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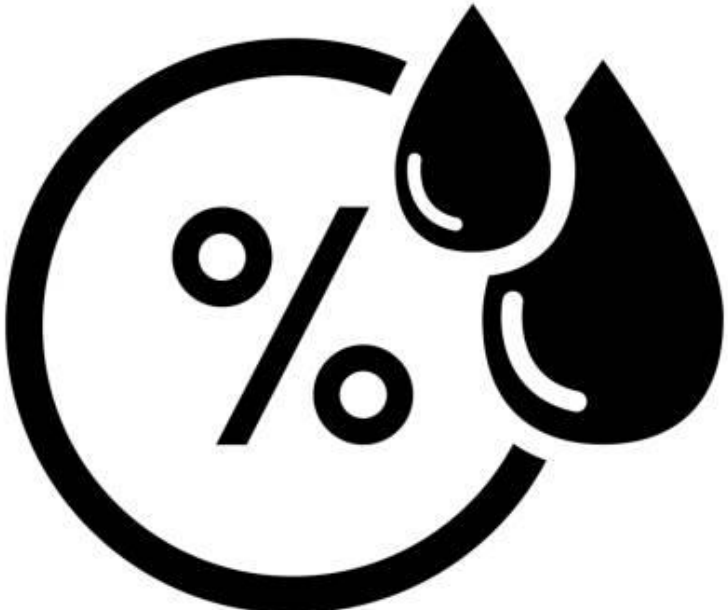


Humidity Control

Your No. 1 IAQ Liability

"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…

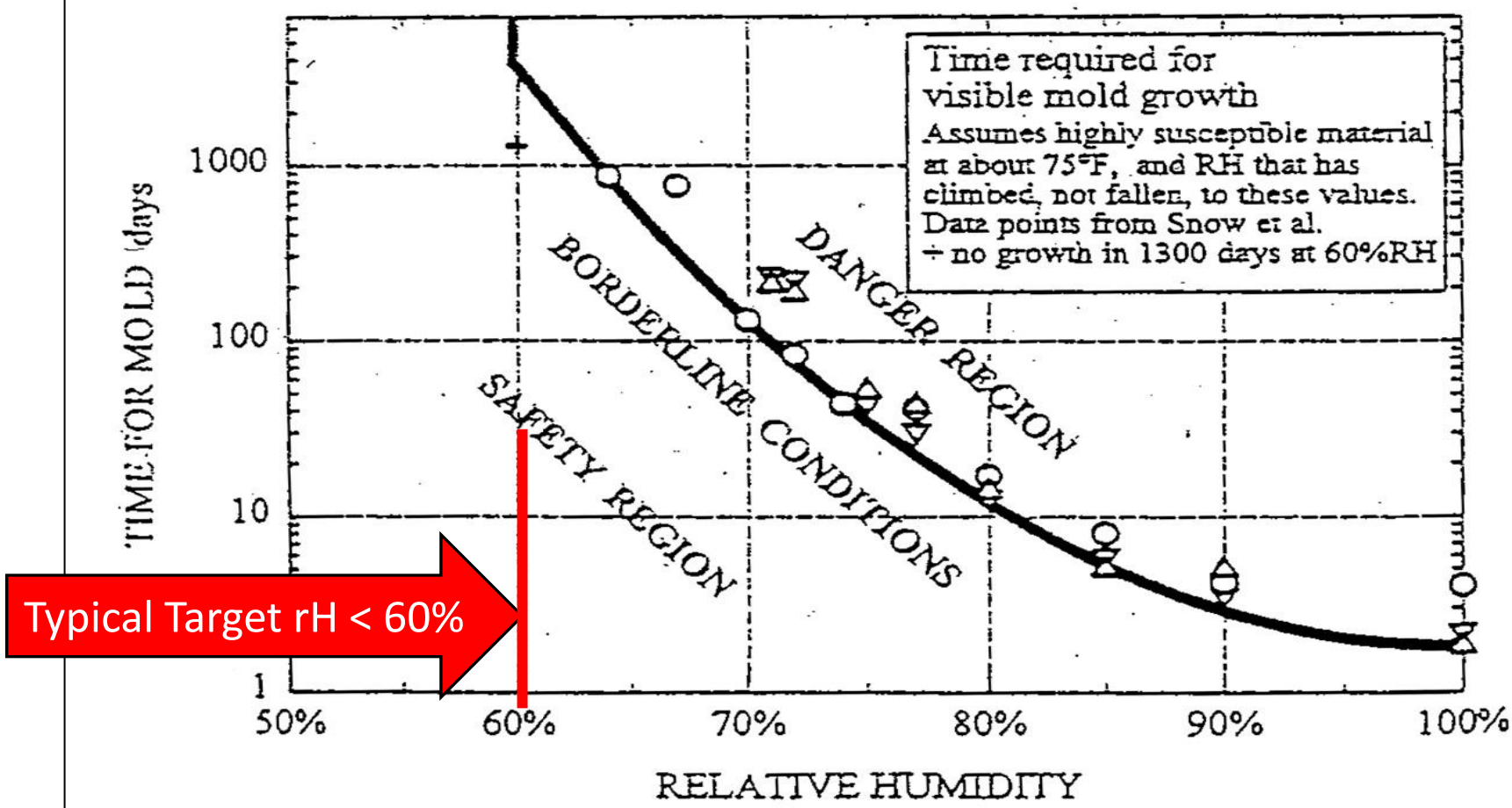


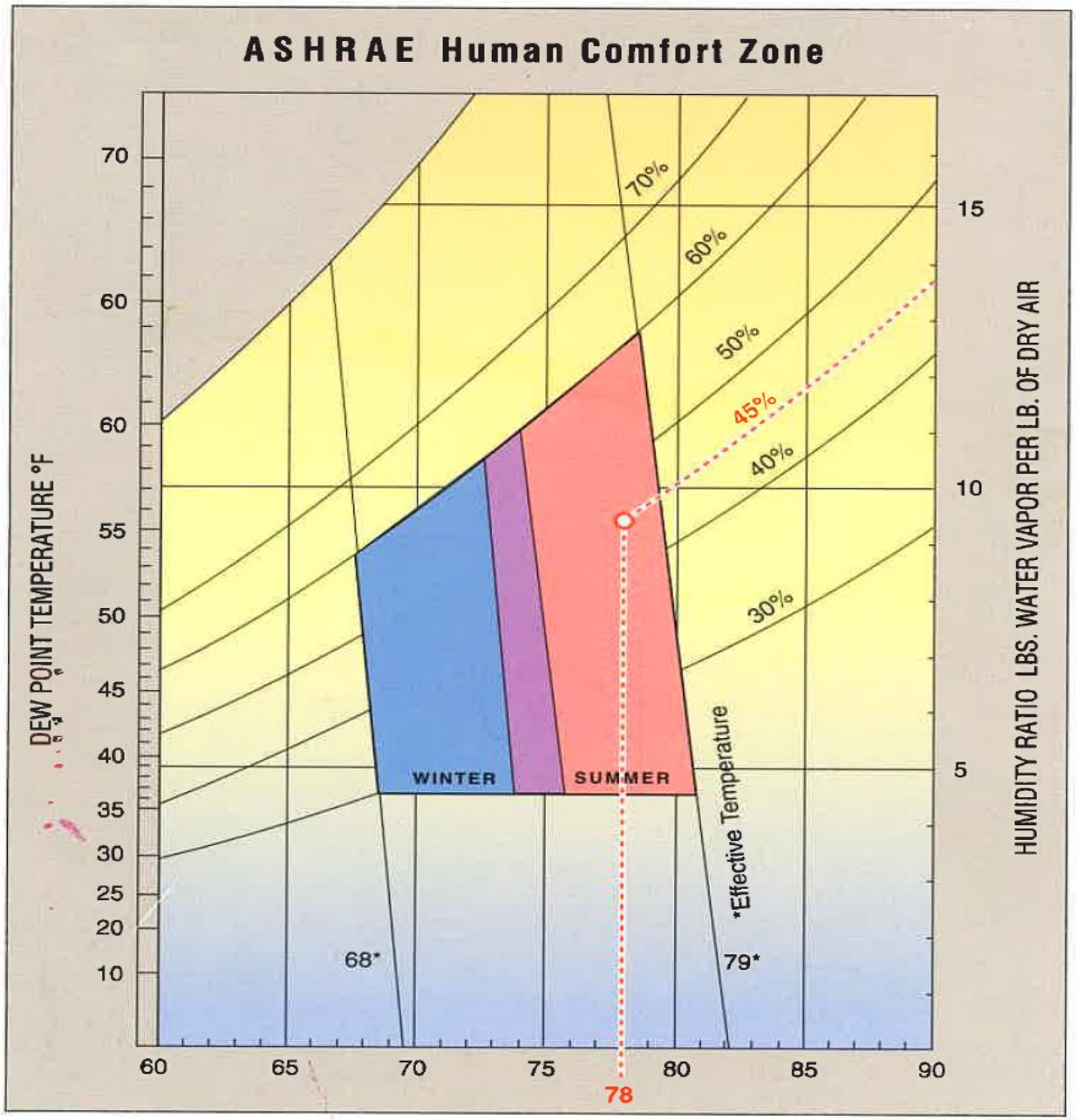
Fig. 2 Time Required for Visible Mold Growth

