Tom Durkin, PE

ASHRAE Fellow

Distinguished Lecturer

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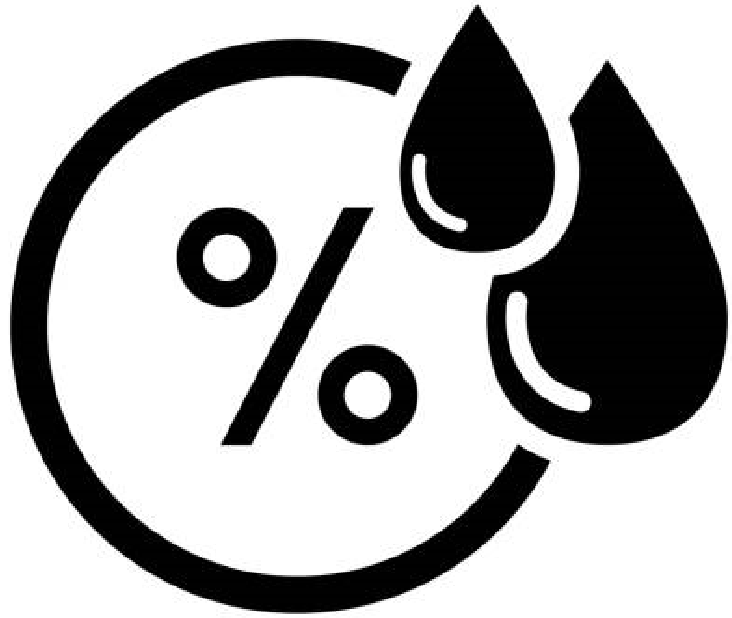


Humidity Control

Your No. 1 IAQ Liability

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

My background…

Registered Professional Engineer

18 years as a facilities/maintenance engineer and plant operator

36 years as a design engineer

LEED Accredited Professional

Licensed Boiler Inspector

Certified Energy Auditor

ASHRAE Fellow

Awards

1997, 98	Consulting Engineers of Indiana *Grand Project Award*
1998, 99	American Consulting Engineers Council *Honor Award*
1999, 2010	Governor's Pollution Prevention Award - Indiana
2002	Governor's Energy Efficiency Award - Ohio
2007	PM Magazine Design Excellence Award
2009, 2013	ASHRAE Technology Award
2012	Election to ASHRAE College of Fellows
2016	Association of Energy Engineers Achievement Award

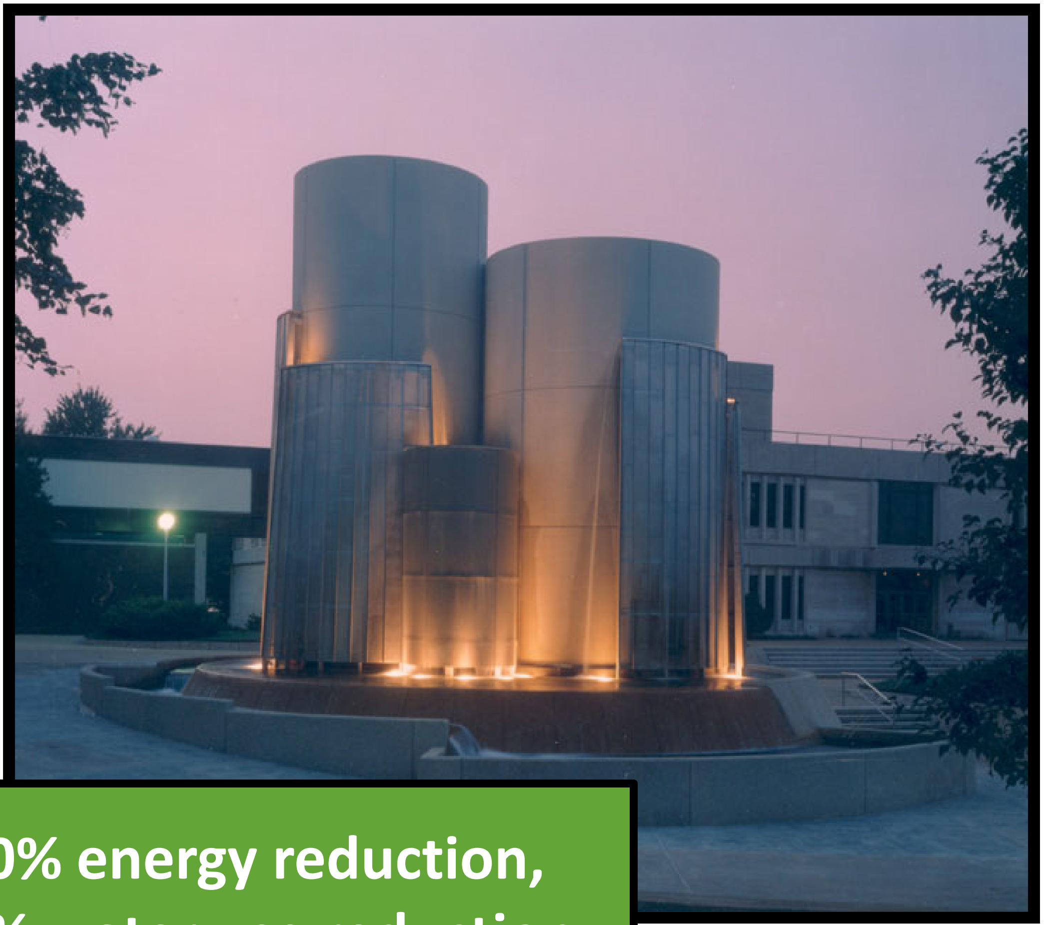
17 articles about HVAC innovations

Co-author of
HVAC Pump Handbook, Rev. 2

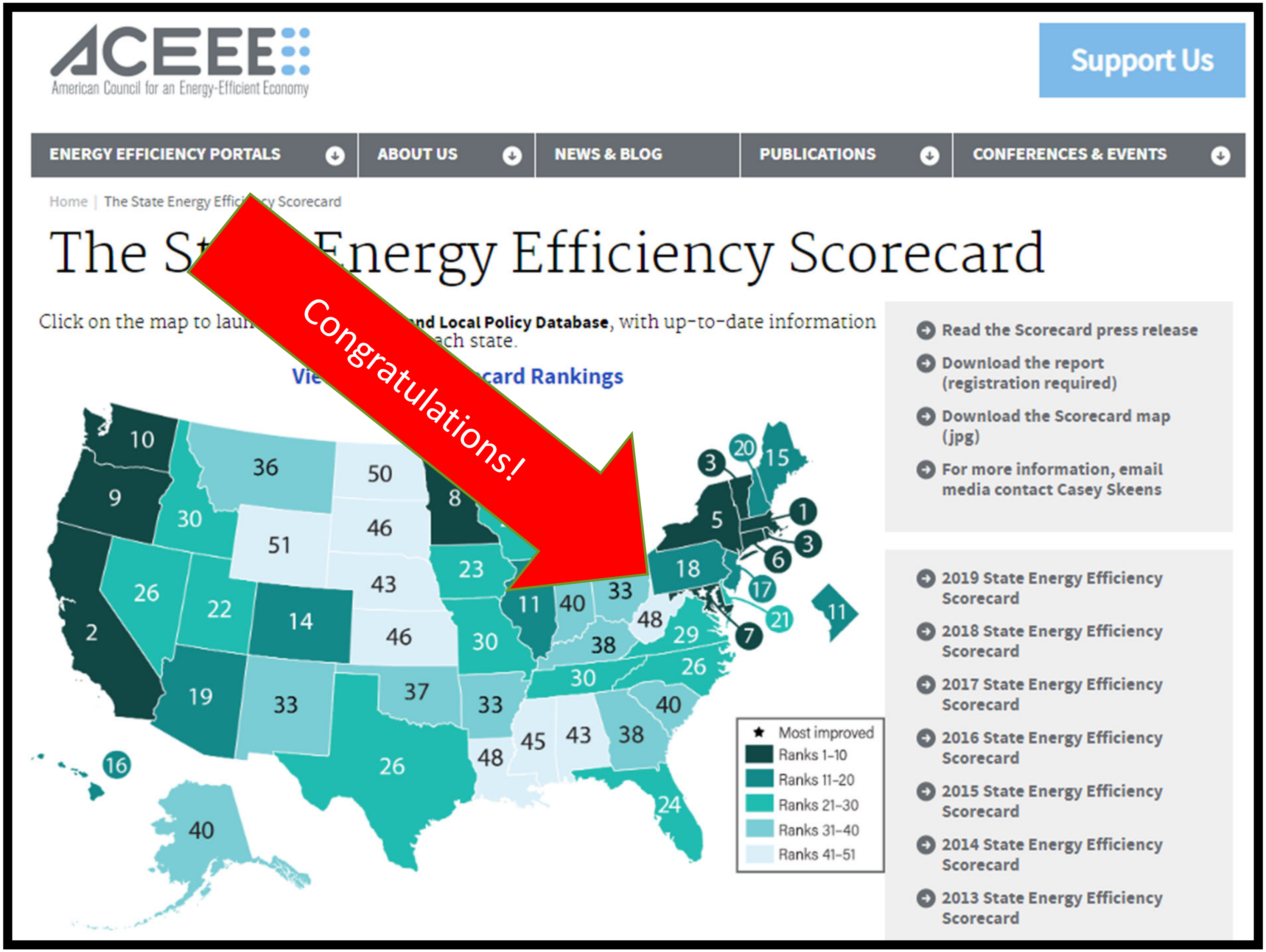
My Engineering Philosophy

Our clients are our partners, and we are stewards of their resources.

- Up-to-date, high-performance technology, judiciously applied.
- Environmentally-friendly, energy-efficient design.
- Affordable solutions that are less expensive to build.
- Simpler solutions that are easier to operate and maintain.
- On-going relationships that our clients can trust.



60% energy reduction, 95% water use reduction



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10
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21
7
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Most improved
Ranks 1–10
Ranks 11–20
Ranks 21–30
Ranks 31–40
Ranks 41–51
Read the Scorecard press release
Download the report (registration required)
Download the Scorecard map (jpg)
For more information, email media contact Casey Skeens
2019 State Energy Efficiency Scorecard
2018 State Energy Efficiency Scorecard
2017 State Energy Efficiency Scorecard
2016 State Energy Efficiency Scorecard
2015 State Energy Efficiency Scorecard
2014 State Energy Efficiency Scorecard
2013 State Energy Efficiency Scorecard


It’s not easy being green.
KERMIT THE FROG
PHOTO BY CSMACLAREN

Tom Friedman

3-time Pulitzer Prize Winner, talking about politicians who refuse to accept climate science.

