ENTHALPY Measurements at UCSD and Application to Building Ventilation

Author: Wen-Han Liu
Advisor: Jan Kleissl
What is ENTHALPY?

- Also known as “Heat Content.”
- Enthalpy (h) of moist air include:
  - **Sensible Heat**: enthalpy of the dry air.
  - **Latent Heat**: enthalpy of the evaporated water.
- Specific “h” of moist air can be expressed as:

  \[ h = h_a + q \cdot h_w \]

  where:
  - \( h_a \) = specific enthalpy of dry air (kJ/kg)
  - \( h_w \) = specific enthalpy of moist air (kJ/kg)
  - \( q \) = humidity ratio (kg H2O/kg Air)

Overall Equation:

\[ h = 1.006 \, (kJ/kg.\,^\circ C) \cdot T + Q(kg/kg) \cdot [1.84 \, (kJ/kg.\,^\circ C) \cdot T + 2,502 \, (kJ/kg)] \]

Source: Engineering Toolbox
How Can Air ENTHALPY Be Used?

- Air enthalpy can be used to improve efficiency and reduce energy usage in conventional Heating, Ventilation, and Air Conditioning (HVAC) Systems.

- New HVAC controllers are smartly designed.
  - Cooling: If outside air enthalpy is less than enthalpy of return air, outside air flow is maximized. If outside air enthalpy is greater than enthalpy of return air, outside air flow is minimized.

- ASHRAE CODE-55
  - Indoor wind speed of 0.8 m/s can offset a temperature rise of about 2.6°C (4.7°F).
  - Upper limit of comfort = 0.012 humidity ratio.

Diagram Source: University of Virginia

Source: ASHRAE
# UCSD Room Temperature Settings

## Office/Administrative Spaces

<table>
<thead>
<tr>
<th>Setting</th>
<th>Heating Mode</th>
<th>Cooling Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupied 6 a.m. – 6 p.m. weekdays</td>
<td>Keeps temperature above 70°</td>
<td>Keeps temperature below 74°</td>
</tr>
<tr>
<td></td>
<td>No heating or cooling occurs between 70° and 74°</td>
<td></td>
</tr>
<tr>
<td>Standby 4:30–8 p.m. weekdays</td>
<td>Keeps temperature above 68°</td>
<td>Keeps temperature below 76°</td>
</tr>
<tr>
<td></td>
<td>No heating or cooling occurs between 68° and 76°</td>
<td></td>
</tr>
<tr>
<td>Unoccupied 8 p.m.– 6 a.m. 7 days a week</td>
<td>Keeps temperature above 66°</td>
<td>Keeps temperature below 78°</td>
</tr>
<tr>
<td></td>
<td>No heating or cooling occurs between 66° and 78°</td>
<td></td>
</tr>
</tbody>
</table>

## Labs

<table>
<thead>
<tr>
<th>Setting</th>
<th>Heating mode</th>
<th>Cooling mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupied 6 a.m.–6 p.m. weekdays</td>
<td>Keeps temperature above 70°</td>
<td>Keeps temperature below 74°</td>
</tr>
<tr>
<td></td>
<td>No heating or cooling occurs between 70° and 74°</td>
<td></td>
</tr>
<tr>
<td>Unoccupied 6 p.m.–6 a.m. 7 days a week</td>
<td>Keeps temperature above 68°</td>
<td>Keeps temperature below 76°</td>
</tr>
<tr>
<td></td>
<td>No heating or cooling occurs between 68° and 76°</td>
<td></td>
</tr>
</tbody>
</table>
Timeseries Measurements at CMRR STATION

- Humidity Ratio (g/kg)
- Temperature (°F)
- Enthalpy (Btu/lb)

Graphs showing the variations in humidity ratio, temperature, and enthalpy over time from 06/25 to 08/20.
Average Diurnal Variation in Enthalpy at CMRR
Average Monthly Variation at CMRR
Temperature Versus Enthalpy

Air Enthalpy Average

Temperature Average
Timeseries Measurements

- Humidity Ratio (g/kg)
- Temp (°F)
- Enthalpy (Btu/lb)
Average Diurnal Variation in Enthalpy

**Diagram:**
- Title: Air Enthalpy Average
- Y-axis: Enthalpy Average (Btu/lb)
- X-axis: Time (Hour)
- Lines:
  - Blue circles: CMRR
  - Red crosses: Elliott
  - Green triangles: SIO
- Graph shows variation in enthalpy throughout the day, peaking around the middle of the day.
Temperature Vs. Enthalpy

Temperature Average

Air Enthalpy Average

Time (Hourly)
Works Cited

- http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1003&context=cedr/cbe [Slide 2]
- http://utilities.fm.virginia.edu/energy/Clark%20Poster.pdf [Slide 3]
- http://blink.ucsd.edu/Blink/External/Topics/Policy/0,1162,16614,00.html [Slide 4]