ASHRAE 2007 Applications Handbook, Chapter 21

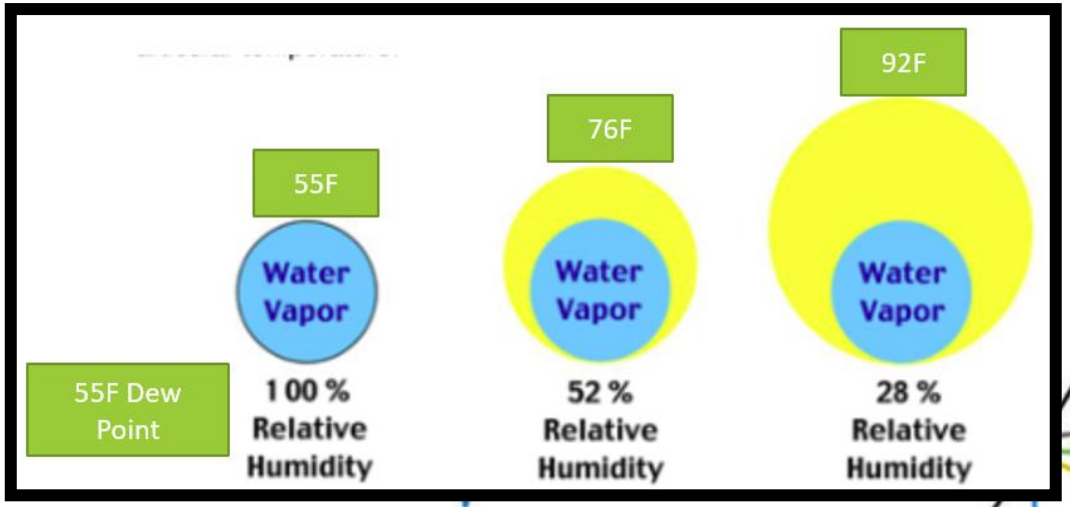
ASHRE Std. 55

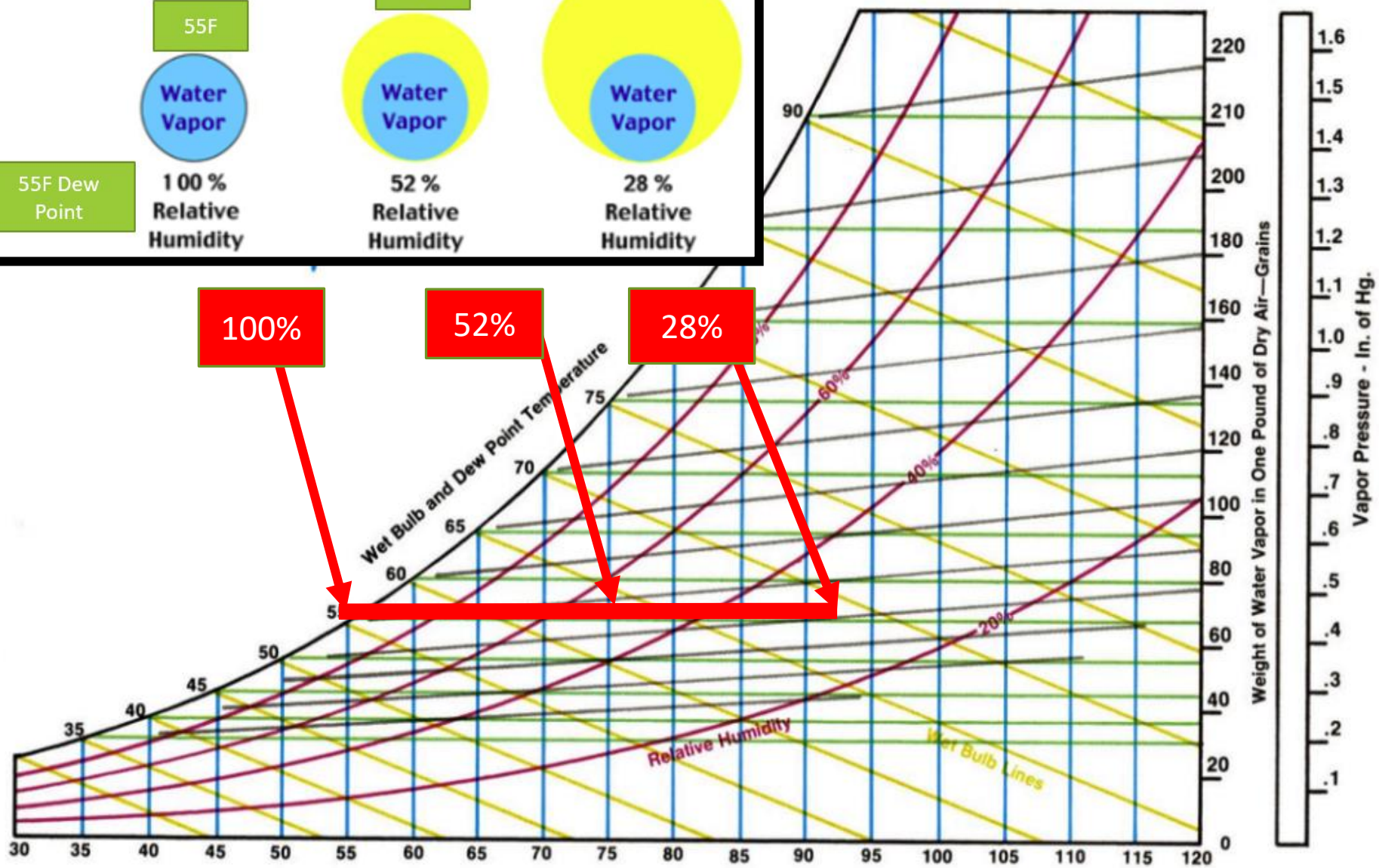
Comfort Zone

Where 90% of appropriately dressed occupants feel comfortable



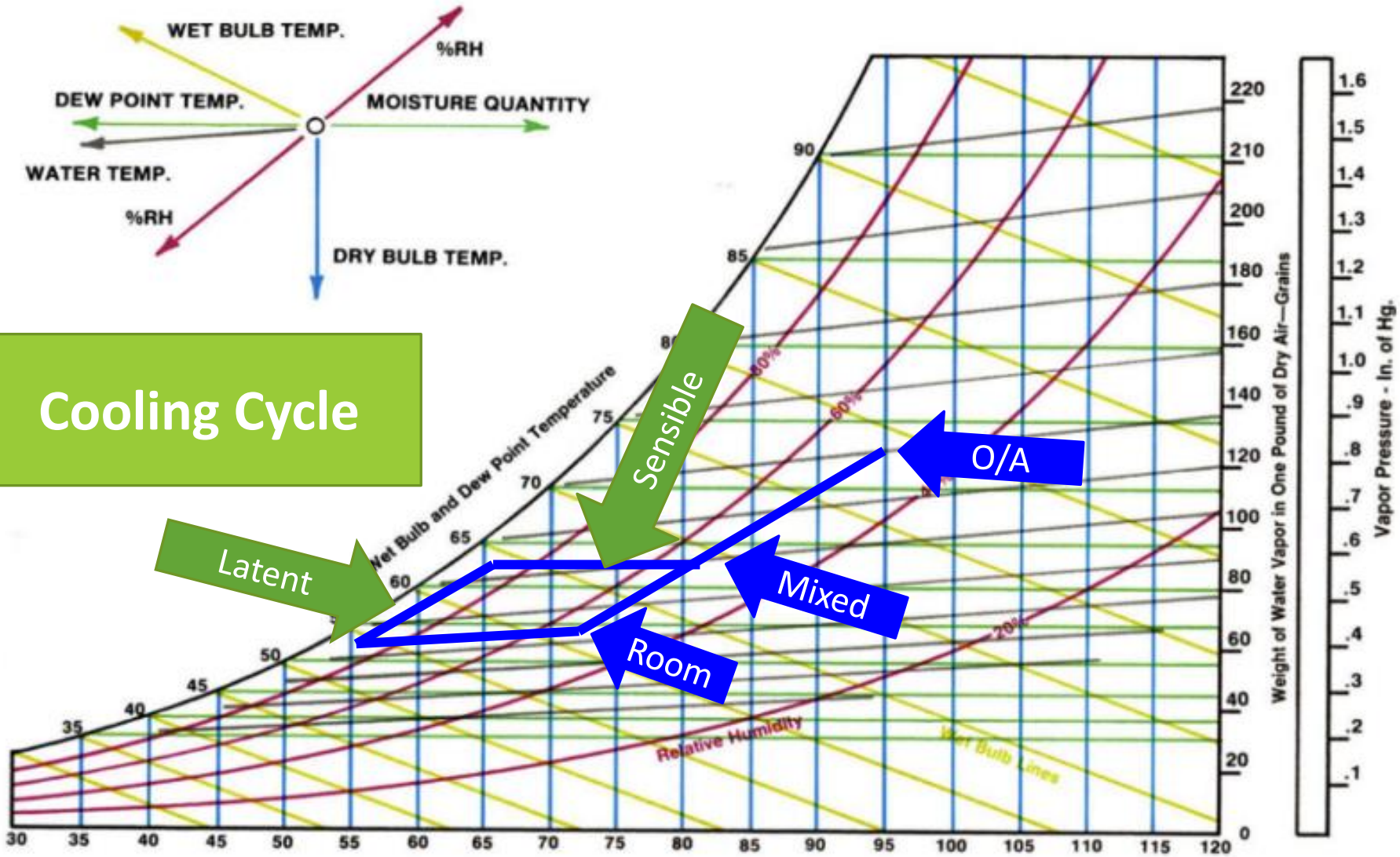
Chapter 5 of the 1993 ASHRAE Handbook of Fundamentals contains this graphic representation of the summer comfort zone. The society's research predicts that most people will be most comfortable at 78°F and 45% rh during the cooling season. The Munters MakupAire system pre-conditions the fresh air, delivering it to the building at a temperature and moisture level that maintains the space at comfortable conditions with great energy efficiency.



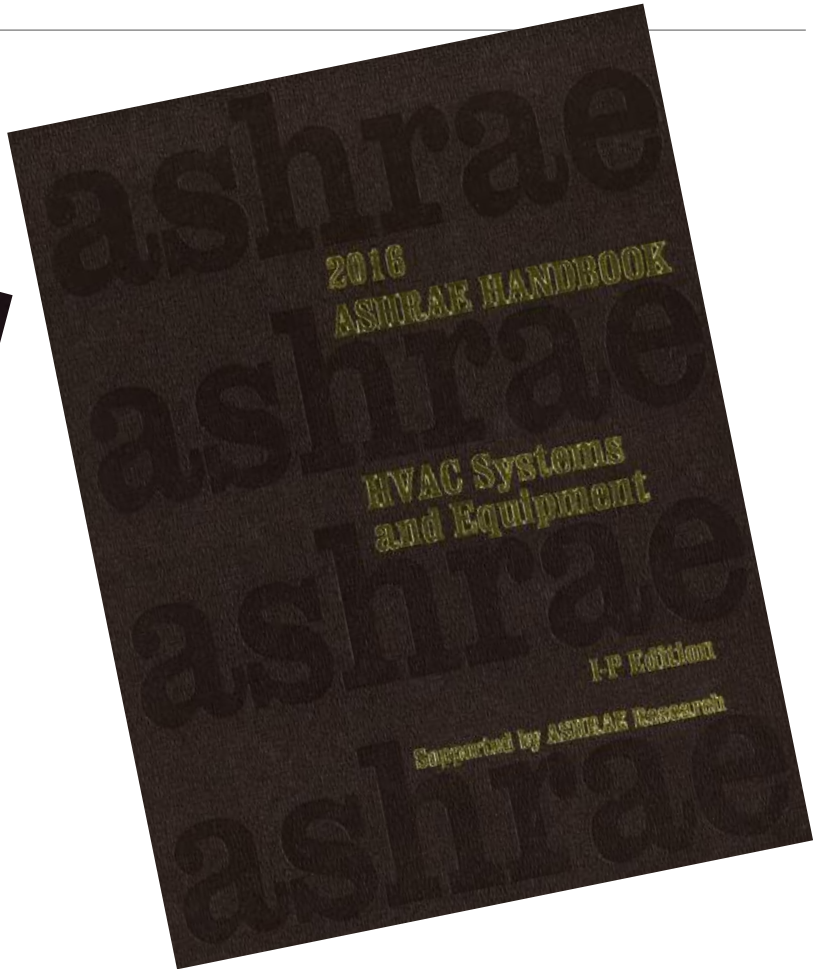


% Humidity is Relative to Temperature

Cooling Cycle



What does ASHRAE say?



2019 Applications Handbook

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 <u>active</u> control

- Dedicated Outdoor Air Systems (DOAS)
- Reheat Systems

It may be <u>passive</u> control

- Variable Air Volume (VAV)
- Face & By-Pass (F&BP)

It may not be ignored.

<u>Incidental</u> 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.

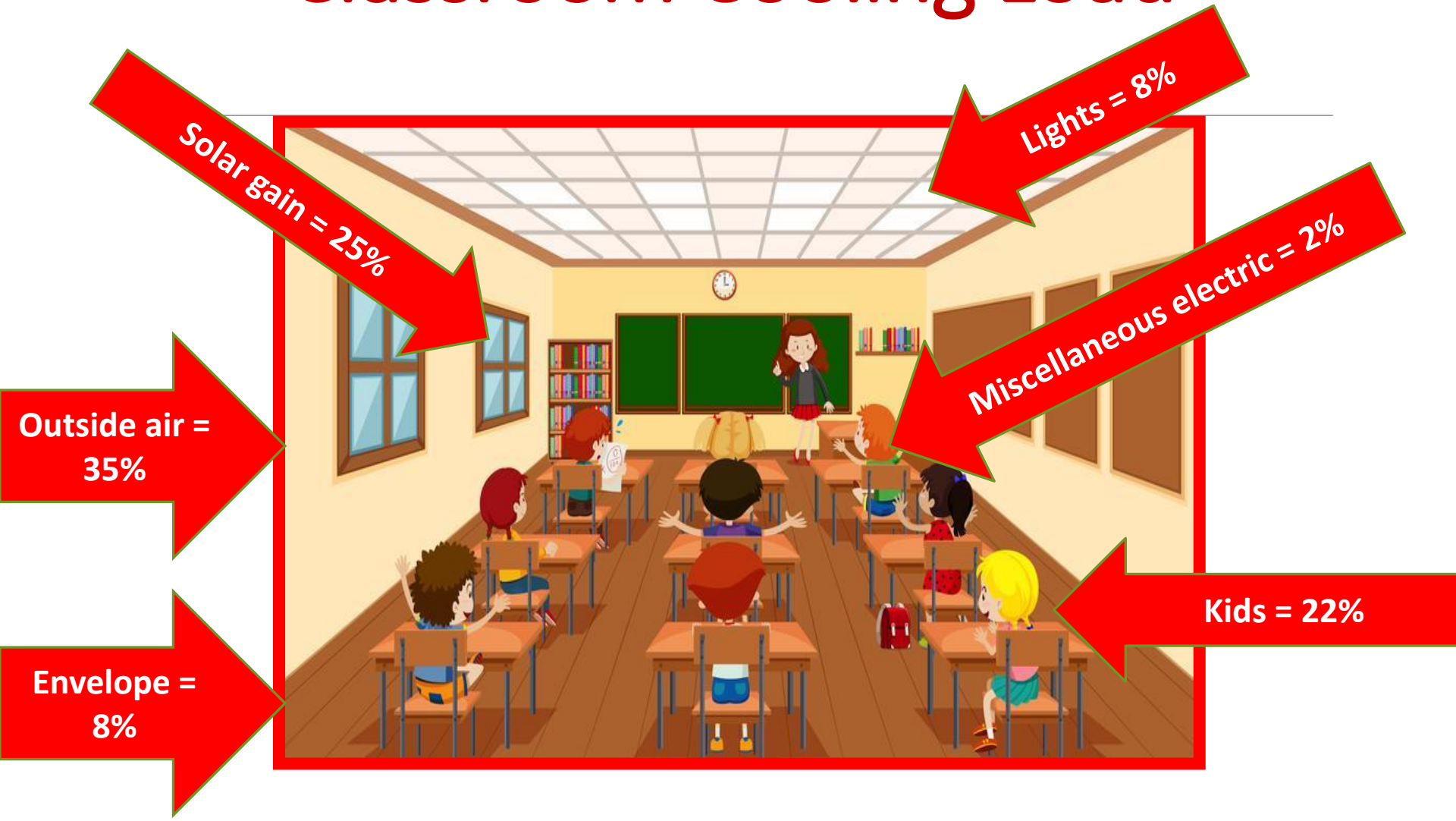
We didn’t use to worry about this. What happened?

The Sensible Heat Ratio changed

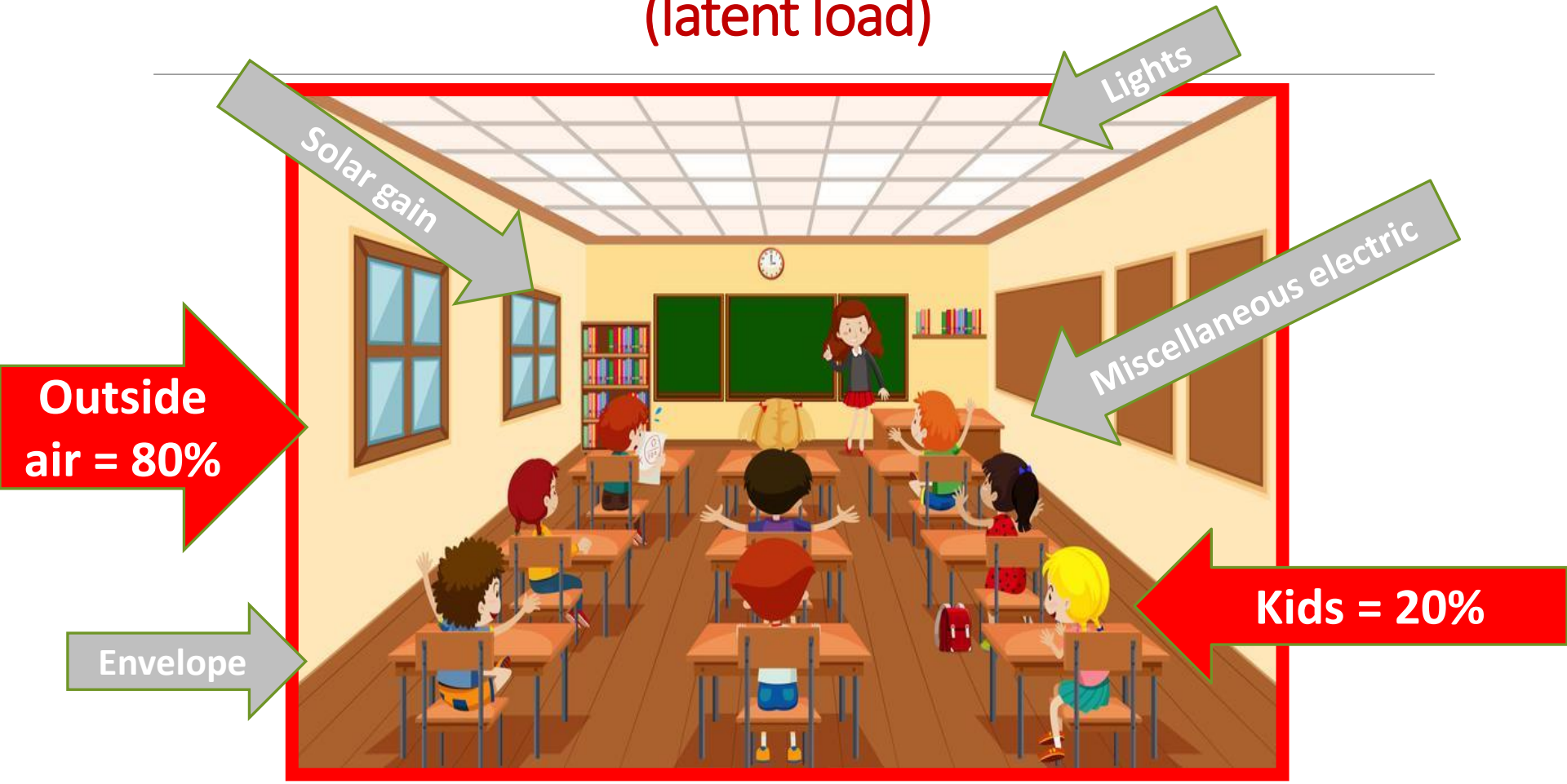
- Average occupant density is down
- Latent load may be increasing
- Sensible load is decreasing…Improvements in lighting and envelope efficiency

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

Classroom Cooling Load



Classroom Moisture Contribution
(latent load)



Tom's 35-70-95 Axiom

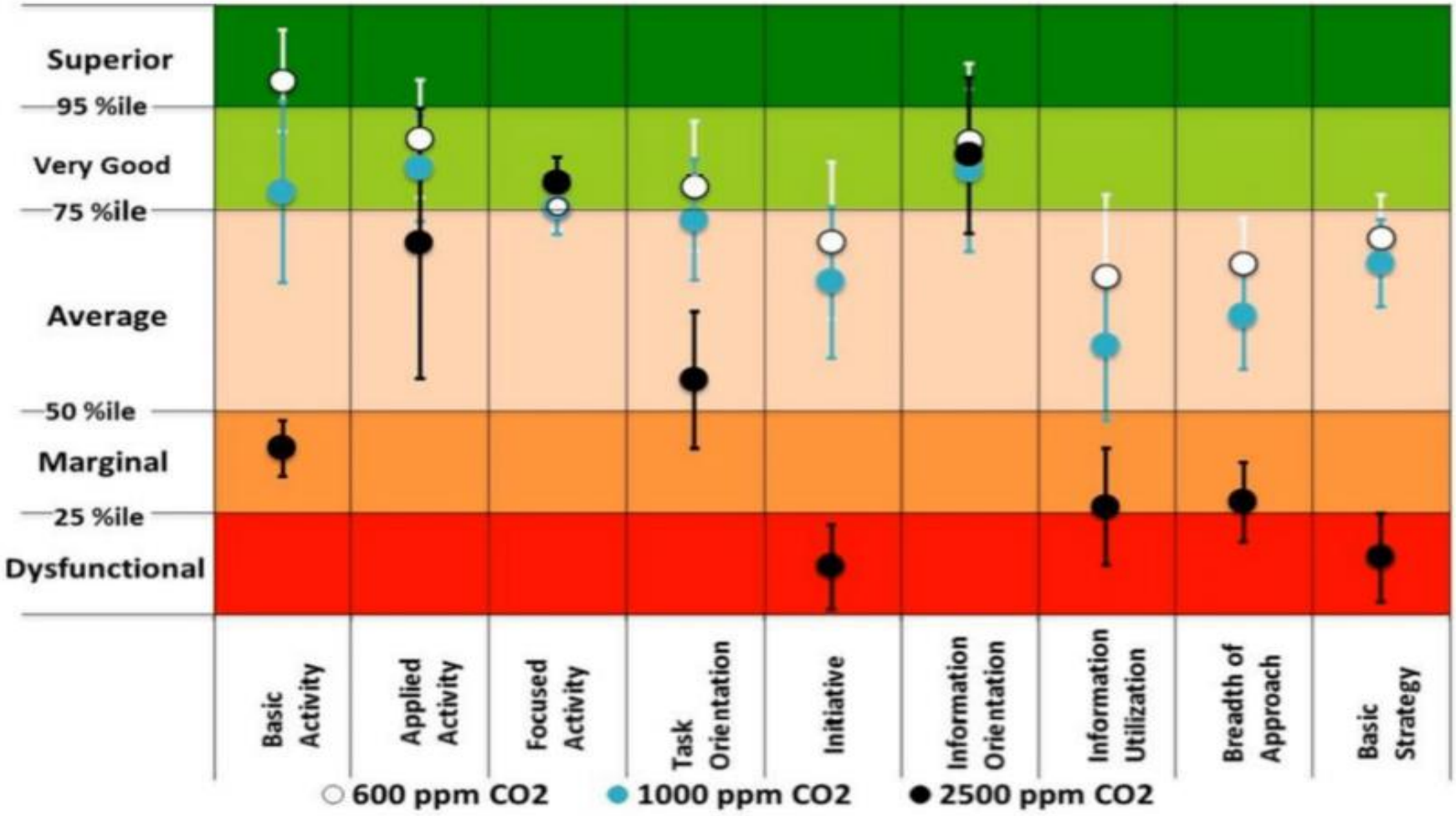
"Outside air is essential for a healthy and effective learning environment. But outside air is at least 35% of the cooling load, 70% of the heating load and 95% of the potential humidity problems."

