Lessons Learned

ASHRAE BOSTON CHAPTER
September 21, 2016

By Steven Tafone, PE
Lessons Learned Seminar Outline

- Design Lessons Learned
  - Electric for HVAC Engineers
  - Direct return vs. reverse return piping systems
  - Primary-secondary piping bridge
  - AHU’s and Dedicated Outdoor Air Systems
  - Humidity systems
  - Miscellaneous problems encountered
  - Control valve pipe sizing
  - What’s wrong with this picture

Troubleshooting

- Questions and answers
ELECTRIC FOR THE HVAC ENGINEER
WHY IS ELECTRIC 3-4 TIMES MORE EXPENSIVE TO HEAT WITH THAN GAS?
Power Generation

Diagram: Flow of energy from gas/oil boiler to various components including generator, condenser, and alternate co-generation steam with indicated BTU values.
Single Phase

Figure 4-6  Alternating Current Waveform
3 Phase Power

Figure 4-8 Three-Phase Alternating Current Waveform
Selection of Voltage

- Based on planned load of building at time of design
- 120V 1φ- Typical outlet and incandescent light
- 208-230V 1φ- Residential and small commercial- Large appliances and office equipment and lights
- 208-230V 3φ- Small commercial- motors
- 277V 1φ- Small to large commercial- lights and small motors
- 460V 1φ, 3φ- Large commercial- motors
- 2,300V 3φ- Large commercial and industrial
- 4,160V 3φ- Large industrial
- 13,200V 3φ- Large industrial
208 VAC ≠ 230 VAC

- True most motors are 208-230/240 VAC
- But what about 24 VAC control circuits derived from transformers??
  - NEMA allows +/- 10%
  - 230 VAC → 24 VAC
  - 208 VAC → 21.7 VAC (10%)
  - 187 VAC → 19.5 VAC (19%)
Electric for the HVAC Engineer

- Trane, York and Carrier do not allow aluminum conductors on their chillers
- Don’t use HOA switches with VFD’s
- Don’t use HOA’s with large motors, especially fans with belts.
  - How does a HOA work?
- Don’t use 3 phase motors below ½ HP.
  - Why?
Electric Motors

- Function: Converts electric energy into mechanical energy.
- Opposite of generators
- Size rated in horse power (HP & Watts)
- Available in 1 or 3 phase and with different voltages
- Most single phase motors have internal overloads and don’t require starters
- Large single phase motors require start and/or run capacitors
- Three phase motors can reverse rotation by switching two wires
- Three phase motors require starters for motor protection
Motor Starters

- Function- Devices that starts, stops and protects the motor
- Four different types of starters
  - 1. Across the line
  - 2. Reduced Voltage (Part winding)
  - 3. Reversing
  - 4. Soft Start
  - HOA- Hand/Off/Auto
  - Phase loss- When one fuse in a 3Ø circuit is blown
  - Motor Control Center (MCC)- Provides circuit protection and remote control of motors
Simple Relay

![Diagram of a simple relay with coils and contacts labeled as Control Circuit, Coil, Contact, and To Load Controlled.]
Old Style Heater
New Style Heater
BACK TO HVAC
Which of the following statements are true:
1. Direct return systems cost less to install?
2. Reverse returns are self-balancing?
3. Reverse returns cost less to balance?
De-coupler to be 12” maximum. Why? If pipe is sized at 4’ H20/100’ then 10’ pipe would have 0.4’ pressure drop.
De-coupler Piping
AHU and DOAS

- Why do Engineers convert steam to HW then use the HW for AHU’s instead of just using the steam??
- Why do Engineers use 1/3rd-2/3rd valves instead of 1 segmented ball valve with a 300:1 turn down ratio??
- Do run around (freeze) pumps prevent water freezing in coils??
- Circulating pumps are required when using HW for heating!!
Freezstat
Freezstat Problems

- Is there a circulating pump on the HW?
- Is there a reset schedule on the HW system?
- Is the entering air blended on systems with return air?
- Is there a gremlin causing the problem?
Air Movement in AHU
## Water Flow vs. Heat Transfer

