Energy Efficiency in HVAC Systems

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Energy Efficiency
Efficiency Controllers

- BAS (EMS) Programming
- Air Side Economizers
- Heating Systems
- Cooling Systems
- Dampers
More Efficiency Controllers:

- Filters
- Variable Frequency Drives (VFD/VSD)
- Terminal Air Boxes
- Sensors
BAS (EMS) PROGRAMMING
BAS (EMS) Programming

- What is it?
- What language do they speak?
- Why do we care?
- Control Logic
  - IF
    - If Outside air is greater then 98 degrees
  - OR
    - Either pump #1 OR pump #2 must be ON
BAS (EMS) Programming

- **Control Logic**
  - **AND**
    - Both Supply and Return Fans must be ON
  - **NOT**
    - Turns a TRUE statement FALSE
  - **XOR**
    - Either Pump #1 OR Pump #2 are needed to ....
      - (Exclusive OR)
BAS (EMS) Programming

- What control scheme is in place?
  - DDC

- Who is responsible for controls?
  - Contract
  - As Needed

- What in-house expertise is available?
Discharge Air Temperature

DA-T=55
BAS (EMS) Programming

- **80 Degrees Outside Air Temperature**
  - 55 Degree Discharge Air
    - Provide a Cool Environment
      - Reheat to 72 degrees
    - Remove Humidity
      - 60% Relative Humidity Maximum
BAS (EMS) Programming

- **15 Degrees Outside Air Temperature**
  - 55 Degree Discharge Air
    - Exhaust 72 degree Return Air
    - Pull in 15 degree Outside Air
    - Reheat to 55 degrees
      - 40 degree difference
    - Reheat to 72 degrees in building
  - Humidity
    - 20% Relative Humidity Minimum
Outside Air Reset Schedule

- OA-T
  - Present Value: 30.03
  - Input Ref
  - REL

- OA-T-LOW
  - Present Value: 5.00
  - Input Ref
  - REL

- OA-T-HIGH
  - Present Value: 40.00
  - Input Ref
  - REL

- DA-T-LOW
  - Present Value: 55.00
  - Input Ref
  - REL

- DA-T-HIGH
  - Present Value: 65.00
  - Input Ref
  - REL

- DAT-SP
  - Present Value
  - Output Ref
  - @10

  - DAT-SP
    - Present Value
    - Output Ref
    - @10

  - DAT-SP
    - Present Value
    - Output Ref
    - @10

  - DAT-SP
    - Present Value
    - Output Ref
    - @10

  - DAT-SP
    - Present Value
    - Output Ref
    - @10
Control, Control, Control

- Eliminate the wild swings
- Don’t over cool or over heat
  - Energy wasted
  - Complaints
  - Lost Productivity
PID Loop

- PID is an acronym for "Proportional", "Integral", and "Derivative." These three types of control signals working together provide the most effective means available for maintaining a set point with good system response.

- The Proportional control signal is based on the difference between the set point and the actual error.
The Integral control signal's purpose is to eliminate the offset error inherent in Proportional control. Under some conditions, the system may "overshoot" the desired set point. To compensate for this effect, Derivative control is provided.

Derivative control works by effectively applying the "brakes" to the Integral control signal. The Derivative control detects that the error is approaching zero and incrementally cancels the Integral correction signal, thus minimizing overshoot while allowing the control signal to bring the system to the exact setpoint.
Set Points

RAH-SP

RFCFM-SP

DAT-SP

DAP-SP

MAT-SP
Air Side Economizers
Due to its temperate climate and tech focus, California is often the centerpiece of Air-Side economizer studies. Some of the figures are staggering:

- A data center in San Francisco can achieve full economization 97.7% of the year (Sorell, 2007)

- A data center in San Jose can reduce cooling costs by 60% through Air-Side economization (Pacific Gas and Electric, 2006)

- A Sacramento facility envisions, through Air-Side economization, a 30% savings over conventional data centers (Bowman, 2009)

- For 3500 hours per year, metro Los Angeles has dry bulb temperatures below 59 degrees F. (EYP Mission Critical Facilities, 2006)
Air Side Economizer

Enabled
Enthalpy Control
Heating Systems
Terminal Reheat

HEATING WATER
Heating Water Reset

- HE1V2-O: 0.0 %, -3 % open
- HE1V2-Pos: 3.8 psi
- HE1V1-0: 31.7 %
- HE1V1-Pos: 20 % open
- HE-1: 178.8 deg F, 179.4 deg F
- HWS-SP
- HWS-T
- HWR-T: 156.6 deg F
- OA-T: 41.1 deg F
- Command Output Filter: Off
- Command Output Filter: Normal
- Command Output Filter: On
- Command Output Filter: Normal

Condensate Return Station
Boilers
Kitchen Makeup Air
Cooling Systems
300 Ton Centrifugal Chiller
Chilled Water Temperature

![Graph showing the coefficient of performance (COP) of a chilled water system as a function of temperature. The graph indicates a positive correlation between temperature and COP.]
Cooling Tower
Cooling Tower Fans
Why is Proper Maintenance Important?