Four excellent reasons to…

ventilate appropriately but only when the kids are there.

Std. 90.1 has several smart O/A management schemes

CO_2 and Cognitive Performance



"Is CO2 an Indoor Pollutant? Higher Levels of CO2 May Diminish Decision Making Performance"; William J. Fisk, Usha Satish, Mark J. Mendell, Toshifumi Hotchi, Douglas Sullivan; Indoor Environment Group Lawrence Berkeley National Laboratory Berkeley, CA; March 2013

Over ventilating does not improve performance.

Night

when is your humidity exposure is most severe

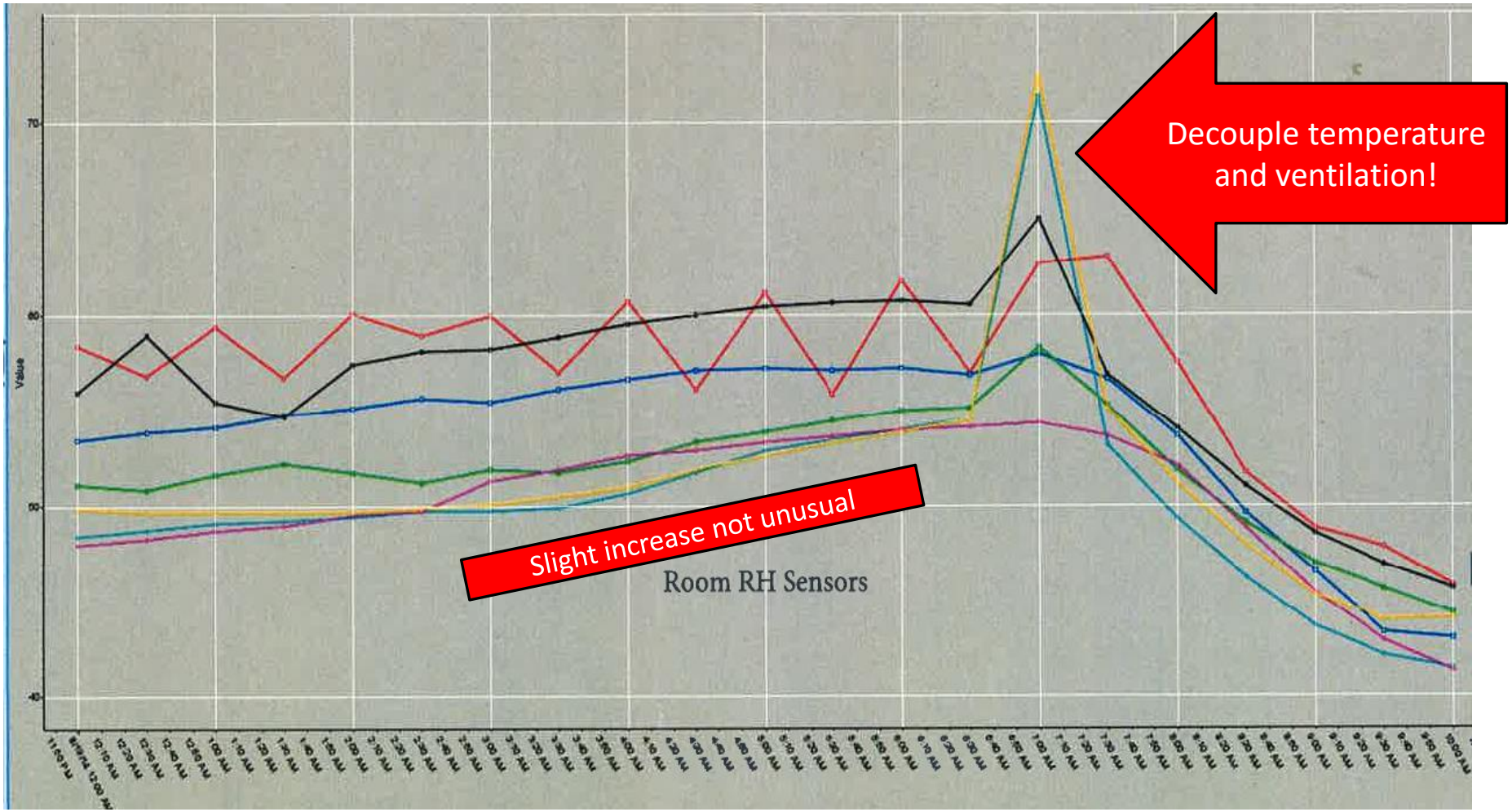
- Dew on the grass = 100% rH
- Outside temp below room temp = no load
- Unoccupied space = almost zero load
- Exhaust fans running at night = building negative pressure = lots of infiltration

Don’t run systems in occupied mode at night!

What <u>should</u> happen at night
(or unoccupied)

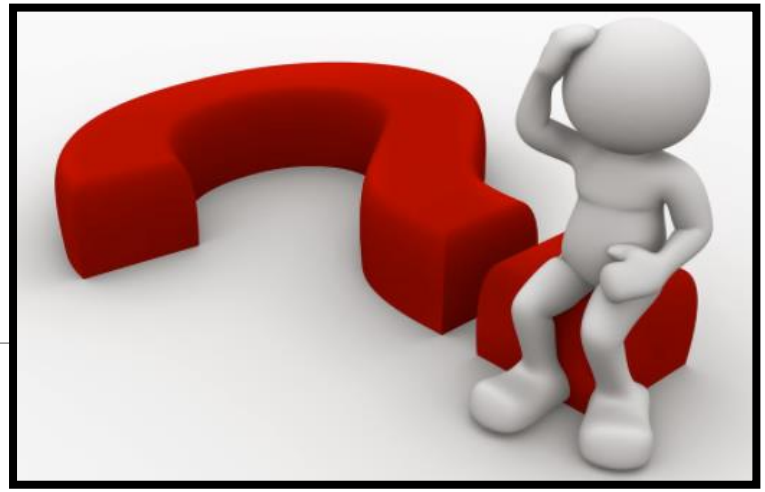
- All exhaust fans off
  - Don't let building go negative
- HVAC system is off, to be started by either
  - Room temp above night set point, 78 or 80F
  - Room humidity above 60%
- AHUs run with
  - 54F LAT
  - O/A dampers closed
  - Fans on low speed, controlling to "Day" temperature
- Morning start-up in "Day-Unoccupied" mode

What does happens at night?



Courtesy: Jerry Weber, PE

The Problem



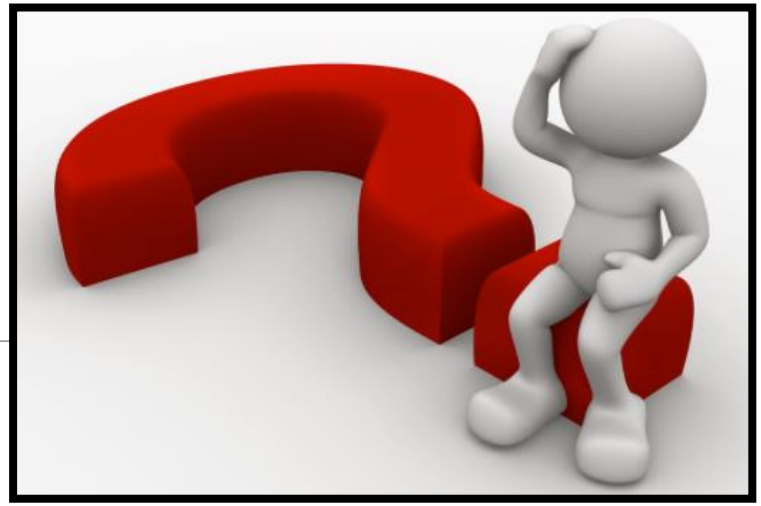
The moisture comes from outside air

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

Not an option when codes require continuous ventilation

Take A Fresh Look at Face and Bypass

The History of F&BP

The four main causes of humidity problems

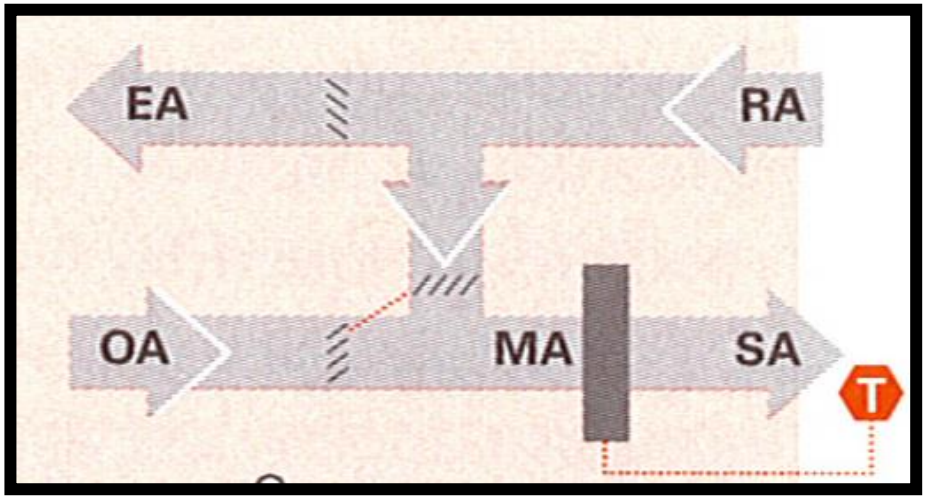
1. Valve control of constant volume equipment
2. Oversized air side equipment
3. Building under negative pressure, i.e. not controlling exhaust fans
4. Around-the-clock operation

Take A Fresh Look at Face and Bypass

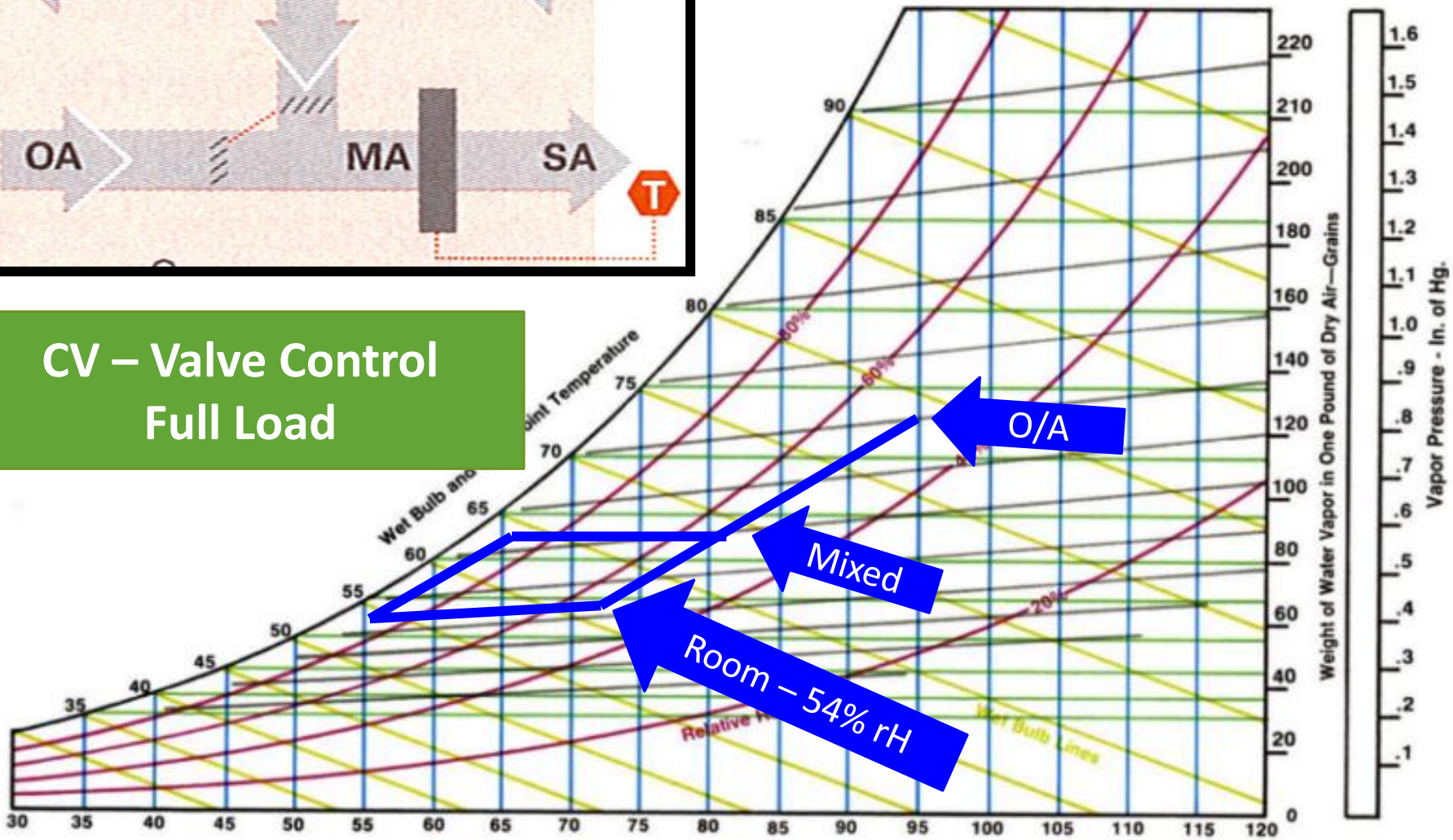
A constant volume system operating at a part load condition that would be satisfied by a LAT of 65F

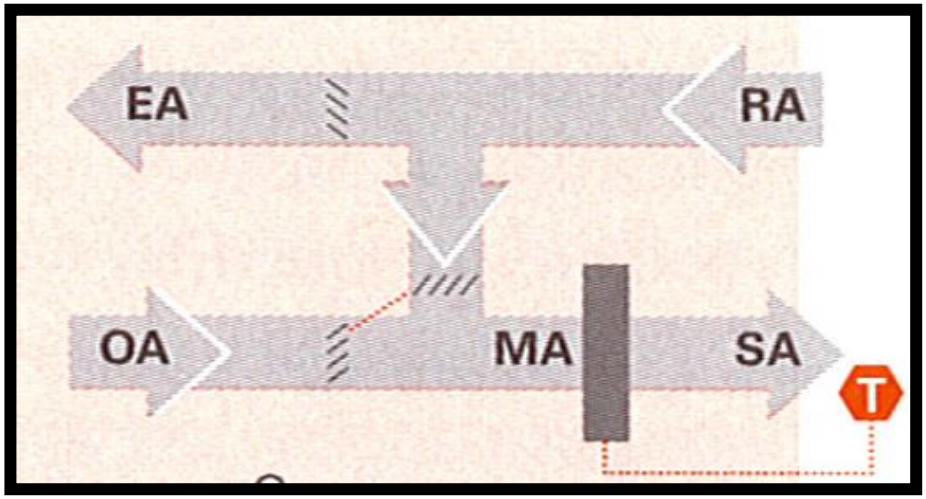
- Valve control = 68% rH, $0.20/hr
- F&BP control = 56% rH, $0.22/hr
- Reheat control = 54% rH, $0.42/hr

