Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings
CEUs for this workshop

Be sure to scan the QR for Tuesday, Wednesday, and Thursday workshops to get points towards your IGSHPA certification CEUs.
Speaker Bio

- Bachelor of Science:
  - Mechanical Engineering
  - Purdue Fort Wayne
- Current Role:
  - Sr. Director of Engineering @ WaterFurnace International
- Experience
  - 20 years @ WaterFurnace in engineering & new product development
  - 18 years on developing and expanding commercial offering
  - Mechanical journeyman, IGSHPA certified, EPA certified
- Patents (3 awarded / 30 application):
  - Space conditioning and monitoring method
  - Air conditioning system with vapor injection
  - Variable capacity heat pump system

Tim A. Hammond
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

Basic Water-Source Heat Pump

- PSC or 5spd or VS ECM Fan Motor
- LED’s for Fault and Status
- Thermostat
- Heat Pump Control
- Single Speed or Dual Capacity

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Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

- Better load matching
- Leaving Air Temperature Control
- Space & Humidity Control
- Ability to monitor input kW
- Ability to measure air/water flow
- Reduce Ventilation Energy Consumption
- Solutions for diverse applications
- Integrate latest code requirements
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

21st Century Water Source Heat Pumps

- True Permanent Magnet DC Inverter Compressor
- Variable Speed EC Direct Drive Plenum Fan
- Electronic Expansion Valve
- Modulating Hot Gas Reheat
- Variable Speed EC Pumps & modulating water valves
- Advanced Controls & Communicating Sensors
- Energy Recovery
- Air & Water Economizer
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

Variable Speed Heat pump
Without Energy Recovery

Variable Speed Heat Pump
With Energy Recovery

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Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

A Complete, Whole-Building Variable Capacity System

Need to Know:

Affinity Laws

\[ HP_2 = HP_1 \left( \frac{F_2}{F_1} \right)^3 \]
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

A Complete, Whole-Building Variable Capacity System:

Affinity Laws:
Energy Consumption Reduces by the Cube of the Reduction of the:

- The WSHP Compressor refrigerant flow
- The WSHP Fan airflow
- The WSHP Water Coil water flow
- The System Water Loop water flow
- The System Makeup Air airflow
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

- Perm Magnet VFD: 94% Max Cap, 93% Min Cap
- VFD Induction: 3600 rpm SS Full Load
- Part Load Operation: 75%

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Variable Speed WSHP 10 Ton Example:

<table>
<thead>
<tr>
<th>Load</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate, gpm</td>
<td>34.0</td>
</tr>
<tr>
<td>WPD, ft/hd</td>
<td>6.33</td>
</tr>
<tr>
<td>Air flow, cfm</td>
<td>4200</td>
</tr>
<tr>
<td>TC MBTUH</td>
<td>132.2</td>
</tr>
<tr>
<td>SC MBTUH</td>
<td>106.2</td>
</tr>
<tr>
<td>S/T Ratio</td>
<td>0.80</td>
</tr>
<tr>
<td>Input Power</td>
<td>9.79</td>
</tr>
<tr>
<td>EER</td>
<td>13.50</td>
</tr>
</tbody>
</table>

- Water loop conditions – 86 °F
- Cooling with 10 °F delta T on condenser
- Constant entering water
- Variable airflow
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

Variable Speed WSHP 10 Ton Example - Cooling

<table>
<thead>
<tr>
<th>Load</th>
<th>100%</th>
<th>75%</th>
<th>50%</th>
<th>25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate, gpm</td>
<td>34.0</td>
<td>28.0</td>
<td>20.0</td>
<td>10.0</td>
</tr>
<tr>
<td>WPD, ft/hd</td>
<td>6.33</td>
<td>4.69</td>
<td>2.64</td>
<td>1.76</td>
</tr>
<tr>
<td>Air flow, cfm</td>
<td>4200</td>
<td>3150</td>
<td>2100</td>
<td>1400</td>
</tr>
<tr>
<td>TC MBTUH</td>
<td>132.2</td>
<td>101.9</td>
<td>64.3</td>
<td>31.1</td>
</tr>
<tr>
<td>SC MBTUH</td>
<td>106.2</td>
<td>73.0</td>
<td>40.7</td>
<td>18.1</td>
</tr>
<tr>
<td>S/T Ratio</td>
<td>0.80</td>
<td>0.72</td>
<td>0.63</td>
<td>0.58</td>
</tr>
<tr>
<td>Input Power</td>
<td>9.79</td>
<td>7.19</td>
<td>4.19</td>
<td>1.56</td>
</tr>
<tr>
<td>EER</td>
<td>13.50</td>
<td>14.18</td>
<td>15.34</td>
<td>19.92</td>
</tr>
</tbody>
</table>

