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Humidity Control
Your No. 1 IAQ Liability

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“My guess is that hell is hot, but purgatory is humid.”
Humidity Problems

The potential is everywhere

Mold and mildew will propagate with
  ◦ Moist environment
  ◦ A food source (anything organic)

It’s not like stepping off a diving board...
Typical Target rH < 60%

Fig. 2  Time Required for Visible Mold Growth
ASHRAE Std. 55

Comfort Zone

Where 90% of appropriately dressed occupants feel comfortable
% Humidity is Relative to Temperature
Cooling Cycle

- Sensible
- Latent
- Mixed
- Room
- O/A
What does ASHRAE say?
Chapter 64 “Moisture Management in Buildings”

Issues seldom have a single cause, usually a combination of

- HVAC risk factors, 9 listed
  - FAILURE TO KEEP LONG-TERM INDOOR AIR PRESSURE POSITIVE
  - ROOM UNIT DESIGN AND OPERATIONAL SEQUENCE

- Architectural risk factors, 8 listed

- Operational risk factors, 5 listed

- Occupant risk factors, 5 listed
Humidity Problems

Can be caused by the mechanical system
- How it is designed
- How it is operated
- How it is built

Can be caused by structural or architectural problems
- Roof or envelope leaks
- Standing water in a crawl space

Can be caused by custodial practices
- Shampooing carpets *
Construction Issues

- Coils piped backwards *
- Poorly insulated pipes, temperature degradation *
- Vapor barrier breaches causing drips and mold on insulation jacket *
Designing for Humidity Control

It may be active control
- Dedicated Outdoor Air Systems (DOAS)
- Reheat Systems

It may be passive control
- Variable Air Volume (VAV)
- Face & By-Pass (F&BP)

It may not be ignored.

Incidental doesn’t work!
Incidental?

Google search for “resident hall mold”

Fan coils with modulating control valves
or
DX or PTACs
and
Inadequate building pressurization or O/A conditioning
Scary stuff
We didn’t use to worry about this. Those systems used to work. What happened?

The weather is wetter, more humid and cooling season is longer.

The natural equilibrium has been upset.
We didn’t use to worry about this. What happened?

The natural equilibrium has been upset.

ASHRAE Std. 62-1989 increased O/A from 5 CFM/person to 15.

➢ BTUs required to dehumidify 5 CFM equal the sensible and latent load of one person.
We didn’t use to worry about this. What happened?

The Sensible Heat Ratio changed
- Average occupant density is down
- Latent load may be increasing
- Sensible load is decreasing...Improvements in lighting and envelope efficiency

The thermostat responds to sensible load, and there won’t be any latent removal unless the dew point is depressed.
Classroom Cooling Load

- Outside air = 35%
- Kids = 22%
- Envelope = 8%
- Solar gain = 25%
- Lights = 8%
- Miscellaneous electric = 2%
Classroom Moisture Contribution (latent load)

Outside air = 80%

Kids = 20%

Solar gain

Lights

Miscellaneous electric

Envelope
Tom’s 35-70-95 Axiom

“Outside air is essential for a healthy and effective learning environment. But outside air is at least 35% of the cooling load, 70% of the heating load and 95% of the potential humidity problems.”

Four excellent reasons to...

ventilate appropriately but only when the kids are there.

Std. 90.1 has several smart O/A management schemes
Over ventilating does not improve performance.

CO₂ and Cognitive Performance

Night
when is your humidity exposure is most severe

- Dew on the grass = 100% rH
- Outside temp below room temp = no load
- Unoccupied space = almost zero load
- Exhaust fans running at night = building negative pressure = lots of infiltration

Don’t run systems in occupied mode at night!
What **should** happen at night (or unoccupied)

- All exhaust fans off
  - Don’t let building go negative

- HVAC system is off, to be started by either
  - Room temp above night set point, 78 or 80°F
  - Room humidity above 60%

- AHUs run with
  - 54°F LAT
  - O/A dampers closed
  - Fans on low speed, controlling to “Day” temperature

- Morning start-up in “Day-Unoccupied” mode
What does happen at night?

Decouple temperature and ventilation!