(OAT = 95 DB/78 WB, 74F set point)

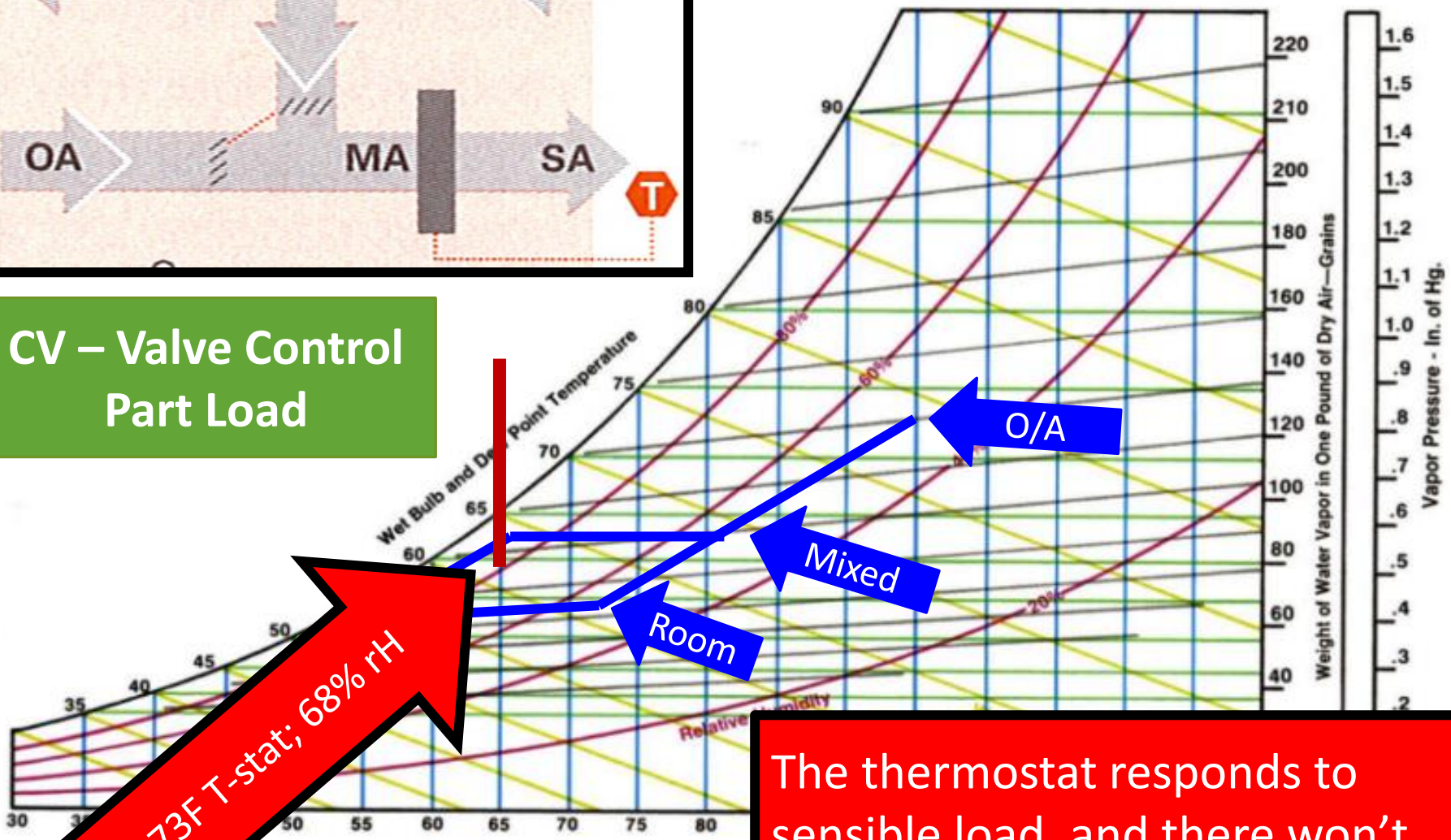


CV – Valve Control
Full Load





CV – Valve Control Part Load

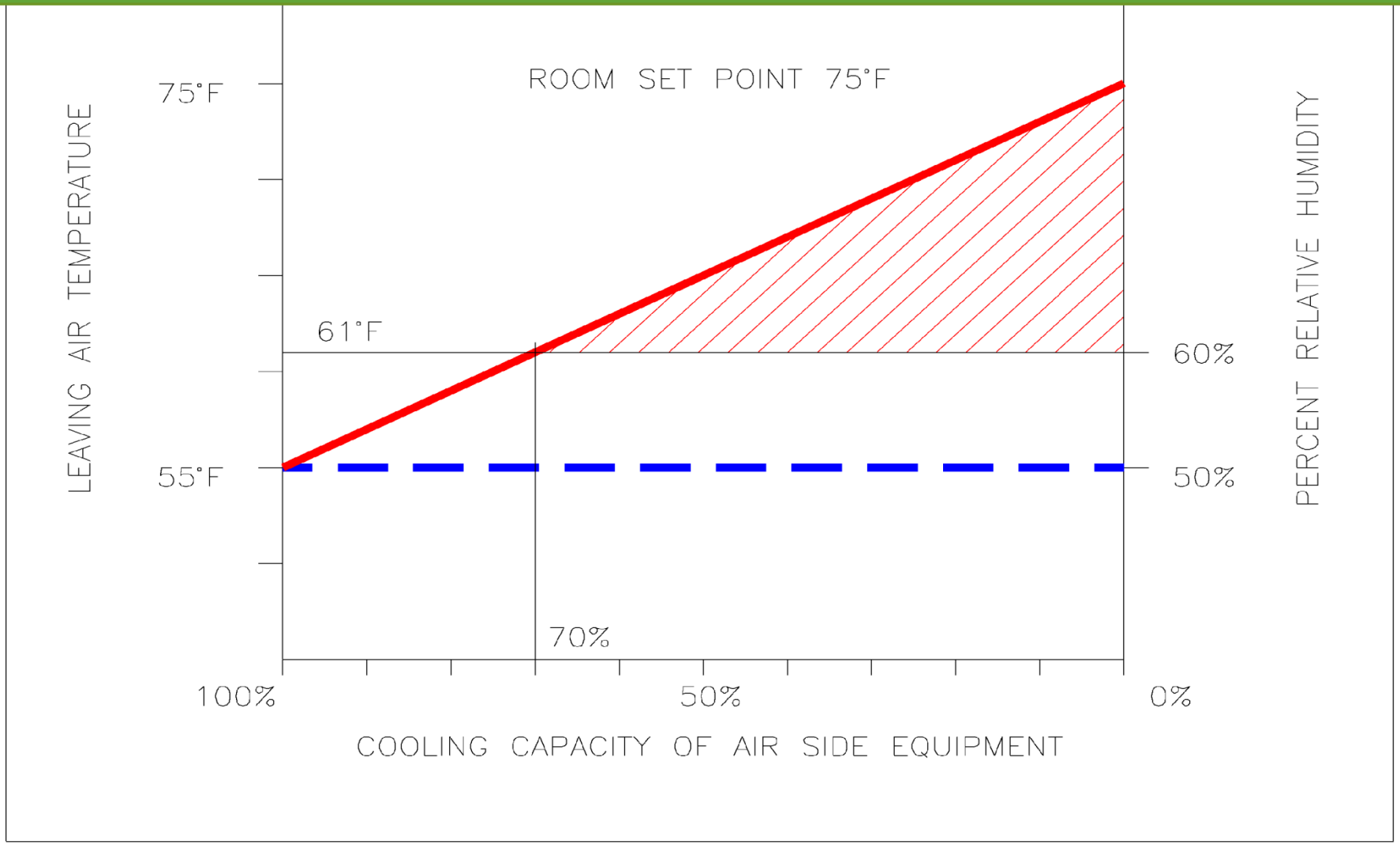


65F LAT; 73F T-stat; 68% rH

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

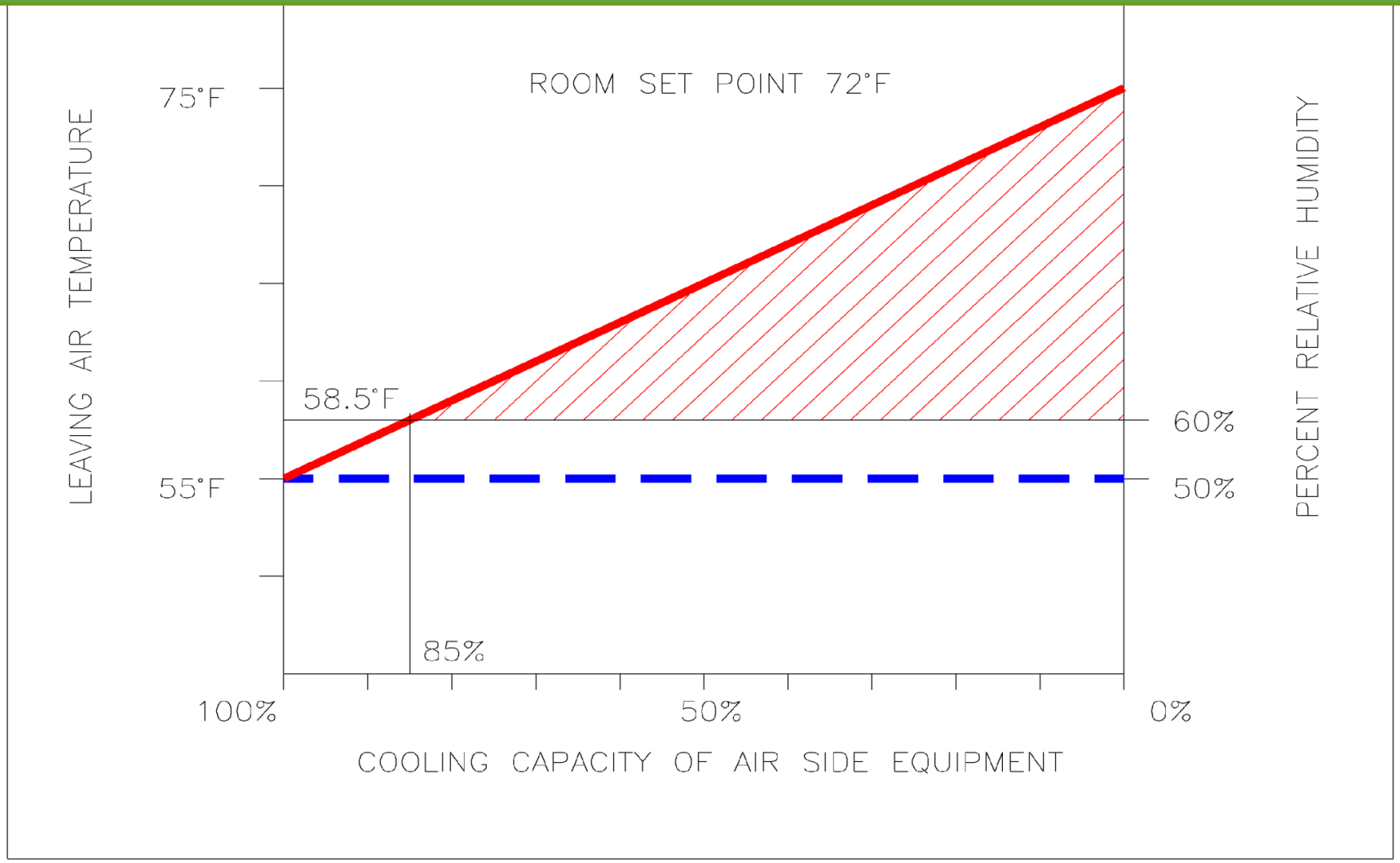
Constant Volume Valve Control HVAC

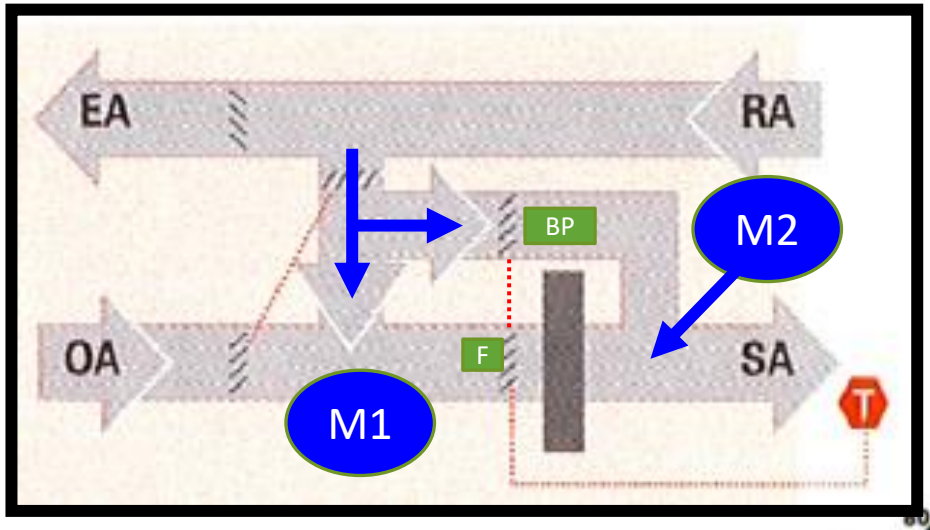
(incidental humidity control)



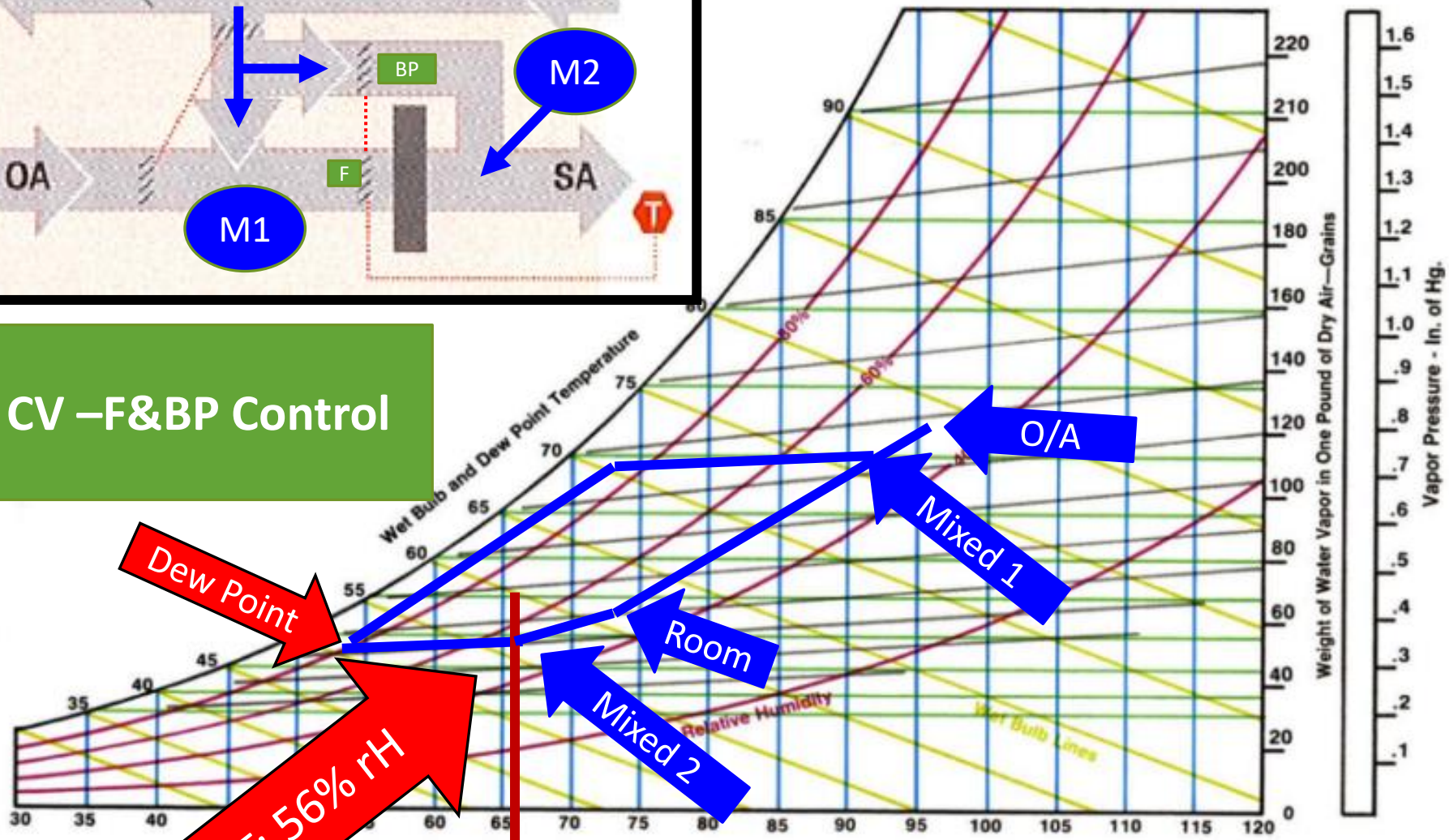
Constant Volume Valve Control HVAC

(incidental humidity control)