- An improperly maintained cooling tower will produce warmer cooling water, resulting in a condenser temperature 5 to 10 degrees F higher than a properly maintained cooling tower. This reduces the efficiency of the chiller, wastes energy, and increases cost.

- The chiller will consume 2.5 to 3.5 percent more energy for each degree increase in the condenser temperature
Poor Performance

- **Scale Deposits**
  - When water evaporates from the cooling tower, it leaves scale deposits on the surface of the fill from the minerals that were dissolved in the water. Scale build-up acts as a barrier to heat transfer from the water to the air. Excessive scale build-up is a sign of water treatment problems.

- **Clogged Spray Nozzles**
  - Algae and sediment that collect in the water basin as well as excessive solids get into the cooling water and can clog the spray nozzles. This causes uneven water distribution over the fill, resulting in uneven air flow through the fill and reduced heat transfer surface area. This problem is a sign of water treatment problems and clogged strainers.
Poor Performance

- **Poor Air Flow**
  - Poor air flow through the tower reduces the amount of heat transfer from the water to the air. Poor air flow can be caused by debris at the inlets or outlets of the tower or in the fill. Other causes of poor air flow are loose fan and motor mountings, poor motor and fan alignment, poor gear box maintenance, improper fan pitch, damage to fan blades, or excessive vibration. Reduced air flow due to poor fan performance can ultimately lead to motor or fan failure.

- **Poor Pump Performance**
  - An indirect cooling tower uses a cooling tower pump. Proper water flow is important to achieve optimum heat transfer. Loose connections, failing bearings, cavitation, clogged strainers, excessive vibration, and non-design operating conditions result in reduced water flow, reduced efficiency, and premature equipment failure.
WATER COST SAVING OPPORTUNITIES IN BUILDING HVAC SYSTEMS

• Meter cooling tower and closed system water usage
• Reduce cooling tower bleed rate
• Obtain credit on cooling tower evaporation
• Eliminate leaking makeup and bleed valves
• Use a blend of soft water for cooling tower makeup
• Use air handler condensate for cooling tower makeup
• Use reclaim or gray water for tower makeup
• Use rain water for tower makeup
• Identify and correct closed system leaks
## COOLING TOWER EVAPORATION CREDIT

<table>
<thead>
<tr>
<th>Cooling Load (Tons)</th>
<th>Evaporation Rate (GPD)</th>
<th>Annual Evaporation</th>
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<tbody>
<tr>
<td>50</td>
<td>2,160</td>
<td>$1,971</td>
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<tr>
<td>500</td>
<td>21,600</td>
<td>$19,710</td>
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<tr>
<td>1,000</td>
<td>43,200</td>
<td>$39,420</td>
</tr>
<tr>
<td>2,500</td>
<td>108,000</td>
<td>$98,550</td>
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</tbody>
</table>

*Based on sewage surcharge of $2.50/1,000 gallons water*
Dampers
Exhaust Air Dampers
Outside Air Dampers
Louver Dampers

- The louver type of damper consists of several blades mounted parallel across a duct, with centrally pivoted shafts extending out through a frame and driven by a linkage. Louver dampers are versatile, able in theory to handle any application in the power plant. Some of their advantages:
  - Fit anywhere in ducting, at any altitude.
  - Compact, no bonnet, little external clearance needed.
  - Lightweight
  - Drive and linkage more readily accessible
  - Control function simple with opposed blades.
  - Thin metal blade construction gives quick response to thermal transients.
  - Fast opening and closing.
  - Low leakage to outside environment.
  - Good modulation and control characteristics.
  - Actuation power requirements are low.
  - Normally does not require a support structure.
Louver Dampers - Basic Disadvantages

- Large leakage perimeter.
- Leakage through seals goes downstream inside the duct.
- Comparatively high pressure drop because of blade and seal obstruction of flow.
- Obstructions such as seals, shafts, stops, and fasteners tend to catch ash and scrubber slop.
- Inherent flimsiness of long thin blades tends to promote flutter.
- Blades and seals, always in the flow, tend to corrode and erode more.
- Blades can buckle and warp, causing leakage and lockup.
- Bearing troubles are possible.
- Inadequate drive power and blade strength to crush through concretions and force a seal.
- Larger flange-to-flange required to contain blade(s) in full open position.
- Sealing problems in dirty applications.
- More moving parts and thus increased maintenance.
**OPPOSED BLADES LOUVER DAMPERS**

- **OPPOSED BLADES LOUVER DAMPERS** are the most effective type of damper for controlling the flow of gases with the least disturbance to flow in ducts. Each pair of blades is carefully fitted to ensure precise operation in opposing directions, and thus creating highly controllable passages for the gas.

