Tan Hall - A Monitoring Based Commissioning Case Study

Presented by:
David Jump, PhD, P.E.
Quantum Energy Services & Technologies, Inc.
February 8, 2007
Tan Hall Project

• 2004-05 UC/CSU/IOU Partnership
  – Retro-commissioning
    • ID and install energy-savings tune-ups
  – Establish monitoring procedures to verify and maintain savings
    • Enhance monitoring systems
    • Whole building meters, chiller kW
  – Timeline: 3 months
Building Description

• Occupied in 1995
• 106,000 ft² chemistry bldg.
  – Lab/office suites
  – 102 fume hoods
  – 100% outside air
• 7 stories above grade / 2 below grade
• Basement supply / rooftop exhaust
Chilled Water System

- 475-ton Chiller
- 2 - 20 hp CHW pumps
- Constant volume
- Local control

- Cooling tower located in Latimer Hall
- 2 – 20 hp CW pumps
- Constant volume
Hot Water System

- Steam-to-hot water HX
- 2 - 15 hp HW pumps
- Constant volume
Main Air Handling System

- 4 supply fans, 100 hp, basement
- 4 exhaust fans, 60 hp, roof
- Variable speed
- Steam pre-heat coils
  - maintain SA temperature ~ 65 F
Supply Fans
Exhaust Fans
Other Systems

• Equipment cooling water
  – Serves refrigeration systems

• Spot cooling water
  – Serves process loads
Energy Management System

• Barrington EMS
• Customized web-based interface
  – Export trended data
• 6 months of 1-minute interval data archived
  – most points archived
  – received data to Dec. 2004
Utility Monitoring System

• Monitors campus building electric meters
• Tan Hall’s 480V & 220V electric meters
• Archives 15-minute data for past 12 months
  – Export trended data
MBCx Process

• Narrow scope to central plant
• Preliminary activities
  – Inspect equipment
  – Review documentation
  – Interview operators
• Develop Measurement & Verification Plan
  – EMS trends, independent data loggers
• Collect data, analyze
MBCx Process, cont.

- Establish energy baseline
- Identify and quantify ECMs
  - Non-retrofit
  - Controls tune-ups, optimization strategies
- Implement measures (UCB)
- Collect post-installation data
- Final Report
Final Report Outline

• Introduction

• Systems Descriptions
  – Components
    • Equipment list
    • Diagrams
  – Purpose
    • General
    • Usage schedules
    • Control points list
    • Set points & sequences of operations
Final Report Outline, cont.

• Investigated Systems
  – Monitoring and testing performed
  – Analysis and findings
  – Recommendations
    • ECM descriptions
      – Savings summary table
      – Description of findings
      – Corrective action and source of savings
      – Description of energy analysis method and assumptions
      – Scope of effort to correct flaws and improve performance
      – Estimated costs
      – Recommendations for maintaining savings
Final Report Outline, cont.

- Measurement and Verification Results
  - Approach
  - Baseline
  - System-by-system results
  - On-going M&V and diagnostics
- Appendices
# Results – Estimated Savings

<table>
<thead>
<tr>
<th>No.</th>
<th>Measure</th>
<th>kWh Savings</th>
<th>Steam savings lbs</th>
<th>kW Savings</th>
<th>$ Total Savings</th>
<th>$ Cost</th>
<th>Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Eliminate Simultaneous operation of CHW &amp; CW pumps</td>
<td>68,849</td>
<td></td>
<td>33.3</td>
<td>$9,639</td>
<td>$2,900</td>
<td>0.3</td>
</tr>
<tr>
<td>2</td>
<td>Repair chiller outside air lockout temperature</td>
<td>361,184</td>
<td></td>
<td>0.5</td>
<td>$29,046</td>
<td>$0</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>Raise chiller lockout temperature and SAT set point</td>
<td>119,767</td>
<td></td>
<td>8.3</td>
<td>$16,767</td>
<td>$0</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>Repair malfunctioning heating coil valve control</td>
<td>103,775</td>
<td>10,543,991</td>
<td>48.8</td>
<td>$98,880</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Totals</strong></td>
<td><strong>653,575</strong></td>
<td><strong>10,543,991</strong></td>
<td><strong>91</strong></td>
<td><strong>$154,333</strong></td>
<td><strong>$2,900</strong></td>
<td>neg.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>% Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Annual kWh Use (2005-2006)</td>
</tr>
<tr>
<td>Steam Use - lbs (1997-1998)</td>
</tr>
</tbody>
</table>
Eliminate simultaneous pump operation

- CHWP-1 & CHWP-2 run simultaneously
  - Balancing valves 75% closed
  - Sequence: primary / backup
- Similar for CWP-1 & CWP-2

- Corrective action
  - Rebalance flows
  - Modify chiller controls to run one pump at a time
Repair Chiller OA Lockout Operation

![Graph showing energy consumption over time with measure implemented]