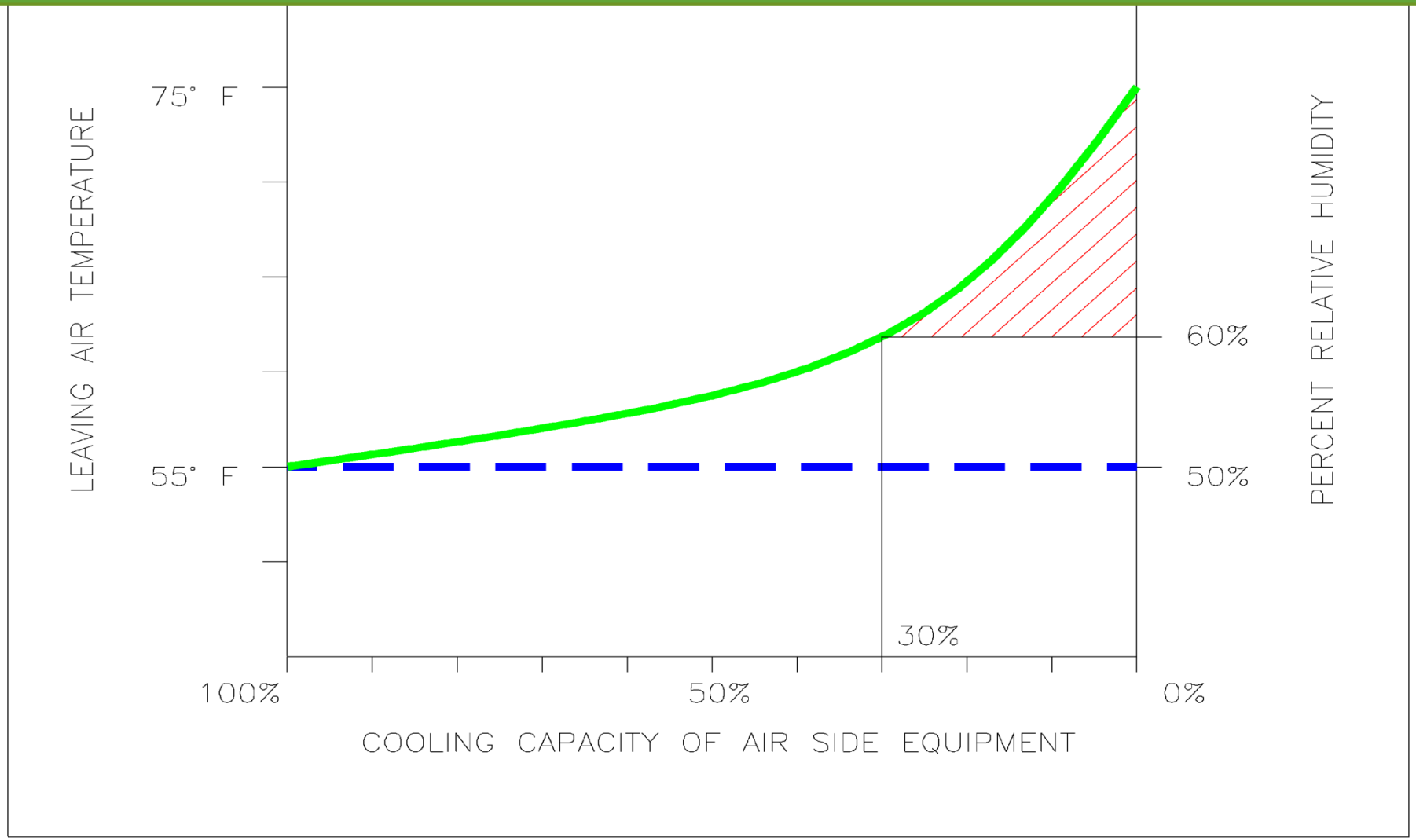


CV –F&BP Control



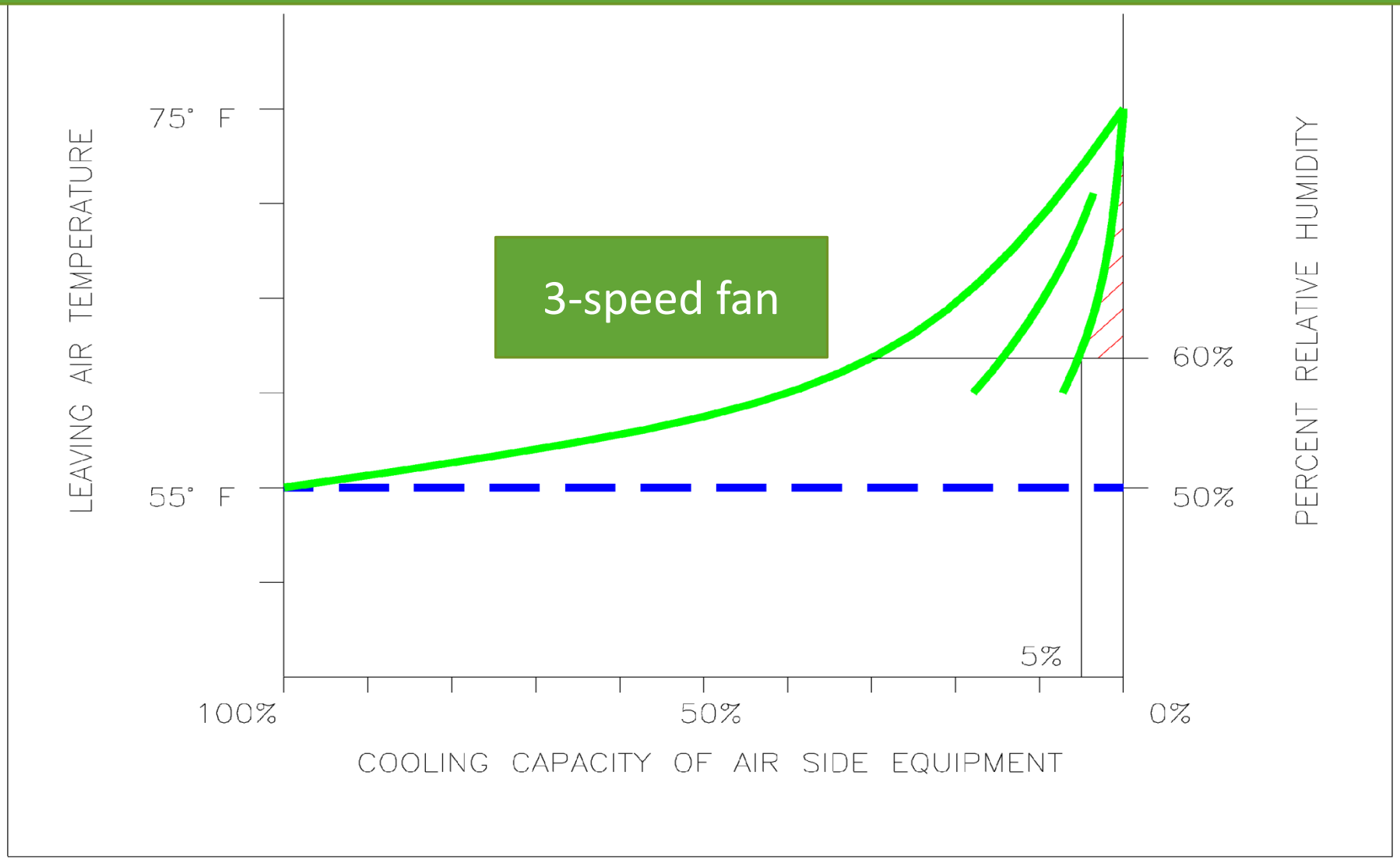
Constant Volume F&BP HVAC

(passive humidity control)



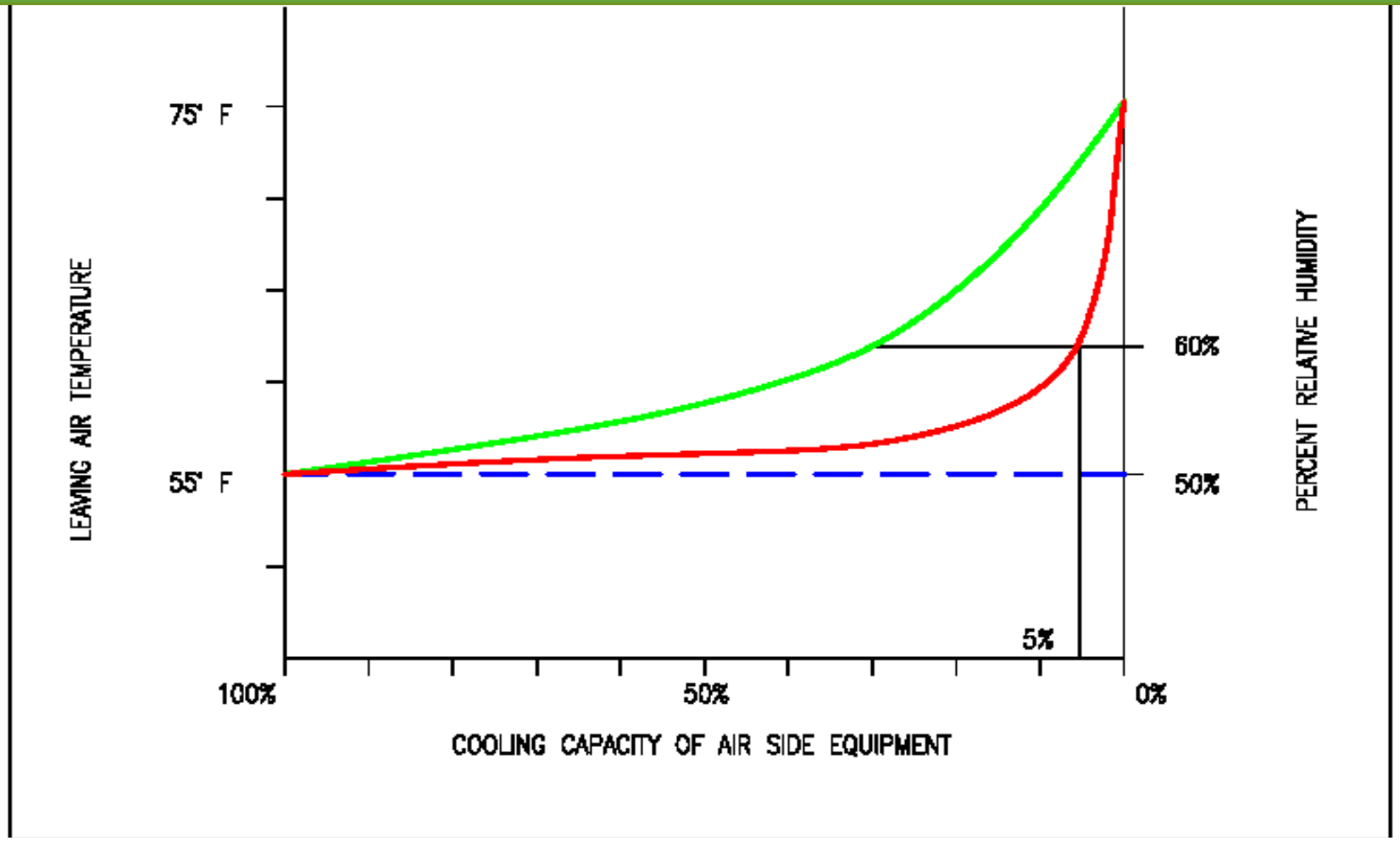
Constant Volume F&BP HVAC

(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 CO_2 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

[redacted]

engineers newsletter

providing insights for today's hvac system designer

it may take more than you think to

Dehumidify with Constant-Volume Systems

from the editor…
ASHRAE Standard 62, "Ventilation for Acceptable Indoor Air Quality," recommends that the relative humidity not exceed 60 percent at any load

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 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…

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

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

The air streams…

Outside air…never by-pass this

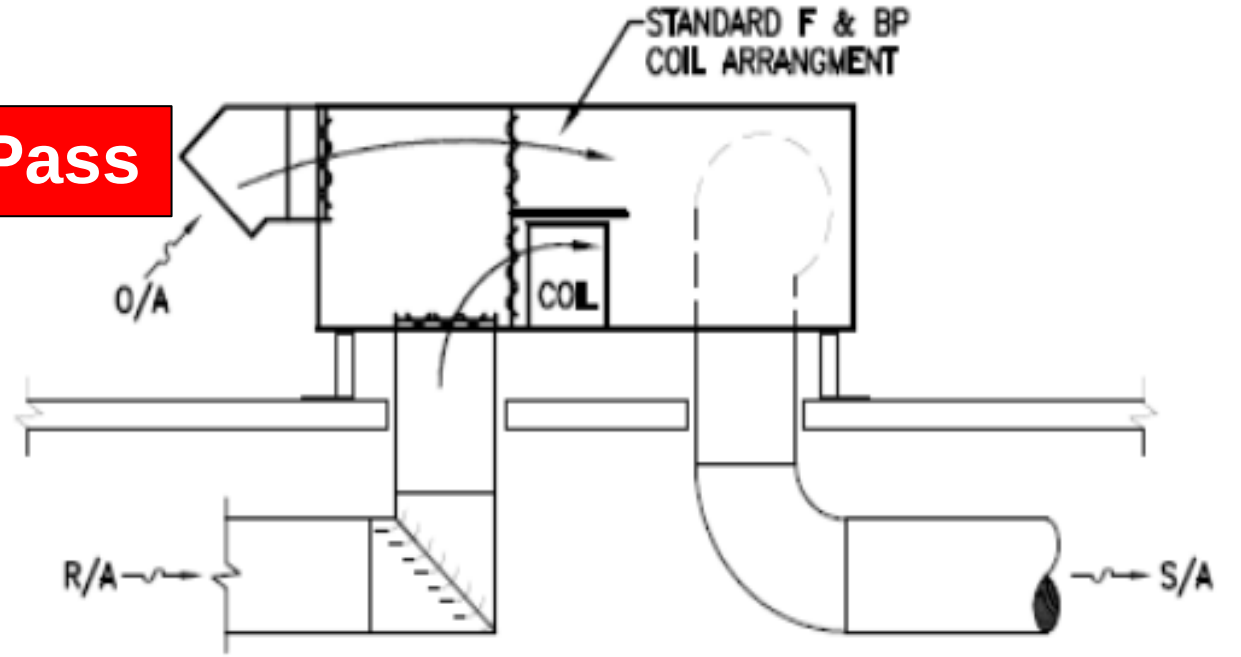
Mixed air…try to avoid by-passing this

Return air…arrange ducts and equipment to **make this happen**

Stratification is your friend!