- The drive shafts are supported in maintenance-free bearings. A special non-binding, fully adjustable external linkage is used to operate the damper. A wide variety of operators can be specified - electric, pneumatic, hydraulic or manual.
Filters
Air Flow
Filter Rack
Filter Efficiency

- Minimum Efficiency Reporting Value = MERV

- A filter rating system devised by the American Society of Heating, Refrigeration and Air conditioning Engineers (ASHRAE) to standardize and simplify air filter efficiency ratings for the public. The higher the MERV rating, the higher the efficiency of the air filter. Simply stated, a MERV 12 filter will remove smaller particles more efficiently from the air than a MERV 8 filter.
Some examples of MERV ratings

- 95% or MERV 14 — typically applied as the final filter in hospital HVAC systems.
- 85% or MERV 13 — typically applied in above average commercial applications.
- 65% or MERV 11 — applied in standard commercial buildings, such as office space.
- 25% or MERV 6 and 7 — pleated panel filters, applied in office environments, and as pre-filters.
- <20% or MERV 1 through 5 — typical polyester or fiberglass throwaway panels and metal washable filters.
Filter Pressure Drop
Variable Frequency Drives
Design Parameters

- 95 Degree Outside Air
  - Pumps pushing enough chilled water to cool entire facility.
  - Chiller carrying full load to keep water at 42 degrees.
  - Cooling tower rejecting enough heat to keep condenser water at 75 degrees.
  - Air Handlers supplying sufficient air so that all terminal air boxes are satisfied.
But . . . .

- Space is satisfied – at set point
  - Don’t require that much air
    - Minimum air changes only
  - Don’t require that hot (cool) air. (PID Loop)

- Building is cool
  - Chiller not under full load
  - Cooling tower not receiving hot water

- Worst Case Scenario Equipment not Needed
Chilled Water Pump Speed
VAV Terminal Air Box
VAV with Terminal Reheat

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
<th>Description</th>
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<tbody>
<tr>
<td>OCC-C</td>
<td>Occupied</td>
<td>Occupied Command</td>
</tr>
<tr>
<td>BOX-MODE</td>
<td>Satisfied</td>
<td>Vav Box Mode</td>
</tr>
<tr>
<td>DA-F</td>
<td>391.9 cfm</td>
<td>Discharge Air Flow</td>
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<tr>
<td>DAF-SP</td>
<td>390.0 cfm</td>
<td>Discharge Air Flow Setpoint</td>
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<tr>
<td>ZN-T</td>
<td>70.4 deg F</td>
<td>Zone Temperature</td>
</tr>
<tr>
<td>ZNT-SP</td>
<td>70.0 deg F</td>
<td>Zone Temperature Setpoint</td>
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<tr>
<td>DA-T</td>
<td>49.5 deg F</td>
<td>Discharge Air Temperature</td>
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<tr>
<td>DPR-O</td>
<td>35.3 %</td>
<td>Damper Output</td>
</tr>
<tr>
<td>HTG-O</td>
<td>0.0 %</td>
<td>Heating Output</td>
</tr>
<tr>
<td>HTG-EN</td>
<td>True</td>
<td>Heating Enable</td>
</tr>
</tbody>
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<td>Occupied</td>
<td>Occupied Command</td>
</tr>
<tr>
<td>BOX-MODE</td>
<td>Heating</td>
<td>Vav Box Mode</td>
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<tr>
<td>DA-F</td>
<td>805.1 cfm</td>
<td>Discharge Air Flow</td>
</tr>
<tr>
<td>DAF-SP</td>
<td>800.0 cfm</td>
<td>Discharge Air Flow Setpoint</td>
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<tr>
<td>ZN-T</td>
<td>66.6 deg F</td>
<td>Zone Temperature</td>
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<tr>
<td>ZNT-SP</td>
<td>72.0 deg F</td>
<td>Zone Temperature Setpoint</td>
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<tr>
<td>DA-T</td>
<td>50.2 deg F</td>
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<td>DPR-O</td>
<td>53.3 %</td>
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<td>HTG-O</td>
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<tr>
<td>HTG-EN</td>
<td>True</td>
<td>Heating Enable</td>
</tr>
</tbody>
</table>
VAV System

Supply Fan Motor receives 45.98 Hz. This equates to 76% of full speed.
Sensors
RTD

![Graph showing the resistance (R) in ohms (Ω) as a function of temperature (T) in °K. The graph indicates a decrease in resistance with increasing temperature.]
Critical Sensor

- “Controlling to a set point”
  - Discharge air Temperature
  - Outside Air Temperature
  - Duct Static Pressure
Where do we go from here?

- Set up a PM Program
  - Perform Preventive Maintenance Tasks
  - Record critical data
    - Discharge air temperatures
    - Setback settings
    - Water temperatures
      - Chilled
      - Heating
- Repair all broken equipment
COMMISSIONING TRIANGLE

BUILD IT FAST

BUILD IT FAST

BUILD IT GOOD

BUILD IT GOOD

PICK TWO

BUILD IT CHEAP
Re-Commissioning

- Did you get what you need?
- Did they install what was specified?
- Does it work as intended?
QUESTIONS ?