Energy Optimization of a Large Central Plant Chilled Water System

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Agenda

- Objectives
- System Description
- Data Collection & Models
- System Optimization Opportunities
- System Optimization Results
- Conclusions
Objectives

- Conduct a chilled water system Energy Savings Assessment (ESA) using a Systems Approach at the Oak Hill Plant site

- Identify (and quantify) chilled water plant energy savings opportunities

- Assist plant personnel to gain familiarity with certain best practices and to continue to identify energy efficiency improvement opportunities at the site
System Description

- **Chilled Water loop (42°F supply temperature)**
  - Chiller #1: Trane CVHF 1280 Centrifugal – 1,250 RT
  - Chiller #2: Trane CVHF 1280 Centrifugal – 1,250 RT
  - Chiller #3: Trane CVHF Centrifugal – 1,470 RT (New)
  - Chiller #4: York YSNNNNS7 Screw – 1,180 RT
  - Chiller #5: York YSNNNNS7 Screw – 1,180 RT
  - Chiller #6: York YSNNNNS7 Screw – 1,180 RT

- **Glycol loop (32°F supply temperature)**
  - Glycol Chiller #1: Trane CVHF 770 Centrifugal – 600 RT
  - Glycol Chiller #2: Trane CVHF 770 Centrifugal – 600 RT
  - Glycol Chiller #3: Trane CVHF 770 Centrifugal – 600 RT
System PFD

Water Chillers (42°F)

Glycol Chillers (32°F)

Air Coils
Identified Chiller Plant Best Practices

- Site-level integrated chilled water and glycol loops
- High efficiency two-stage centrifugal chillers for base load and screw machines to provide for swing capacity
- Use of variable speed drives on the secondary pumping loop
- Use of variable speed drives on the condenser water pumps
- Use of two-speed fans on the cooling towers
- Significant instrumentation, data monitoring and controls
- Use of real-time data for tracking efficiency metrics (kW/ton) and a Historian for analysis
- Good periodic maintenance practices for equipment (oil analysis, cleaning of heat exchanger tubes, eddy current testing, etc.)
- Periodic calibration of all critical instrumentation
Data Collection

- Hourly average data for one year (10/01/07 – 09/30/08) for each chiller
  - Ambient conditions
    - Temperature
    - Humidity
  - Chilled water flow
  - Condenser water flow
  - Power consumption
  - Chilled water supply and return temperatures
  - Condenser water supply and return temperatures
  - Bypass flow
Chilled Water Plant Efficiency

Overall Plant Efficiency (kW/RT)
## Chilled Water Plant Efficiency

<table>
<thead>
<tr>
<th>Chiller #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Overall Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating hours</td>
<td>7,469</td>
<td>7,458</td>
<td>2,633</td>
<td>6,877</td>
<td>6,336</td>
<td>2,591</td>
<td><strong>8,750</strong></td>
</tr>
<tr>
<td>Load (RT)</td>
<td>924</td>
<td>944</td>
<td>868</td>
<td>887</td>
<td>863</td>
<td>846</td>
<td><strong>3,428</strong></td>
</tr>
<tr>
<td>Power (kW)</td>
<td>553</td>
<td>511</td>
<td>610</td>
<td>599</td>
<td>561</td>
<td>591</td>
<td><strong>2,144</strong></td>
</tr>
<tr>
<td>Efficiency (kW/RT)</td>
<td>0.597</td>
<td>0.541</td>
<td>0.705</td>
<td>0.677</td>
<td>0.650</td>
<td>0.704</td>
<td><strong>0.623</strong></td>
</tr>
</tbody>
</table>
Chiller Efficiency

![Chiller Efficiency Chart]

- Chiller Efficiency (kW/RT)
- Condenser Water Temperature (°F)
Chiller Efficiency

Chiller Efficiency (kW/RT) vs Chilled Water Supply Temperature (°F)
Energy Savings Opportunity

- **Reduce condenser water temperature**
  - Condenser water maintained currently at 75°F
  - Controlled by two-speed fans
  - Typically, 10% energy used by fans, 20% by pumps and 70% by compressor
  - Compressor kW/RT increases with higher condenser water temperature
  - Float condenser pressure for maximum savings
  - Implementation to lower condenser water to 70°F
  - Potential savings ~7%
Energy Savings Opportunity