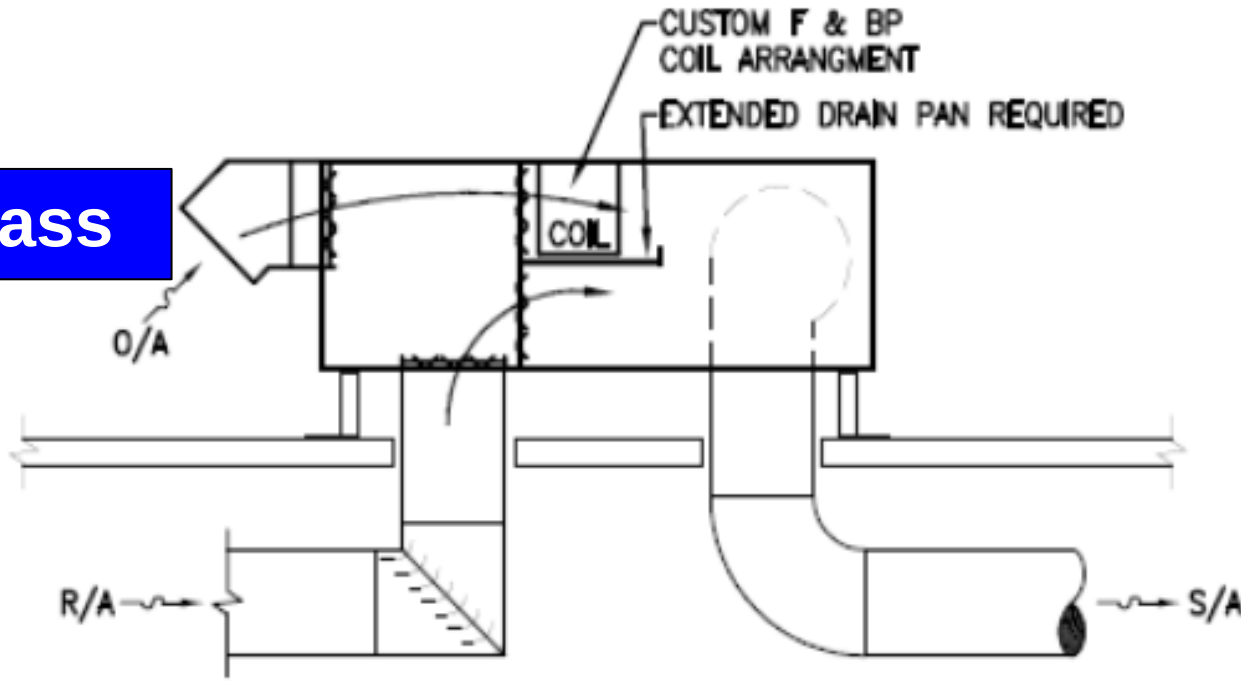
Incorrect – O/A By-Pass

Typical
Internal F&BP



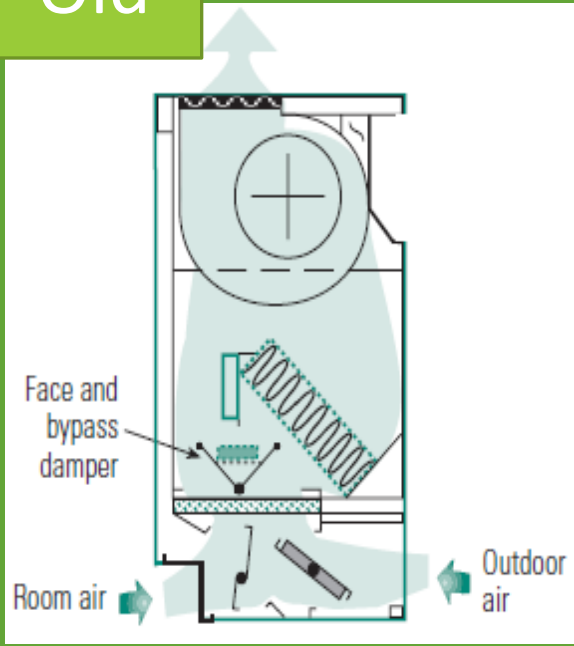
Correct – R/A By-Pass

Custom
Internal F&BP



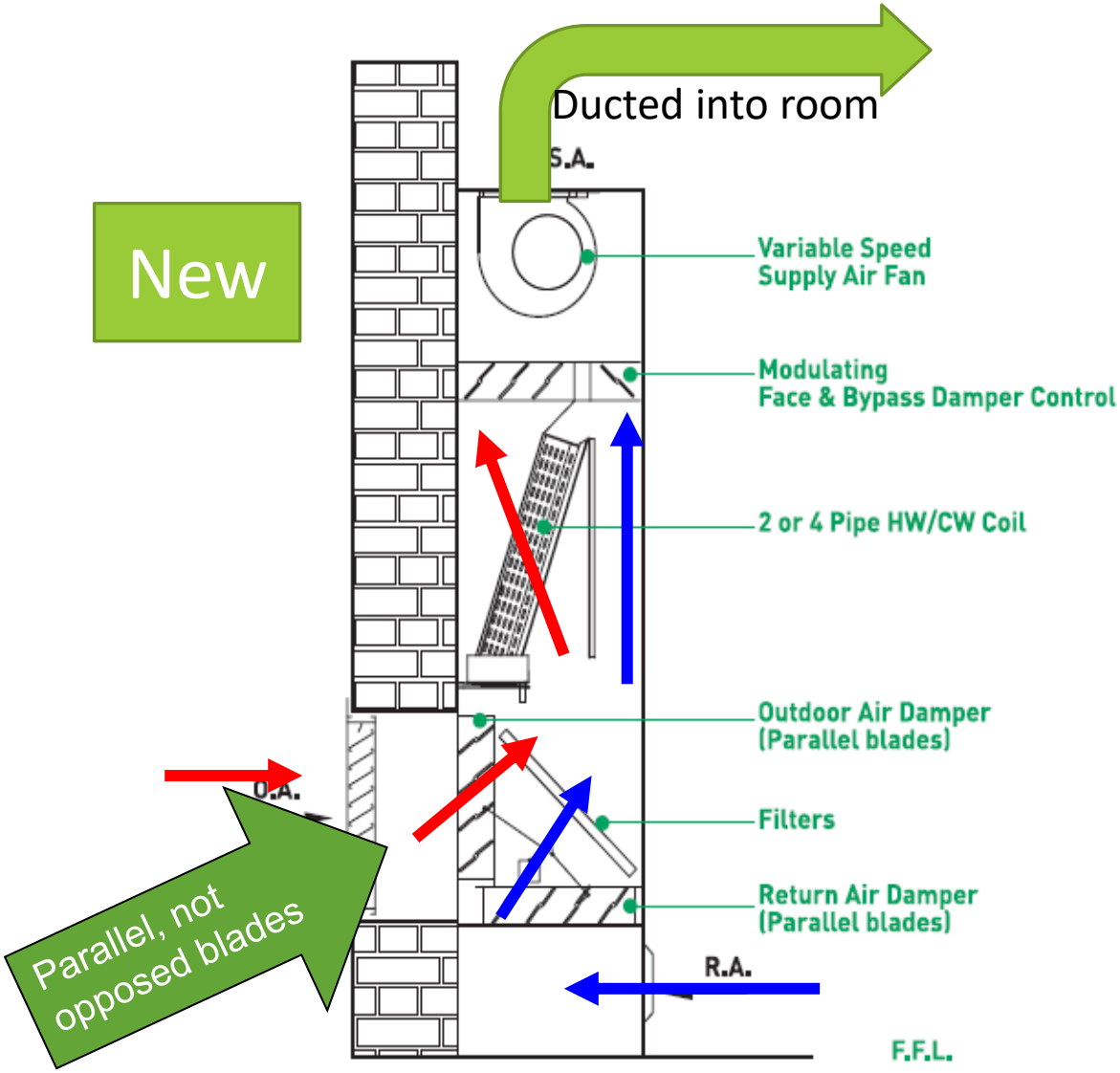
Classroom Unit Ventilator

Old



Under-the-window UV

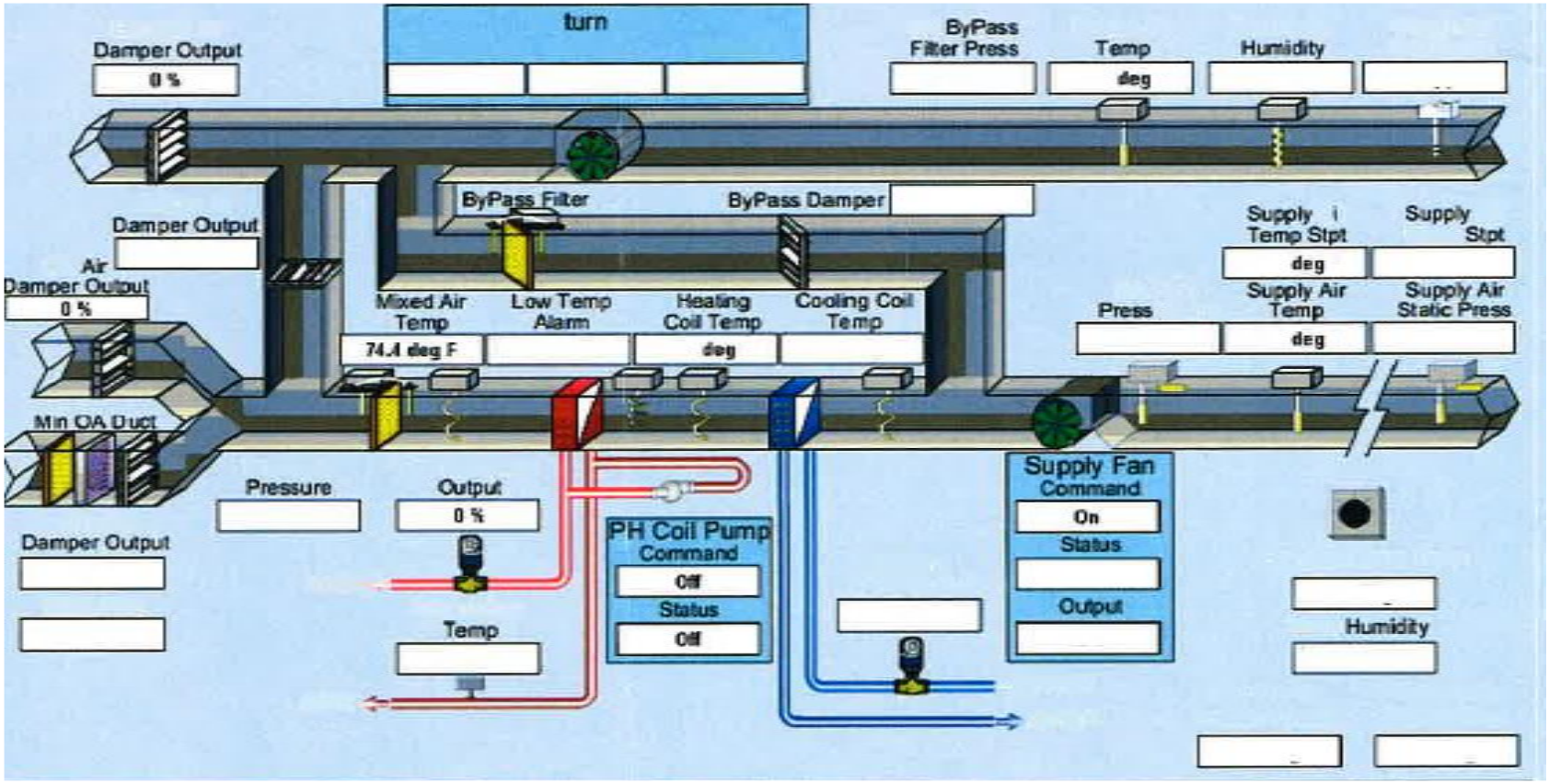
New



Vertical Ducted UV

R/A By-Pass on a VAV System

Raising SAT with zero cost reheat

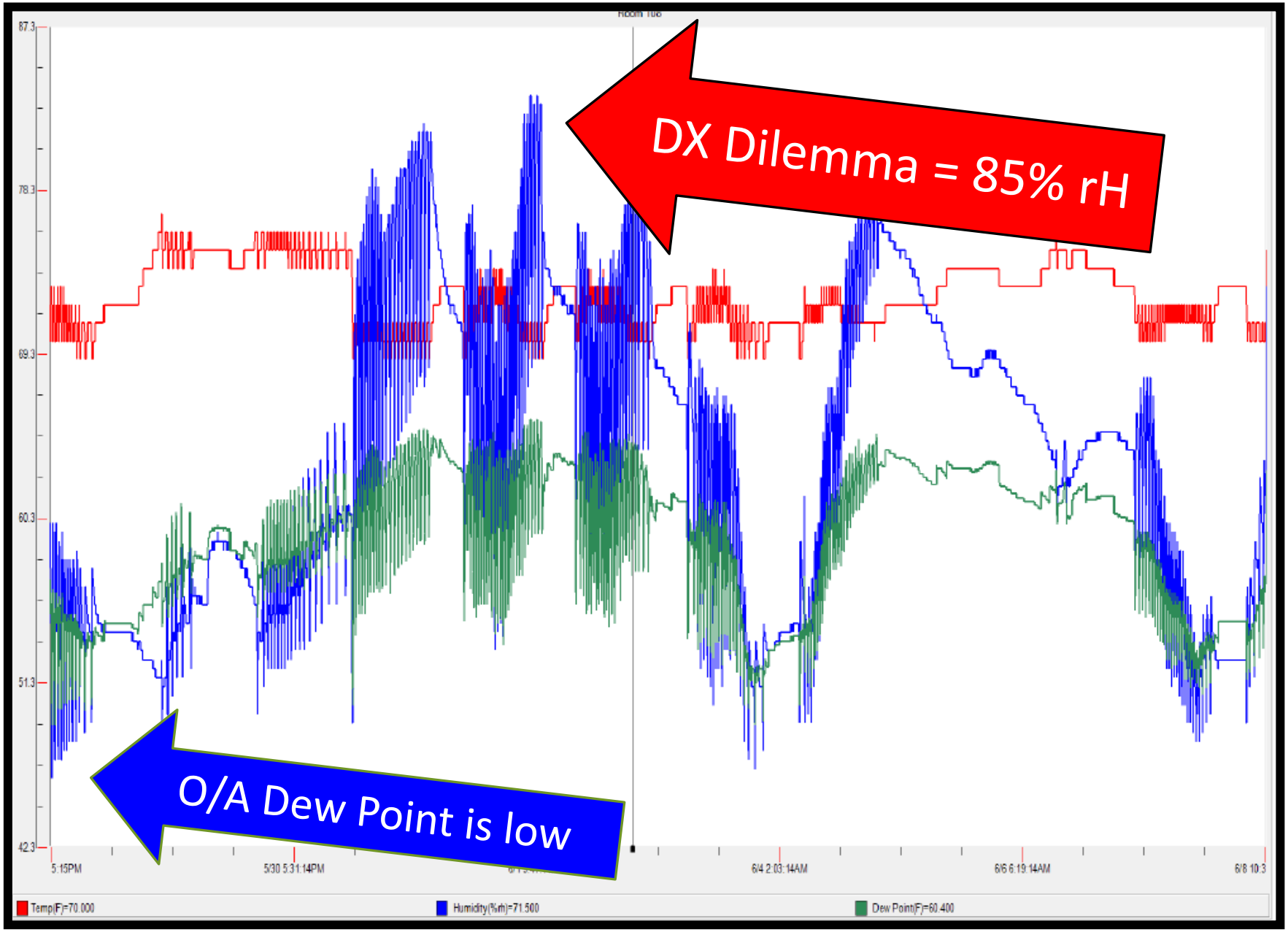


Under-floor air system

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



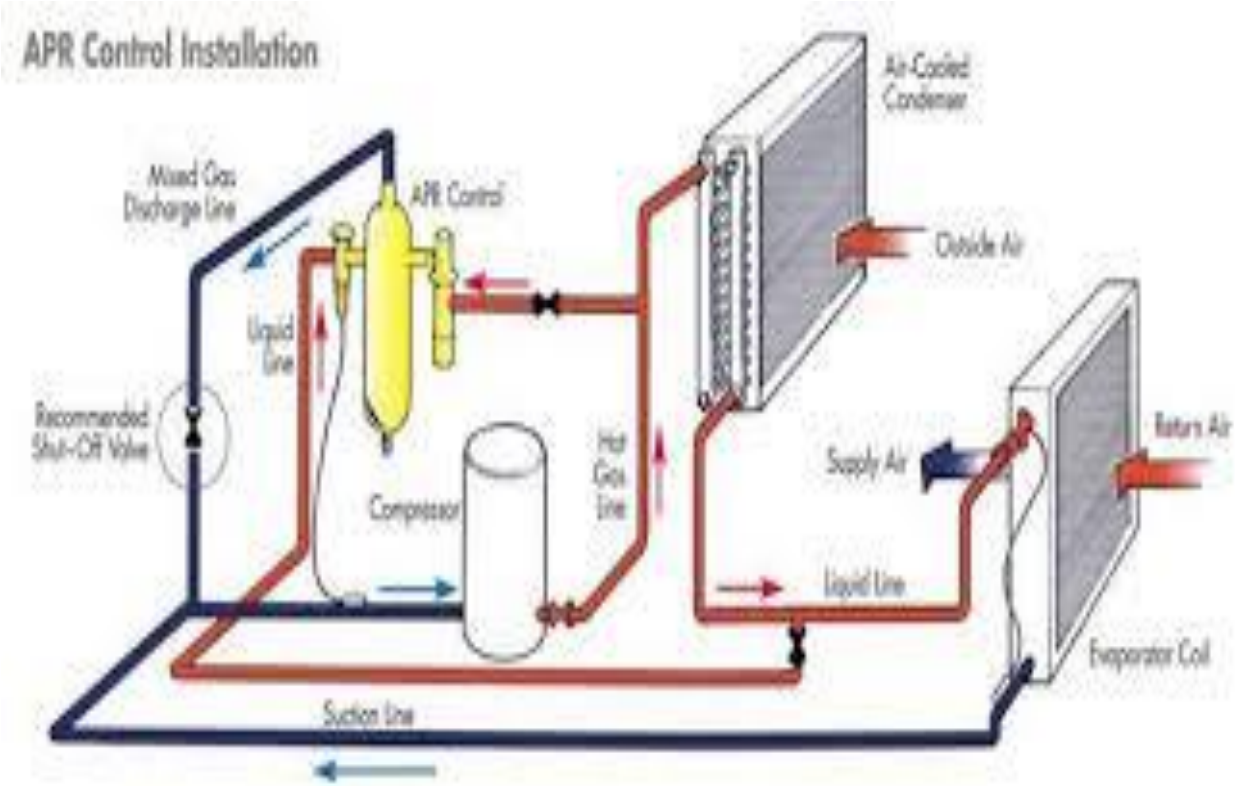
One way to make your phone ring.