<table>
<thead>
<tr>
<th>% Water Flow Rate</th>
<th>% Heat Transfer</th>
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<tr>
<td>100</td>
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<tr>
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<td>84</td>
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<td>20</td>
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</table>
Snow Melt

- Requirement depends on how the wind blows
  1. Radiant systems
  2. Unit heaters
  3. Electric screens
  4. Pre-heat coil upstream of filters
Condensate Drains

- Look at standard detail before using.
- Will trap fit or will holes be required in the floor to get the trap to work?
Humidity Systems

- There are 2 types of humidity systems
  1. Those that leak water into the space.
  2. Those that will leak water into the space.

- Control valve must shut system off when not in use.
- Is there a drain pan under the duct humidifier?
- Use as insulating jacket on the humidifier.
- Some humidifiers require a 0 pressure condensate return
- Verify the system pressure is the same as the available pressure
- Is the humidifier baffled correctly in the AHU?
Humidifier Baffle
Humidifier Baffle
Miscellaneous Issues

- Cooling tower sand filters
  - Are floor drains adequately sized?
- Control valves with over sized piping.
Valve Sizing

3. **Piping Geometry Factor**: Reducing pipe sizes for installation of a smaller than pipe size valves will reduce the effective Cv of the valve. The greater the pipe reduction, the greater loss of Cv. Using the Adjusted Cv’s for Piping Geometry Factors chart, verify that the corrected Cv for the valve size selected, meets or exceeds the required Cv calculated in step 2.

**Note**: 3-way Cv’s have already been adjusted.

### Adjusted Cv’s for Piping Geometry Factors

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<th>Size</th>
<th>2-1/2&quot;</th>
<th>3&quot;</th>
<th>4&quot;</th>
<th>5&quot;</th>
<th>6&quot;</th>
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<td></td>
<td>18280</td>
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</table>
TIME TO PLAY WHAT’S WRONG WITH THIS PICTURE?
What’s Wrong with this Picture
Answer
Multiple Stacked Chillers

Variable Flow Chiller Schematic

*Less than 30 second stroke time required.
**Maintain 2 minute loop time at all load conditions.
What’s Wrong with this Picture
Answer
What’s Wrong with this Picture

Series 4030
3x1.5x8 @ 1765 rpm

PT50-5-0 (3.21.0.4)
ANSI/HI 14.6.3.4.1

--- Admin Data ---
Tag Num: P-1.7 & 1.8
Service:
Location:

--- Motor Data ---
Motor Size: 3 hp
Motor Speed: 1800 rpm

--- Design Duty Point ---
Flow: 62 usgpm
Head: 50 ft
Impeller: 6.972 in

--- Performance Data ---
• NPSHR: 3.8062 ft
• Eff. @ Design: 47.58 %
• BHP @ Design: 1.65 hp
• Mtr Capacity @ Rated Spd: 3.00 hp
• %Mtr Safety: 82.33%
• BEP @ Design Imp.: 54.91 % @ 104.5 usgpm
• Impeller Max BHP @ Flow: 2.35 hp @ 145.0 usgpm
• %max imp. range: 44.42 %
• Outlet Velocity: 9.77 ft/s
Pump Sequence

- When the lead pump is >95% speed for 10 minutes, the lag pump shall start and increase in speed while the lead pump decreases in speed until both pumps are at the same speed to maintain system pressure.

- When both pumps are <25% speed for 10 minutes, the lead pump shall stop and the lag pump shall increase in speed to maintain system pressure.