- Turn down 10:2.5 tons
- 73% reduction in ft of head
- 84% reduction in kW

Variable airflow

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Variable Speed WSHP 10 Ton Example - Cooling

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<tbody>
<tr>
<td>EWT, F</td>
<td>86</td>
<td>73.5</td>
<td>62</td>
<td>55</td>
</tr>
<tr>
<td>Flow Rate, gpm</td>
<td>34.0</td>
<td>28.0</td>
<td>16.0</td>
<td>8.0</td>
</tr>
<tr>
<td>ft/hd</td>
<td>6.33</td>
<td>4.87</td>
<td>2.65</td>
<td>2.07</td>
</tr>
<tr>
<td>Air flow, cfm</td>
<td>4200</td>
<td>3150</td>
<td>2100</td>
<td>1400</td>
</tr>
<tr>
<td>TC MBTUH</td>
<td>132.2</td>
<td>104.3</td>
<td>69.7</td>
<td>36.2</td>
</tr>
<tr>
<td>SC MBTU</td>
<td>106.2</td>
<td>73.3</td>
<td>41.4</td>
<td>18.8</td>
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<tr>
<td>S/T Ratio</td>
<td>0.80</td>
<td>0.70</td>
<td>0.59</td>
<td>0.52</td>
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<tr>
<td>Input Power</td>
<td>9.79</td>
<td>6.27</td>
<td>3.33</td>
<td>1.034</td>
</tr>
<tr>
<td>EER</td>
<td>13.50</td>
<td>16.64</td>
<td>20.93</td>
<td>35.06</td>
</tr>
</tbody>
</table>

- 2% full load
- 61.7% @ 75%
- 23.8% @ 50%
- 12.5% @ 25%

Part load 98% of the time!
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Variable Speed WSHP 10 Ton Example - Cooling

Variable EWT & Constant airflow

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<td>16.0</td>
<td>8.0</td>
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<tr>
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<td>6.33</td>
<td>4.87</td>
<td>2.65</td>
<td>2.07</td>
</tr>
<tr>
<td>Air flow, cfm</td>
<td>4200</td>
<td>4200</td>
<td>4200</td>
<td>4200</td>
</tr>
<tr>
<td>TC MBTUH</td>
<td>132.2</td>
<td>107.3</td>
<td>76.6</td>
<td>42.7</td>
</tr>
<tr>
<td>SC MBTU</td>
<td>106.2</td>
<td>84.8</td>
<td>58.3</td>
<td>31.5</td>
</tr>
<tr>
<td>S/T Ratio</td>
<td>0.80</td>
<td>0.79</td>
<td>0.76</td>
<td>0.74</td>
</tr>
<tr>
<td>Input Power</td>
<td>9.79</td>
<td>6.96</td>
<td>3.96</td>
<td>1.26</td>
</tr>
<tr>
<td>EER</td>
<td>13.50</td>
<td>15.42</td>
<td>19.34</td>
<td>33.91</td>
</tr>
</tbody>
</table>

- CFM constant at all load %
- Minimal reduction in EER
- Still significant benefit by load matching
- But meet ventilation needs
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

A Complete, Whole-Building Variable Capacity System

Requires:

- Consulting Engineer: No new skills to learn
- Mechanical Contractor: No new skills to learn
- Control Contractor: No new skills to learn
- Commercial Rep: No new engineering support tools to learn
- Risk?: No new Risks for any Trade
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

- **WSHP Typical Operation:**
  - Constant Air Volume
  - Compressor operates to *space (thermostat)*
  - Cycling on/off
  - Blower operates off/on based on compressor
  - Air leaving the heat pumps varies
  - VS ECMs are common but just staged with compressor; not intelligent control
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- **WSHP Typical Operation:**
- Dehumidification is a by-product
- Not controlled
- Satisfy the sensible demand
- Doesn’t satisfy the latent demand

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Flow Meter

Sensor Kits
- Energy Monitoring
- Refrigeration Monitoring
- Performance Monitoring

Two Way Communication means INFORMATION!

