Section 5 of 5

Humidity Control Design

- 5-step design process
- Humidity loads
- DH capacity equations
Typical pre-design questions

• How much can I spend?
• How dry does the building have to stay?
• How humid is the outdoor air?
• Is it OK if the system “runs ragged” a few hours a year, or is the humidity “critical?”
• Is winter humidification needed? To what level?
5-Step design procedure answers these questions in a logical, efficient sequence:

1. Define the Purpose of the Project
2. Establish Control Levels
3. Calculate Moisture Loads
4. Select & Test Equipment
5. Select & Locate Controls
Step 1 - Define the purpose of the project

- Why insist the client define the purpose?
  - If client has no problem... no reason to spend money on humidity control.
  - If consequences are not defined... impossible to say what that budget must be... and impossible to make rational decisions on the owner’s behalf.

- A good project purpose definition includes what...
  - ...results are expected
  - ...happens when the results are NOT achieved
  - ...shortcoming is acceptable
A *poor* definition of the project’s purpose

“Control the humidity within the usual limits for a hotel”

- Does not define the PURPOSE - what the system must *accomplish*…
  - Human comfort?
  - Control everywhere?... or just in the pool area?
  - Both high and low limits?
  - Always? Usually? Only when rooms are occupied?
A good definition of the project’s purpose

“Control the humidity in the hotel so that…”

- Neither condensation nor high rh can occur in building cavities that would allow mold growth or other moisture damage to the building or its furnishings.
- Guest rooms, meeting rooms, dining rooms and offices are held within the ASHRAE comfort zones during both summer and winter seasons.
- The system achieves these goals during all but 2% of the hours in a typical year.
Step 2 - Establish control levels and design conditions

What humidity level will achieve the project purposes?

- RH range, or dew point range?
- High limit only.. low limit only?... or both?
- When does it matter?.. All the time?.. Just when occupied?.. Just when UNoccupied?

How many hours each year can be allowed above system’s design loads? (Annual hours of increased risk in a “typical” year)

- ASHRAE 2% design = 0.02 * 8760 = 175 hours
- 1% of 8760 = 88 hours
- 0.4% of 8760 = 35 hours
Helping the **client** figure out the best **control level** for **his/her** project

Work from the client’s definition of the project purpose!
- Discuss and understand client’s past experiences
- Use any guidelines from client’s own industry

Consult ASHRAE references on the effects of humidity
- **ASHRAE Humidity Control Design Guide**
- **ASHRAE Guide for Buildings in Hot & Humid Climates**
- **ASHRAE Handbook - Applications**
- **ASTM manual 40 - Moisture Analysis and Condensation Control in Building Envelopes**
Helping the client figure out the design conditions for his/her project

Work from the client’s definition of the project purpose

- How often do problems occur without control?
- What are the economic consequences, if any? (hundreds of dollars... or millions?)

Ask the client to decide how many hours of increased risk are acceptable.

- First: obtain costs and performance. Then...
- It’s the client’s decision, and it’s important that they realize that fact!
Selecting outdoor air dew point design conditions

Indoors
- Temperature: 78°F
- Dew Point: 55°F
- Relative Humidity: 65 gr/lb

Peak temperature
- Temperature: 92°F
- Dew Point: 116 gr/lb

Peak dew point
- Temperature: 85°F
- Dew Point: 146 gr/lb
### Differences between peak DB and peak DPT

#### Dayton, OH

<table>
<thead>
<tr>
<th>0.4% Dry Bulb</th>
<th>0.4% Dew Point</th>
<th>Difference at peak dew point</th>
</tr>
</thead>
<tbody>
<tr>
<td>90° DB 74° MCWB</td>
<td>81° DB 74° MCWB</td>
<td>-9°F DB</td>
</tr>
<tr>
<td>98 gr/lb</td>
<td>128 gr/lb</td>
<td>+30 gr/lb</td>
</tr>
</tbody>
</table>

#### Phoenix, AZ

<table>
<thead>
<tr>
<th>0.4% Dry Bulb</th>
<th>0.4% Dew Point</th>
<th>Difference at peak dew point</th>
</tr>
</thead>
<tbody>
<tr>
<td>110° DB 69.6° MCWB</td>
<td>82° DB 75° MCWB</td>
<td>-28°F DB</td>
</tr>
<tr>
<td>44 gr/lb</td>
<td>120 gr/lb</td>
<td>+76 gr/lb</td>
</tr>
</tbody>
</table>
36 hours of higher load risk vs. 2,000 hours

Climatic Design Conditions - Tampa, FL USA
Dew Point (Dpt) for Dehumidification
Dry Bulb (DB) for Cooling

