LATENT LOADS, PSYCHOMETRICS, AND THE SENSIBLE HEAT RATIO

Lisa White, PHIUS Certification Manager
AGENDA

1. BACKGROUND
2. PHIUS+ 2015 COMPLIANCE
3. CAPABILITIES OF WUFI PASSIVE/PLUS
4. CHALLENGES OF HANDLING LATENT LOADS
PASSIVE BUILDING PRINCIPLES

CONTINUOUS INSULATION

AIR-TIGHT CONSTRUCTION

OPTIMIZED WINDOWS & SOLAR GAINS

BALANCED VENTILATION WITH HEAT RECOVERY

MINIMIZED MECHANICAL SYSTEMS
DRIVERS OF LATENT LOADS

- Internal loads
- Occupants
- Exchange through opaque partitions
- Natural Ventilation
- Mechanical Ventilation
- Infiltration
<table>
<thead>
<tr>
<th>Continuous Insulation</th>
<th>Heating Load</th>
<th>Sensible Cooling Load</th>
<th>Latent Cooling Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="downarrow.png" alt="Down Arrow" /></td>
<td><img src="downarrow.png" alt="Down Arrow" /></td>
<td><img src="stopsign.png" alt="Stop Symbol" /></td>
</tr>
<tr>
<td>Air-Tight Construction</td>
<td><img src="downarrow.png" alt="Down Arrow" /></td>
<td><img src="downarrow.png" alt="Down Arrow" /></td>
<td><img src="downarrow.png" alt="Down Arrow" /></td>
</tr>
<tr>
<td>Optimized Windows/Shading</td>
<td><img src="downarrow.png" alt="Down Arrow" /></td>
<td><img src="downarrow.png" alt="Down Arrow" /></td>
<td><img src="stopsign.png" alt="Stop Symbol" /></td>
</tr>
<tr>
<td>Balanced Ventilation w/Heat &amp; Moisture Recovery</td>
<td><img src="downarrow.png" alt="Down Arrow" /></td>
<td><img src="downarrow.png" alt="Down Arrow" /></td>
<td><img src="downarrow.png" alt="Down Arrow" /></td>
</tr>
</tbody>
</table>
RESULT OF APPLYING PASSIVE BUILDING PRINCIPLES:

SENSIBLE COOLING LOAD

LATENT COOLING LOAD

SENSIBLE HEAT RATIO
SENSIBLE HEAT RATIO

\[
\frac{\text{Sensible Cooling Load}}{\text{Total Cooling Load}} = \frac{\text{SHR} = 1, \text{No latent load}}{\text{HIGH SHR} = \text{Low latent load relative to total load}}
\]

LOW SHR = High latent load relative to total load
VLI (Ventilation Load Index):
“the load generated by one cubic foot per minute of fresh air brought from the weather to space-neutral conditions over the course of one year”
<table>
<thead>
<tr>
<th>City</th>
<th>State</th>
<th>Ventilation Load Index (Ton-hrs/scfm/yr)</th>
<th>Cumulative Load Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Latent + Sensible Total Latent:Sensible</td>
<td></td>
</tr>
<tr>
<td>Albuquerque</td>
<td>NM</td>
<td>0.2 + 1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Boston</td>
<td>MA</td>
<td>2.0 + 0.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Detroit</td>
<td>MI</td>
<td>2.4 + 0.3</td>
<td>2.7</td>
</tr>
<tr>
<td>Minneapolis</td>
<td>MN</td>
<td>2.4 + 0.4</td>
<td>2.8</td>
</tr>
<tr>
<td>Pittsburgh</td>
<td>PA</td>
<td>2.5 + 0.4</td>
<td>2.9</td>
</tr>
<tr>
<td>New York</td>
<td>NY</td>
<td>2.6 + 0.5</td>
<td>3.1</td>
</tr>
<tr>
<td>Chicago</td>
<td>IL</td>
<td>2.6 + 0.5</td>
<td>3.1</td>
</tr>
<tr>
<td>Las Vegas</td>
<td>NV</td>
<td>0.2 + 3.7</td>
<td>3.9</td>
</tr>
<tr>
<td>Indianapolis</td>
<td>IN</td>
<td>4.0 + 0.6</td>
<td>4.6</td>
</tr>
<tr>
<td>Lexington</td>
<td>KY</td>
<td>4.1 + 0.6</td>
<td>4.7</td>
</tr>
<tr>
<td>Colorado Spr.</td>
<td>CO</td>
<td>0.6 + 4.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Omaha</td>
<td>NE</td>
<td>4.0 + 0.8</td>
<td>4.8</td>
</tr>
<tr>
<td>Phoenix</td>
<td>AZ</td>
<td>1.3 + 5.0</td>
<td>6.2</td>
</tr>
<tr>
<td>St. Louis</td>
<td>MO</td>
<td>5.3 + 1.1</td>
<td>6.4</td>
</tr>
<tr>
<td>Oklahoma City</td>
<td>OK</td>
<td>5.0 + 1.6</td>
<td>6.6</td>
</tr>
<tr>
<td>Richmond</td>
<td>VA</td>
<td>5.9 + 0.8</td>
<td>6.7</td>
</tr>
<tr>
<td>Raleigh</td>
<td>NC</td>
<td>6.0 + 0.9</td>
<td>6.9</td>
</tr>
<tr>
<td>Atlanta</td>
<td>GA</td>
<td>6.2 + 0.9</td>
<td>6.9</td>
</tr>
<tr>
<td>Nashville</td>
<td>TN</td>
<td>6.2 + 1.4</td>
<td>7.6</td>
</tr>
<tr>
<td>Little Rock</td>
<td>AK</td>
<td>7.3 + 1.6</td>
<td>8.8</td>
</tr>
<tr>
<td>Charleston</td>
<td>SC</td>
<td>9.0 + 1.2</td>
<td>10.3</td>
</tr>
<tr>
<td>San Antonio</td>
<td>TX</td>
<td>10.4 + 2.4</td>
<td>12.8</td>
</tr>
<tr>
<td>New Orleans</td>
<td>LA</td>
<td>12.3 + 1.8</td>
<td>14.1</td>
</tr>
<tr>
<td>Miami</td>
<td>FL</td>
<td>17.8 + 2.7</td>
<td>20.5</td>
</tr>
</tbody>
</table>
PsyCalc