<table>
<thead>
<tr>
<th>Account</th>
<th>Date</th>
<th>Channel</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bldg 480 kW</td>
<td>12/21/2005</td>
<td>kW</td>
<td>kW</td>
</tr>
<tr>
<td>Bldg 480 kW</td>
<td>12/21/2005</td>
<td>Oat</td>
<td>°F</td>
</tr>
</tbody>
</table>

Measure implemented
Raise Chiller Lockout Temperature and SAT

• Current conditions
  – Chiller OA lockout = 60 F
  – SAT set point = 60 F

• Design called for
  – Chiller OA lockout = 65 F
  – SAT set point = 63 F

• Raise both from 60 to 63 F
Repair Malfunctioning Heating Valve Control

<table>
<thead>
<tr>
<th>Account Date</th>
<th>Channel</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tan 05/11/2006</td>
<td>OAT</td>
<td>°F</td>
</tr>
<tr>
<td>Tan 05/11/2006</td>
<td>SAT</td>
<td>°F</td>
</tr>
<tr>
<td>Tan 05/11/2006</td>
<td>Chiller Request</td>
<td>On/Off</td>
</tr>
</tbody>
</table>
## M&V Results

<table>
<thead>
<tr>
<th>System</th>
<th>Equipment</th>
<th>Affected by ECM?</th>
<th>Available Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Whole Building</strong></td>
<td>Main 480/277 Electric Meter</td>
<td></td>
<td>kW</td>
</tr>
<tr>
<td></td>
<td>Main 220/110 Electric Meter</td>
<td></td>
<td>kW</td>
</tr>
<tr>
<td></td>
<td>Main Steam Meter</td>
<td></td>
<td>lbs/hr</td>
</tr>
<tr>
<td><strong>Chilled Water System</strong></td>
<td>Chiller (VS)</td>
<td></td>
<td>kW*</td>
</tr>
<tr>
<td></td>
<td>Primary Chilled Water Pumps CHWP-1, CHWP-2 (CS)</td>
<td>Status</td>
<td></td>
</tr>
<tr>
<td><strong>Condenser Water System</strong></td>
<td>Condenser Water Pumps CDWP-1, CDWP-2 (CS)</td>
<td>Combined with CHW System</td>
<td>Status</td>
</tr>
<tr>
<td></td>
<td>Cooling Tower (CS, 2-speed)</td>
<td></td>
<td>Not Avail.</td>
</tr>
<tr>
<td><strong>AHU-3</strong></td>
<td>AHU-3 Supply Fans SF-1, SF-2, SF-3, SF-4 (CS)</td>
<td></td>
<td>S/S &amp; Speed</td>
</tr>
<tr>
<td></td>
<td>AHU-3 Exhaust Fans EF-1, EF-2, EF-3, EF-4 (CS)</td>
<td></td>
<td>S/S &amp; Speed</td>
</tr>
<tr>
<td></td>
<td>Terminal Boxes and Fume Hoods associated with AHU-3</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td><strong>General Exhaust</strong></td>
<td>Chiller Room GE-1, GE-2, GE-3</td>
<td></td>
<td>S/S &amp; Speed</td>
</tr>
<tr>
<td></td>
<td>Main Lobby Exhaust GE-4</td>
<td></td>
<td>Status</td>
</tr>
<tr>
<td><strong>Heating Water System</strong></td>
<td>Heat Exchanger HWC-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hot Water Pumps HHWP-1, HHWP-2</td>
<td></td>
<td>Status</td>
</tr>
</tbody>
</table>
M&V Plan

• Baseline and post-install periods
• Tally systems energy totals each day
  – kWh
  – Peak period kWh
  – Steam lbs
• Plot daily totals and independent var. data
  – Avg. daily OAT
• Define a baseline model
  – Project into post-install period
  – Difference is savings
Steam Use

Date

Daily Steam lbs

0 20,000 40,000 60,000 80,000 100,000 120,000

Chiller kW Monitoring

Measures Implement

Deg. F

Steam Avg. Daily Temp.

©California Commissioning Collaborative
AHU-3 kWh

Prefilters and bags changed.
SF-1 Fails. The other fans ramp up to meet
SF-1 repaired. Fans return to pseudo-

Date
Pre and Post Installation Whole Building Daily kWh
Peak Period kWh vs Oat

- Base
- Post
- Fitted values

kWh
5000
6000
7000
3000
4000
50
60
70
80
90
40
Oat
Pre and Post Installation Daily Steam System lbs

- Steambaseline
- Steampost
## M&V Results

<table>
<thead>
<tr>
<th>Savings</th>
<th>Targeted</th>
<th>Estimated</th>
<th>Verified</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh</td>
<td>200,000</td>
<td>653,575</td>
<td>663,184</td>
</tr>
<tr>
<td>kW</td>
<td>-</td>
<td>91</td>
<td>69</td>
</tr>
<tr>
<td>Steam, lbs</td>
<td>-</td>
<td>10,543,991</td>
<td>5,995,232</td>
</tr>
</tbody>
</table>