Zone Sensor

HMI

System Control

Heat Pump Control

ModBus

VS Pump/Mod Valve

VS Compressor Drive

VS Compressor

VS Plenum Fan

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Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

• **Variable Speed WSHP Operation:**
  - Compressor can now operate based on space, leaving air temperature, saturated suction temperature.

• Blower operation can now change as well

• What improvements can we make that typically limit traditional WSHP units?
  - Dehumidification demand
  - Leaving air temperature control
  - VAV applications
  - Ventilation / DOAS
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

Variable Speed EC Plenum Fan Benefits

- No Belts, Pulleys, or VFDs
- Integrated drive built into the motor
- Communicating with heat pump control
  - Controlled by heat pump or others
  - Get real time data (kW, rpm, faults, etc)
  - Reportable over the network
- Airflow measuring built-in
  - CFM setpoint for easy configuration
  - Eliminate blower speed adjustments
  - Factory installed so no field hassle
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• **Modulating Hot Gas Reheat:**
  - Control leaving air temperature & relative humidity in the space
  - Compressor varies to meet dehumidification demand
  - Reheat valve varies to meet supply air temperature requirement
  - Blower varies to meet space requirement
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

- **Cooling**  
  - Normal air conditioning  
  - Supply Air = 55 F  
  - Space Condition 73.0 F / 50% RH

- **Cooling with dehumidification**  
  - Adjust supply air to sub-cool the air  
  - Supply Air = 64 F  
  - Space Condition 72.8 F / 63% RH

- **Dehumidification**  
  - Delivers neutral air to the space  
  - Supply Air = 72 F  
  - Space Condition 71.4 F / 63% RH
Head Pressure Control for Neutral Air

- Cold/geothermal loop during shoulder season
- Control compressor discharge gas temperature with water flow
- Cold/geo loop at shoulder season
- Recover condenser heat to temper the supply air
Variable Speed WSHP means Variable Air Volume!

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Traditional WSHP

Variable Speed WSHP

Single Zone Constant Temperature

Single Zone Variable Temperature

Multi-Zone Variable Temperature

Single Zone Variable Temperature
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

- **Single Zone VAV:**
  - Blower operates to *space* demand
  - Comp operates to *SAT* setpoint
  - Constant leaving air temperature output
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- Single Zone VAV with Humidity Control
- Blower still operates to space demand
- Comp operates to SST setpoint
  - SST – Saturated Suction Temperature
- Reheat valve operates to SAT
  - Space Condition
    - 72.3 F / 63% RH
- Still constant temperature output
  - With humidity control
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

- **Variable Speed WSHP Advantage:**
- Dehumidification control
- Wider range of Outdoor Air / Return Air temperatures possible
- Can adjust to control multiple or reset conditions
### Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

#### Variable Speed WSHP 10 Ton Example - Cooling

**Humidity Control**

<table>
<thead>
<tr>
<th>Load</th>
<th>100%</th>
<th>100%</th>
<th>100%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>EWT, F</td>
<td>86</td>
<td>86</td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>Flow Rate, gpm</td>
<td>34.0</td>
<td>34.0</td>
<td>34.0</td>
<td>34.0</td>
</tr>
<tr>
<td>ft/hd</td>
<td>6.33</td>
<td>6.33</td>
<td>6.33</td>
<td>6.33</td>
</tr>
<tr>
<td>Air flow, cfm</td>
<td>4200</td>
<td>3150</td>
<td>2400</td>
<td>1600</td>
</tr>
<tr>
<td>TC MBTUH</td>
<td>132.2</td>
<td>128.5</td>
<td>123.1</td>
<td>114.8</td>
</tr>
<tr>
<td>SC MBTU</td>
<td>106.2</td>
<td>91.8</td>
<td>80.3</td>
<td>66.9</td>
</tr>
<tr>
<td>Latent Clg</td>
<td>26.0</td>
<td>36.7</td>
<td>42.8</td>
<td>47.9</td>
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<tr>
<td>S/T Ratio</td>
<td>0.80</td>
<td>0.71</td>
<td>0.65</td>
<td>0.58</td>
</tr>
<tr>
<td>Input Power</td>
<td>9.79</td>
<td>8.83</td>
<td>8.36</td>
<td>8.08</td>
</tr>
<tr>
<td>EER</td>
<td>13.50</td>
<td>14.56</td>
<td>14.73</td>
<td>14.21</td>
</tr>
<tr>
<td>Heat Rejected</td>
<td>166.7</td>
<td>158.7</td>
<td>150.1</td>
<td>139.3</td>
</tr>
</tbody>
</table>