- **Constraints / Precautions - Reduce condenser water temperature**
  - Check manufacturers’ recommendations – 65°F minimum condenser water temperature
  - Refrigerant Stacking issues
  - Concerns about leaks in low pressure (R123) chillers
Energy Savings Opportunity

- Reduce number of operating chillers
Energy Savings Opportunity

- **Reduce number of operating chillers**
  - Typically, one more chiller than needed – capacity in excess of 1,200 RT on average and sometimes as high as 2,000 RT
  - Bypass flowmeter readings (average ~2,500 gpm)
  - Benefits of shutting down one chiller
    - Reduction of overall chillers kW/RT
    - Reduction in pumping power
    - Improved heat transfer in the evaporators
    - Reduction in maintenance costs
  - Preliminary estimates ~10% energy savings
Energy Savings Opportunity

- **Increase primary chilled water flow through chillers**
  - Design rating is based on 42°F chilled water, 85°F condenser water and 100% load (Tons)
  - But this happens for 1-3% of the operating hours
  - Chiller has a lot more capacity at off-design conditions
  - Implement – Variable Primary Flow and increase chilled water flow
  - Chiller moves to full-load conditions and kW/RT reduces
  - Preliminary estimates ~5-10% energy savings

- **Constraints / Precautions**
  - Pumping power capability
  - Compressor horsepower limitation
Energy Savings Opportunity

- **Transfer load from 32°F glycol loop to 42°F chilled water loop**
  - Full load operating efficiency
    - 32°F glycol chiller – 0.727 kW/RT
    - 42°F water chiller – 0.60 kW/RT
  - It is possible to transfer 50% of the glycol loop load
  - Potential energy savings – 3-5%
- **Constraints / Precautions**
  - Load balancing issues
  - Availability of additional heat transfer area on the chilled water loop
  - Change of control setpoints
Energy Savings Opportunity

- **Implement SMART algorithm to reset chilled water supply temperature**
  - 1°F increase in chilled water supply temperature leads to a reduction of 0.015 kW/RT
  - DAS has information on chilled water flow control valve positions of almost all the air-handling units
  - Automatically increase chilled water supply temperature till a control valve reaches 80% open
  - Currently, done on a manual basis

- **Constraints / Precautions**
  - Dynamic flow issues
  - Will have to ensure “no hunting”
Best Practices

- Implement real-time calculation of chiller efficiencies and trending
  - Will provide information for further optimization
  - All the data is already available

- Implement a Chiller Chemistry™ program
  - Fluids – Refrigerant, Oil and Water should be tested every six months
  - An engineering analysis combining all these results
  - Root-cause analysis
  - Best Predictive Maintenance – can be done online
## Energy Savings Opportunities

<table>
<thead>
<tr>
<th>Opportunity</th>
<th>Energy Savings</th>
<th>Cost Savings ($)</th>
<th>Project Cost ($)</th>
<th>PB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce condenser water temperature</td>
<td>815,000 kWh</td>
<td>53,000</td>
<td>40,000</td>
<td>N</td>
</tr>
<tr>
<td>Reduce number of operating chillers</td>
<td>1,400,000 kWh</td>
<td>91,000</td>
<td>25,000</td>
<td>N</td>
</tr>
<tr>
<td>Increase primary chilled water flow through the chillers</td>
<td>930,000 kWh</td>
<td>60,000</td>
<td>10,000</td>
<td>N</td>
</tr>
<tr>
<td>Transfer load from the 32°F glycol loop to the 42°F chilled water loop</td>
<td>315,000 kWh</td>
<td>20,000</td>
<td>25,000</td>
<td>M</td>
</tr>
<tr>
<td>Implement SMART algorithm to reset chilled water supply temperature</td>
<td>NC</td>
<td>NC</td>
<td>NC</td>
<td>M</td>
</tr>
<tr>
<td>Implement real time monitoring and add trending of efficiency</td>
<td>NA</td>
<td>NA</td>
<td>25,000</td>
<td>N</td>
</tr>
<tr>
<td>Implement a Chiller Chemistry™ PM program</td>
<td>NC</td>
<td>NC</td>
<td>5,000</td>
<td>N</td>
</tr>
</tbody>
</table>

*NA – Not Applicable
**NC – Not Calculated (See write up for details)
Conclusions

- Instrumentation & monitoring of “critical” parameters was key for optimization of the chilled water plant

- A Systems Approach is needed for optimizing any energy system

- Typically, chilled water and refrigeration systems are neglected in plants but they offer significant energy savings potential
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Discussion & Questions