- When the single pump is at 25% speed and the system pressure is greater than the setpoint, the bypass valve shall modulate toward open.
# Pump Speed vs Head

<table>
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<tr>
<th>% speed</th>
<th>HEAD Ft</th>
<th>HEAD Ft</th>
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<td>90%</td>
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<td>80%</td>
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<tr>
<td>10%</td>
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</table>
Single Pump

**E-1510 2BD**

**1750 RPM**

**Head (Feet):**
- 9.375”
- 1350 RPM
- 1800 RPM

**Design Capacity:** 200.0 GPM
**Design Head:** 80.0 Feet

- **Suction Size:** 2.5”
- **Suct. Velocity:** 13.4 fps
- **Discharge Size:** 2”
- **Disc. Velocity:** 19.1 fps

- **Min. Imp. Dia.:** 7”
- **Max. Imp. Dia.:** 9.5”
- **Cut Dia.:** 9.375”

- **Max. Flow:** 306 GPM
- **B.E.P. Flow:** 204 GPM

- **Eff. @ Duty-Point:** 75.21%
  - **Motor Size:** 7.50 HP

- **B.H.P. @ Duty-Point:** 5.49 BHP
  - **Max. B.H.P. for Imp. Cut:** 6.85 BHP
Parallel Pumps

Diagram showing the performance of a parallel pump system, with curves indicating head versus capacity at different RPMs: 450 RPM, 900 RPM, 1350 RPM, and 1800 RPM. The diagram includes a label for E-1510 2BD 1750 RPM.
What’s Wrong with this Picture

**ENERGY RECOVERY VENTILATION UNIT**

<table>
<thead>
<tr>
<th>UNIT #</th>
<th>MANUFACTURER</th>
<th>MODEL NUMBER</th>
<th>MAX O.A. CFM</th>
<th>EXT. S.P.</th>
<th>MIN O.A. CFM</th>
<th>V/PH/Z</th>
<th>FAN HP</th>
<th>MAX CFM</th>
<th>EXT. S.P.</th>
<th>V/PH/Z</th>
<th>FAN HP</th>
<th>COOLING DATA</th>
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</thead>
<tbody>
<tr>
<td>ERV-1</td>
<td>GREENHECK</td>
<td>ERCH-45-15L-BP-1G-01</td>
<td>2,000</td>
<td>1.5</td>
<td>1,000</td>
<td>460/3/60</td>
<td>3</td>
<td>2,000</td>
<td>1.5</td>
<td>460/3/60</td>
<td>3</td>
<td>93.1</td>
</tr>
</tbody>
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**NOTES:**

1. FURNISH ERV-1 WITH THE FOLLOWING OPTIONS/ACCESSORIES:
   - OA LOW LEAKAGE DAMPER
   - EA LOW LEAKAGE DAMPER
   - MODULATING WHEEL FROST CONTROL
   - MODULATING ENERGY WHEEL
   - WEATHER HOOD - DOWNTURN
   - OCCUPIED RECIRC DAMPER - MOTORIZED LOW LEAKAGE
   - DIRTY FILTER SENSOR
   - SUPPLY/EXHAUST DUCT SMOKE DETECTOR
   - MERV-13 SUPPLY/ MERV-8 EXHAUST FILTERS
   - MICROPROCESSOR CONTROLS - BMS INTERFACE - BACKNET MSTP
   - ROOF CURB - 24 INCH VIBRATION ISOLATION TYPE
   - PAINTED EXTERIOR - COLOR PER ARCH.
   - MODULATING WHEEL - OA ENTHALPY CONTROL
   - SUPPLY AND EXHAUST FAN VFD'S
   - CONVENIENCE OUTLET
   - EXTERIOR SERVICE LIGHT

**ROOF-TOP UNIT WITH O.A. EXHAUST**

<table>
<thead>
<tr>
<th>UNIT #</th>
<th>EXHAUST @ ENERGY W</th>
<th>EAT(DB/WB)</th>
<th>LAT(DB/WB)</th>
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<tbody>
<tr>
<td>ERV-1</td>
<td>70.0/53.0</td>
<td>19.2/17.2</td>
<td></td>
</tr>
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</table>
## ENERGY RECOVERY VENTILATION UNIT