A Healthy and Effective Indoor Environment

Never Compromise

- Indoor air quality
- Occupant comfort
- Humidity control

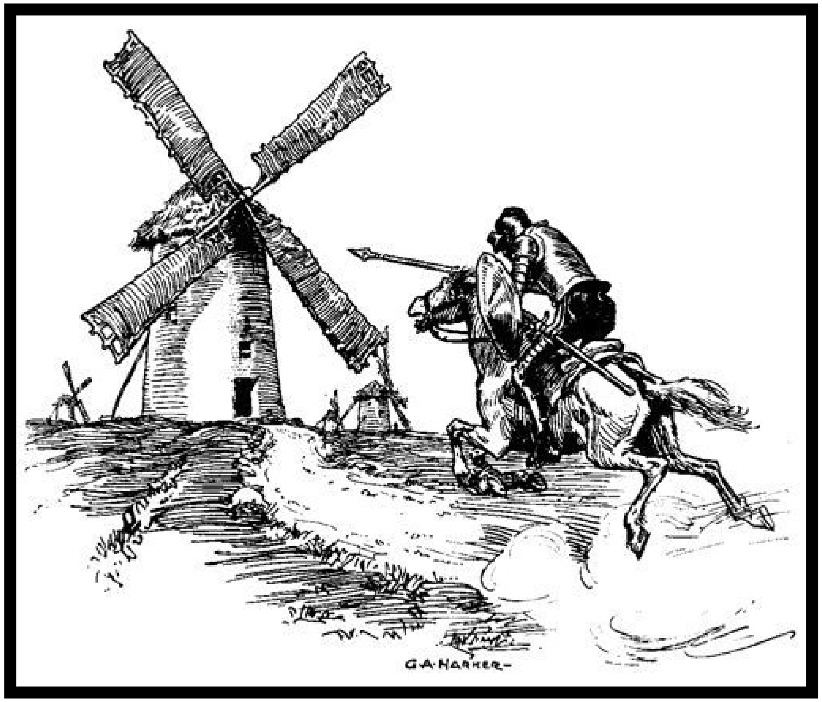
The Doctor is in

Energy Efficiency and Energy Conservation

The Quest…

Systems that do all the above and are

- Less expensive to build
- Less expensive to operate
- Easier to maintain



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…

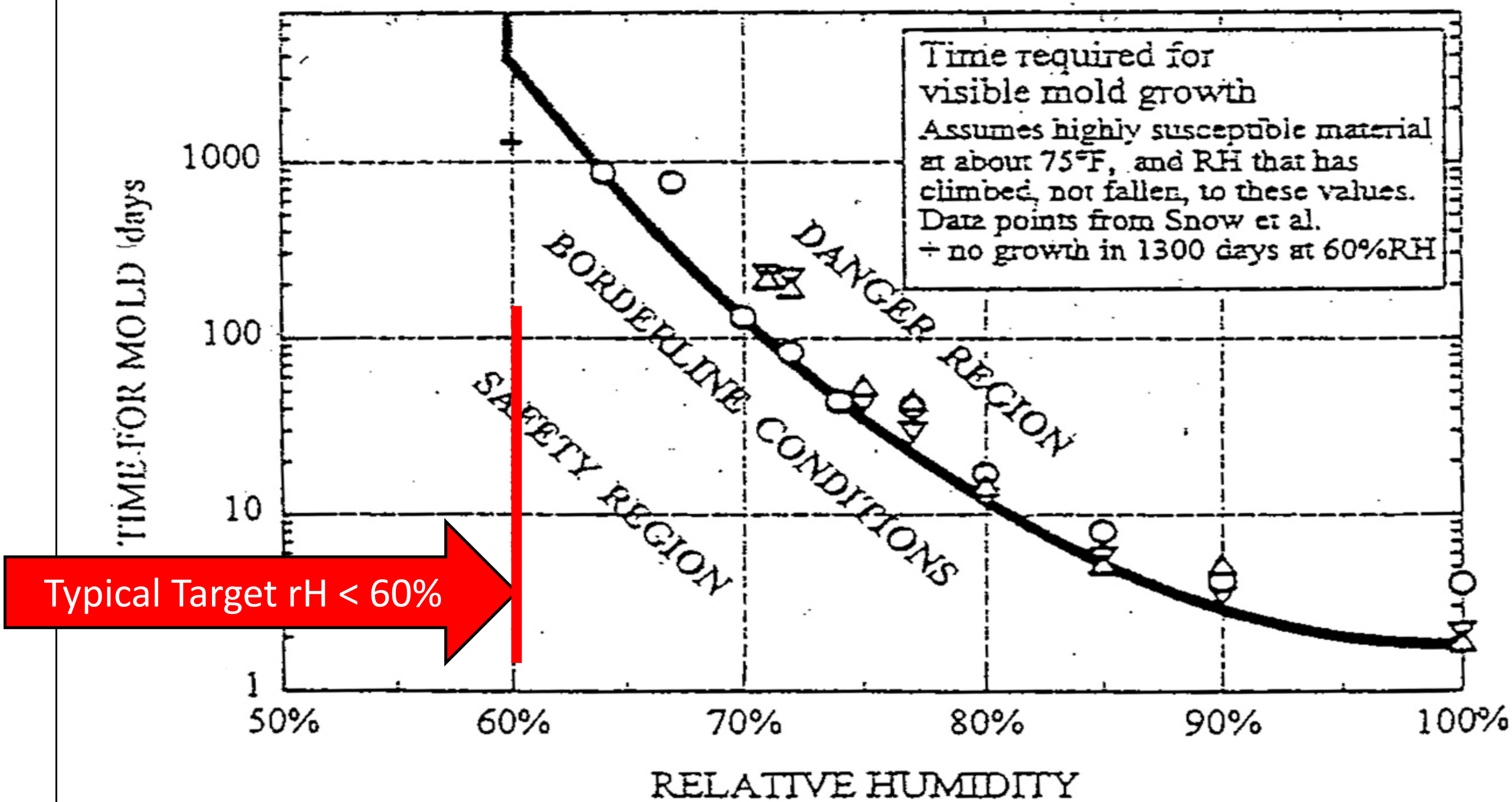


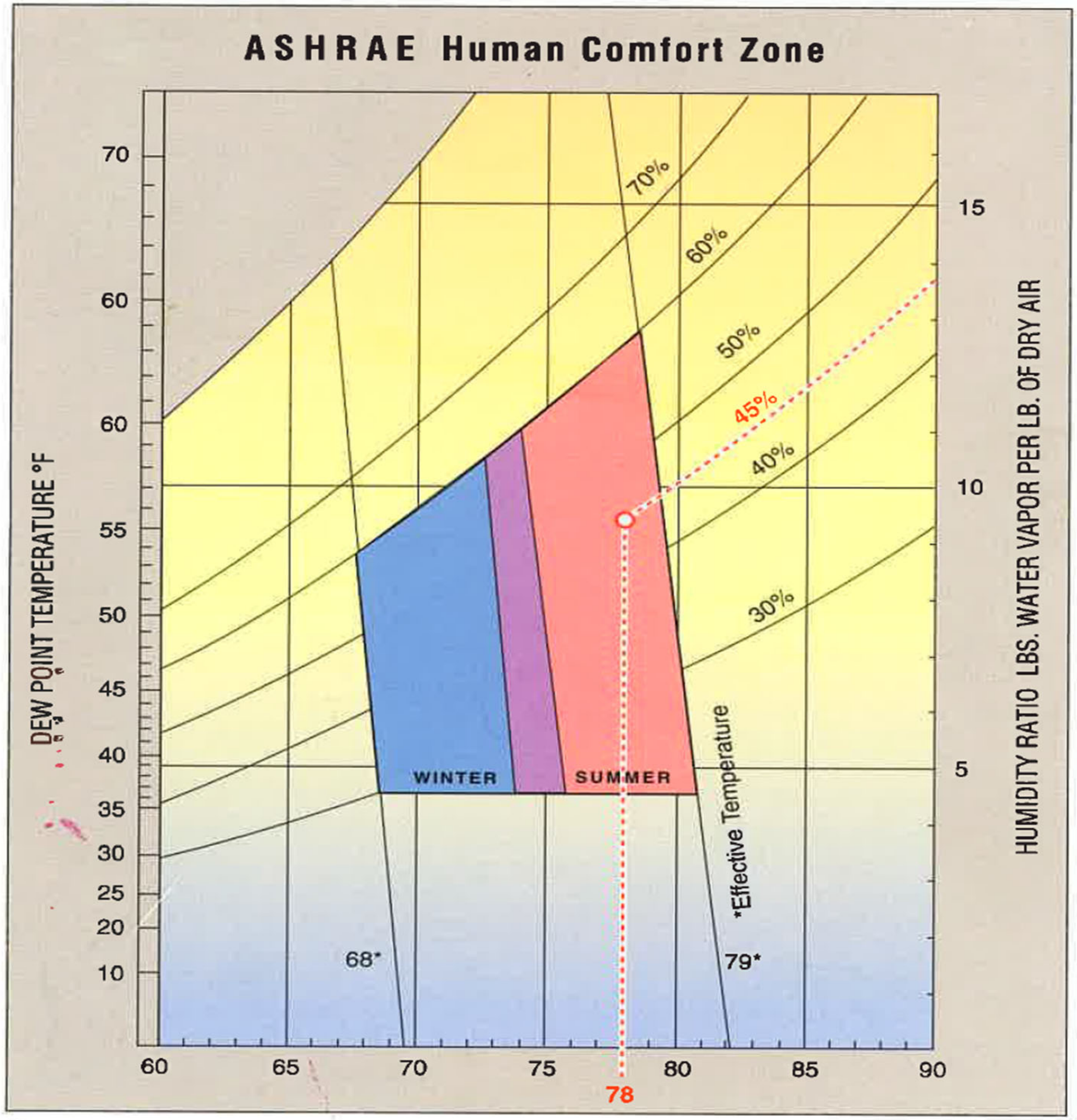
Fig. 2 Time Required for Visible Mold Growth

ASHRAE 2007 Applications Handbook, Chapter 21

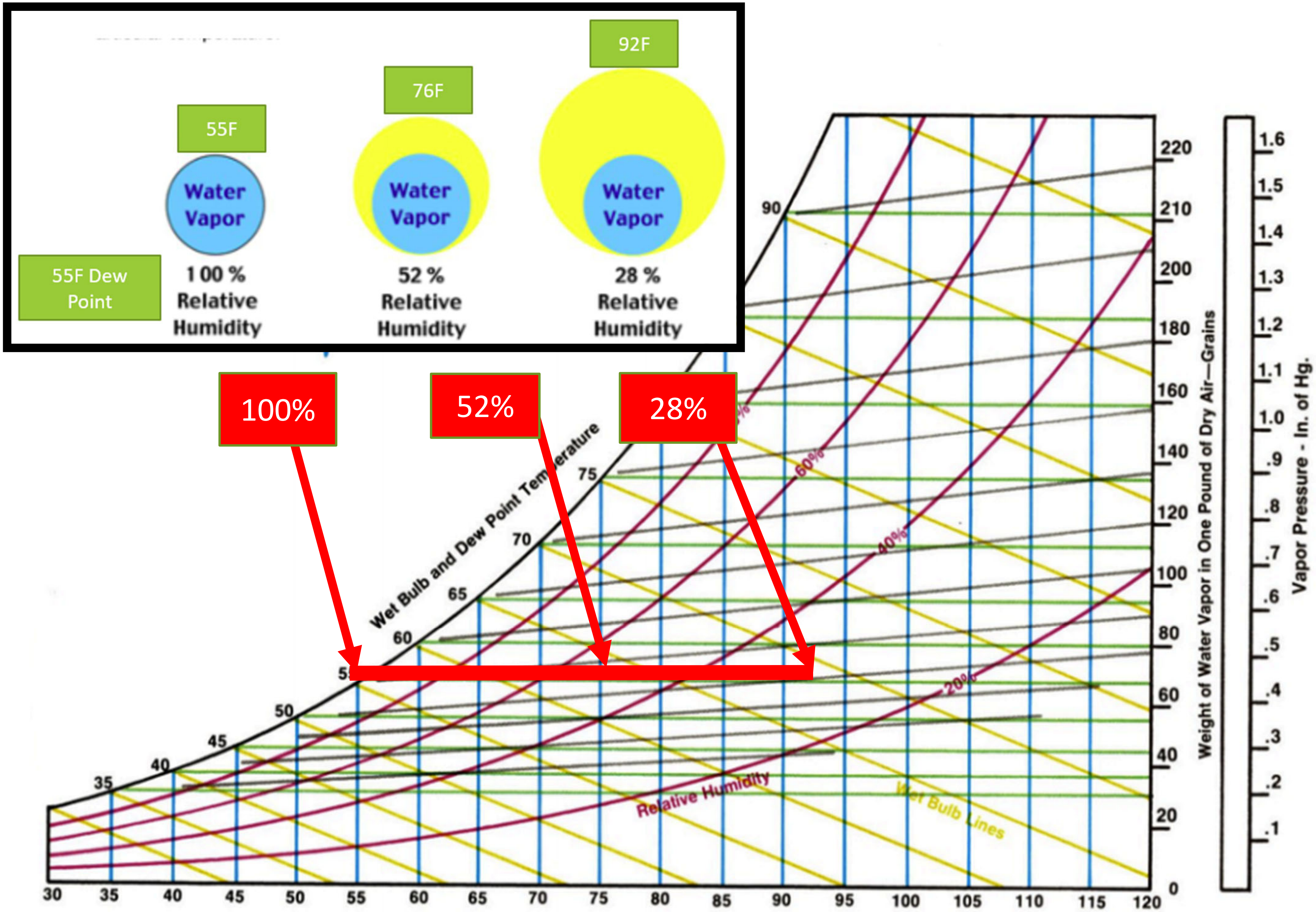
ASHRE Std. 55

Comfort Zone

Where 90% of appropriately dressed occupants feel comfortable

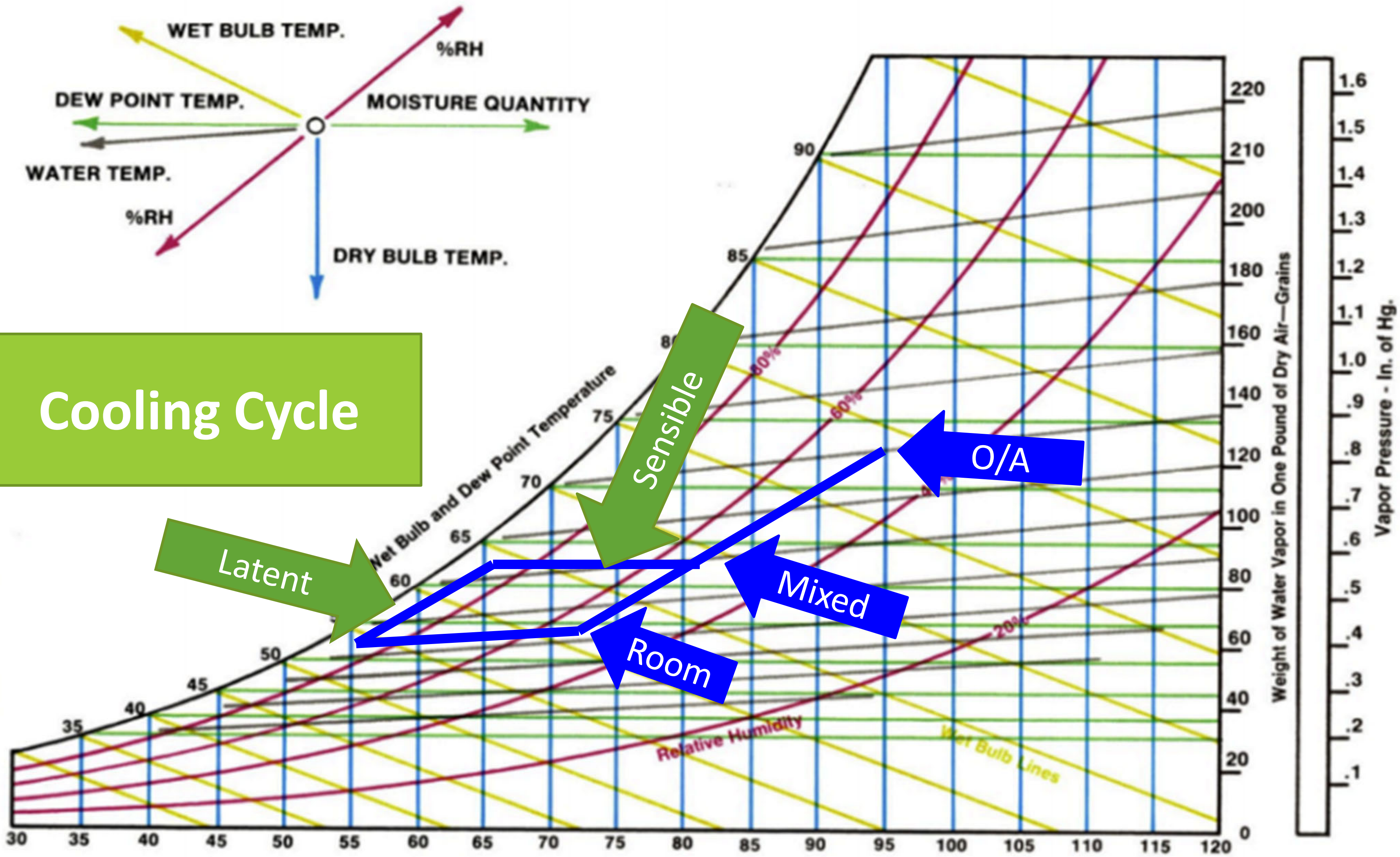


Chapter 5 of the 1993 ASHRAE Handbook of Fundamentals contains this graphic representation of the summer comfort zone. The society's research predicts that most people will be most comfortable at 78°F and 45% rh during the cooling season. The Munters MakupAire system pre-conditions the fresh air, delivering 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 *

A Biggie on Humidity Control

Cleaning carpets can be a major source of school humidity problems

- Do not expect the HVAC system to dry carpets
- Do not expect carpet fans to dry carpets
- Use dehumidifiers and run them until the carpet passes the sock test

Construction issues

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

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. 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.

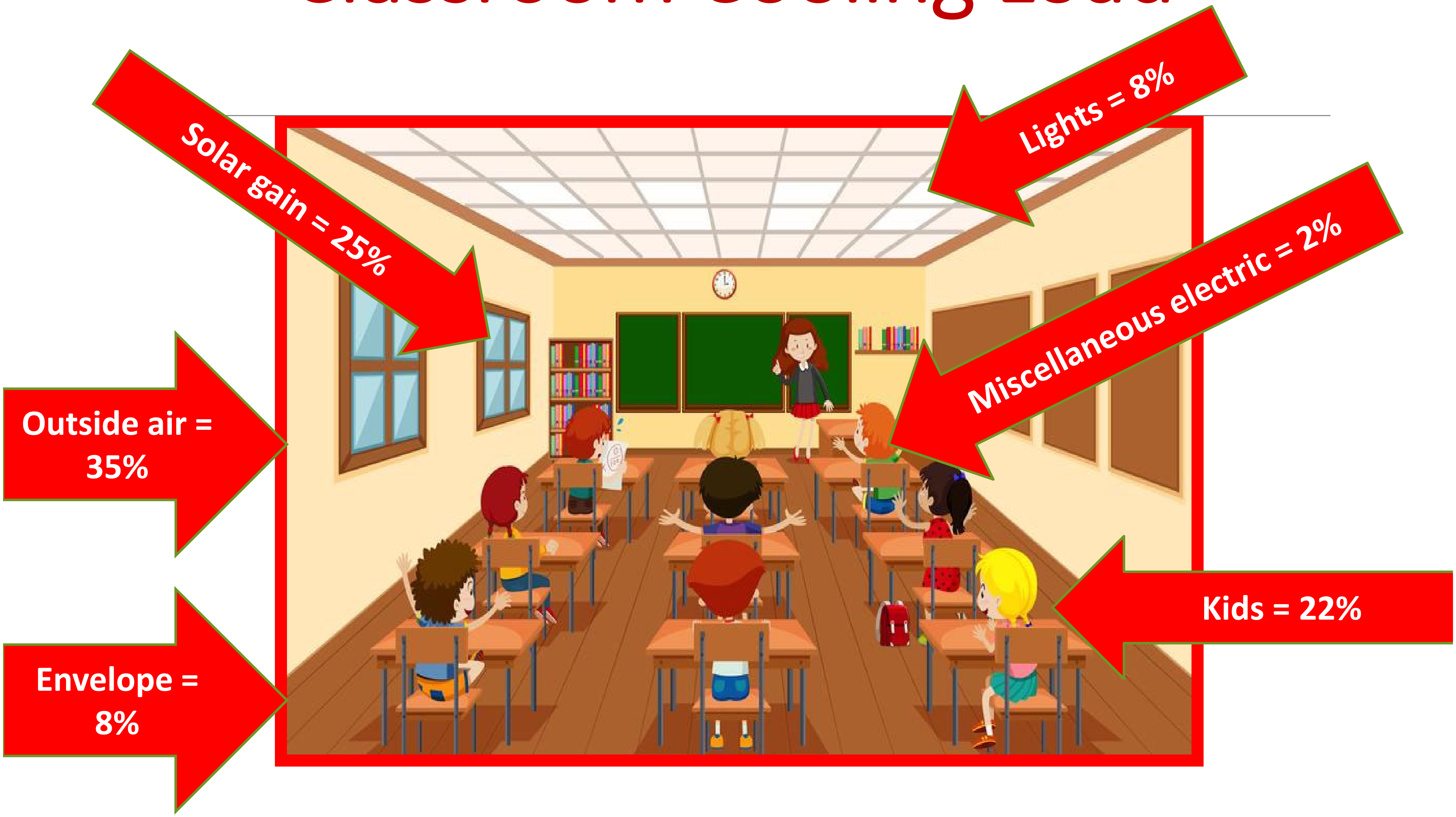
We didn't use to worry about this. What happened?