Psychrometric Chart - Inch-Pound Units
See Level = Saturated Pressure 29.9 inches of Mercury

Tampa, FL - TMY-2 Hourly Weather Observations
Hours of occurrence during a typical year

- 287.0 - 258.3
- 229.6 - 200.9
- 172.2 - 143.5
- 143.5 - 114.8
- 114.8 - 86.1
- 86.1 - 57.4
- 57.4 - 28.7
- 28.7 - 0.0

36 hours above Peak dew point
Over 2,000 hours of humidity loads above Peak Dry Bulb
Step 3 - Estimate humidity loads

- Identify and quantify all load sources
- Focus on the big ones (and don’t get wound up in the small ones)
- Recognize that there are few absolutes... “engineering judgment” must be frequently applied.
Humidity load elements - Commercial buildings

People

Ventilation & Makeup air

Humid air infiltration

1. **Wind** creates positive pressure on one side of the building and negative pressure on the other, driving humid air into the building.
2. **Stack Effect** pulls humid air into the building at lower levels, replacing the buoyant warm air which rises and leaks out of the building at higher levels.
3. **Local Negative Pressure** often occurs in one part of the building, pulling in humid air even though most of the building might be under a net positive air pressure.

Permeation through solid materials

Low Vapor Pressure (Dry Air) vs. High Vapor Pressure (Humid Air)

Damp materials

Wet surfaces

Door openings
The ventilation, makeup air and infiltration loads require the most attention
Typical loads - Various applications

The Biggies...
Ventilation, makeup air and air leakage
That’s why it makes sense to locate the DH component in the DOAS unit - Remove the biggest loads BEFORE they get into the building.

“That’s Where the Money is...”

— Willie Sutton
Dry the incoming air deeply enough to remove (all or most) of the internal humidity loads.

Deliver air *below* the dew point desired in the space so the supply air can absorb the internal DH loads, maintaining control.
Step 4 - Equipment selection: Calculate air flow and supply air humidity ratio needed to remove indoor humidity loads

How much air? How dry?

DH equipment load

Indoor load
Dehumidification equation

\[ \text{lbs/h} = \frac{\text{CFM} \times 4.5 \times (\text{gr/lb}_1 - \text{gr/lb}_2)}{7000} \]

Where:
- \( \text{lbs/h} \) = Pounds of water vapor per hour
- \( \text{CFM} \) = Standard cubic ft/min
- \( \text{gr/lb}_1 \) = Higher humidity ratio
- \( \text{gr/lb}_2 \) = Lower humidity ratio
- \( 7000 \) = grains of water vapor in a pound
Rearrange that one equation... and you’ll have most of the important answers for design.
Step 5 - Select and locate controls

- Dew point-based control is usually best
  - No significant temperature dependence
  - Dew point stays more constant than rh.
  - RH sensors need very careful placement
  - Temperature dependence makes readings swing widely

- Best to co-locate db and rh sensors, convert to dew point and control on that value

- Fact to keep in mind: all sensors are incorrect, all of the time.
  - Reduce the error with calibration after installation, and annually thereafter.
  - Know what the error and response lag are, and adapt system operation accordingly
Dew point sensor-transmitters are becoming common.
Humidity sensor issues for designers: Accuracy vs. range and cost

- Budget and select sensors that will accomplish the PURPOSE of the project
- 30 to 70% RH - Not (usually) expensive
- Below 20% - Expensive
- Below 10% - Very expensive
Humidity sensor issues for designers: Calibration

- All sensors are inaccurate, all the time. To improve accuracy, calibrate in place!
  - Worst case: outdoor air
  - Highly variable
  - Frequent condensation
  - Heavy particulate load

- When to calibrate?
  - During commissioning, at least
  - Once a year, before humidity matters
  - Outdoor air, more frequently
Humidity sensor issues for designers: Response time

- When humidity changes, sensors require **time** to respond
- Response times vary
- Expensive sensors respond in less than a minute, lower cost sensors need many minutes
- Wet air to dry air takes longer
- After condensation, response time can lengthen to HOURS, depending on temperature & moisture in the new air stream
Summary - Humidity Control Design

- 5-step design process answers the key questions in a logical, efficient manner
  - CRITICAL foundation and starting point: The end user’s definition of the project’s PURPOSE, eg: if it successful, what will happen or what will be avoided?

- Design conditions: Use ASHRAE peak dew point—NOT peak dry bulb conditions
  - 30% to 70% more moisture at peak dew point
  - Peak dew point occurs at moderate temperatures, when AC is not working continuously

- Humidity loads in commercial-institutional buildings are dominated by ventilation/Makeup air
  - Dry the incoming air deeply enough to remove most/all of the smaller internal humidity loads