Energy Saving Potential of Indirect Evaporative Cooling as Fresh Air Pre-cooling / Recovery in Doha

ASHRAE conference
Doha April 27th 2019
Outline

• Fresh Air Challenges at Buildings now
• Standard and current practice
• Fresh Air load and its effect on the Indoor AC system
• Indirect Evaporative Cooling Technology
• 100% Fresh Air IEC / Hybrid Cooling
• Selection software
• Evaporative Recovery
• Mall of Qatar Case Study
The Problem

- ASHRAE 62.1 is considered “The Ventilation Standard for Acceptable Indoor Air Quality” the basis for ventilation codes including the International Mechanical Code (IMC).
- Most Buildings Fresh air load in hot and humid climate areas is higher than the internal load itself.
Current practices

Directing a hot fresh air into the building via duct work is usual practice

- Using DOAS “Dedicated Outside Air Cooling AHU”
- Using a Recovery Method “Enthalpy Wheel, Run Around Coils, Heat pipe”
- Adding the load to the internal AC system
In most cases the fresh air cooling load is higher than the whole building cooling load.
That hot Fresh air imposes a great energy demand on the building AC System

High Energy Demand = High Energy bills
The Objective:

Tempering that hot fresh air using a high efficiency Cooling (Indirect Evaporative Cooling System)
What is Evaporative Cooling
• INDIRECT EVAPORATIVE COOLING (IEC)
At its heart Air$_2$O uses a two-stage evaporative cooling solution - in the first stage, outdoor air is passed through the evaporative cooling section. As the warm air is cooled, so is the water.
Indirect Evaporative Cooling
This cool water is then transferred to a high efficiency heat exchanger, over which the primary outdoor air is passed, to deliver the first stage of cooling with no additional moisture. (This same concept can also be utilized to provide ultra-efficient heat recovery of air-conditioned buildings.)

10000 cfm = 22
10000 cfm = 22 TON no Compressor
100% Fresh Air IEC / Hybrid Cooling

- IEC technology allows us to include a DX or Chilled Water Coil to provide cooling without compromise and meet design leaving air conditions
10000 cfm = 47 Ton (IEC+DX) with only a 25 Ton Compressor

Psychrometric Chart

22°C DB
33°C DB/27°C WB
46°C DB/30°C WB
### 10000 CFM FAHU unit
**IEC with DX vs DX alone**

<table>
<thead>
<tr>
<th>Description</th>
<th>AIR2O IEC + DX</th>
<th>DX Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Load</td>
<td>47 TR</td>
<td>47 TR</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>35.7 KWh</td>
<td>57.2 KWh</td>
</tr>
<tr>
<td>EER</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Saving</td>
<td>37.5 %</td>
<td>-</td>
</tr>
</tbody>
</table>
US Dept. of Energy World Weather Data

EPW FILES or TMY3
Doha Annual Weather Pattern – Past 30 years

Psychometric Chart

Comfort Line

Air₂O
Intelligent cooling
### A 10,000 CFM 100% Fresh Air Unit with IEC+DX vs DX

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indirect Efficiency</td>
<td>80.00%</td>
</tr>
<tr>
<td>Fresh Air intake %</td>
<td>100.00%</td>
</tr>
<tr>
<td>CFM</td>
<td>10,000</td>
</tr>
<tr>
<td>KWH Saving (Fresh Air load )</td>
<td>38.02%</td>
</tr>
<tr>
<td>DX Needed W IDEC</td>
<td>54.87</td>
</tr>
<tr>
<td>AC Needed W/O IDEC</td>
<td>88.54</td>
</tr>
<tr>
<td>Reduction in Comp Size (peak )</td>
<td>38.02%</td>
</tr>
<tr>
<td>Average EER For fresh AIR</td>
<td>17.75</td>
</tr>
</tbody>
</table>
Evaporative Recovery (ER)

- Evaporative Recovery (ER) technologies using a cooling tower and coil arrangement.
- Evaluate the potential percentage of energy savings when applying indirect evaporative cooling (IEC) for fresh air pre-cooling as opposed to using the DX-based system.
- Evaluate and compare the energy performance of ER in the same application.
The Heat Rejecter

- The first stage of the ER system consists of the heat rejecter, which is basically a cooling tower in the upstream of the building exhaust air.

- It also shows the water temperature approach is reduced to 0.5 °C (1°F) above the wet bulb temperature of the exhaust air, which is much lower than standard cooling towers.

- This extremely low approach temperature is a unique feature of the ER cooling tower, thanks to its patented non-aerosol design, large top surface area, and low water flow rate.
The Water Coil

- The second stage of the ER system consists of a water coil inside finned heat exchanger in the upstream of the outdoor air.
- A secondary fan draws hot and humid outdoor air through the cold water coil heat exchanger.
- The pre-cooled outdoor air leaves the water coil and enters the building, reducing the ventilation load of the building HVAC system.