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

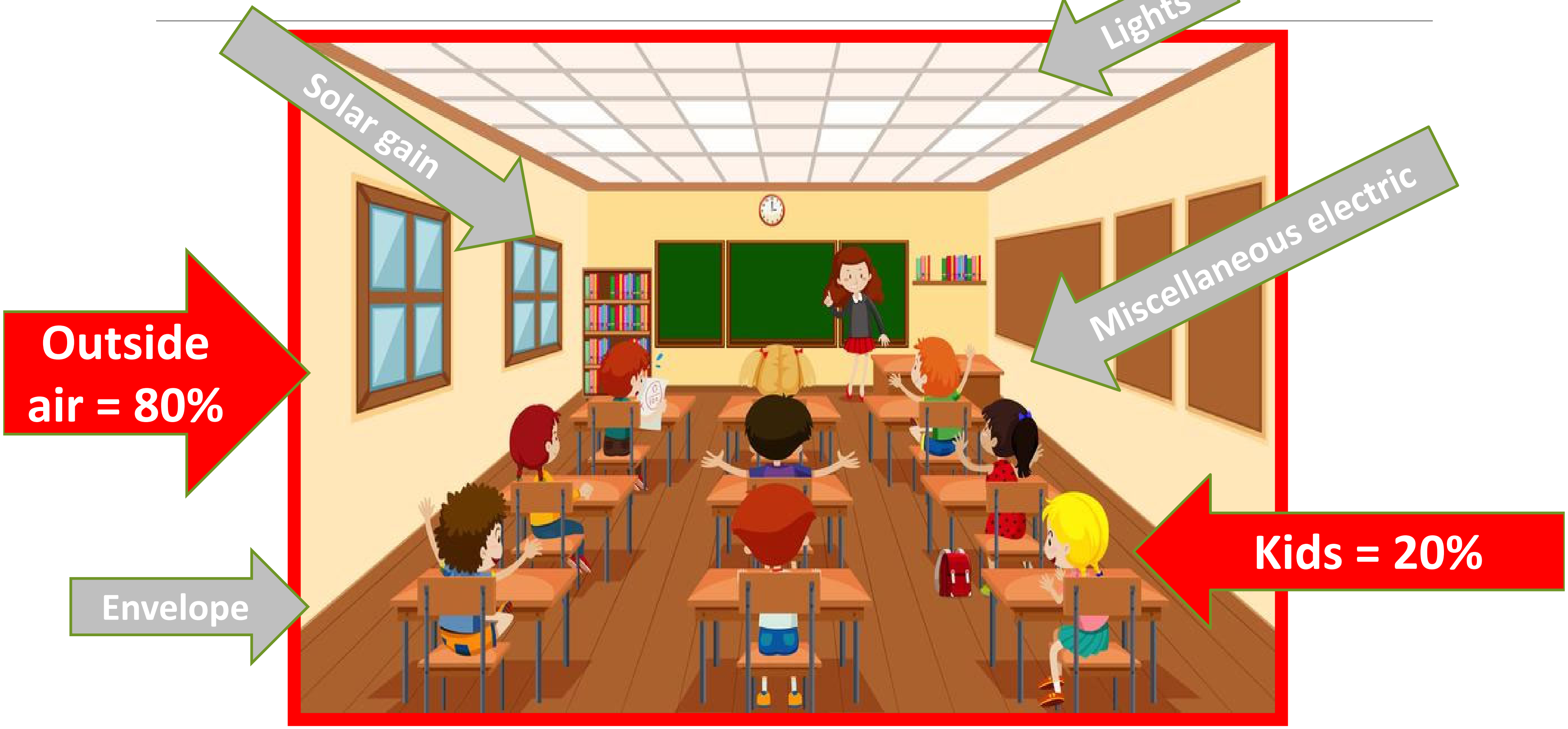
The thermostat responds to sensible load, and there won't be any latent removal unless the dew point is depressed.

Classroom Cooling Load



Classroom Moisture Contribution

(latent load)



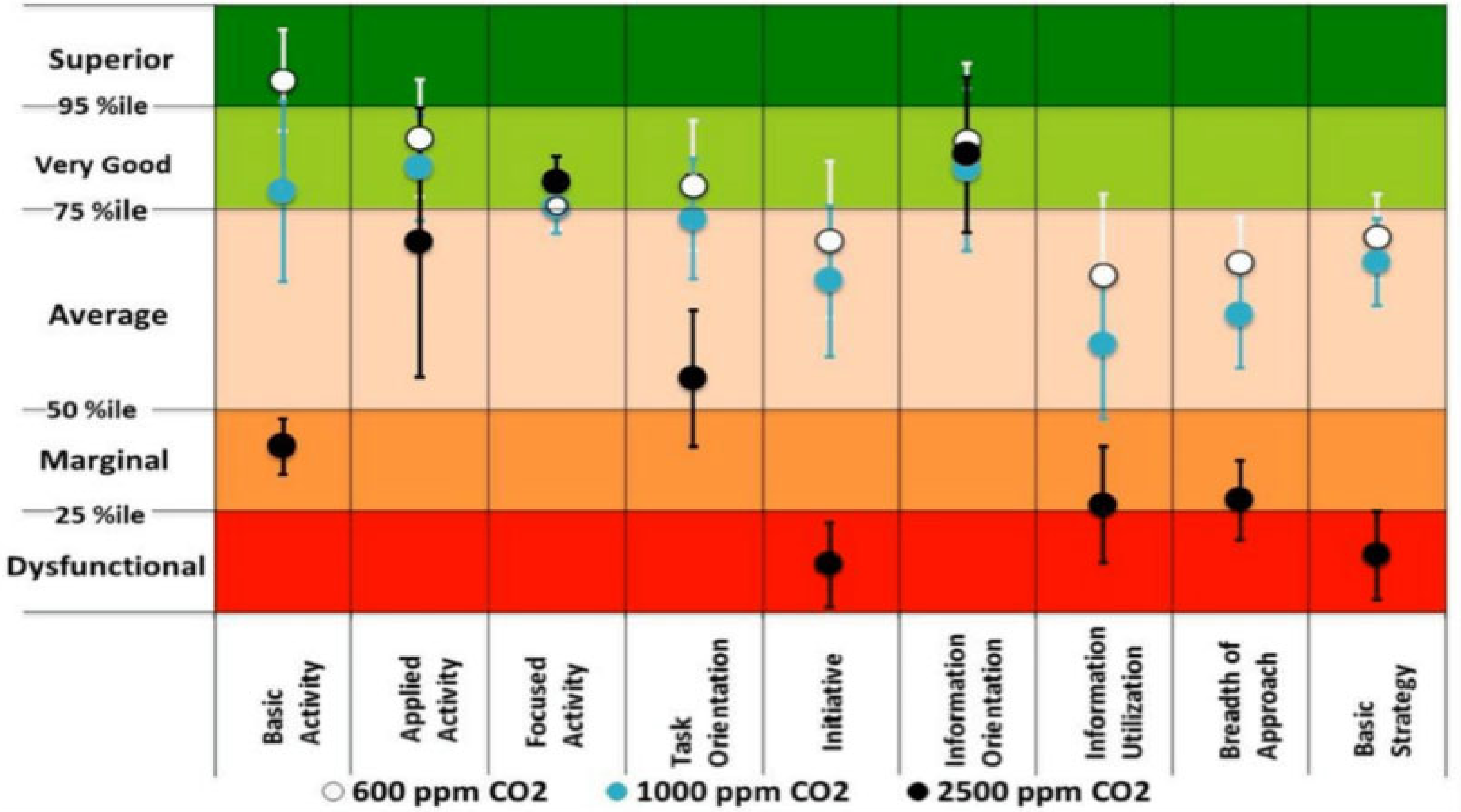
Tom's 35-70-95 Axiom

"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.

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.

When is your humidity exposure the worst?

- Dew on the grass = 100% rH
- Outside temp below room temp = less load
- Unoccupied space = almost zero load
- Exhaust fans running at night = building negative pressure = lots of infiltration

Decouple Ventilation and Temperature

"Traditional" temp control sequence (holdover from our pneumatic control days)

- Occupied = day temperatures, O/A dampers open
- Unoccupied = setback temperatures, O/A dampers closed, cooling not available

Decouple Ventilation and Temperature

"Modern/smarter/more efficient" temp control sequence

- Day/Night = Temperature
- Occupied/Unoccupied = O/A dampers

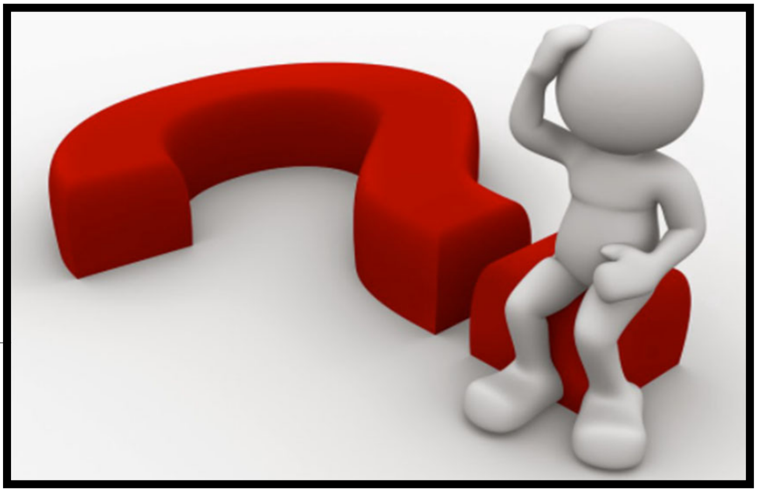
Three options:

- Day/Occupied
- Day/Unoccupied
- Night/Unoccupied

More Zones

Std. 90.1 has several smart O/A management suggestions

The Problem



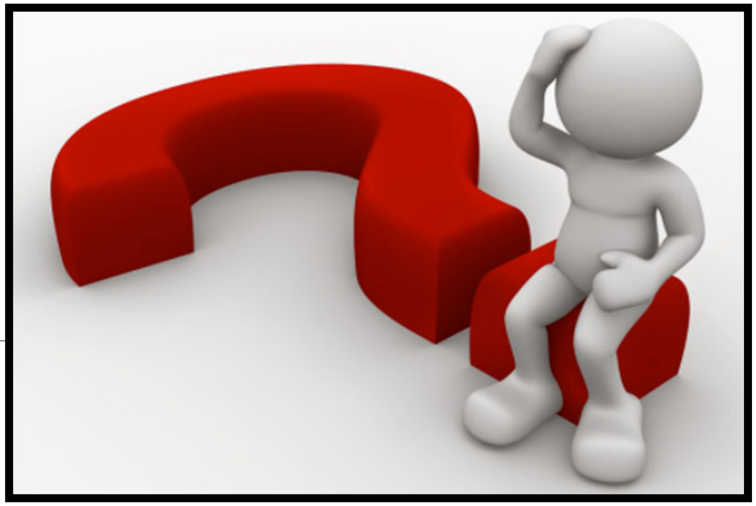
The moisture comes from outside air

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

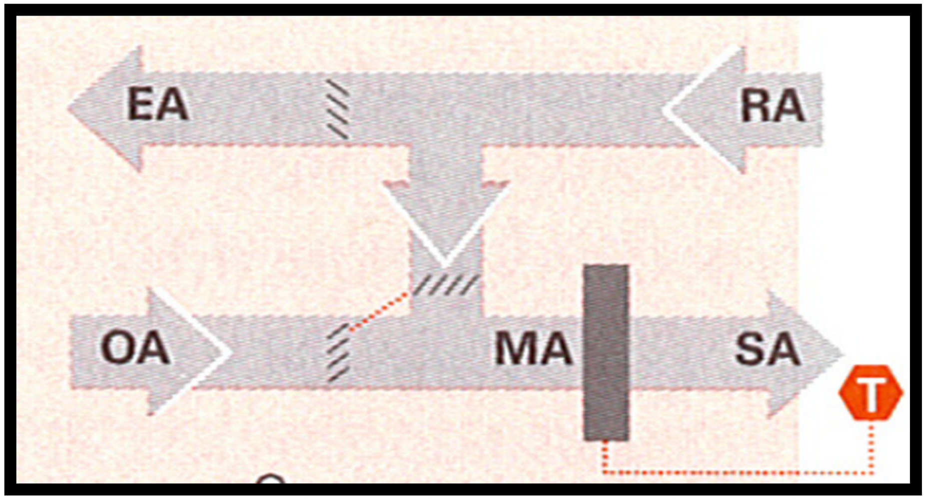
1. Valve control of constant volume equipment
2. Oversized air side equipment
3. Building under negative pressure, i.e. not controlling exhaust fans
4. Around-the-clock operation

Take A Fresh Look at Face and Bypass

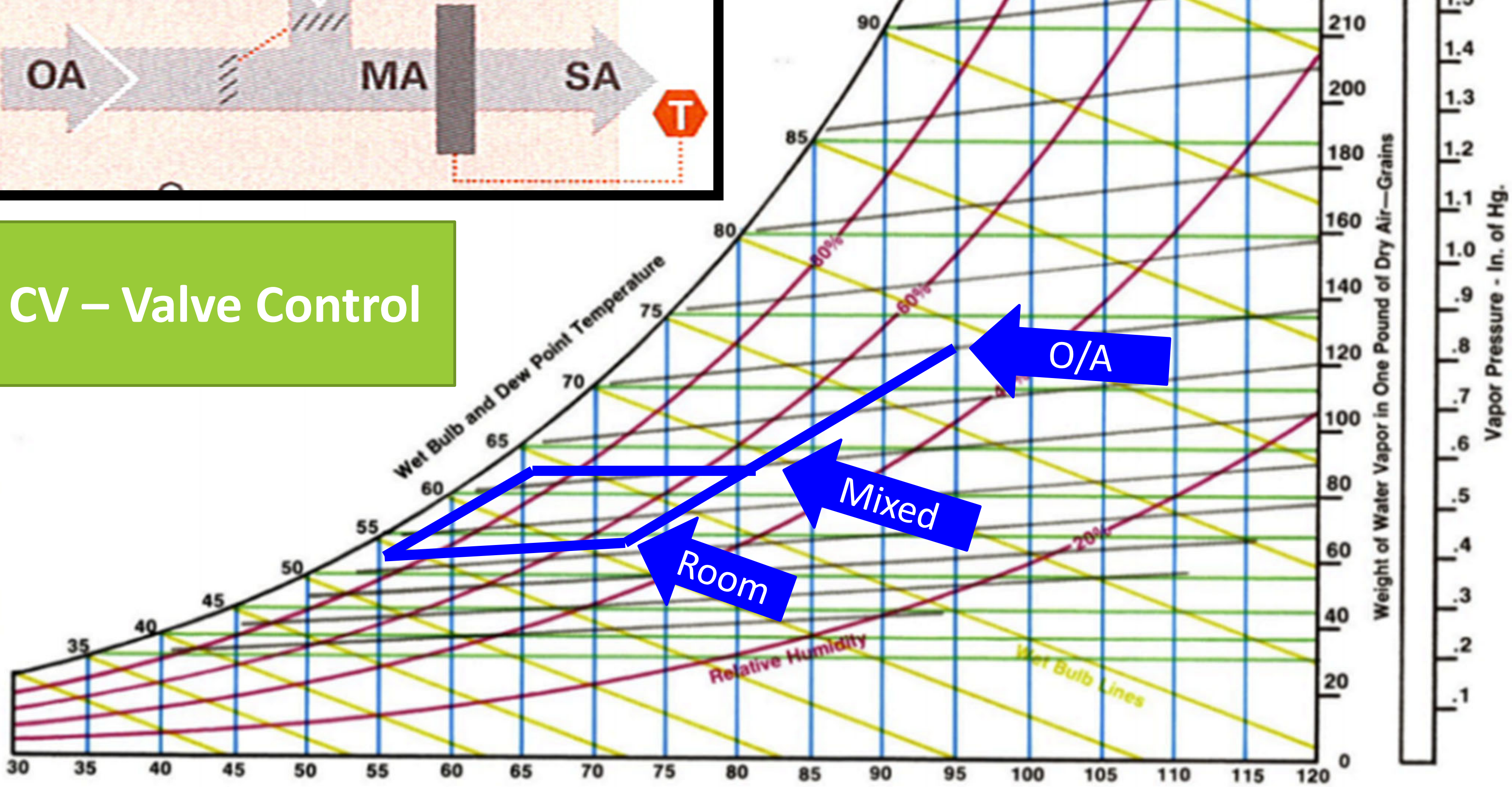
A constant volume system operating at a part load condition that would be satisfied by a LAT of 65F

