Humidity Control
Principles and Practice

Including Advice From A Famous Bank Robber

Distinguished Lecture

Lew Harriman
Mason-Grant Consulting
Portsmouth, NH
MasonGrant.com
Outline

1. Examples of common humidity control problems
Outline

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2. Principles of humidity control
Outline

1. Examples of common humidity control problems
2. Principles of humidity control
3. 5-Step design process for humidity control
Outline

1. Examples of common humidity control problems
2. Principles of humidity control
3. 5-Step design process for humidity control
4. Summary
Who do you work for?

- HVAC Design consulting firm
- Architectural design firm
- Design-build or Energy Service company
- Contracting or HVAC service company
- Facility manager/building operator
- Utility: Power or gas company
Great Clinic building, great HVAC system… So why did it grow mold 3 times in five years?

Indoor dew point = 12.0°C (54°F) - Excellent!
Great Clinic building, great HVAC system... So why did it grow mold 3 times in five years?

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Indoor dew point = 12.0°C (54°F) - Excellent!
Great Clinic building, great HVAC system... So why did it grow mold 3 times in five years?
School - Plenty of system capacity!... Why mold?

Photograph 1: Mold growth on classroom wall after 72 hours.
New training building and new HVAC equipment... Why mold and equipment failures?
Humidity control costs money. Define the PURPOSE for humidity control before you begin any project.

Dehumidification performance of equipment must equal or exceed the building’s humidity loads. Therefore...

- Quantify all humidity loads and...
- Quantify dehumidification performance
Quick refresher...
Psychrometrics for humidity control

75°F
50% RH
50% RH - Half of the maximum amount at 75°F
A relative measurement—it depends on temperature

75°F
50% RH
Humidity ratio - “absolute” humidity

75 °F
50% RH
65 gr/lb
Dew point: The temperature at which moisture begins to condense out of the air (also "absolute")

75°F
50% RH
65 gr/lb
55°F
Dew point: The temperature at which moisture begins to condense out of the air (also “absolute”)

75°F
50% RH
65 gr/lb
55°F
Example: Predicting condensation risk on cold supply air diffusers

78°F
65% RH
Example: Predicting condensation risk on cold supply air diffusers

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78°F
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Dew Point

65°C
65% RH

78°F
Exercise: Predicting condensation from humid air infiltration into air conditioned buildings
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In Chicago, summertime outdoor air being sucked into the building cavities is 84°F, 134 gr/lb.
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How cold does an indoor wall surface have to be to produce condensation?
Exercise: Predicting condensation from humid air infiltration into air conditioned buildings

In Chicago, summertime outdoor air being sucked into the building cavities is 84°F, 134 gr/lb.

How cold does an indoor wall surface have to be to produce condensation?

In other words - What is the dew point of air at 84°F, 134 gr/lb = ___?___)
Predicting condensation risk inside interior walls and above ceilings

84°F
134 gr/lb
Predicting condensation risk inside interior walls and above ceilings

84°F
134 gr/lb

78°F
Predicting condensation risk inside interior walls and above ceilings

84°F
134 gr/lb

Psychrometric Chart

78°F
Predicting condensation risk inside interior walls and above ceilings

84°F
134 gr/lb

78°F
134 gr/lb
Predicting condensation risk inside interior walls and above ceilings

84°F
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78°F

Psychrometric Chart

This chart was designed by James Judge, P.E. of Judge Company, Bedford, NH. The chart was constructed using the algorithms contained in the ASHRAE Handbook of Fundamentals 1997. (www.EMC.com 2013)
Predicting condensation risk inside interior walls and above ceilings

84°F
134 gr/lb

78°F

Psychrometric Chart
This chart was designed by James Judge, E.C. of house; Company, Bedford, MA. The chart was
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84°F
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Psychrometric Chart
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Predicting condensation risk inside interior walls and above ceilings