Slight increase not unusual

Room RH Sensors

Courtesy: Jerry Weber, PE
The Problem

The moisture comes from outside air

Most (all) A/C systems will dehumidify when fully loaded

But at all loads less than full load, one of these three has to change or you’ll *sub-cool the space*

➢ The time it runs
➢ The volume of air
➢ The temperature of the air
The Problem

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Most (all) A/C systems will dehumidify when fully loaded

But, at all loads less than full load, one of these three has to change or you’ll **sub-cool the space**

- The time it runs
- The volume of air
- The temperature of the air

Not an option when codes require continuous ventilation
The History of F&BP

The four main causes of humidity problems

1. Valve control of constant volume equipment
2. Oversized air side equipment
3. Building under negative pressure, i.e. not controlling exhaust fans
4. Around-the-clock operation
A constant volume system operating at a part load condition that would be satisfied by a LAT of 65F

- Valve control = 68% rH, $0.20/\text{hr}$
- F&BP control = 56% rH, $0.22/\text{hr}$
- Reheat control = 54% rH, $0.42/\text{hr}$

(OAT = 95 DB/78 WB, 74F set point)
The thermostat responds to sensible load, and there won’t be any latent removal unless the dew point is depressed.
Constant Volume Valve Control HVAC
(incidental humidity control)
Constant Volume Valve Control HVAC

(in incidental humidity control)
CV – F&BP Control

- EA → RA
- OA → SA
- BP

- M1
- M2

Arrows indicate flow directions:
- O/A
- Mixed 1
- Mixed 2
- Room
- Dew Point

65F LAT; 56% rH
Constant Volume F&B BP HVAC
(passive humidity control)
Constant Volume F&BP HVAC
(improved passive humidity control)
Combined F&BP with Variable Speed Fan (ECM)
(passive humidity control)
How big is that red area?

8,760 Hours in a year
- Eliminate O/A below 59F WB
- Eliminate weekends and nights
- Occ sensor controls O/A damper
  - Minimal load in the space

What’s left = about 20 Hrs/Yr

Add CO2 sensor for O/A control,
What’s left = 0
“Performance Analysis of 2-Pipe HVAC”

Carl Gist, Senior Thesis
University of Southern Indiana

Data from twenty (20) F&BP schools ~ Ohio River valley, 95/78 design

After eliminating obvious equipment issues, such as chiller outages or sensor issues

- 30 total hrs above 60% rH, 12 when occupied
- 65% rH highest observed
- No problems or complaints
“Ironically, the widely used single-zone CV system is particularly problematic for dehumidification.”

The Difficulty with CV Dehumidification
Contrary to popular belief, indoor moisture control is an issue in almost all geographic locations, not just in areas where hot, humid conditions prevail. Whenever a high relative humidity exists at or near a cold, porous surface, moisture absorption increases.

Ironically, the widely used single-zone CV system is particularly problematic for dehumidification.

and moisture-related problems (increased maintenance, premature replacement of equipment and furnishings, and increased health risks) become likely.

If properly designed and controlled, the HVAC system can significantly reduce the moisture content of indoor air. Ironically, the most widely used means of ventilation—the single-zone, constant-volume (CV) system—is also the most problematic when it comes to dehumidification.

A basic CV system consists of an air handler that serves a single thermal zone. The air handler supplies the zone

with a constant volume of air, usually a mixture of outdoor air and recirculated return air, at a variable temperature.

A thermostat senses the zone dry-bulb temperature and compares it to the set point. The thermostat then modulates the capacity of the cooling coil, adjusting the supply-air temperature until the sensible capacity of the cooling coil matches the sensible load and the zone temperature matches the set point.

Designers typically (and appropriately) size cooling coils based on the peak sensible load, that is, when it is hottest outdoors. In many climates, however, the latent load on the cooling coil—and often the total load (sensible plus latent)—peaks when outdoor dew point, not dry bulb, is highest.

Consequently, in some air-handler arrangements, coils selected for the highest sensible load may not provide sufficient cooling capacity when the highest latent load occurs. More importantly, however, coils controlled to maintain the dry-bulb temperature in the space often operate without adequate latent capacity at part-load conditions. Here’s why…
The air streams...

Outside air...never by-pass this
Mixed air...try to avoid by-passing this
Return air...arrange ducts and equipment to **make this happen**

Stratification is your friend!
Incorrect – O/A By-Pass

Typical Internal F&BP

Correct – R/A By-Pass

Custom Internal F&BP
Classroom Unit Ventilator

Old

Under-the-window UV

New

Vertical Ducted UV

Parallel, not opposed blades
R/A By-Pass on a VAV System

Raising SAT with zero cost reheat

Under-floor air system
Humidity Cause #1a
“The DX Dilemma”

Continuous fan and intermittent compressor operation will result in humidity problems.

- Will dehumidify only when compressor is running and after the coil gets cold
- When compressor shuts off and fan continues to run, moisture on the coil will be re-entrained into air
One way to make your phone ring.