Hours between 65°F DB
85°F DB
>65 gr/lb

Chicago, IL
1760 hours

20% of year!
PHIUS+ 2015

Performance based standard with prescriptive requirements

Concerned with both energy and comfort

1. Defines infiltration limit
2. Defines ventilation requirements
3. WUFI Passive software used for compliance
0.05 CFM50/ft² envelope
OR
0.08 CFM75/ft² envelope
SUMMARY OF VENTILATION REQUIREMENTS

PHIUS+ Certification GuideBook v1.1

3.5.3 Ventilation
The ventilation system must be capable of at least 0.3 ACH (based on the net volume) on its maximum setting.

PHIUS+ Single Family Quality Assurance Workbook v4.0

1.11: Rater-measured bathroom exhaust rates meets one of the following: 
>= 20 cfm continuous OR 50 cfm intermittent

1.13: Rater-measured kitchen exhaust rates meets one of the following: 
>=25 cfm continuous, 100 cfm intermittent for range hoods, or 5ACH based on kitchen volume

Balanced Ventilation Required

- Unbalanced has consequences for both energy modeling, building durability and IAQ
- Heat recovery is not required, or more than one fan necessarily, but air flow balance is required
- All air flow must be within 10% supply/exhaust, or below a 5 Pa pressurization / depressurization due to the whole-building ventilation.
WUFI PASSIVE

ANNUAL LATENT COOLING DEMAND (kBTU/ft².yr)

Influenced by:

• Natural ventilation (windows), day & night
• Mechanical ventilation
  • Includes latent recovery
  • Includes bypass/economizer mode
• Infiltration
• Maximum dehumidification ratio -- default = 0.012 lb/lb (can input different value)
• Internal sources – default value of 0.00041 lb/ft².hr (can input different value)
PHIUS SET-POINT FOR MAX DEHUMIDIFICATION RATIO IS 0.012 lb/lb (77F, 60% RH, 62F DP)

ASHRAE HANDBOOK HVAC APPLICATIONS – CHAPTER 62 (75F, 50% RH, 55F DP)
Latent cooling demand estimated almost 2x higher with new set-point!!
## WUFI PASSIVE

**MANUAL J - LATENT COOLING LOAD (kBTU/hr)**

### Climate / ventilation
- Outdoor design temperature [°F]: 95
- Indoor design temperature (optional) [°F]: 77
- Outdoor - Indoor moisture difference [%]: 50
- Air changes per hour [1/hr]: 0.05
- Altitude correction factor [-]: 1

### Loads
<table>
<thead>
<tr>
<th>Nr.</th>
<th>Internal load</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Small Plant</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Coffee maker - warmer</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Dishwasher</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Microwave</td>
<td>6</td>
</tr>
</tbody>
</table>