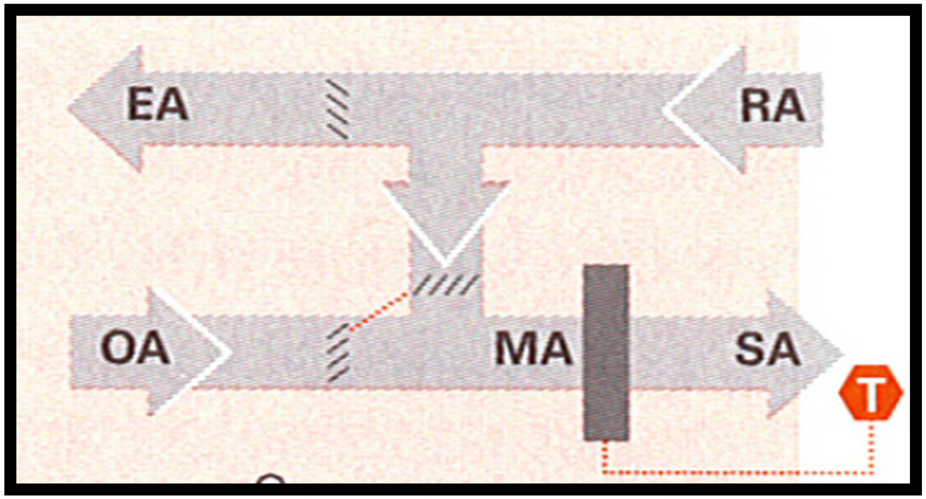
- Valve control = 68% rH, $0.20/hr
- F&BP control = 56% rH, $0.22/hr
- Reheat control = 54% rH, $0.42/hr

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



CV – Valve Control





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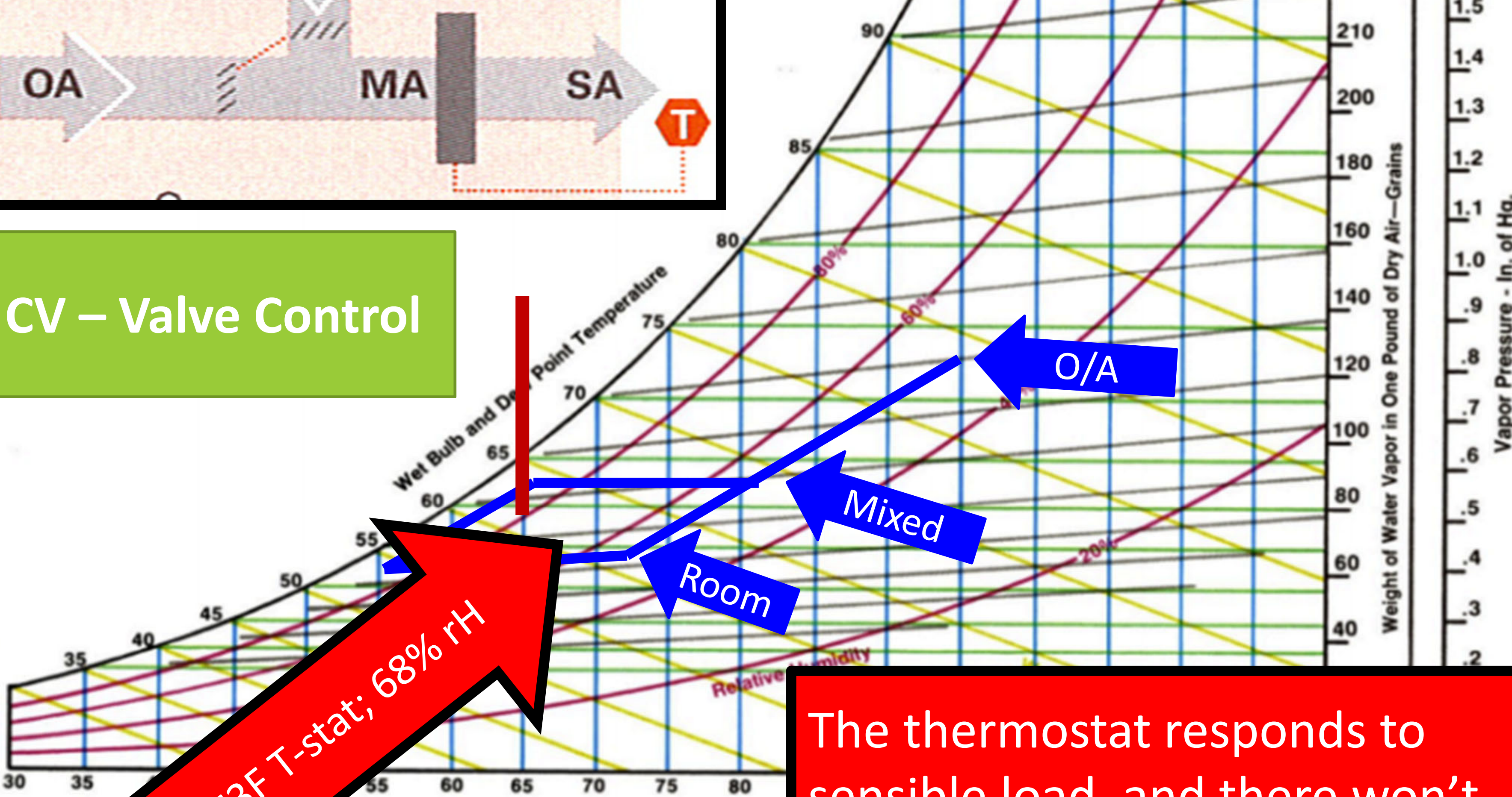
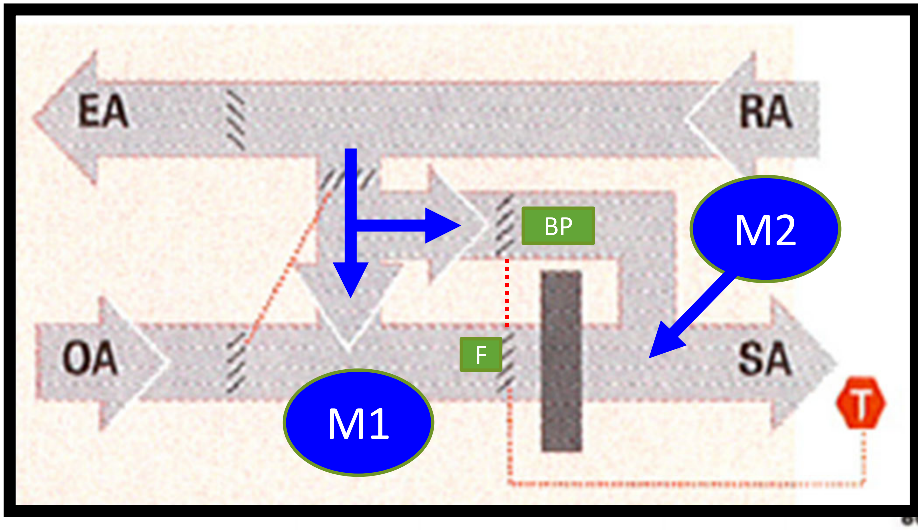
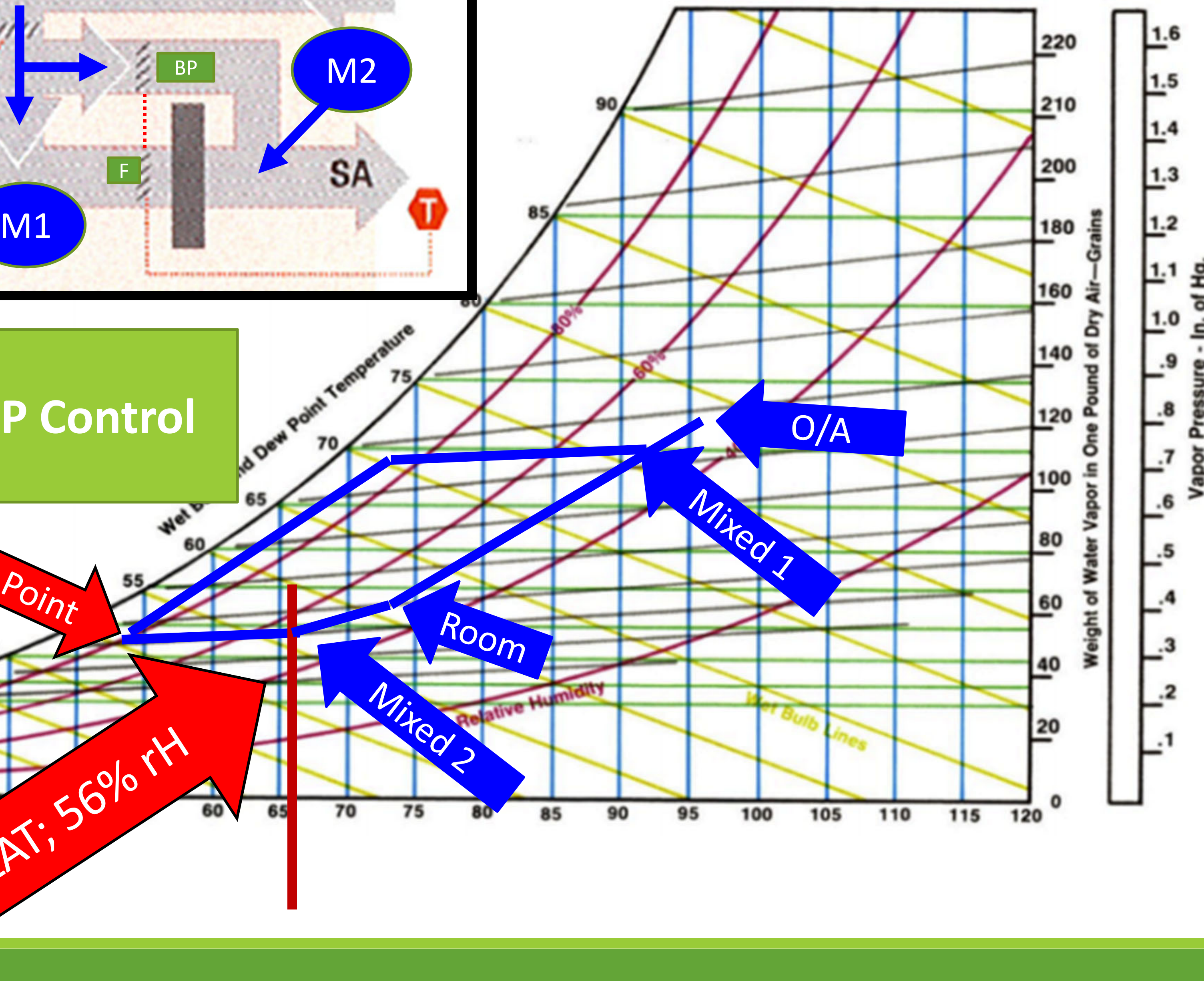


The thermostat responds to sensible load, and there won't be any latent removal unless the dew point is depressed.

CV –F&BP Control





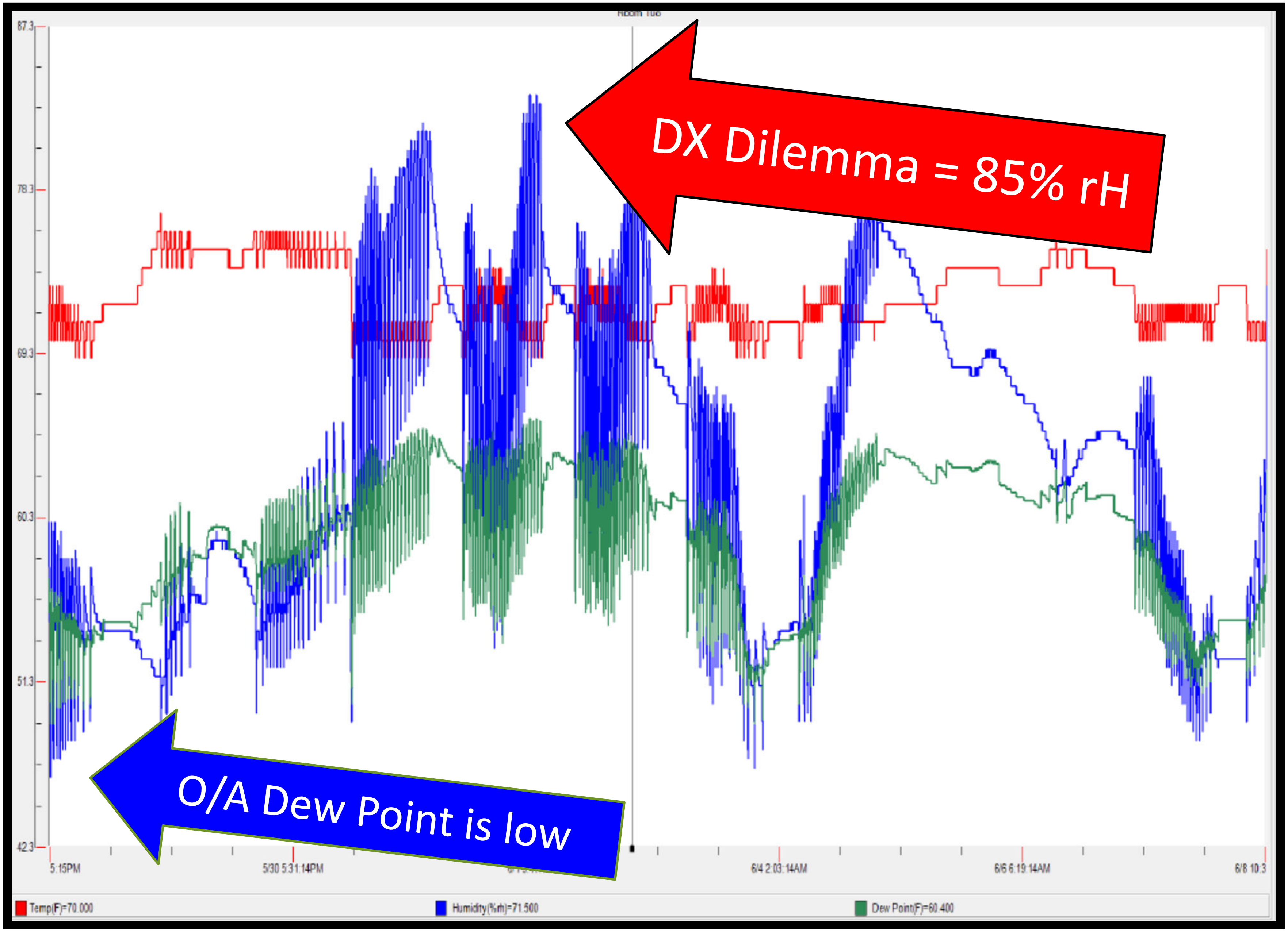
Humidity Cause #1a
"The DX Dilemma"

Continuous fan and intermittent compressor operation

- 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

Hot Gas By-Pass or DOAS or RH or APR valve required (older).