- 2x increase in latent cooling BTUHs
- Recovering & re-using BTUHs to reheat the air to prevent over-cooling
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Variable Speed WSHP 10 Ton Example - Heating

Heating LAT Control

<table>
<thead>
<tr>
<th>Load</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>EWT, °F</td>
<td>68</td>
</tr>
<tr>
<td>Flow Rate, gpm</td>
<td>34.0</td>
</tr>
<tr>
<td>ft/hd</td>
<td>6.60</td>
</tr>
<tr>
<td>Air flow, cfm</td>
<td>4000</td>
</tr>
<tr>
<td>HC MBTUH</td>
<td>160.7</td>
</tr>
<tr>
<td>Entering Air</td>
<td>45.0</td>
</tr>
<tr>
<td>Leaving Air</td>
<td>82.00</td>
</tr>
<tr>
<td>Input Power</td>
<td>7.48</td>
</tr>
<tr>
<td>COP</td>
<td>6.30</td>
</tr>
</tbody>
</table>

- Warm-up incoming air
- Leaving Air Temperature control
- High rise buildings to prevent condensation on windows
Multi-Zone VAV Operation:

- Blower operates to duct static pressure setpoint
- Compressor operates to SAT setpoint
- Constant leaving air temperature output
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

- **Multi-Zone VAV with Humidity Control:**
- Blower **still** operates to **duct static pressure** setpoint
- Compressor operates to **SST** setpoint
  - SST – Saturated Suction Temperature
- Reheat valve operates to **SAT**
- **Still** constant temperature output
  **With humidity control**
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

• Supply Air Reset:

• SAT Reset based on:
  • Space temperature
  • Return air temperature
  • Outdoor air temperature

• Independent heating & cooling settings

• Cooling Example:
  • SAT - 55 F & RAT – 75 F
  • Return air drops to 74 F
  • Adjust SAT to 58 F
  • 1 down / 3 up
  • Both settings adjustable
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

Variable Speed Heat pump
Without Energy Recovery

Variable Speed Heat Pump
With Energy Recovery

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Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

- Energy Recovery Case:
  - Ventilation dramatically increases load on the building
  - Ventilation needed to meet code
  - Most states are requiring some form of energy recovery on the building
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

- 30 Tons of refrigeration saved @ 8000 cfm
- Rebates for +70% effectiveness
- Tax benefit when tied to a geothermal heat pump
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

• **Variable Speed WSHP can:**

• Trim leaving air temperature

• Eliminate compressor cycling to provide more consistent leaving air temperature control
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

<table>
<thead>
<tr>
<th>ASHRAE Zone</th>
<th>Location</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outdoor Airflow Rate, cfm</strong></td>
<td>4000</td>
<td></td>
</tr>
<tr>
<td><strong>Exhaust Airflow Rate, cfm</strong></td>
<td>4000</td>
<td></td>
</tr>
<tr>
<td><strong>Electric Utility Rate, $/kW-h</strong></td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td><strong>Fuel Rate, $/MMBtu</strong></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Gas Heating Efficiency, %</strong></td>
<td>82%</td>
<td></td>
</tr>
<tr>
<td><strong>Baseline Cooling Efficiency, EER</strong></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>WSHP DOAS, EER</strong></td>
<td>14.5-22.0</td>
<td></td>
</tr>
</tbody>
</table>

Baseline DOAS .......... Cooling $944 | Heating $11,133
Baseline with Energy Recovery .......... Cooling $382 | Heating $4206
WSHP DOAS with Energy Recovery .......... Cooling $118 | Heating $1167

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- Energy Recovery Operating Zones
  - Energy recovery cooling
  - Economizer
  - Economizer with energy recovery
  - Energy recovery heating
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings
Application of Advanced Variable Speed Water Source DOAS to Commercial Buildings

21st Century Water Source Heat Pumps

- True Permanent Magnet DC Inverter Compressor
- Variable Speed EC Direct Drive Plenum Fan
- Electronic Expansion Valve
- Modulating Hot Gas Reheat
- Variable Speed EC Pumps & modulating water valves
- Advanced Controls & Communicating Sensors
- Energy Recovery
- Air & Water Economizer
Questions?

Geothermal: The Genius Renewable

Live at Groundwater Week in partnership with NGWA

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