
<td>14.2/15.1</td>
</tr>
</tbody>
</table>

- No CHW reset
- CHW reset, trim chiller or warm CHW applications

Supply/return CHW temp, °C

**EarthWise Free Cooling**

- Parallel piping
- Switchover free cooling / mechanical cooling
- Mixing issue – “all or nothing”
EarthWise Free Cooling

- “Sidecar” piping resolves mixing issue
- Supplement to cooling chillers
- CT may be dedicated to free cooling chiller for cold climate operation

EarthWise Free Cooling

- Series CHW piping takes advantage of low flow CHW system efficiency
- Supplement to cooling chillers; electric trim chiller
- CT may be dedicated to free cooling chiller for cold climate operation
EarthWise Free Cooling Controls

- System Level integration of controls ensures optimal control and efficiency