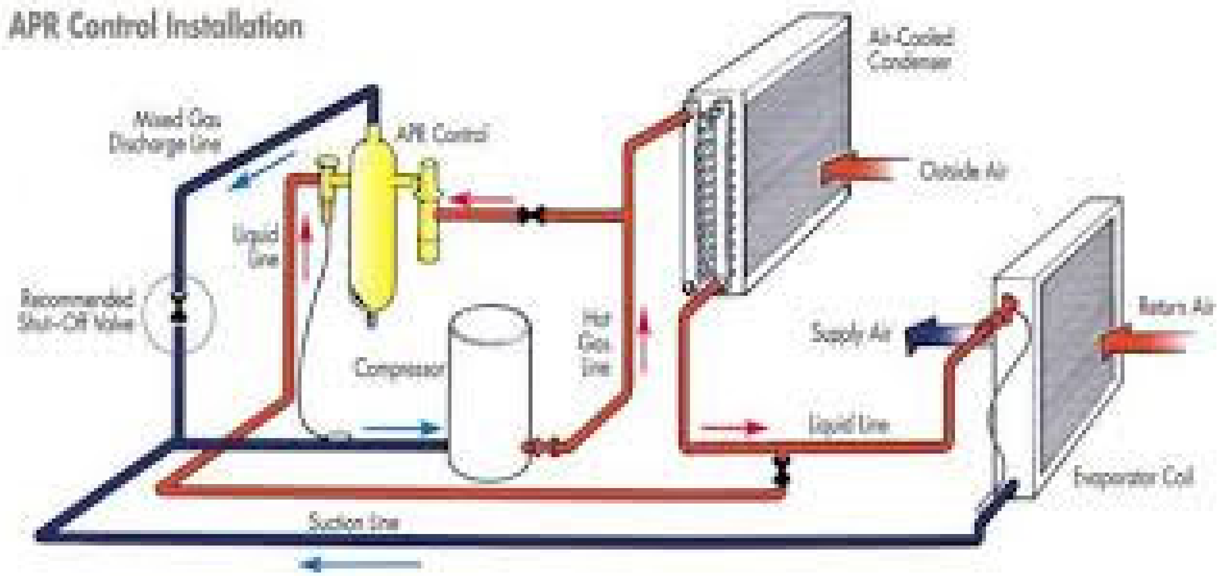
Variable speed fans/compressors (newer).



One way to make your phone ring.

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

2019 Applications Handbook, Chap. 8 has 5 different DOAS arrangements

DOAS

Pros

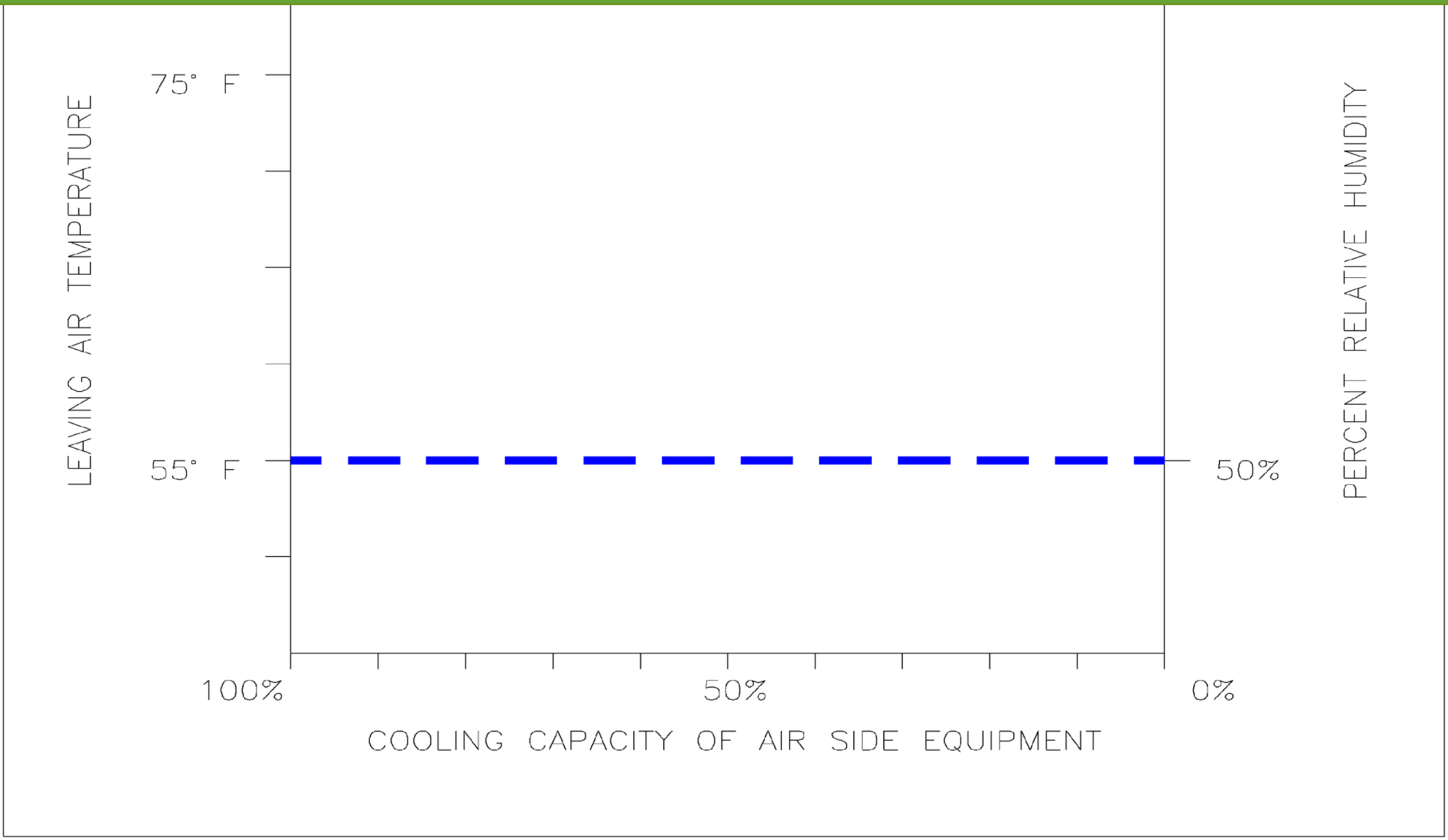
- Straight-forward solution
- Direction the industry is favoring
- If done well, it can be very efficient

Cons

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

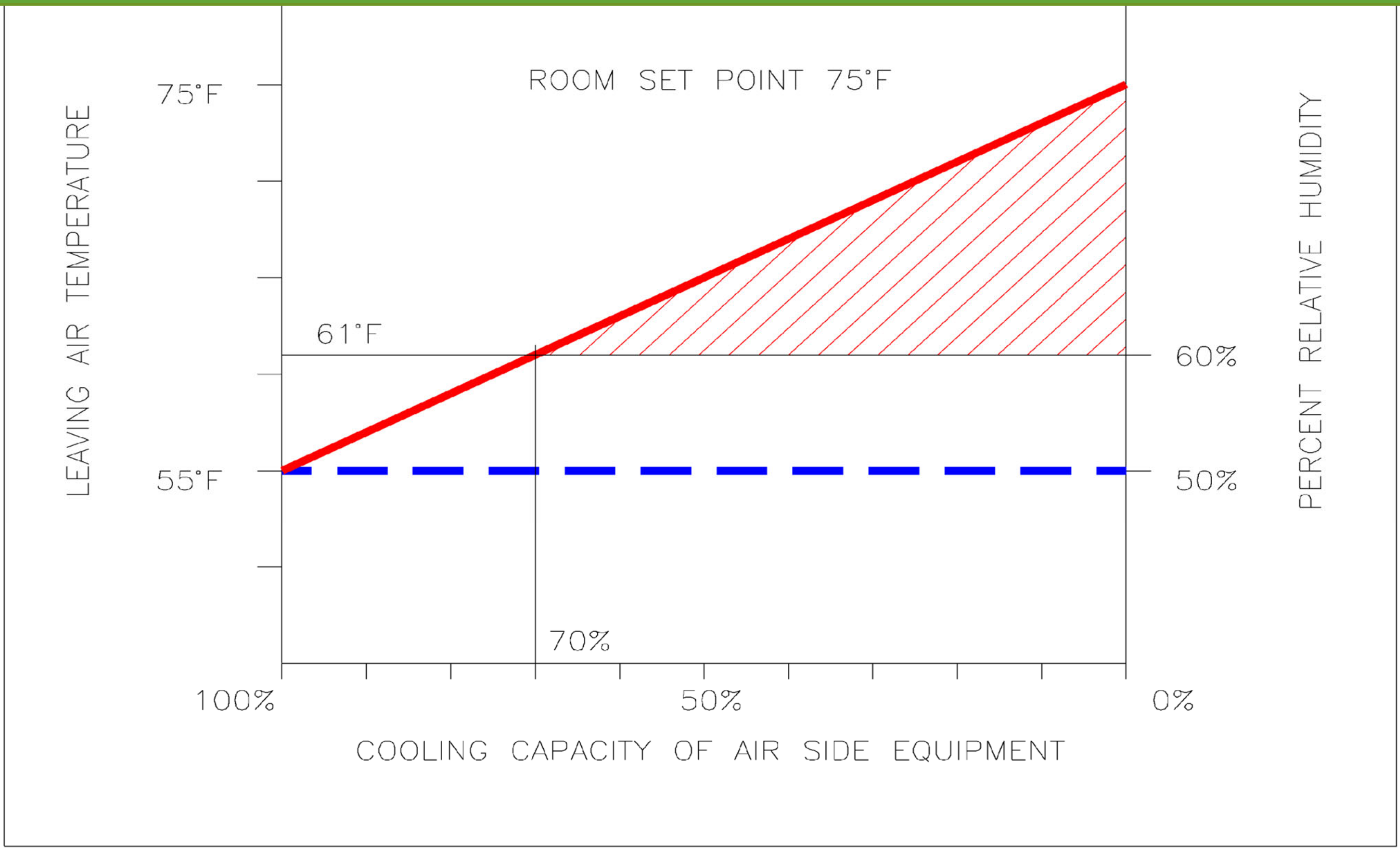
Variable Volume HVAC

(passive humidity control)



Constant Volume Valve Control HVAC

(incidental humidity control)



Constant Volume Valve Control HVAC

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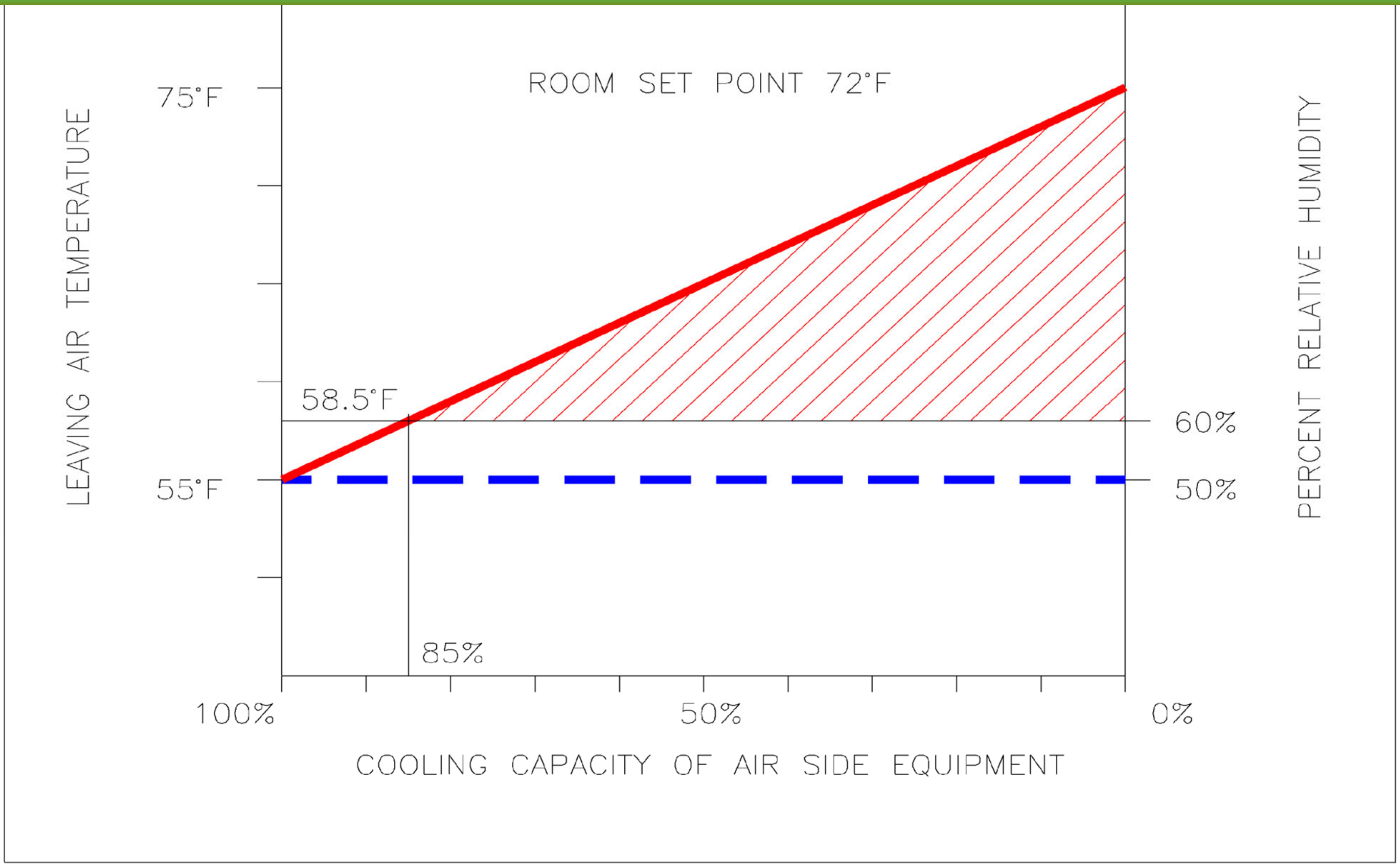
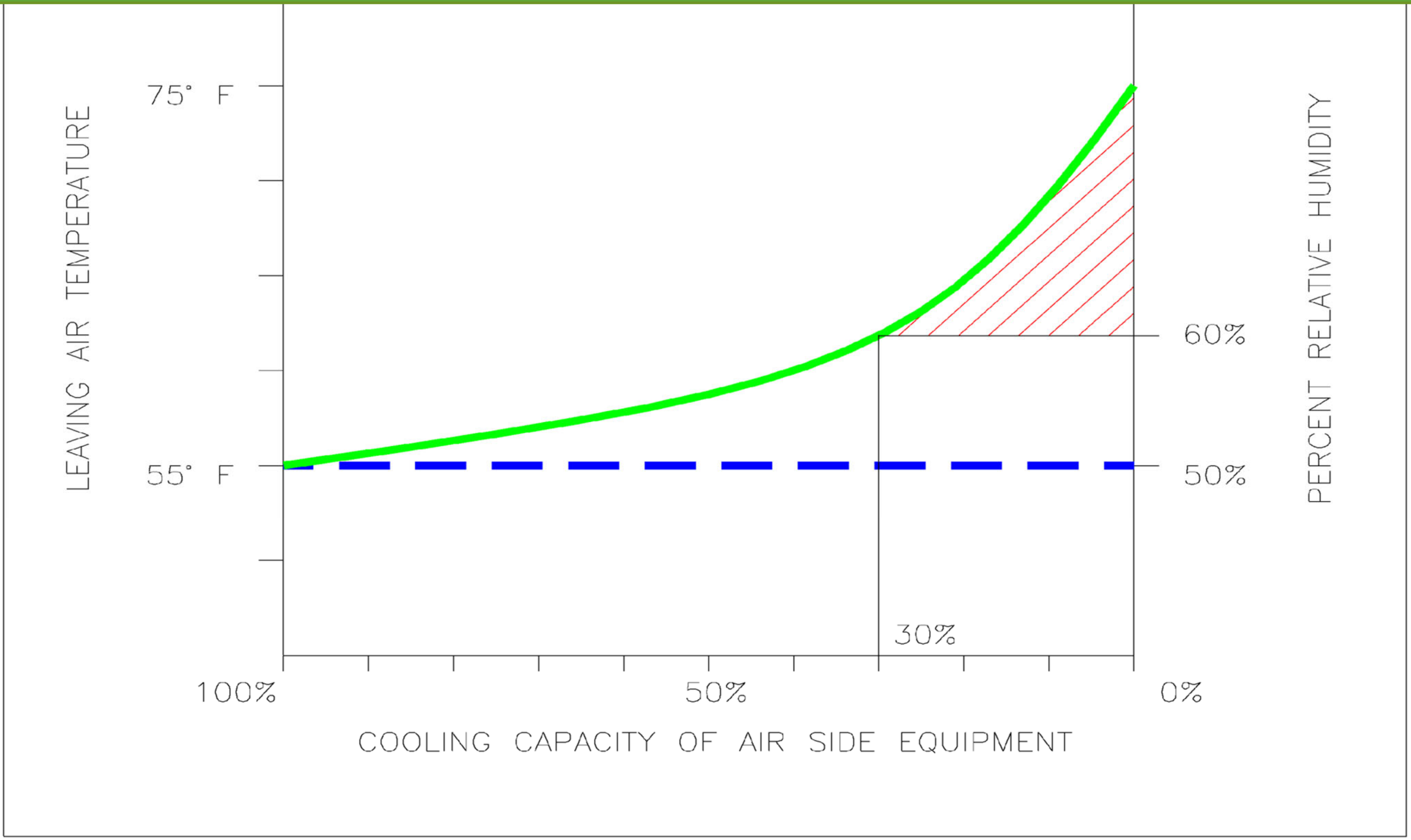