DX Dilemma = 85% rH

O/A Dew Point is low
Dealing with the DX Dilemma

Hot Gas By-Pass or DOAS or RH or APR valve required (older).
Variable speed fans/compressors (newer)

APR Valve

- Retrofit
- Modulating unloader for capacity control
- Effective dehumidifier
- No threat of freezing coil
DOAS - An Excellent Solution
(active humidity control)

Decoupled or Dedicated Outside Air System

Provide a separate system to treat the outside air before it goes to the room
  ◦ Dehumidified in summer
  ◦ Heated in winter

Recent ASHRAE Guidelines for DOAS applications, publication RP-1712
DOAS

Pros
- Straight-forward solution
- Direction the industry is favoring
- If done well, it can be very efficient

Cons
- Additional infrastructure
- Cannot run economizer cooling
- Most systems are “all-on or all-off”
Variable Volume HVAC
(passive humidity control)

Intrinsically safe for humidity control
Variable Volume HVAC w/RH at Min Load
(active humidity control)
VAV Terminal

ASHRAE Guideline 36 – High performance Sequences

Diagram showing the airflow in VAV Terminal, with lines indicating Max DAT, Heating and Cooling Minimum, Discharge Air Temperature Setpoint, Cooling Maximum Airflow, Active Airflow Setpoint, DAT = AHU SAT, Heating Loop Signal, Deadband, and Cooling Loop Signal.
Minimize (eliminate?) reheat:
- wide dead band, 3F min.
- occ sensor reset damper to zero
- supply air temp reset

Check diffuser performance at Htg Max
Reheat Control
(active humidity control)

The usual solution for VAV systems at minimum flow

Acceptable solution for CV systems
  ◦ Review Std. 90.1

A heating source available 12 months of the year

Requires either
  ➢ Heating coil in the reheat position (glycol in CHW), or
  ➢ Three coil unit, and
  ➢ Additional controls (humidistat)
Constant Volume w/Reheat
(active humidity control to address “incidental” control)

RH doubles the cost to operate!
And it may not work???
Whadda ya mean it won’t work?

1. Heat coil warms the leaving air (cold) side of cooling coil.
2. Latent re-entrainment of condensate
3. Duct mount RH coil to avoid both
Re-Heating Cost

Electric @ $0.010/kWh = $2.93/therm
Conventional boiler @ $0.80/therm= $1.21/therm
Low temp boiler = $0.88/therm
Geo heating = $0.85/therm
HRC heating = ($0.10/therm)
   If main chiller is air cooled

HRC combined C.O.P. is about 7.7
A Better Solution
for “incidental” situations

➢ Decouple make-up air

➢ Cycle fan on call for cooling
  ➢ Time delay on fan start, get coil cold before starting fan
  ➢ Leaving air temp sensor, set for 54F
  ➢ Vary fan speed to match load
  ➢ Fan stops when at set point, avoid latent re-entrainment
  ➢ Wide deadband
Recap...
Sources of Humidity Problems

Structural or Architectural problems
  ◦ Repair them

Custodial practices
  ◦ Use dehumidifiers

Mechanical system
  ◦ Design
  ◦ Construction
  ◦ Operation

Review Chapter 64 of 2019 Applications Handbook
Recap...
Mechanical System Design

Things to avoid...
- Constant volume valve control
- DX with continuous fan and intermittent compressor operation
- Over-sizing air handling equipment
Recap...

Mechanical System Operation

- Avoid 24 hour operation...match operation to occupancy
- Control exhaust fans
- Avoid low cooling set points
- Ventilate appropriately but only when the people are present
Recap...
Mechanical System Design

Active humidity control
- DOAS
- Reheat

Passive humidity control
- VAV
- Face & By-Pass
Recap...
Mechanical System Design

Active humidity control
- DOAS
- Reheat

All are correct

Passive humidity control
- VAV
- Face & By-Pass

The only wrong answer is to ignore humidity control.
TIME OUT!

In the era of Covid, how should we operate?

Increase ventilation above Std. 62, including opening windows

Better filtration...MERV-13
Will capture most virus
CDC Infection Control Pyramid

ELIMINATION
- to physically remove the pathogen

ENGINEERING CONTROLS
- to separate the people and pathogen

ADMINISTRATIVE CONTROLS
- to instruct people what to do

PERSONAL PROTECTIVE EQUIPMENT
- to use masks, gowns, gloves, etc.

Figure 3. Traditional infection control pyramid adapted from the US Centers for Disease Control. 

MERV-13 min.
Increase O/A
Social Distance

Most effective
Least effective
For effective infection control

Per Harvard School of Public Health...

Based on Minimum MERV rating of 13 or higher

4 air changes per hour = Good

5 air changes per hour = Excellent

6 air changes per hour = Ideal

- **ASHRAE 62.1 = 3 ACH +/-**

**Think about**

- Ventilation effectiveness, i.e. high supply/low return
1. Match ventilation schedule to occupancy
2. Do not run nights and week-ends
3. Shut off toilet exhausts
4. Do not over-ventilate
5. CO2 and occupancy sensors: good ideas for humidity control and saving money

1. Run ventilation 2 hrs before and after occupancy
2. Run ventilation nights and week-ends
3. Toilet room exhaust 24/7
4. AHUs at 100% outside air, if possible
5. Do not use CO2 to limit ventilation

Track the space rH.
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Questions?

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