84°F
134 gr/lb

75°C Dew Point

78°F
Designing for humidity control - 5-part sequence

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

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

Does not define 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?
“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 level that achieves purpose for humidity control

1. Define the Purpose of the Project
2. Establish Control Levels
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55°F Dew Point
Step 2 - Establish control level that achieves purpose for humidity control

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55 °F Dew Point
Step 3 - Calculate the humidity loads

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Humidity Control: Principles and Practice
Illinois ASHRAE Chapter - May 2013
Step 3 - Calculate the humidity loads

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3. Calculate Moisture Loads
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Largest loads?
Ventilation/makeup air and infiltration

Dehumidification Load Estimates For Tampa, Florida
Outdoor Dew Point Design: 85°F 144 gr/lb [29.4°C 20.5 g/kg]

- Small hospital
- Gaming casino
- Movie theater
- Nursing homes
- 16 classrooms
- Military barracks
- Swimming pool
- Low-rise hotel
- Low-rise office
- Small retail

Ventilation air
Air leaking into the building

- People
- Door openings
- Domestic loads
- Humid inventory
- Wet surfaces
- Vapor permeation
Largest loads?
Ventilation/makeup air and infiltration

Dehumidification Load Estimates For Tampa, Florida
Outdoor Dew Point Design: 85°F 144 gr/lb [29.4°C 20.5 g/kg]
Retail building in Chicago - Humidity load estimate

Chicago Retail Dehumidification Load (lb/h @ peak)

- Respiration (PPL): 16.25 lb/h
- Occupant Ventilation: 24 lb/h
- Bldg. Ventilation: 50 lb/h
- Infiltration (ACH Nat): 16 lb/h
- Door Activity: 4 lb/h
- Humid Product: 1 lb/h
- Damp Carpet: 0.5 lb/h
- Permeation (Walls): 1 lb/h

TOTAL LOAD = 110 lb/h, or... 13 gallons/hour
Retail building in Chicago - Humidity load estimate

Ventilation to dilute contaminants from people

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TOTAL LOAD = 110 lb/h, or... 13 gallons/hour
### Chicago Retail Dehumidification Load (lb/h @ peak)

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**TOTAL LOAD:** 110 lb/h, or... **13 gallons/hour**

Ventilation to dilute contaminants from people

Ventilation to dilute contaminants from products and furnishings
Retail building in Chicago - Humidity load estimate

Ventilation to dilute contaminants from people
Ventilation to dilute contaminants from products and furnishings
Air leakage into a “tight” building

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TOTAL LOAD = 110 lb/h, or... 13 gallons/hour
Peak humidity loads - ASHRAE Research 1997
Correcting 100 years of error - Now we know better
Peak humidity loads - ASHRAE Research 1997
Correcting 100 years of error - Now we know better

0.4% Design Conditions for Atlanta, GA
From Chapter 26 of the
1997 ASHRAE Handbook of Fundamentals

**Extreme Moisture**
Occurs at moderate temperature, and
represents a far higher moisture level
than the average moisture at the peak
temperature.

**Extreme Temperature**
With its average coincident wet bulb
temperature is a much lower moisture
level than the true peak moisture.
How to find the peak design dew point?
ASHRAE Fundamentals - 1997 or later
How to find the peak design dew point?
ASHRAE Fundamentals - 1997 or later

...for Cooling load calculations
How to find the peak design dew point?
ASHRAE Fundamentals - 1997 or later

...for dehumidification load calculations, and DOAS system design

...for Cooling load calculations
Chicago - ASHRAE peak humidity design conditions
Chicago - ASHRAE peak humidity design conditions

0.4% Dry Bulb

92° DB
74.6° MCWB

101 gr/lb
Chicago - ASHRAE peak humidity design conditions

<table>
<thead>
<tr>
<th>0.4% Dry Bulb</th>
<th>0.4% Dew Point</th>
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<tbody>
<tr>
<td>92° DB</td>
<td>84° DB</td>
</tr>
<tr>
<td>74.6° MCWB</td>
<td>77.7° MCWB</td>
</tr>
<tr>
<td>101 gr/lb</td>
<td>134 gr/lb</td>
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</tbody>
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Chicago - ASHRAE peak humidity design conditions