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 seperate 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

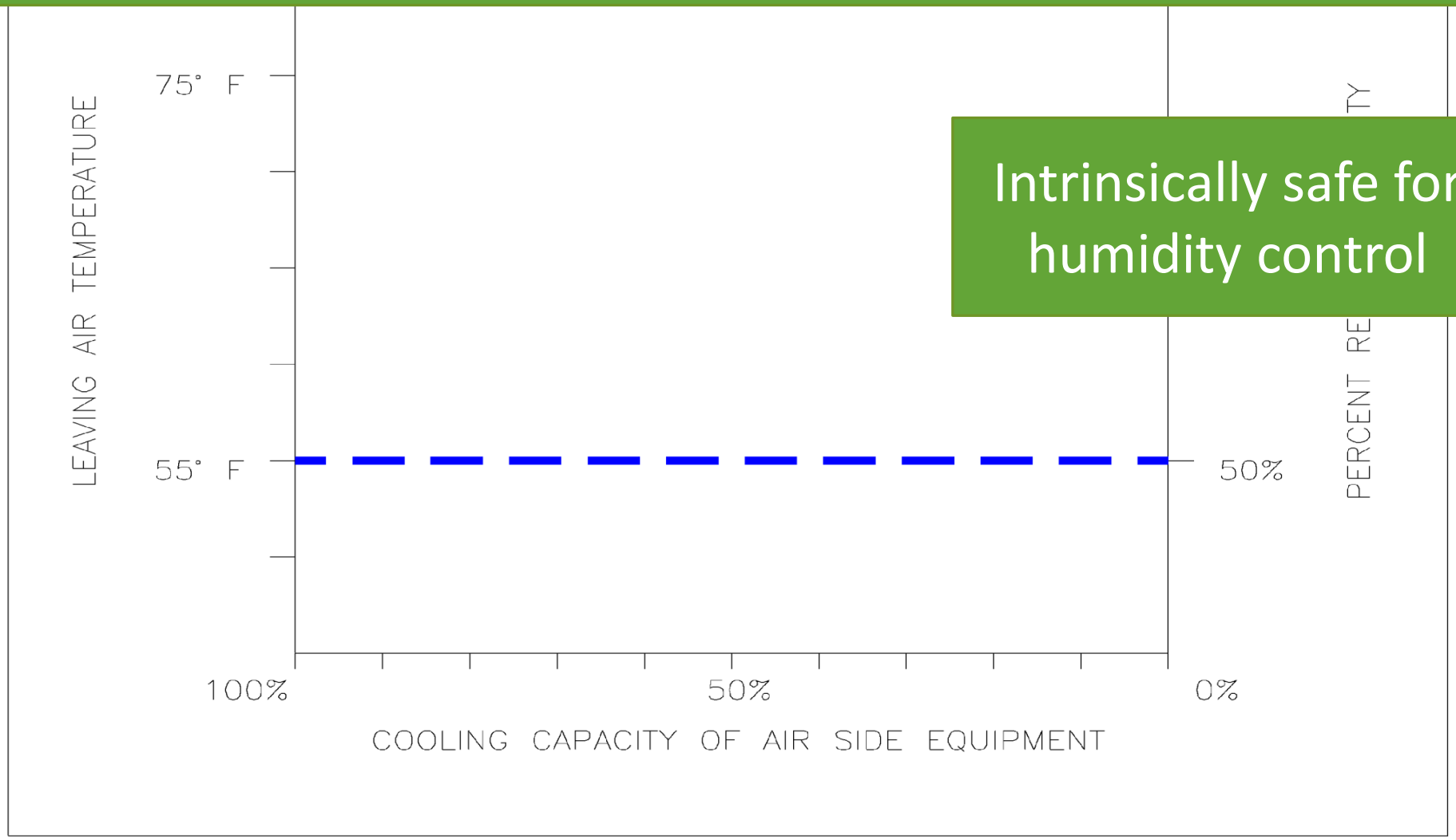
- Straight-forward solution
- Direction the industry is favoring
- If done well, it can be very efficient

Cons

- Additional infrastructure
- Cannot run economizer cooling
- Most systems are “all-on or all-off”

Variable Volume HVAC

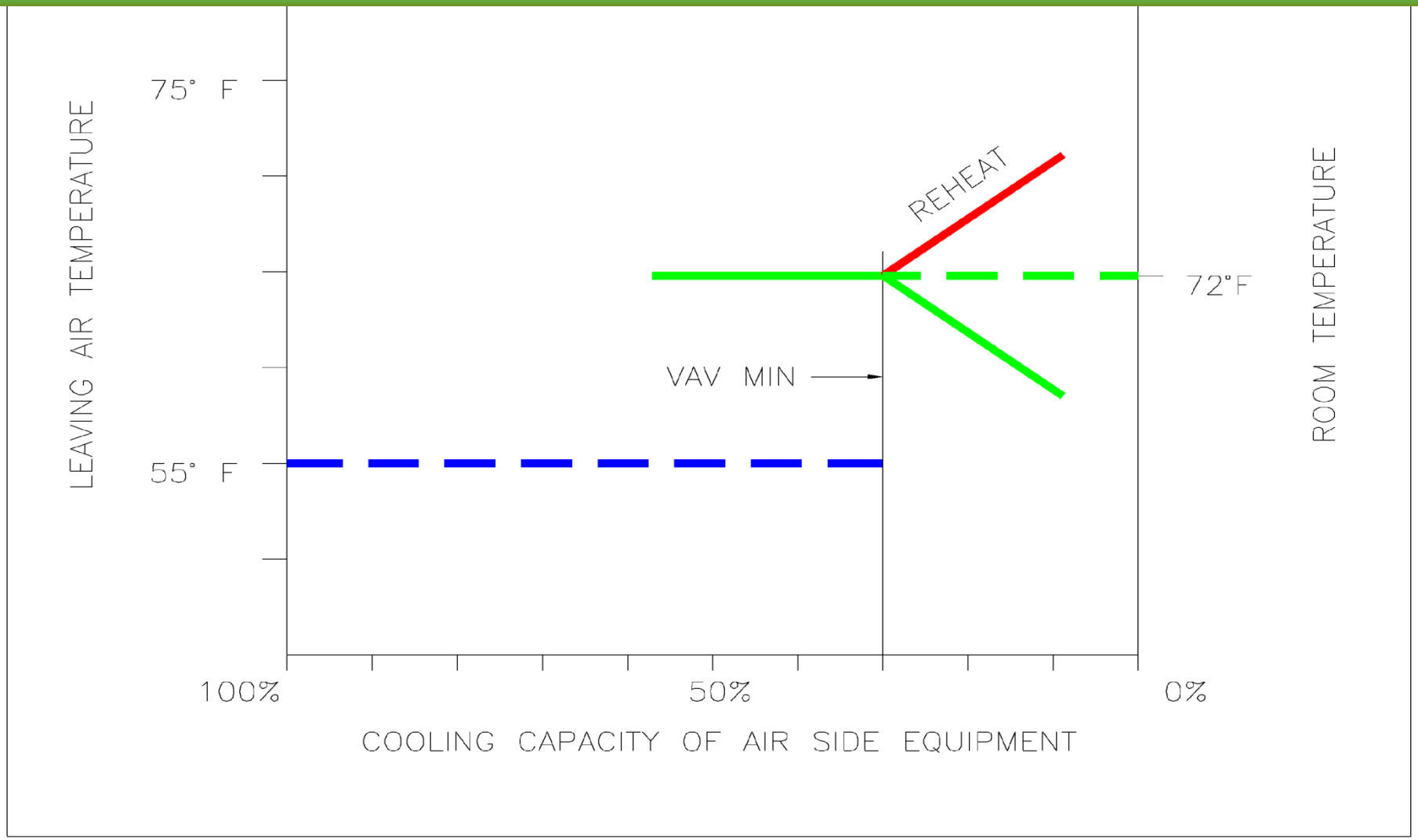
(passive humidity control)



Intrinsically safe for humidity control

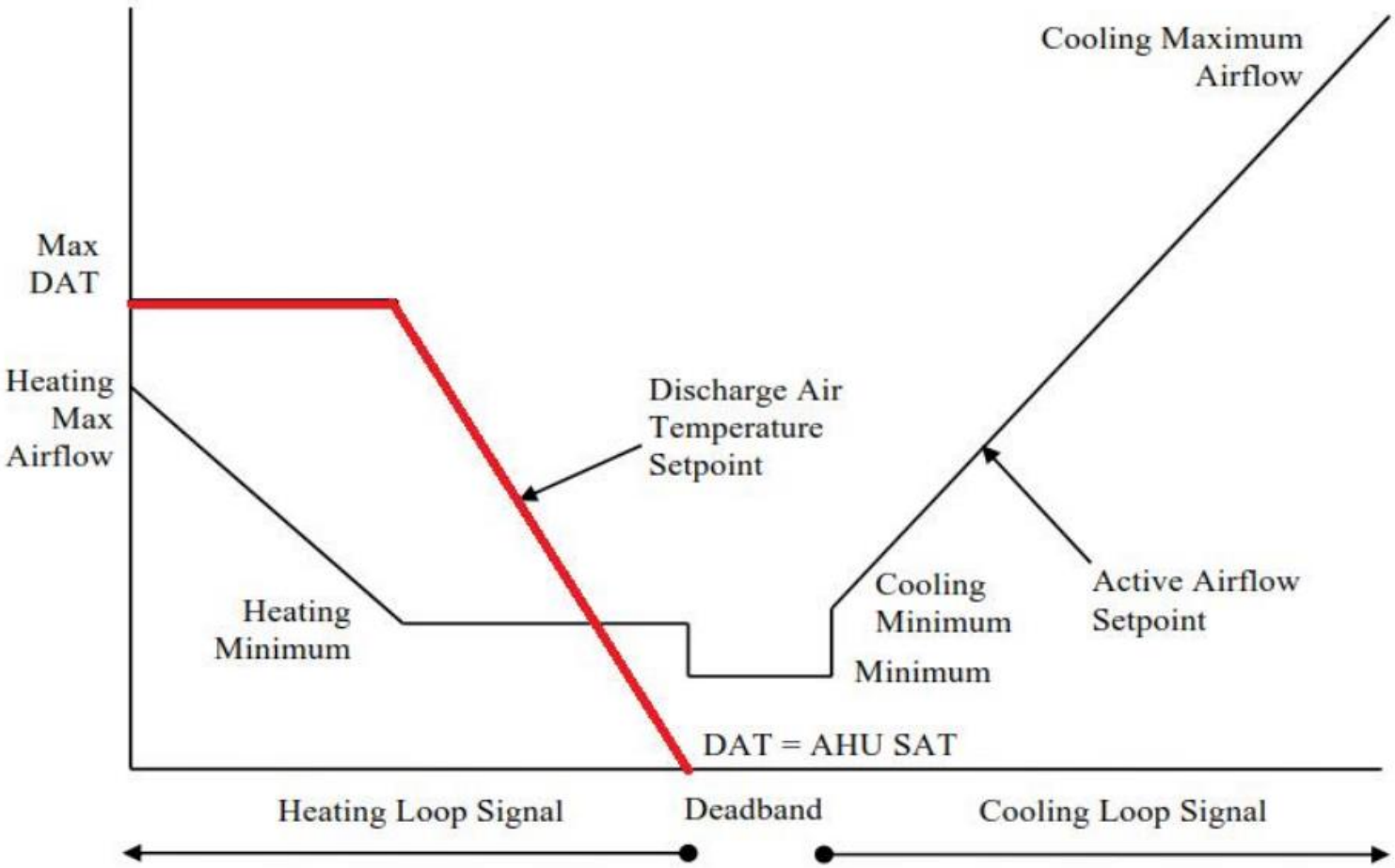
Variable Volume HVAC w/RH at Min Load

(active humidity control)



VAV Terminal

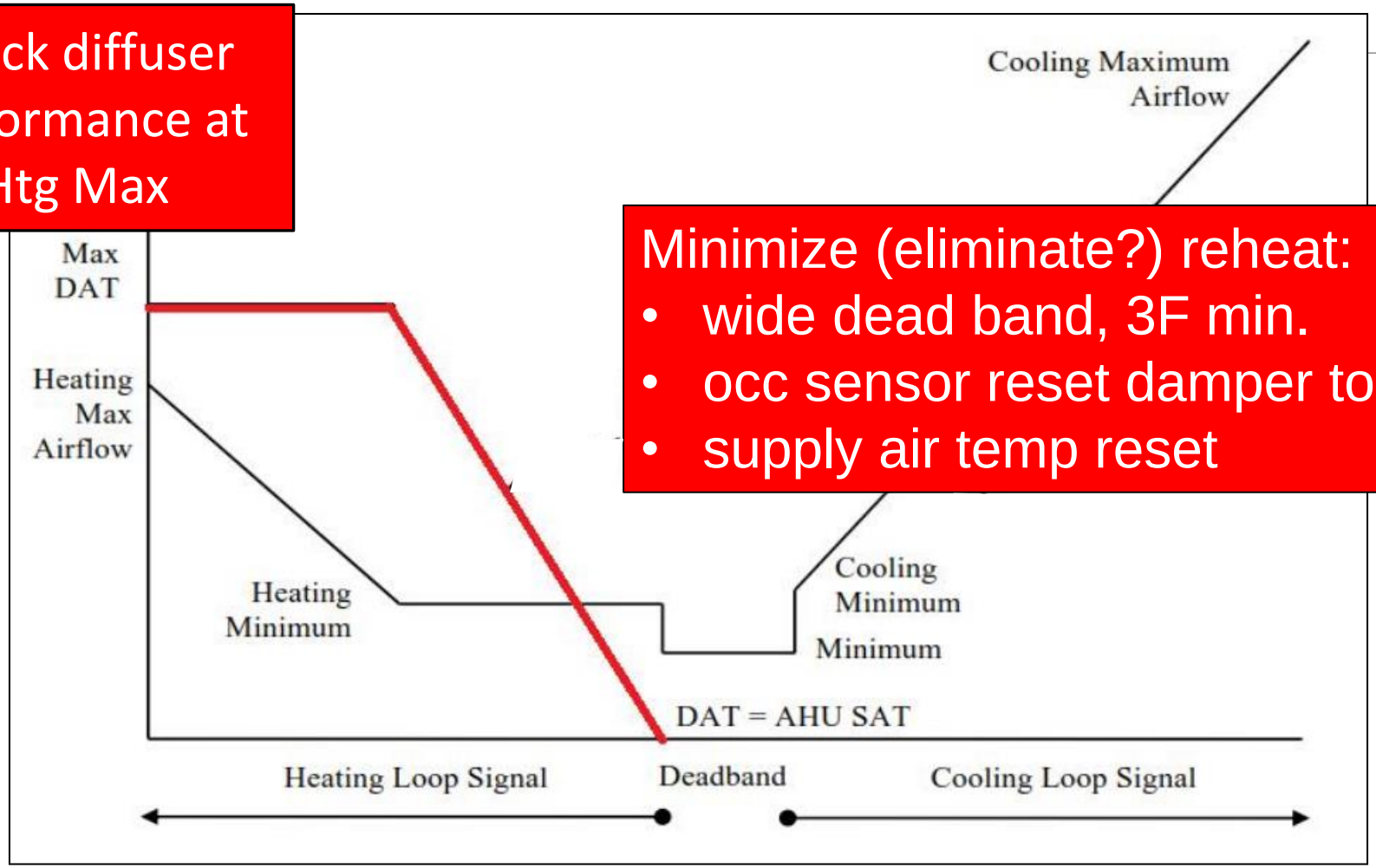
ASHRAE Guideline 36 – High performance Sequences