<table>
<thead>
<tr>
<th>UNIT #</th>
<th>MANUFACTURER</th>
<th>MODEL NUMBER</th>
<th>SUPPLY FAN PERFORMANCE DATA</th>
<th>RETURN FAN PERFORMANCE DATA</th>
<th>COOLING DATA</th>
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<tbody>
<tr>
<td>ERV-1</td>
<td>GREENHECK</td>
<td>EROH-45-15L-8P-1G-01</td>
<td>MAX O.A. CFM 2,000</td>
<td>MAX CFM 2,000</td>
<td>MBH 93.1</td>
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<td>EXT. S.P. 1.5</td>
<td>EXT. S.P. 1.5</td>
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<td>MIN O.A. CFM 1,000</td>
<td>MIN O.A. CFM 1,000</td>
<td>SENS. 60.3</td>
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<td>V/PH/HZ 460/3/60</td>
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<td></td>
<td></td>
<td>FAN HP 3</td>
<td>FAN HP 3</td>
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### NOTES:

1. FURNISH ERV-1 WITH THE FOLLOWING OPTIONS/ACCESSORIES:
   - OA LOW LEAKAGE DAMPER
   - EA LOW LEAKAGE DAMPER
   - MODULATING WHEEL FROST CONTROL
   - MODULATING ENERGY WHEEL
   - WEATHER HOOD - DOWNTURN
   - OCCUPIED RECUR DAMPER - MOTORIZED LOW LEAKAGE
   - DIRTY FILTER SENSOR
   - SUPPLY/EXHAUST DUCT SMOKE DETECTOR
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   - ROOF CURB - 24 INCH VIBRATION ISOLATION TYPE
   - PAINTED EXTERIOR - COLOR PER ARCH.
   - MODULATING WHEEL - OA ENTHALPY CONTROL
   - SUPPLY AND EXHAUST FAN VFD'S
   - CONVENIENCE OUTLET
   - EXTERIOR SERVICE LIGHT

---

**Supplied by Electrical Contractor, installed by Sheet metal Contractor**
What’s Wrong with this Picture
Answer

Makeup water should go here

Not here
What's Wrong with this Picture

### Roof-Top Unit with O.A. ERV - SW

<table>
<thead>
<tr>
<th>UNIT #</th>
<th>MANUFACTURER</th>
<th>MODEL #</th>
<th>UNIT WEIGHT</th>
<th>SUPPLY FAN PERFORMANCE DATA</th>
<th>RETURN FAN PERFORMANCE DATA</th>
<th>COOLING DATA - AIR C</th>
<th>MEH</th>
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<tbody>
<tr>
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<td></td>
<td>MAX CFM</td>
<td>EXT. S.P.</td>
<td>MIN. O.A. CFM</td>
<td>V/P/H1/HZ</td>
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<tr>
<td>RTU-1</td>
<td>JOHNSON CONTROLS</td>
<td>YP4105MVE46BBF3H</td>
<td>22,000 LBS</td>
<td>36,000</td>
<td>2.5</td>
<td>9,000</td>
<td>460/3/60</td>
</tr>
</tbody>
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**Provide units with the following options:**

- ENTHALPY CONTROLLED AIR-SIDE ECONOMIZER
- INVERTER DUTY FAN MOTORS
- STAINLESS STEEL HEAT EXCHANGER
- VFD'S FOR SUPPLY AND RETURN FANS
- STAINLESS STEEL DRAIN PAN
- MERV 13 INTAKE FILTERS
- CONVENIENCE POWER OUTLET (FIELD INSTALLED BY E.C.)
- SERVICE LIGHTS - OUTSIDE & INSIDE UNIT (FIELD INSTALLED BY E.C.)
- SINGLE POINT POWER CONNECTION
- 4 INCH FILTER RACK - MERV 13
- FACTORY INSTALLED CONTROLS WITH INTERFACE TO BMS
- HOT GAS Bypass
- COIL GUARD
- EBTINON FLOW STATION FOR O.A. INTAKE

**Exhaust @ Energy Wheel:**

- EAT(D8/WB)
- LAT(D8/WB)