Figure 3. The componentry and the operational concept of this process.
ER Using Cooling Tower & Coil Arrangement

- Putting the first and second stages together as shown in figure 4, the recovery system is established.
- Complete flexibility in the location of supply and exhaust air streams which.
- Can be located remotely from each other.
- All of the other HRV devices require the air streams to be close together.
Energy Recovery Efficiency

- Typically, there are three recovery transfer efficiencies, namely, temperature, enthalpy, and moisture.
- Enthalpy efficiency is the most important in any recovery process.
- 100% enthalpy efficiency would lower the enthalpy of the outside air.
- By recovering all the cooling capacity from the exhaust air and putting it into the incoming hot outside air.
- Thermal efficiency is how close the intake air temperature gets to the exhaust air temperature.
- Moisture efficiency is the percentage of latent heat from the overall total heat that was recovered.
- Traditional heat recovery systems have 0% of moisture efficiency.
- The ER system ability to transfer latent energy in addition to sensible energy is a big advantage, particularly in hot and humid climates.
- Removes humidity from the outside air in the summer to save dehumidification energy.
ER Energy Savings Calculations

• A 4900 square feet (460 square meters) office building with an internal cooling load of 25 Ton total served by a DX-based AC unit with EER of 11 in a Humid Climatic application.
• Building fresh air requirement 2,500 CFM.
• Summer design condition 78 F (25 C) dry bulb and 50% RH, which gives an enthalpy of 30 Btu/lb. (71 KJ/Kg).
• Assuming design dry bulb temperature 105.8 F (34 C), wet bulb temperature 80.6 F (27 C), enthalpy of 44 Btu/lb. (103 kJ/Kg).
• The ER unit ultimate task is to reduce outside outdoor air temperature as close as possible to that of the room condition to minimize fresh air load impact on the DX AC unit.
• The fresh air cooling load is calculated using the equation:
  \[ Q = \Delta h \times CFM \times 4.45, \text{ hence } Q = (44 - 30) \times 2500 \times 4.45 = 155,750 \text{ BTU/h} \approx 13 \text{ Ton.} \]
## ER Energy Savings Calculations

### Exhaust Air

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Dry Bulb C</td>
<td>25.56</td>
</tr>
<tr>
<td>Wet Bulb C</td>
<td>18.47</td>
</tr>
<tr>
<td>Dew Point C</td>
<td>14.35</td>
</tr>
<tr>
<td>Enthalpy kJ/kg</td>
<td>52.18</td>
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</tbody>
</table>

### Fresh Air

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Dry Bulb C</td>
<td>41.00</td>
</tr>
<tr>
<td>Wet Bulb C</td>
<td>27.00</td>
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<tr>
<td>Dew Point C</td>
<td>22.04</td>
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<tr>
<td>Enthalpy kJ/kg</td>
<td>58.55</td>
</tr>
</tbody>
</table>

### Direct Media

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air CFM</td>
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<tr>
<td>Dry bulb</td>
<td>78.00 F</td>
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<tr>
<td>RH%</td>
<td>50.00 %</td>
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<tr>
<td>Elevation</td>
<td>0.00 FT</td>
</tr>
<tr>
<td>Dew point</td>
<td>52.8</td>
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<tr>
<td>Wet Bulb</td>
<td>65.238 F</td>
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<tr>
<td>HR</td>
<td>0.020317 lbw/lbs</td>
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<tr>
<td>Enthalpy</td>
<td>30.0849 Btu/lb</td>
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<tr>
<td>Humidity</td>
<td>72.6013 grains/lb</td>
</tr>
</tbody>
</table>

### Cooling Coil

- Capacity in ton: 8.8
- Sensible Heat: 7.9
- Latent Heat: 0.9
- Cond: 0.91 GPH

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*Air₂O Intelligent cooling*
ER Energy Savings Calculations

• The ER supply air conditions 70.5 F (21.4C) dry bulb, 70.5 F(21.4C) wet bulb and enthalpy of 34.52Btu/lb.

• Maximum cooling capacity of the ER unit can be determined using the same equation above which yields: (44 - 34.52) * 2500 * 4.45= 105,465 Btu/h. ≈ 8.8 Ton.

• Remaining 4.2 Tons of fresh air load, i.e. (13 – 8.8), will be handled by the DX AC unit.

• The EER of the ER unit will be its cooling capacity, 105,465 Btu/h, divided by its nameplate power, 3,000 watts, which yields a value of 35.1.