VAV Terminal

ASHRAE Guideline 36 – High performance Sequences

Check diffuser performance at Htg Max



Minimize (eliminate?) reheat:

- wide dead band, 3F min.
- occ sensor reset damper to zero
- supply air temp reset

Reheat Control
(active humidity control)

The usual solution for VAV systems at minimum flow

Acceptable solution for CV systems

- Review Std. 90.1

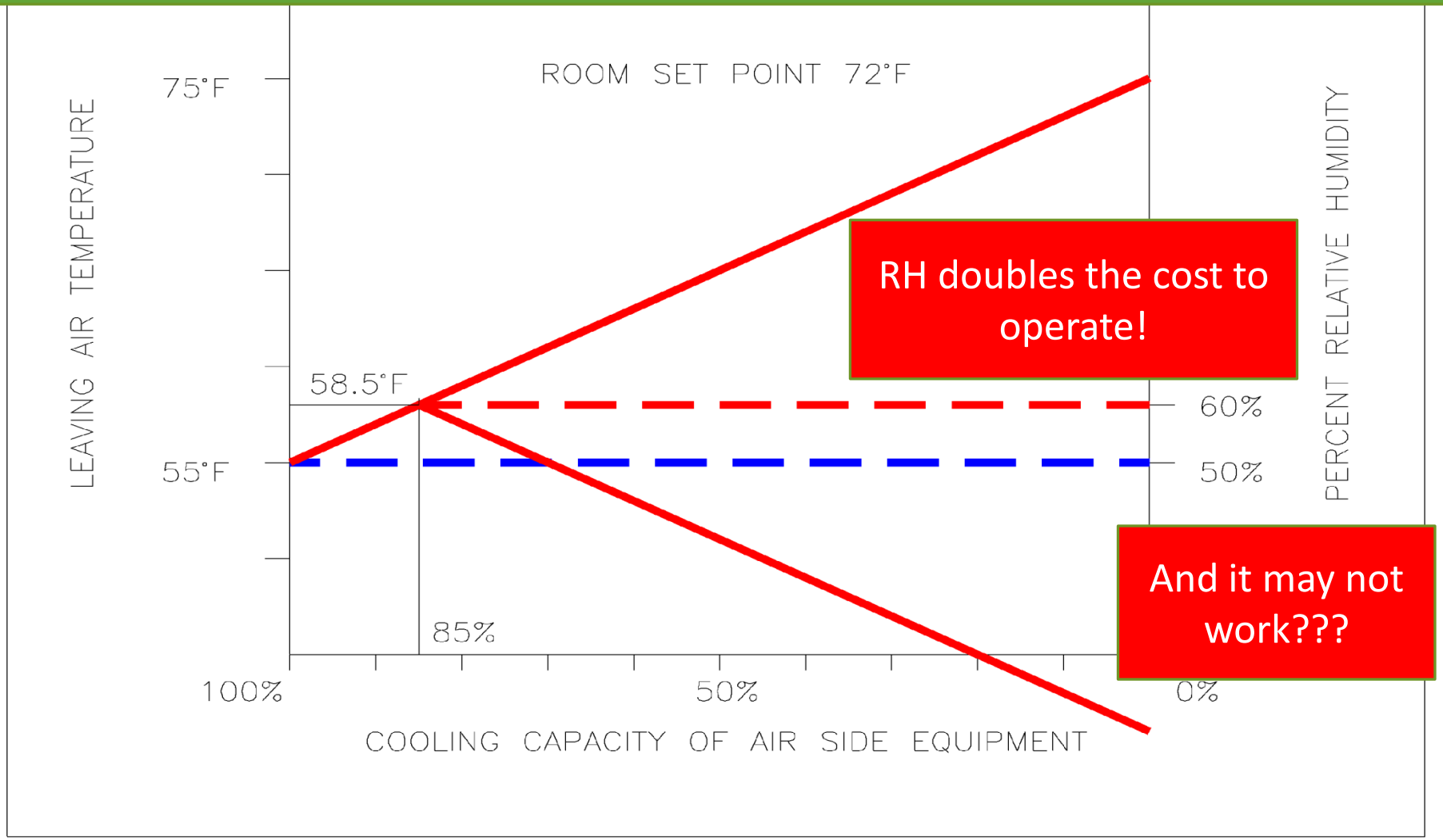
A heating source available 12 months of the year

Requires either

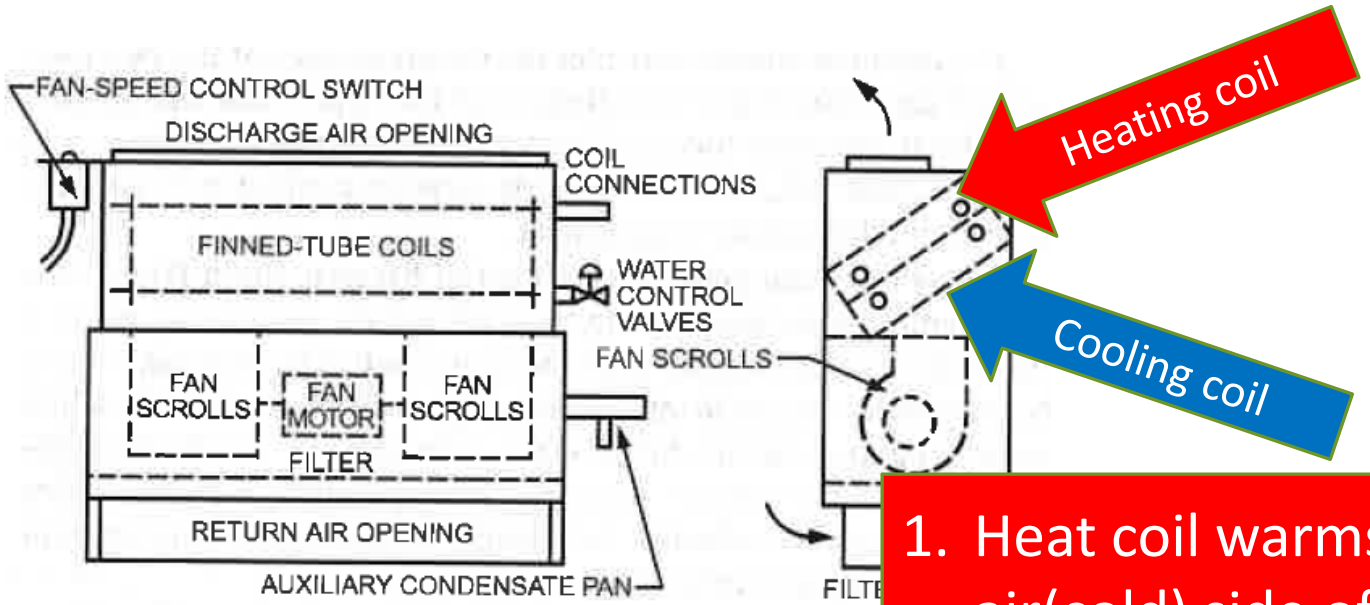
- Heating coil in the reheat position (glycol in CHW), or
- Three coil unit, and
- Additional controls (humidistat)

Constant Volume w/Reheat

(active humidity control to address "incidental" control)



Whadda ya mean it won't work?



Unit ventilators use same/or similar components; see Chapter 28 f
ventilator configurations.

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

Something will happen, but not exactly what we planned

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

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

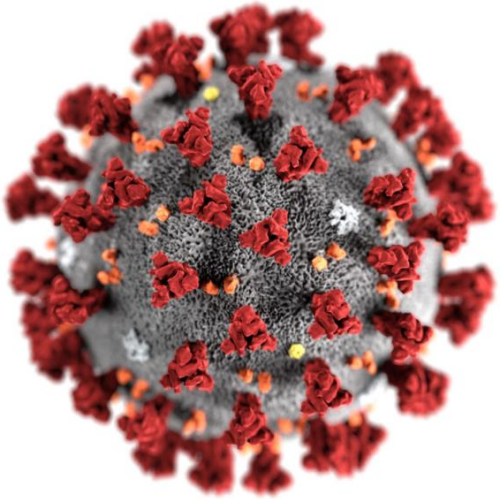
All are correct

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

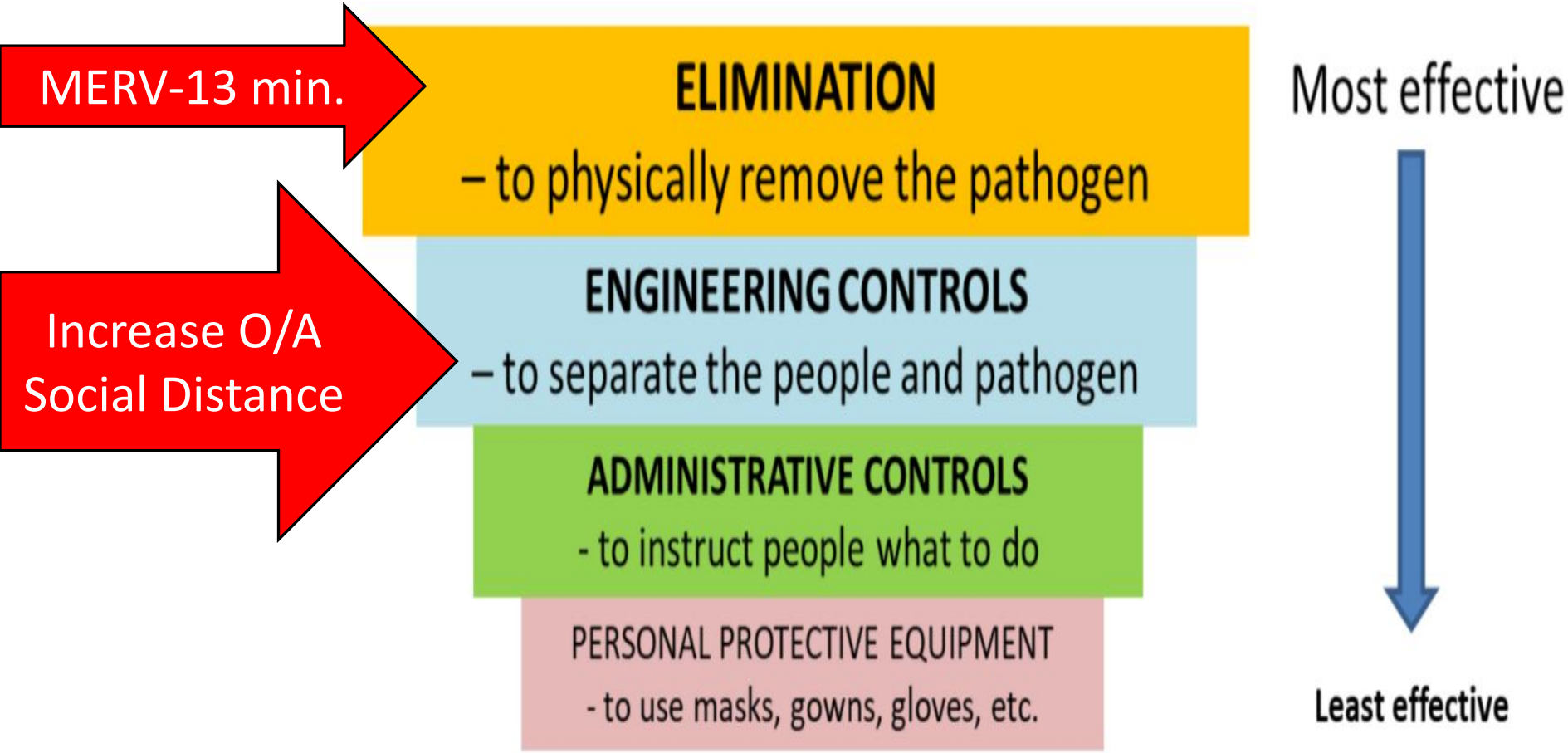


Figure 3. Traditional infection control pyramid adapted from the US Centers for Disease Control[xxxiii].

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

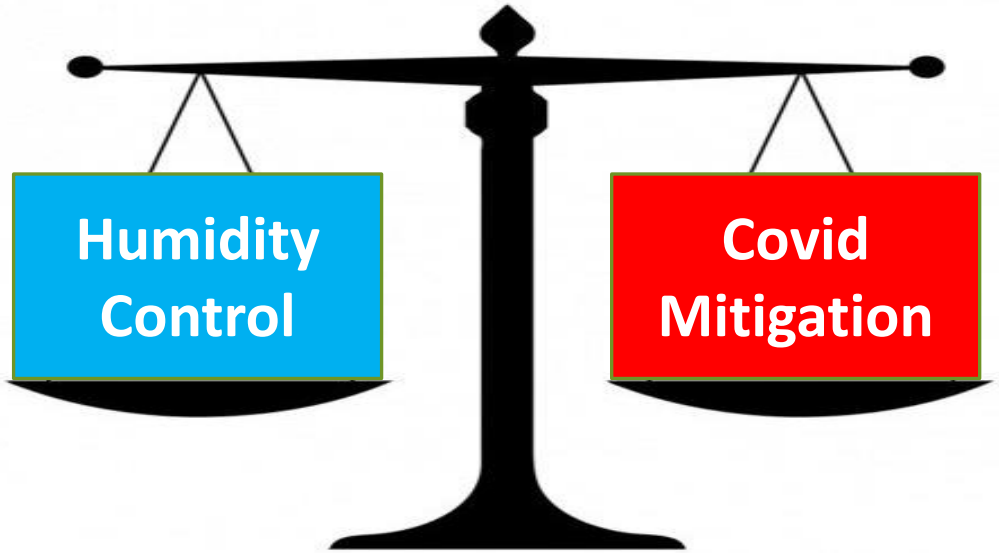
6 air changes per hour = Ideal

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

Think about

- Ventilation effectiveness, i.e. high supply/low return

A Delicate Balance



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. CO_2 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 CO_2 to limit ventilation

Track the space rH.

Questions?

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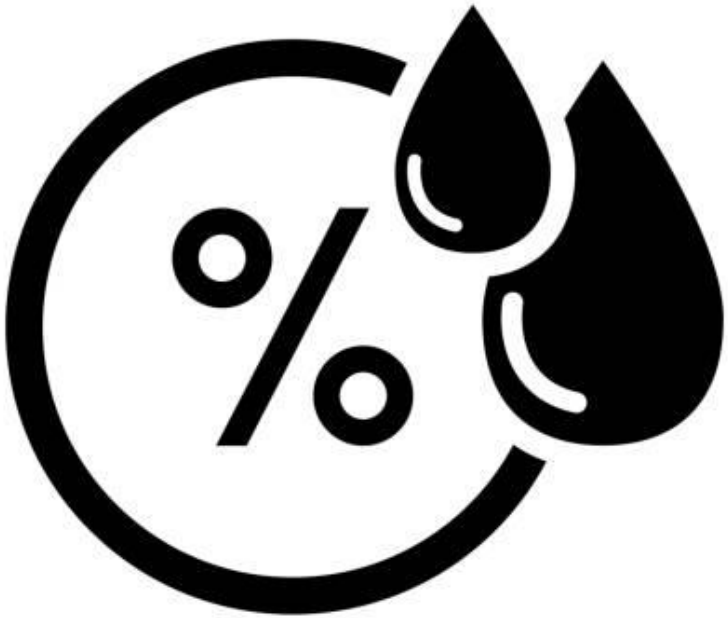

Humidity Control

Your No. 1 IAQ Liability