- RTU-1 700/535 18.6/18.3
## ROOF-TOPE UNIT WITH O.A. ERV - SCHEDULE

<table>
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<th>UNIT #</th>
<th>MANUFACTURER</th>
<th>MODEL #</th>
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<td>JOHNSON CONTROLS</td>
<td>YPAL105MVE44BBF3H</td>
<td>22,000 LBS 36,000</td>
<td>2.5</td>
<td>9,000</td>
<td>460/3/60</td>
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**MODULATING UNITS WITH THE FOLLOWING OPTIONS:**
- ENTHALPY CONTROLLED AIR-SIDE ECONOMIZER
- INVERTER DUTY FAN MOTORS
- STAINLESS STEEL HEAT EXCHANGER
- VFDs FOR SUPPLY AND RETURN FANS
- MERV 13 INTAKE FILTERS
- MODULATING GAS HEAT
- CONVENIENCE POWER OUTLET (FIELD INSTALLED BY E.C.)
- SERVICE LIGHTS - OUTSIDE & INSIDE UNIT (FIELD INSTALLED BY E.C.)
- SINGLE POINT POWER CONNECTION
- 4 INCH FILTER RACK - MERV 13
- FACTORY INSTALLED CONTROLS WITH INTERFACE TO BMS
- HOT GAS BY-PASS
- COIL GUARD
- EBTRON FLOW STATION FOR O.A. INTAKE
- Should state modulating heat wheel with VFD

**ENERGY WHEEL DESIGN CO:**

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<tr>
<th>UNIT #</th>
<th>EXHAUST</th>
<th>ENERGY WHEEL</th>
<th>SUPPLY</th>
<th>ENERGY WHEEL</th>
<th>SUPPLY LEAVING UNIT</th>
<th>TOTAL</th>
<th>WHEEL EFF.</th>
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<tr>
<td>RTU-1</td>
<td>70.0/53.0</td>
<td>18.6/18.2</td>
<td>0.3/0.0</td>
<td>522/42.1</td>
<td>95 (WARMING WARM-UP)</td>
<td>73.0%</td>
<td></td>
</tr>
</tbody>
</table>
What’s Wrong with this Picture
Heat Wheel
Heat Wheel Seal

Air flowing between the rotor and labyrinth seal expands repeatedly, creating a pressure loss that forms an effective seal and prevents air from bypassing the rotor. The labyrinth seal never touches the rotor.
Heat Wheel Problem
Temperature After HW Coil
Heat Wheel
DAT with ON/OFF Heat Wheel
Flow sensors are NOT the same as Pitot tubes.
Pitot Tube

Fig. 3 – Pitot Tube senses total and static pressure. Manometer measures velocity pressure – (Difference between total and static pressures).
Typical VAV
Converting Pressure to CFM

- $V \text{ (FPM)} = 4004 \sqrt{Dp}$
- $\text{CFM} = V \times \text{Area}$
TROUBLESHOOTING CHART
Flowchart For Problem Resolution

- **Is It Working?**
  - **YES**: Don't Mess With It!
  - **NO**: Did You Mess With It?
    - **YES**: YOU IDIOT!
      - **YES**: Will it Blow Up In Your Hands?
        - **NO**: Look The Other Way
        - **YES**: You're SCREWED!
          - **YES**: Can You Blame Someone Else?
            - **NO**: Hide It
            - **YES**: Look The Other Way
      - **NO**: Anyone Else Knows?
        - **YES**: You're SCREWED!
        - **NO**: Hide It
  - **NO**: NO PROBLEM!
Troubleshooting

- Listen to what everyone has to say.
- Do your own research.
- Fix known problems first.
- Change only one thing at a time.
- Check back to verify problem has been corrected.
- Review the manufacturers literature.
- One experiment is worth a thousand expert opinions.
1. What should a AHU HW coil always have?
2. Is it better to have a larger, same size or smaller pipe connected to a control valve?
3. What type of interface is most common with BMS systems?
4. What is the first thing you should do when trying to solve a mechanical problem?
5. What is the difference between a pitot tube and an air flow meter?
6. What should a duct humidifier always have?
7. What voltage should be used for a 1 HP motor?
8. Why is a starter used for a motor??
9. How much heat flow does a control valve at 20% open produce?
10. What is differential pressure?
THE END