• The EER of the hybrid operation of both the ER and the DX AC units will be the weighted average operation of both systems as follows:

$$EER_{Hybrid} = \frac{(EER_{ER} \times Q_{ER}) + (EER_{DX} \times Q_{DX})}{Q_{Total}} = \frac{(35.1 \times 8.8) + (11 \times 4.2)}{13} = 27.4$$

• The corresponding energy savaging of this hybrid ER/DX operation as opposed to using DX AC only can be determined using the following equation:

$$Saving = 1 - \frac{EER_{DX}}{EER_{Hybrid}} = 1 - \left(\frac{11}{27.4}\right) = 59.8\%$$
Expanding the same energy savings calculation method.

<table>
<thead>
<tr>
<th>DB (F)</th>
<th>WB (F)</th>
<th>90</th>
<th>85</th>
<th>80</th>
<th>75</th>
<th>70</th>
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<tbody>
<tr>
<td>120</td>
<td></td>
<td>69.0</td>
<td>69.3</td>
<td>70.3</td>
<td>79.5</td>
<td>89.8</td>
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<tr>
<td>115</td>
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<td>66.4</td>
<td>66.6</td>
<td>65.9</td>
<td>75.3</td>
<td>87.4</td>
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<tr>
<td>110</td>
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<td>63.4</td>
<td>63.5</td>
<td>62.7</td>
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<td>84.0</td>
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<tr>
<td>105</td>
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<td>60.2</td>
<td>59.9</td>
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<tr>
<td>100</td>
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<td>56.7</td>
<td>55.9</td>
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<tr>
<td>95</td>
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<tr>
<td>90</td>
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<td>43.5</td>
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<td>47.4</td>
</tr>
<tr>
<td>85</td>
<td></td>
<td></td>
<td>40.5</td>
<td>36.7</td>
<td>29.5</td>
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<td>80</td>
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<td>29.4</td>
<td>20.4</td>
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</tr>
<tr>
<td>75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10.8%</td>
</tr>
</tbody>
</table>

*Table 1*
Many HVAC designers prefer to work with sizing charts for quick assessments.

Table 1 was used to generate an energy savings chart, shown in figure 6.

Straight lines represent the ER/DX hybrid operation.

Curved lines represent the ER operation.
A Shopping Mall Case Study

- This Evaporative Recovery system is currently being operated at the largest Mall in Qatar successfully since 2016 commissioning where 8 ER units, 50,000 CFM each are installed.
- The energy saving is around 66% on this particular application.
- Recover 1,780 tons and achieved sensible, enthalpy, and moisture efficiencies of 118.18%, 61.31%, and 21.39% respectively.
- Highly efficient energy recovery system.
- All the condensate water is collected and fed back to the same water loop.
- ER unit has numerous advantages over heat wheels, heat pipe and cross-plate heat exchangers.
- Eliminates any cross contamination as the exhaust and supply air is never mixed.
- Minimum internal pressure drop, hence better utilization of power consumed.
Discussion

- Table 1 provides ER energy savings percentages based on *specific* equipment design of a hybrid ER and DX operation.
- ER technology provides its maximum energy savings performance the hotter and more humid the climatic conditions, which is contrary to the common notion that evaporative cooling is only limited to dry climates.
- Reducing the outdoor air temperature below that of the return air, something impossible to achieve with any other conventional HRV system.
- Dry climates heat recovery in the summer time, in general, will not be needed since the wet bulb temperatures of the building return air and the outdoor air are very close.
- IDEC system could be used to carry the full cooling load at 100% fresh air rate.
Conclusion:

• Complete Flexibility
• No Cross Contamination
• Highest efficiencies
• Temperature 118% / Enthalpy 61% / Moisture Efficiencies 21%
• Global Applications
Air$_2$O Projects – 35,000cfm Semi Hybrid units @ IKEA, London
Air\textsubscript{2}O Projects – 50,000cfm Recovery units @ Mall of Qatar, Doha - 9 nos
Air₂O Projects – 20,000cfm Hybrid units @ Al Hazm Mall, Doha, Qatar
Air$_2$O Projects – 20,000cfm Hybrid units @ Madinah Haram, Saudi Arabia - 30 numbers
Air₂O Projects – 10,000 cfm IDEC units @ Dubai Library, UAE - 3 nos
Air$_2$O Projects – 20,000cfm IDEC units @ Toyota Riverview, Mesa
Air$_2$O Projects - 10,000cfm IDEC units @ SKF Warehouse, Utah
Air$_2$O Projects – 5,000cfm Semi Hybrid units @ BYU, Utah
Air$_2$O Projects – 12,500cfm Semi Hybrid units @ Sydney, Australia
Air$_2$O Projects – Numerous sites nationwide
@ Tesco, UK