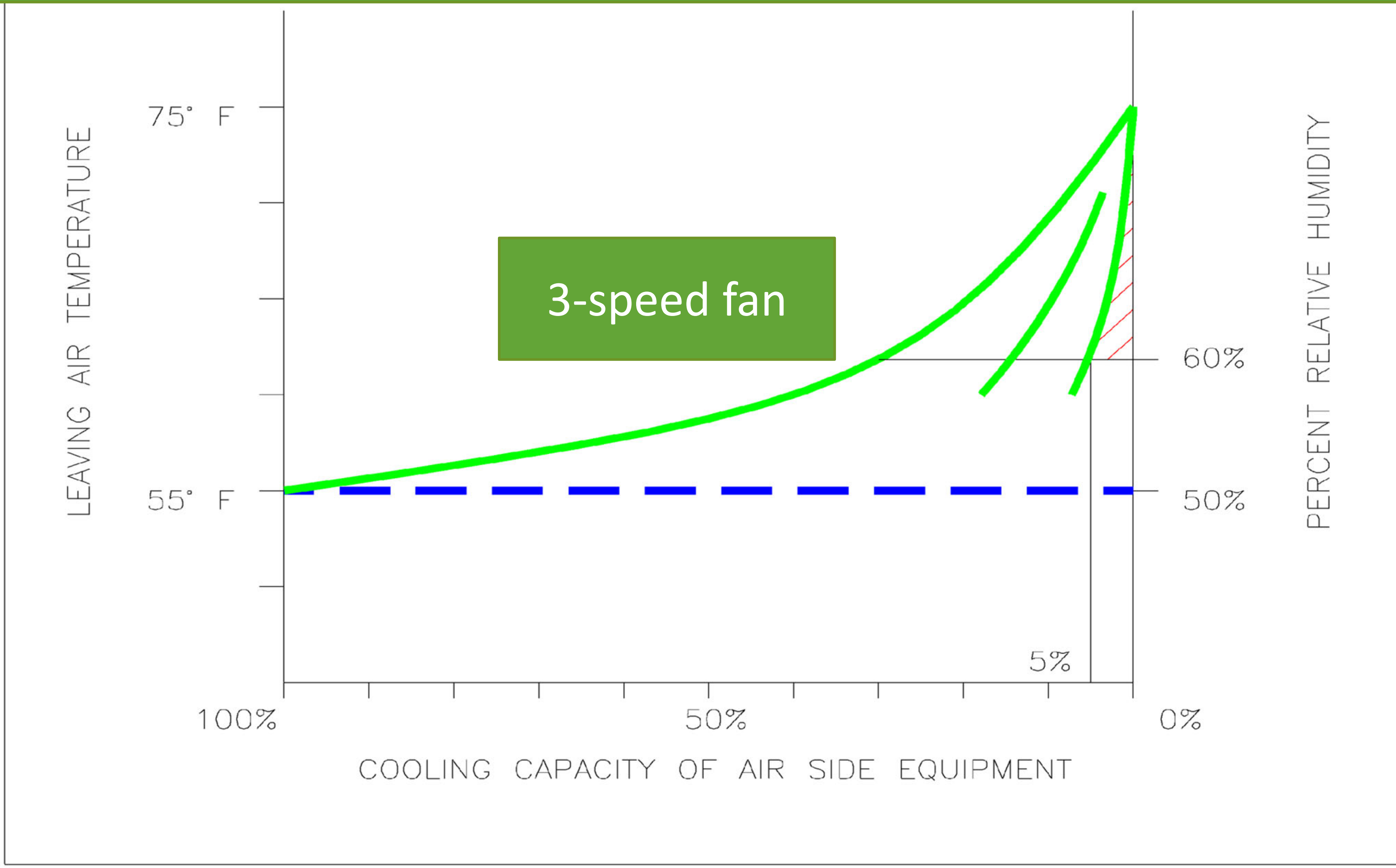
Constant Volume F&BP HVAC

(passive humidity control)



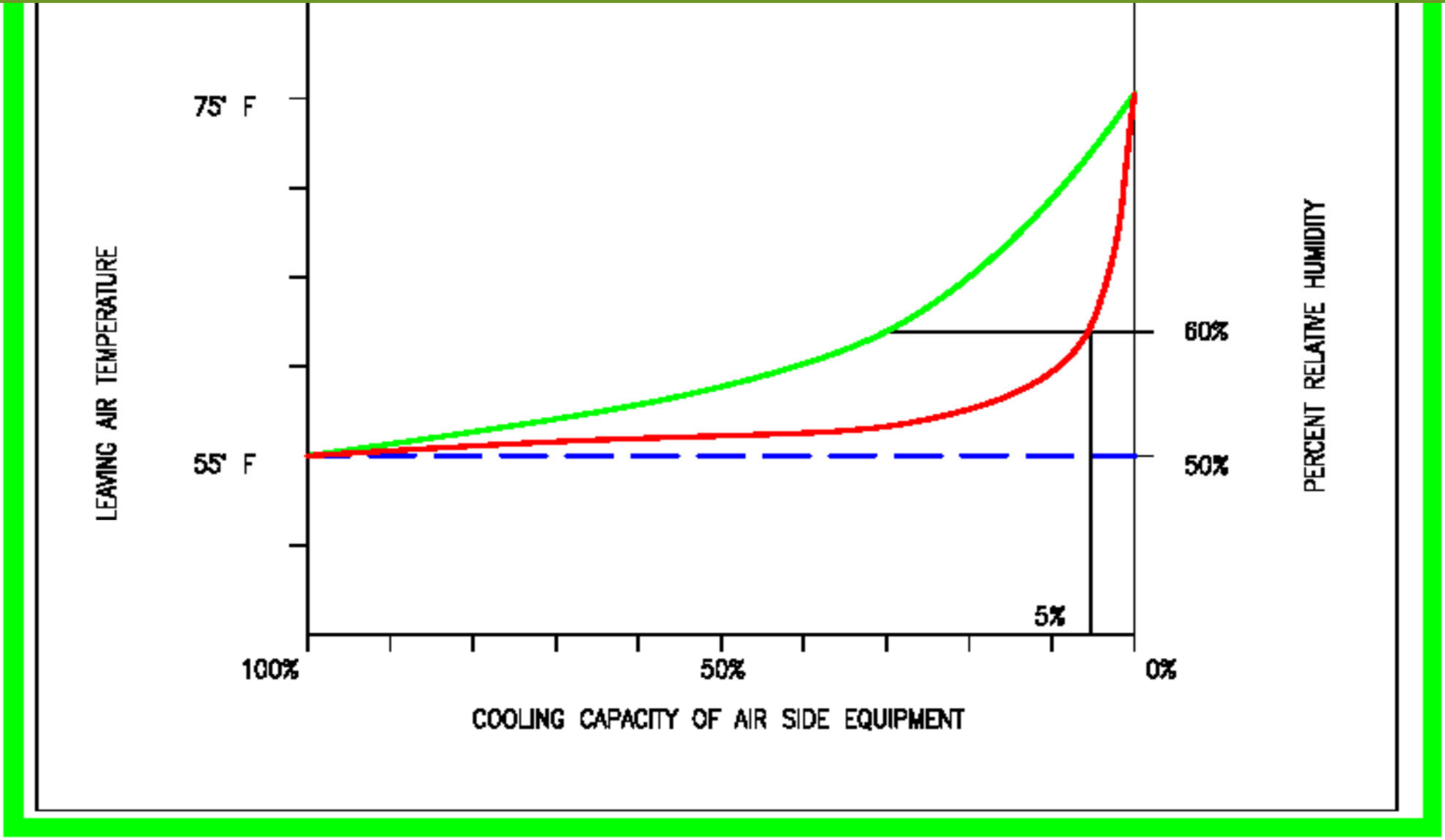
Constant Volume F&BP HVAC

(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
- Minimal load in the space, i.e. occ sensor holding O/A damper open

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”

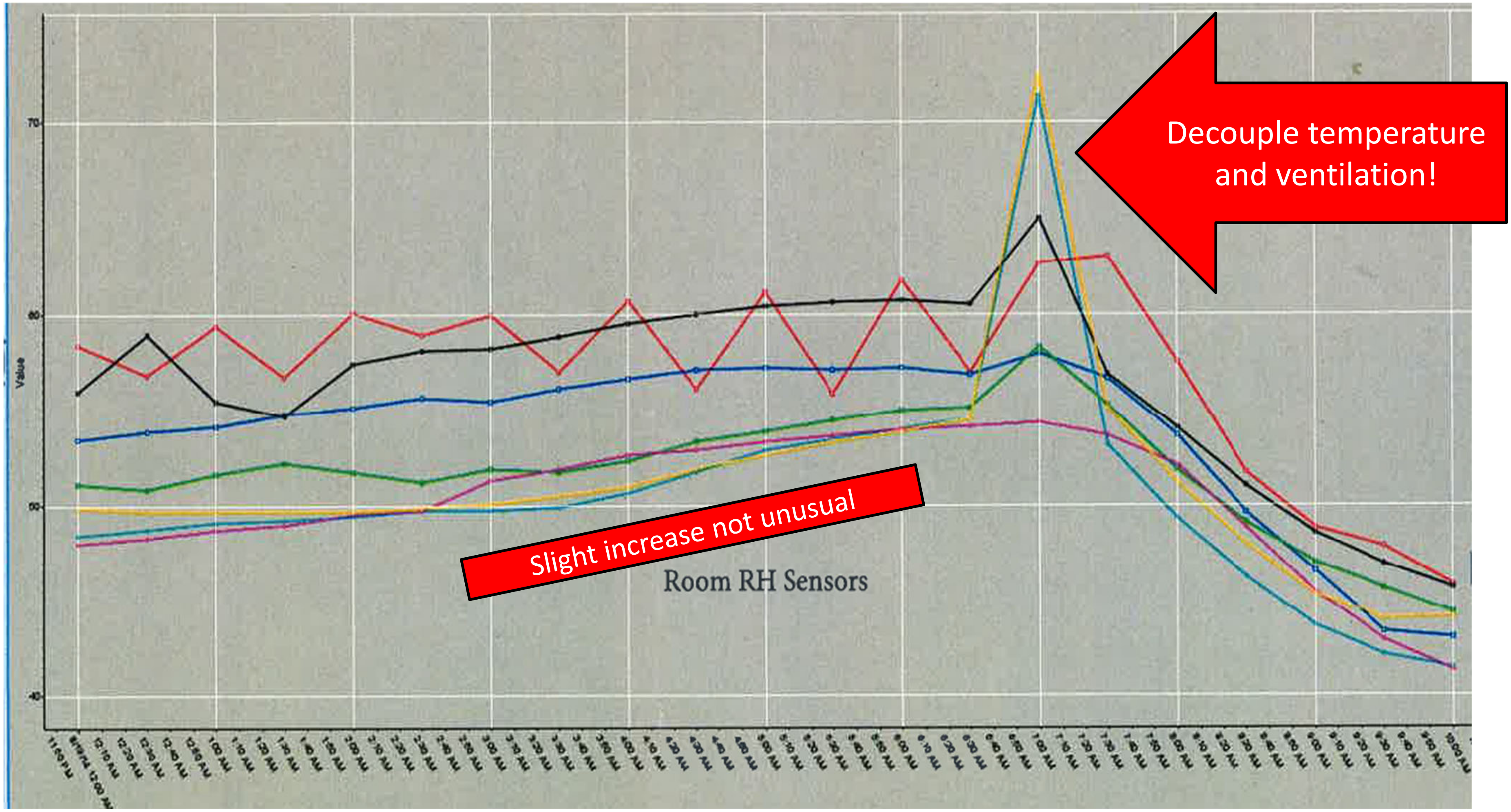
Carl Gist, Senior Thesis
University of Southern Indiana

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

What happens at night?



Courtesy: Jerry Weber, PE

What should happen at night (or unoccupied)

- All exhaust fans off
  - Don’t let building go negative
- Several humidity sensors, one per room is overkill
- HVAC system is off, to be started by either
  - Room temp above night set point, 78 or 80F
  - Room humidity above 58 or 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

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

[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

"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.

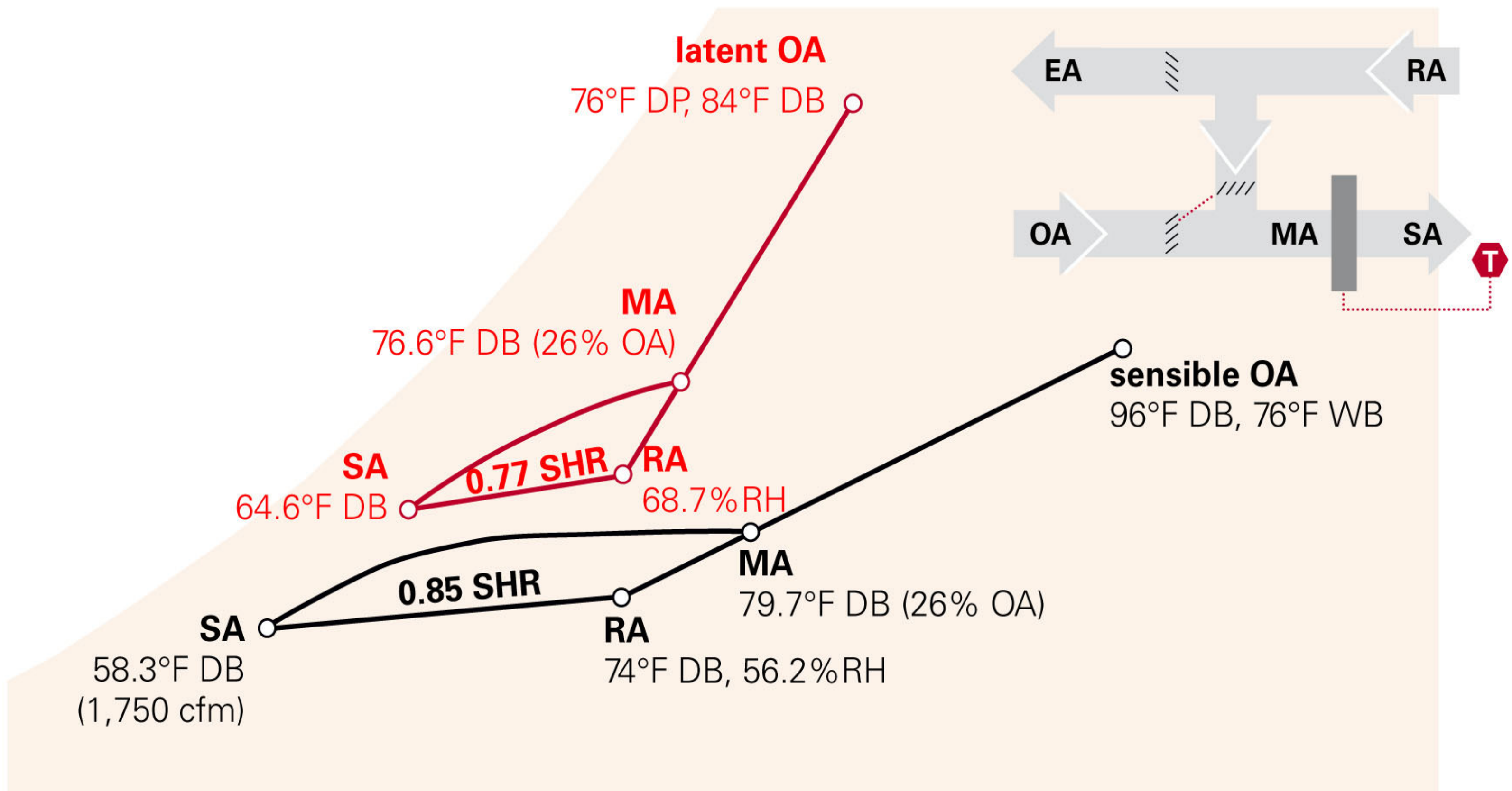
A thermostat senses the zone dry-bulb temperature and compares it to the set point. The thermostat then modulates the capacity of the cooling coil, adjusting the supply-air temperature until the sensible capacity of the cooling coil matches the sensible load and the zone temperature matches the set point.