<table>
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<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>92° DB 74.6° MCWB</td>
<td>84° DB 77.7° MCWB</td>
<td>-8°F DB</td>
</tr>
<tr>
<td>101 gr/lb</td>
<td>134 gr/lb</td>
<td>+33 gr/lb</td>
</tr>
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</table>
Chicago load at peak dry bulb vs. peak dew point
Chicago load at peak dry bulb vs. peak dew point
Chicago load at peak dry bulb vs. peak dew point

![Graph showing Chicago Retail Dehumidification Load]

**Chicago Retail Dehumidification Load (lb/h @ peak)**

- Respiration (PPL): 14.25 lb/h
- Occupant Ventilation: 12 lb/h
- Bldg. Ventilation: 26 lb/h
- Infiltration (ACH Nat): 8 lb/h
- Door Activity: 2 lb/h
- Humid Product: 1 lb/h
- Damp Carpet: 0.5 lb/h
- Permeation (Walls): 0.5 lb/h

**TOTAL LOAD = 65 lb/h, or... 8 gallons/hour**

![Graph showing Chicago Retail Dehumidification Load]

**Chicago Retail Dehumidification Load (lb/h @ peak)**

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**TOTAL LOAD = 110 lb/h, or... 13 gallons/hour**

Humidity Control: Principles and Practice
Illinois ASHRAE Chapter - May 2013
Chicago load at peak dry bulb vs. peak dew point

65 lb/h at peak Dry Bulb
Chicago load at peak dry bulb vs. peak dew point

65 lb/h at peak Dry Bulb

110 lb/h at peak Dew Point
Step 4 - Size and select the dehumidifier

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2. Establish Control Levels
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Step 4 - Size and select the dehumidifier

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Cool-Reheat Dehumidifier
Step 4 - Size and select the dehumidifier

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Cool-Reheat Dehumidifier

Desiccant Dehumidifier
Cool-Reheat Dehumidifier

**Diagram Description:**
A Cool-Reheat Dehumidifier system diagram is shown with labeled components:
- **DX Cooling Coil**
- **Outdoor Condenser**
- **Compressor**
- **Reheat Condenser**

**Diagram Details:**
- **Temperature (°F):**
  - Point A: 80
  - Point B: 50
  - Point C: 75
- **Moisture (gr/lb):**
  - Point A: 124
  - Point B: 54
  - Point C: 54
- **Air Flow (scfm):**
  - All points: 2,000
- **(°C):**
  - Point A: 26.7
  - Point B: 10.0
  - Point C: 23.9
- **(g/kg):**
  - Point A: 17.7
  - Point B: 7.7
  - Point C: 7.7
- **(l/s):**
  - Point A: 942
  - Point B: 942
  - Point C: 942
Desiccant Dehumidifier

Desiccant Dehumidifier
Using Condenser Heat Reactivation

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
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<tbody>
<tr>
<td>Temp.</td>
<td>80</td>
<td>60</td>
<td>77</td>
<td>98</td>
</tr>
<tr>
<td>Moist.</td>
<td>124</td>
<td>77</td>
<td>54</td>
<td>144</td>
</tr>
</tbody>
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<th>(°C)</th>
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<th>(l/s)</th>
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<tr>
<td>A</td>
<td>26.7</td>
<td>17.7</td>
<td>942</td>
</tr>
<tr>
<td>B</td>
<td>16.0</td>
<td>11.0</td>
<td>942</td>
</tr>
<tr>
<td>C</td>
<td>25.0</td>
<td>7.7</td>
<td>942</td>
</tr>
<tr>
<td>D</td>
<td>37.0</td>
<td>20.6</td>
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Measuring Dehumidification

How to measure?
Humidity ratios
(gr/lb or g/kg)
before and after the
dehumidifier
Measuring Dehumidification