### Components

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Name</th>
<th>Cooling load temperature difference [@]</th>
<th>Heat transfer multiplier [@]</th>
<th>Shade line multiplier [@]</th>
<th>Orientation</th>
<th>Area [ft²]</th>
<th>U-value [Btu/hr ft² °F]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Z.1, C. 1</td>
<td>10</td>
<td></td>
<td></td>
<td>S (34 %), E (18 %), W (15 %), N</td>
<td>6163.6</td>
<td>0.0282</td>
</tr>
<tr>
<td>2</td>
<td>Z.1, C. 2</td>
<td>5</td>
<td></td>
<td></td>
<td>Horizontal (100 %)</td>
<td>3116</td>
<td>0.019</td>
</tr>
<tr>
<td>3</td>
<td>Z.1, C. 3</td>
<td>5</td>
<td></td>
<td></td>
<td>Horizontal (100 %)</td>
<td>3116</td>
<td>0.0481</td>
</tr>
<tr>
<td>4</td>
<td>Z.1, C. 4: (SOUTH, Floor 2, Fixed)</td>
<td>1</td>
<td>0.6</td>
<td></td>
<td>S (100 %)</td>
<td>65.5</td>
<td>0.1572</td>
</tr>
<tr>
<td>5</td>
<td>Z.1, C. 5: (SOUTH, Floor 1, Fixed)</td>
<td>1</td>
<td>0.6</td>
<td></td>
<td>S (100 %)</td>
<td>65.5</td>
<td>0.1572</td>
</tr>
<tr>
<td>6</td>
<td>Z.1, C. 6: (SOUTH, Floor 1, Casement)</td>
<td>1</td>
<td>0.6</td>
<td></td>
<td>S (100 %)</td>
<td>81.5</td>
<td>0.1651</td>
</tr>
</tbody>
</table>

### Results

<table>
<thead>
<tr>
<th>Name</th>
<th>Sensible Cooling [Btu/hr]</th>
<th>Latent cooling load [Btu/hr]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opaque components</td>
<td>2781.3</td>
<td>0</td>
</tr>
<tr>
<td>Fenestration</td>
<td>3363.5</td>
<td>0</td>
</tr>
<tr>
<td>Ventilation</td>
<td>6472.7</td>
<td>11114.8</td>
</tr>
<tr>
<td>Internal loads</td>
<td>18004.1</td>
<td>9210</td>
</tr>
<tr>
<td>Infiltration</td>
<td>1051.2</td>
<td>1805.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31672.9</strong></td>
<td><strong>22130</strong></td>
</tr>
</tbody>
</table>

### Interim results
- Cooling temperature difference [°F]: 50
- Average air change rate [1/hr]: 1.5
- Altitude building [ft]: 610
- Status: OK
WUFI PASSIVE – Dynamic (WUFIplus)

Abbate Case Study – Austin, TX
Moisture Flows
Moisture Buffering Effect on Daily RH Fluctuations

Moisture buffering capacity of the envelope dampens daily indoor RH cycles.

- Left graph: Cooling Day Profile July/August
  - Sensible Cooling
  - Latent Cooling

- Right graph: RH Day Profile July/August
  - Low moisture buffering
  - High moisture buffering
CHALLENGES WITH COMPLIANCE WITH PHIUS+ 2015 IN HOT/HUMID CLIMATES

1) Dehumidify to lower RH = increased source energy use

2) Ventilating dehumidifier = difficult meeting heating demand & heating load targets for PHIUS+ 2015 without balanced ventilation with heat recovery
**Best Unit:**

4.2 L/kWh

(8.8 pints/kWh)

= COP 2.6!

Most other high performance units with COP ~1.5-2

For heating equip: equivalent to HSPF ~8

For sensible cooling: equivalent SEER ~12

---

### WUFI Passive Results

**WUFI Passive Results with 0.012 lb/lb Max Dehumidification Ratio**

- Source energy: 5,931 kWh/Person yr

**WUFI Passive Results with 0.009 lb/lb Max Dehumidification Ratio**

- Source energy: 6,723 kWh/Person yr
CHALLENGES OF AVAILABLE EQUIPMENT

1. AIR CONDITIONING UNITS NOT DESIGNED FOR LOW SENSIBLE HEAT RATIO

2. MOST COOLING SYSTEMS ONLY CONTROLLED BY DRY BULB

3. LIMITED EFFICIENCY OF MOISTURE REMOVAL /DEHUMIDIFICATION

4. LIMITED ERV LATENT RECOVERY EFFICIENCY
COMMON MISCONCEPTIONS

1. “ERV IS A DEHUMIDIFIER”

2. “VRF IS THE MAGIC BULLET FOR ALL SYSTEMS DESIGN”

3. “FULL DEHUMIDIFICATION LOAD CAN BE SATISFIED BY SLOWING DOWN SUPPLY AIRFLOW RATE”
WHAT WE NEED

1). An affordable, efficient, reliable, simple mechanical system solution that handles latent loads (ideally before introduced to the space).

2). Awareness and capability of AC systems to control latent loads

3). Re-think ventilation strategies and requirements?

4). WUFI Passive integrated calculation for latent cooling load and output of SHR

5). Deeper understanding of potential of hygric buffering
WHAT ARE THE SOLUTIONS??