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…

WB design vs. DB design

Figure 2. Packaged Air Conditioner (Classroom Example)



Ranking your Options

1.	Basic CV system	66.9% rH	3.68T
2.	Energy Recovery Wheel	65.0% rH	2.47T
3.	Mixed Air By-pass	64.5% rH	3.74T
4.	Return Air By-pass	55.2% rH	3.92T
5.	Supply Air Reheat	52.4% rH	5.21T
6.	DOAS	52.4% rH	4.16T

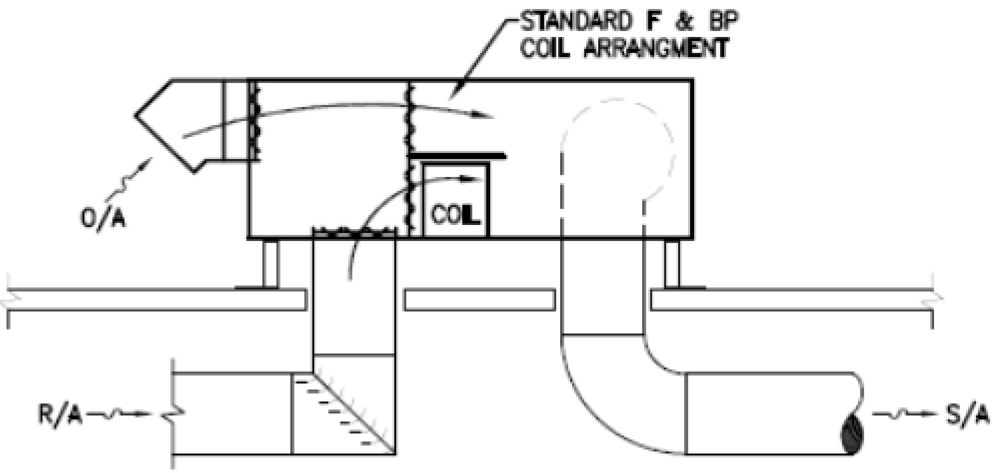
The air streams…

Outside air…never by-pass this

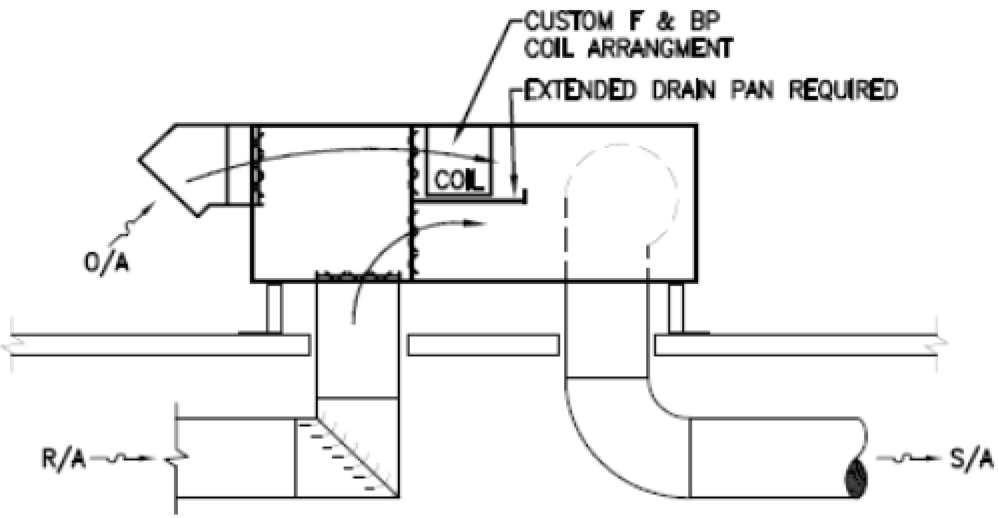
Mixed air…try to avoid by-passing this

Return air…arrange ducts and equipment to
make this happen

Stratification is your friend!



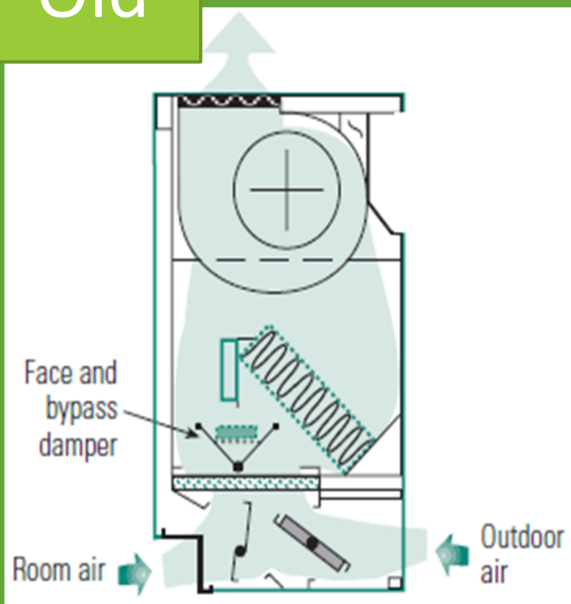
Incorrect – O/A By-Pass



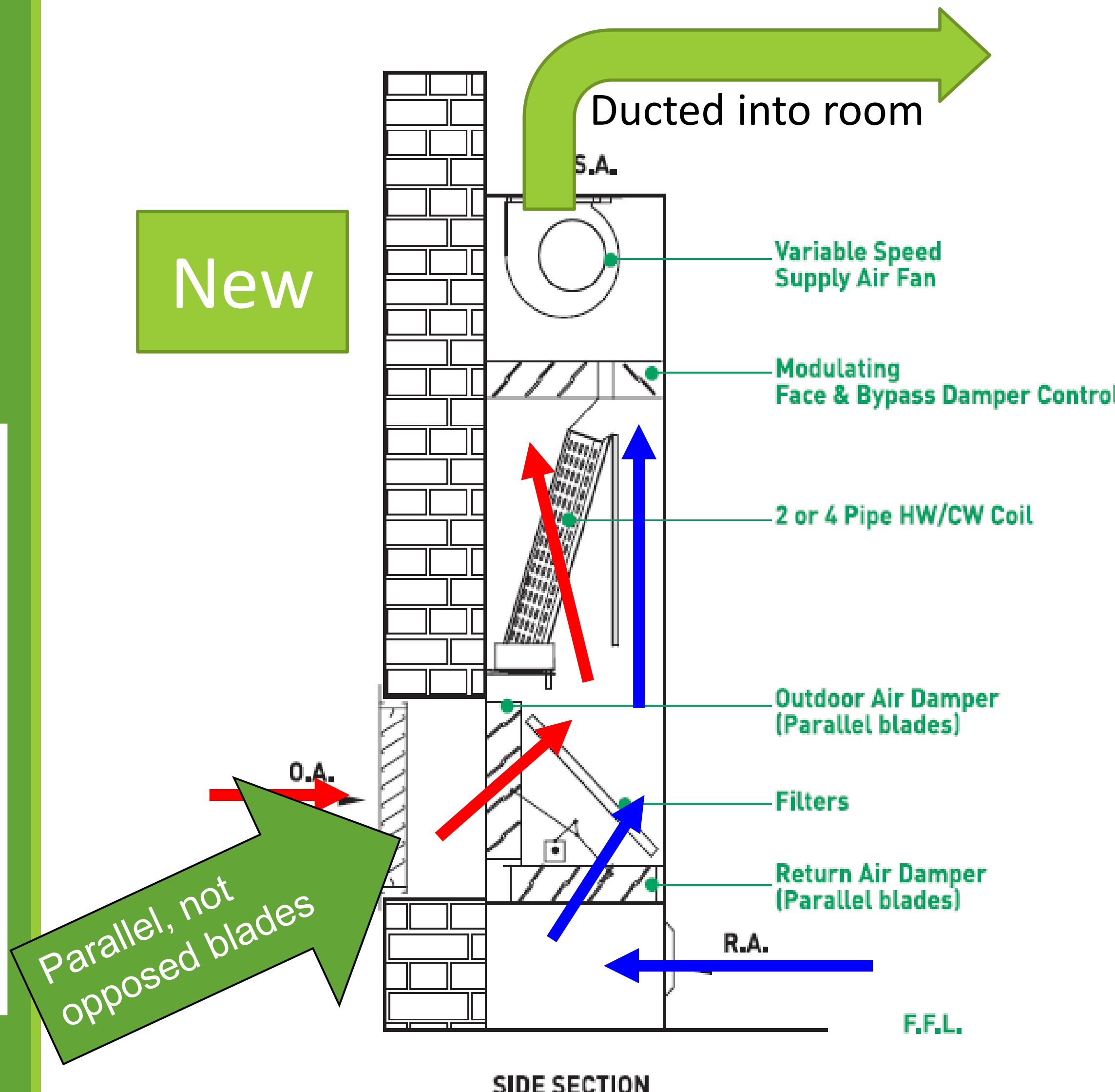
Correct – R/A By-Pass

Classroom Unit Ventilator

Old

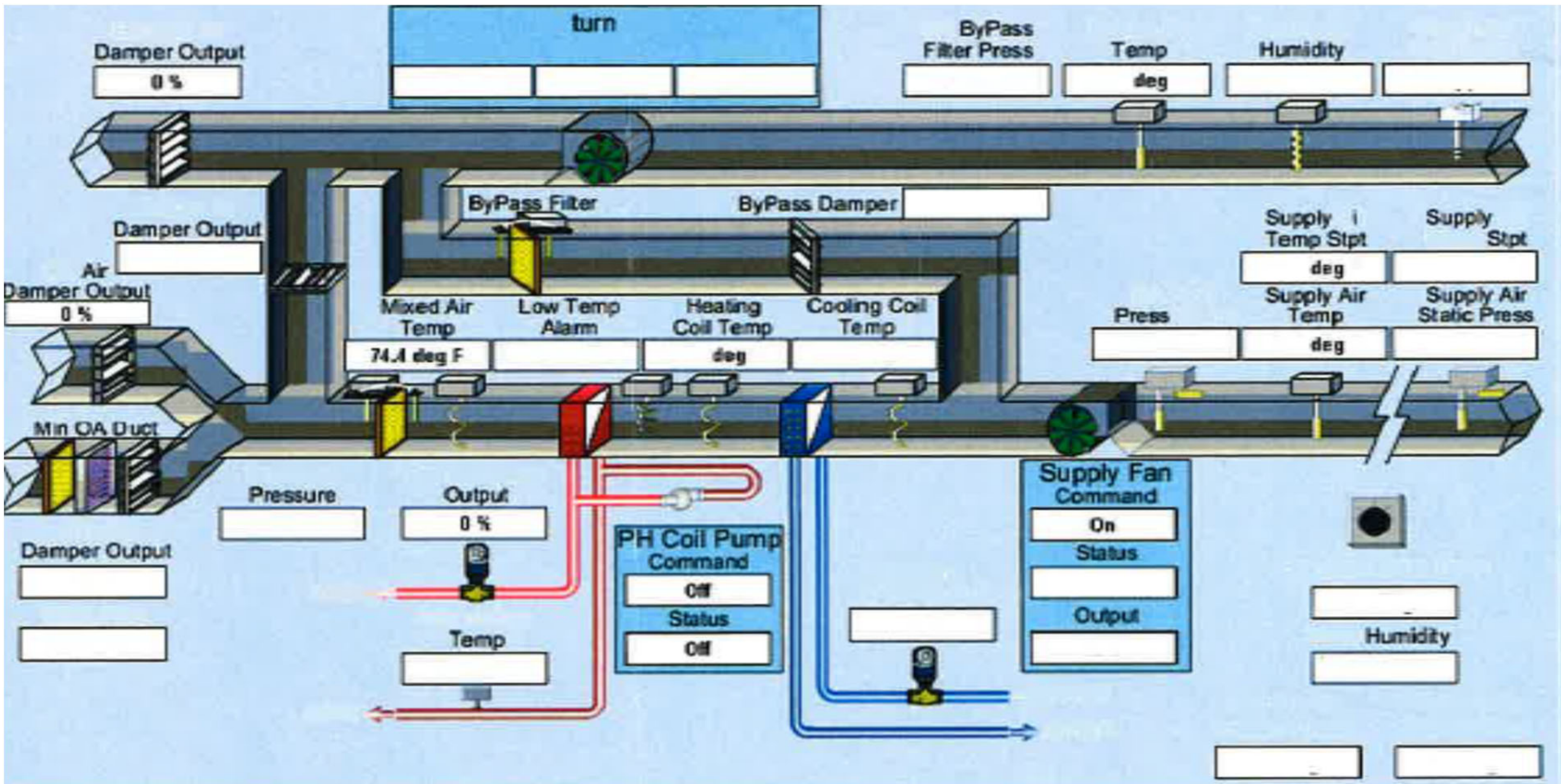


New



R/A By-Pass on a VAV System

Raising SAT with zero cost reheat



Spaces with high latent load; under-floor air

Reheat Control
(active humidity control)

The usual solution for VAV systems at minimum flow

Acceptable solution for CV systems

- Review Std. 90.1

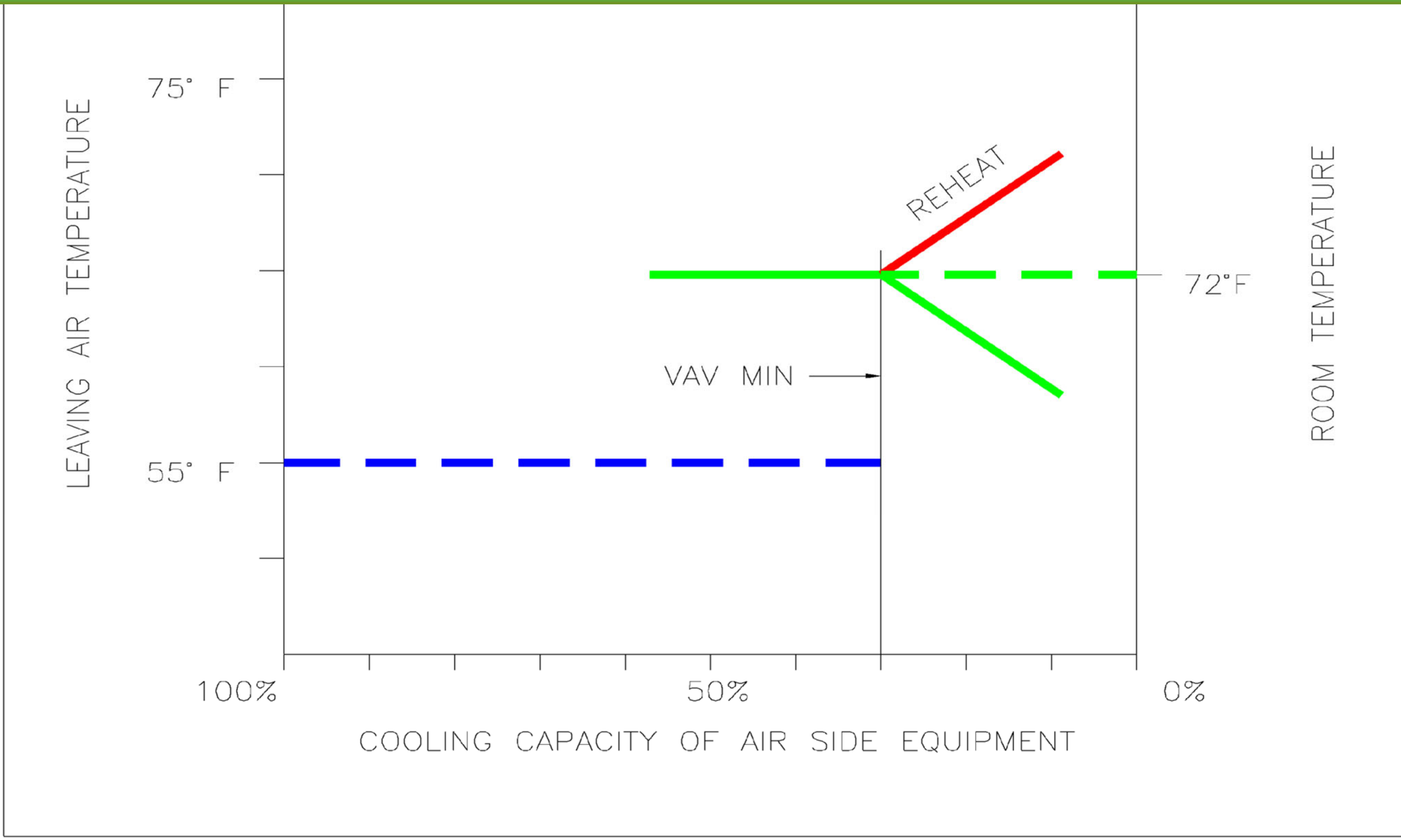
A heating source available 12 months of the year