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Measuring Dehumidification

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Humidity ratios (gr/lb or g/kg) before and after the dehumidifier
Measuring Dehumidification

How to measure?
Humidity ratios (gr/lb or g/kg) before and after the dehumidifier
Finding the humidity ratio from temperature and RH

75°F
50% RH
Finding the humidity ratio from temperature and RH

75°F
50% RH
Finding the humidity ratio from temperature and RH

75°F
50% RH
75°F
50% RH
Finding the humidity ratio from temperature and RH

75°F
50% RH
Finding the humidity ratio from temperature and RH

75°F
50% RH

65°F
65 gr/lb

Psychrometric Chart
Sea level Barometric Pressure = 29.92 in Hg
This chart was designed by James Judge, P.E. of Honeywell Company, Bedford, NH. The chart was constructed using the algorithms contained in the ASHRAE Handbook of Fundamentals 1997. Crown BMEC.com 2013
Dehumidification equation

\[ \text{lbs/h} = \frac{\text{CFM} \cdot \text{gr/lb}_1}{\text{gr/lb}_2 - 7000} \]

Where:
- \text{lbs/h} = \text{Pounds of water vapor per hour}
- \text{CFM} = \text{Standard cubic ft/min}
- \text{gr/lb}_1 = \text{Higher humidity ratio}
- \text{gr/lb}_2 = \text{Lower humidity ratio}
- \text{7000} = \text{grains of water vapor in a pound}
Where to locate the DH in the system?
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Need expert advice?... consult an expert!
Need expert advice?... consult an expert!
Need expert advice?... consult an expert!

Reporter:

“Willie, it’s a Federal Crime! why rob BANKS?”
Need expert advice?... consult an expert!

Reporter:

“Willie, it’s a Federal Crime! why rob BANKS?”

“That’s Where the Money is...”

— Willie Sutton
Willie might ask you... where’s the humidity load?
Willie might ask you... where’s the humidity load?

**Chicago Retail Dehumidification Load (lb/h @ peak)**

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**TOTAL LOAD = 110 lb/h, or... 13 gallons/hour**
Willie might ask you... where’s the humidity load?
Willie might ask you... where’s the humidity load?

"That’s Where the Money is..."

— Willie Sutton
Dry where the load is - DOAS controls humidity

Deliver air below the dew point desired in the space so the supply air can absorb the internal DH loads, maintaining control.
Typical layout - Big box retail

Dry Ventilation Air Unit
For Dehumidification

Rooftop Cooling/Heating Units
For Temperature Control
Add return air connection for humidity control during unoccupied hours and vacations.
Summary - Humidity Control Principles and Practice
Summary - Humidity Control Principles and Practice

• First and most important step: Define the purpose for humidity control
Summary - Humidity Control Principles and Practice

- First and most important step: Define the purpose for humidity control
- To control humidity:
Summary - Humidity Control Principles and Practice

• First and most important step: Define the purpose for humidity control

• To control humidity:
  • Quantify humidity loads and
Summary - Humidity Control Principles and Practice

- First and most important step: Define the purpose for humidity control

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  - Quantify DH equipment performance
Summary - Humidity Control Principles and Practice

- First and most important step: Define the purpose for humidity control

- To control humidity:
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- Biggest humidity load?... Ventilation and makeup air, BY FAR the largest loads
First and most important step: Define the purpose for humidity control

To control humidity:
- Quantify humidity loads and
- Quantify DH equipment performance

Biggest humidity load?... Ventilation and makeup air, BY FAR the largest loads

For easy humidity control - Dry the incoming air in a dedicated outdoor air system (DOAS)
Further ASHRAE Resources

Humidity Control Design Guide

Guide for Buildings in Hot and Humid Climates

ASHRAE Handbook (Applications)

Lew Harriman
2011-2013 Chair, ASHRAE TC 1.12
(603) 431-0635

Thursday, May 16, 13