Water Savings Using The Thermosyphon Cooler Hybrid Heat Rejection System: Case Studies From Atlanta, Phoenix, Seattle, and Boston

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Four Key Points to Remember

Evaporative Cooling is Efficient in Terms of:
- Energy
- Cost
- Space

Lowering Chiller Plant Operating Costs Requires Focusing on Both Energy & Water

Hybrid Systems Increase The Water Resiliency & May Lower The Cost Of Operating The Chiller Plant

Evaluation of Alternatives Requires Detailed System Modeling
### The Pros and Cons of Evaporative Heat Rejection

#### Evaporative Cooling is Efficient in terms of:
- Energy
- Cost
- Space

#### Pros:
- Ability to reject heat to the cooler ambient WB versus DB
- Ability of evaporating moisture to pick up significantly more heat than dry air

#### Cons:
- Consumes massive amounts of water
- Cooling tower blowdown may require additional special disposal requirements
Water & Waste Water Costs Represent A Growing Portion of Total Utility Spend for Many Chiller Plants

Lowering Chiller Plant Operating Costs Requires Focusing on Both Energy & Water
Freshwater Stress - The Global Perspective

Forces Driving Fresh Water Consumption:

- Population growth increases total demand
- Economic growth increases per capita demand

Consumption increases ...

driving Freshwater Stress worldwide
Water & Sewer Prices Are Escalating Quickly

Long-term trends in consumer prices (CPI) for utilities

Exhibit 1. Long-term trends in the Consumer Price Index (CPI) for utilities (1913-2012). The index is set to 100 for 1982-1984 except for telephone and wireless services, where the index is set to 100 for 1997. Date () indicates start of series.
<table>
<thead>
<tr>
<th>City</th>
<th>Water</th>
<th>Sewer</th>
<th>Combined</th>
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<tbody>
<tr>
<td>Atlanta, GA</td>
<td>$8.19</td>
<td>$20.85</td>
<td>$29.04</td>
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<tr>
<td>Phoenix, AZ</td>
<td>$4.78</td>
<td>$3.35</td>
<td>$8.13</td>
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<td>Seattle, WA</td>
<td>$6.87</td>
<td>$15.61</td>
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<td>Boston, MA</td>
<td>$6.86</td>
<td>$8.56</td>
<td>$15.42</td>
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Hybrid Systems

- Adiabatic Dry Coolers
- Parallel or Series Dry Coolers
- Hybrid Wet/Dry Products
- Thermosyphon Cooler Hybrid System (TCHS)
Psychrometric Chart For Atlanta, GA

Summer Design Point
Thermosyphon Cooler Hybrid System (TCHS)

“Wet” when it’s Hot, “Dry” when it’s Not
Thermosyphon Cooler (TSC) – Basic Conceptual Design
The Cooling System Interacts With Its Environment And The Rest of The Plant

1. Weather \( f(\text{hour of the year}) \)
2. Cooling Requirements \( f(\text{Hr of Day, Day of Week, Month of Year, Weather}) \)
3. Water Availability \( f(\text{Hr of Day, Day of Week, Month of Year, Weather}) \)
4. Energy and Water Costs \( f(\text{Hr of Day, Day of Week, Month of Year, Weather}) \)
5. Plant Efficiency \( f(\text{Weather, Control Strategy, Equipment}) \)
6. Heat Rejection Load \( f(\text{Weather, Cooling Load, Plant Efficiency, Cooling Strategy}) \)
Simplified Chiller Plant Schematic
Cooling Tower Only System
Simplified Chiller Plant Schematic
Thermosyphon Cooler Hybrid System – Type A

Chilled Water Loop

Chiller

Condenser Water Loop

Thermosyphon Cooler
Simplified Chiller Plant Schematic
Thermosyphon Cooler Hybrid System – Type B

Thermosyphon Cooler

Chilled Water Loop

Condenser Water Loop

Chiller

Thermosyphon Cooler

FCDC

DC

CT
Interactive System Schematic From The Chiller Plant Simulation Program
Locations, Systems Modeled, and Assumptions

Locations / Energy Cost:
- Atlanta - $0.0783/kWh
- Phoenix - $0.0684/kWh
- Seattle - $0.0596/kWh
- Boston - $0.1245/kWh

Systems:
- Cooling Tower Only with Min CWT = 65F
- TCHS (A) with Min CWT = 65F
- TCHS (B) with Min CWT = 65F
- TCHS (A) with Min CWT = 85F
- TCHS (B) with Min CWT = 85F

Assumptions:
- Constant 500 Tons Base Load
- 44°F Chiller Water Supply
- 2.0 GPM/Ton Chilled Water Flow Rate
- 2.5 GPM/Ton Condenser Water Flow Rate
- Cooling Tower Sized to Produce 85°F Condenser Water at the Summer Design WB
- 0.53 kW/Ton Chiller Efficiency at the Design Point
- Sewer Charges Only Applied to the Cooling Tower Bleed
- Chemical Treatment Costs = $3.50/1000 Gallons of Bleed
- 3.5 Cycles of Concentration
Annual Energy and Water Use – Cooling Tower Only System

500 Ton Chiller Plant - Annual Water and Energy Use
Cooling Tower Only System

<table>
<thead>
<tr>
<th>City</th>
<th>Annual Make-up Water Requirement (Gal)</th>
<th>System Energy (kWh)</th>
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<tbody>
<tr>
<td>Atlanta, GA</td>
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</tr>
<tr>
<td>Boston, MA</td>
<td>7,000,000</td>
<td>4,000,000</td>
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- Cooling Tower Make-up Water
- Electricity
500 Ton Chiller Plant - Annual Utility Costs
Cooling Tower Only (CTO) System and TCHS

<table>
<thead>
<tr>
<th>City</th>
<th>Total Annual Plant Utility Costs (Water + Electricity)</th>
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<tbody>
<tr>
<td>Atlanta, GA</td>
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<td>Boston, MA</td>
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</table>

- Water
- Elec

Annual Energy and Water Cost – Cooling Tower Only System & TCHS

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Atlanta, GA
February 19, 2014
Change in Annual Operating Cost Vs. Minimum Condensing Water Temperature

Comparsion of a Cooling Tower Only System Annual Operaing Costs
500 Ton Base Loaded Chiller in Atlanta, GA

Annual Operating Costs

$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0

Minimum Condenser Water Set Point Temperature

CT Only - Water Costs
CT Only - Elec Costs
CT Only - Total Utility Costs
Lowest Operating Cost Doesn’t Always Mean Lowest Energy Cost

Comparison of a Cooling Tower Only and a Cooling Tower + TSC Hybrid System Annual Operating Costs
500 Ton Base Loaded Chiller in Atlanta, GA

$6K Annual Savings

Minimum Condenser Water Set Point Temperature

CT Only - Water Costs
CT Only - Elec Costs
CT Only - Total Utility Costs
CT + TSC - Water Costs
CT + TSC - Elect Costs
CT + TSC Total Utility Costs

TPC.1/25/14
Make-up Water Requirements
– Cooling Tower Only System

Annual Condenser Make-up Water Requirements
Atlanta, GA Cooling Tower Only

Annual Water Requirement = 7,456,513 Gallons Per Year
Make-up Water Requirements – TCHS

Annual Condenser Make-up Water Requirements
Atlanta, GA TCHS

Annual Water Requirement = 2,888,452 Gallons Per Year
Evaporative Cooling is Efficient in Terms of:
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In Conclusion:
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