Requires either

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

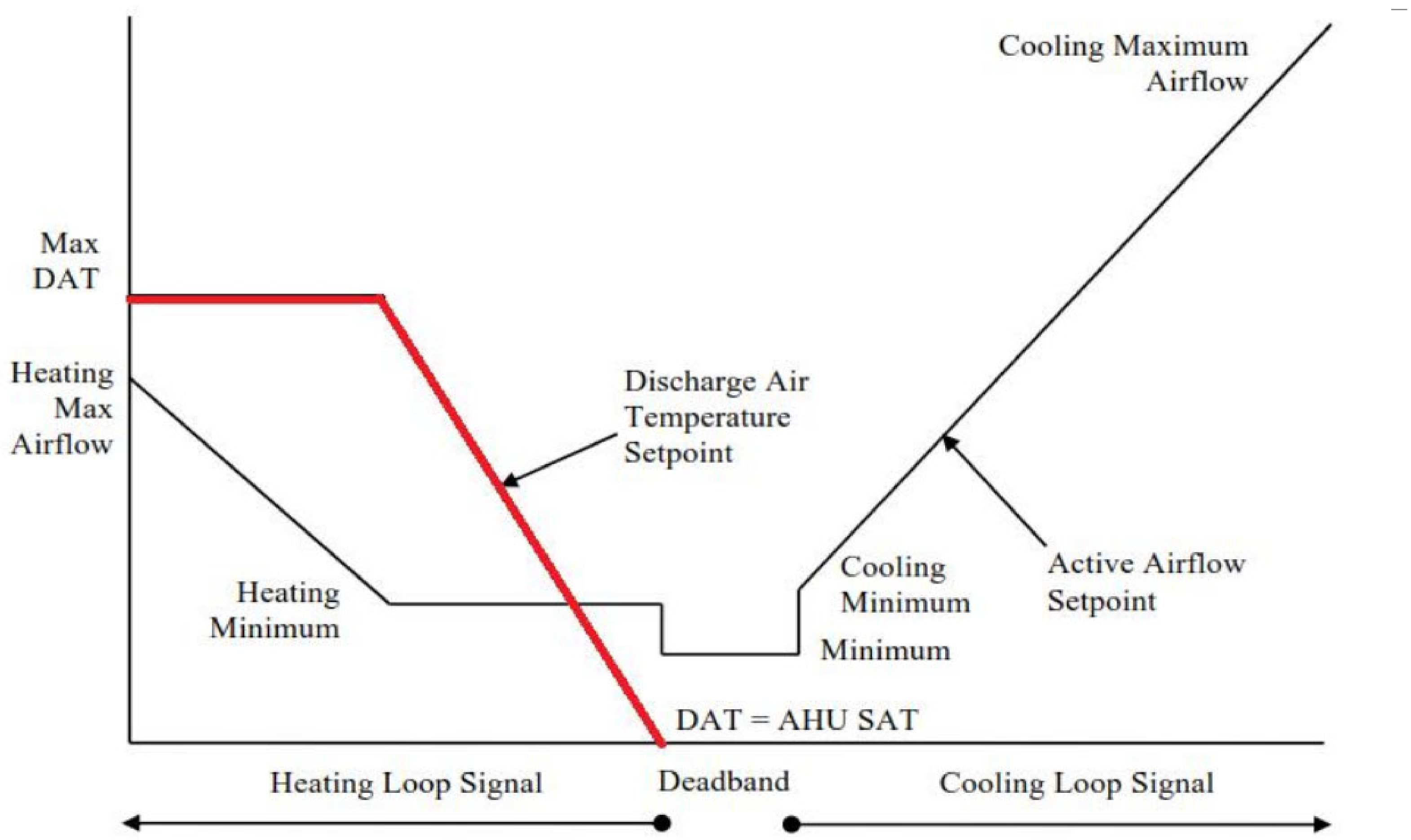
Variable Volume HVAC w/RH at Min Load

(active humidity control)



VAV Terminal

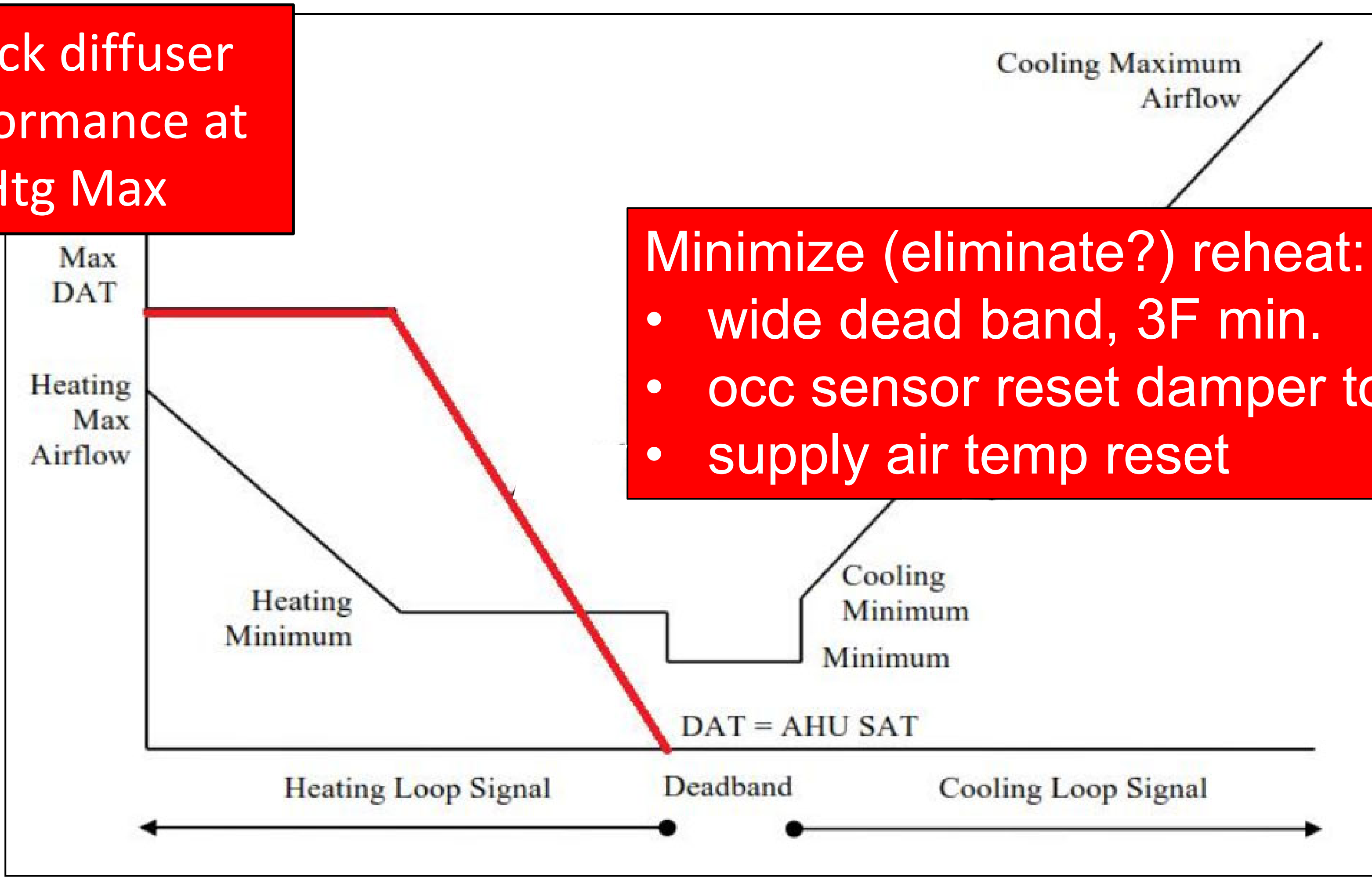
ASHRAE Guideline 36 – High performance Sequences



VAV Terminal

ASHRAE Guideline 36 – High performance Sequences

Check diffuser performance at Htg Max

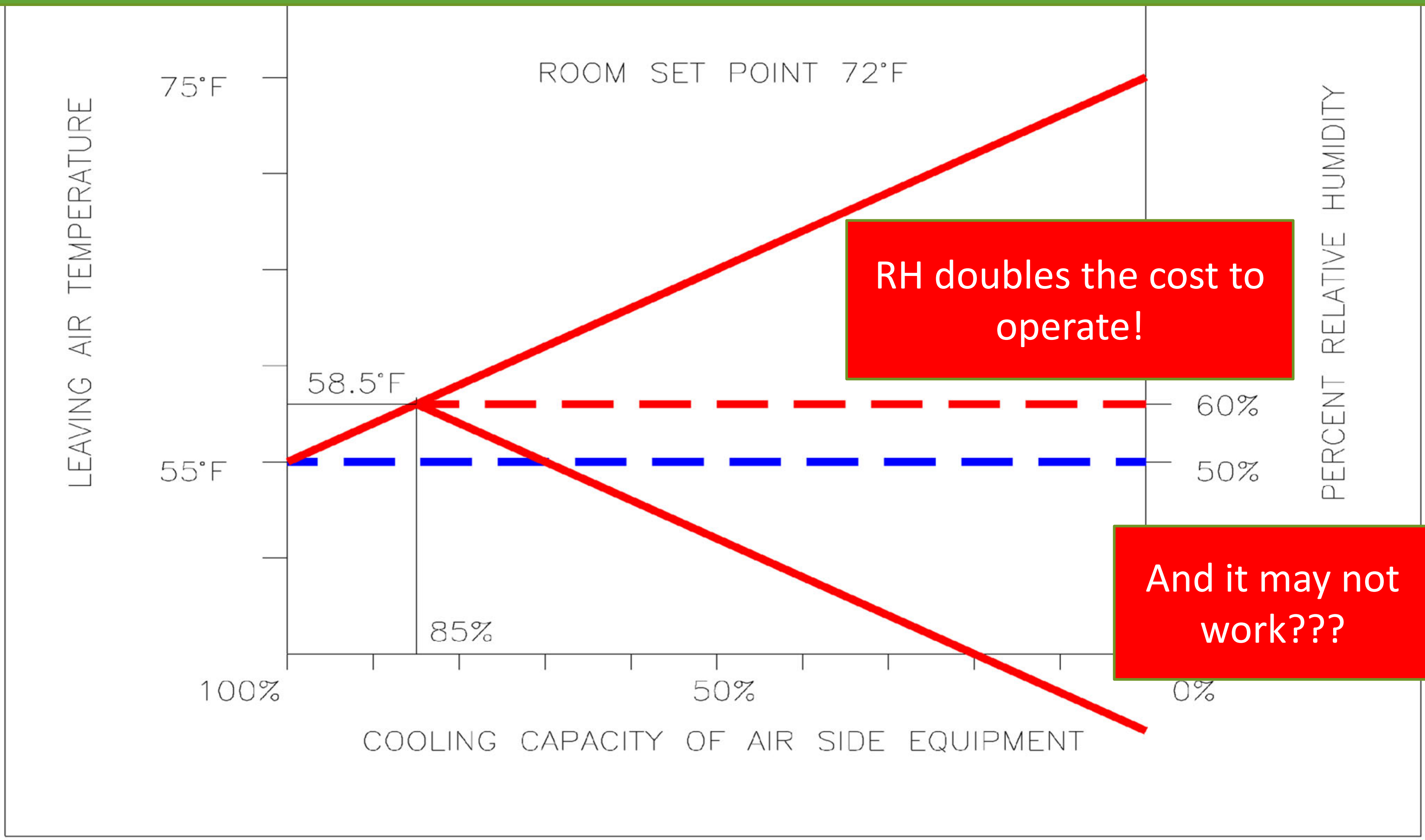


Minimize (eliminate?) reheat:

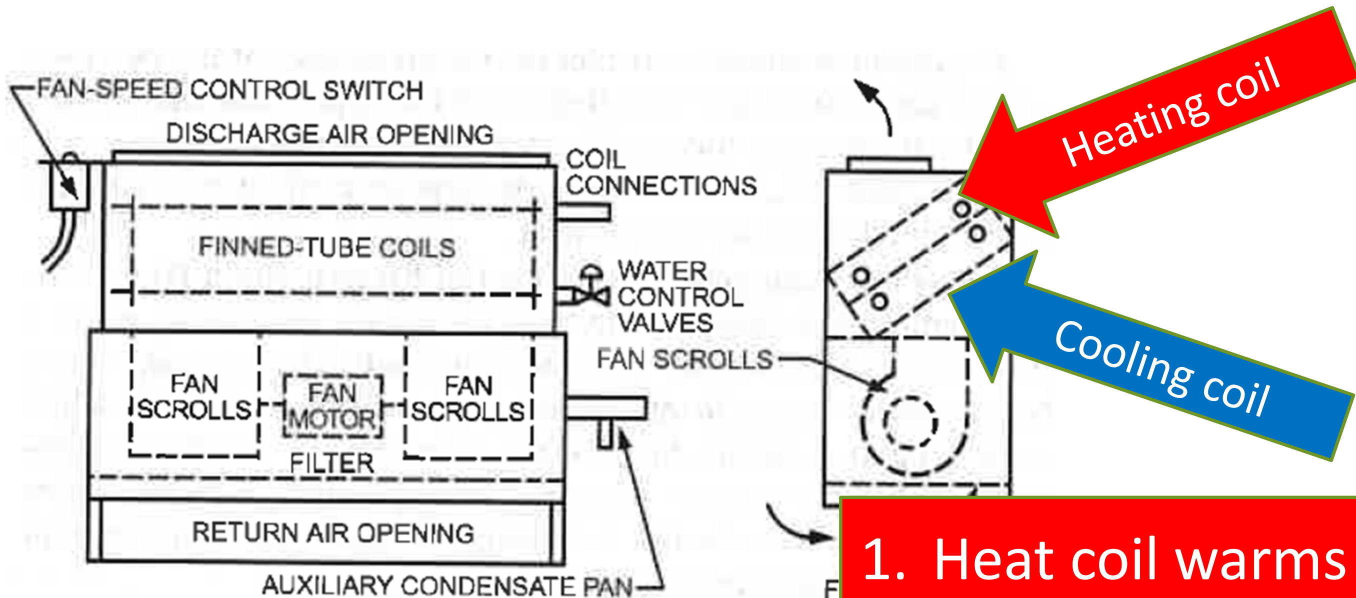
- wide dead band, 3F min.
- occ sensor reset damper to zero
- supply air temp reset

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 2
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

A Better Solution
for “incidental” situations

- Decouple make-up air
- Cycle fan on call for cooling
  - Leaving air temp sensor, set for 54F
  - Time delay on fan start, get coil cold before starting fan
  - Vary fan speed to match load
  - Fan stops when at set point, avoid latent re-entrainment
  - Wide deadband

Re-Heating Cost

Electric = $2.93/therm ($0.010/kWh)

Conventional boiler = $1.21/therm ($0.80/therm)

Low temp boiler = $0.88/therm

Geo heating = $0.85/therm

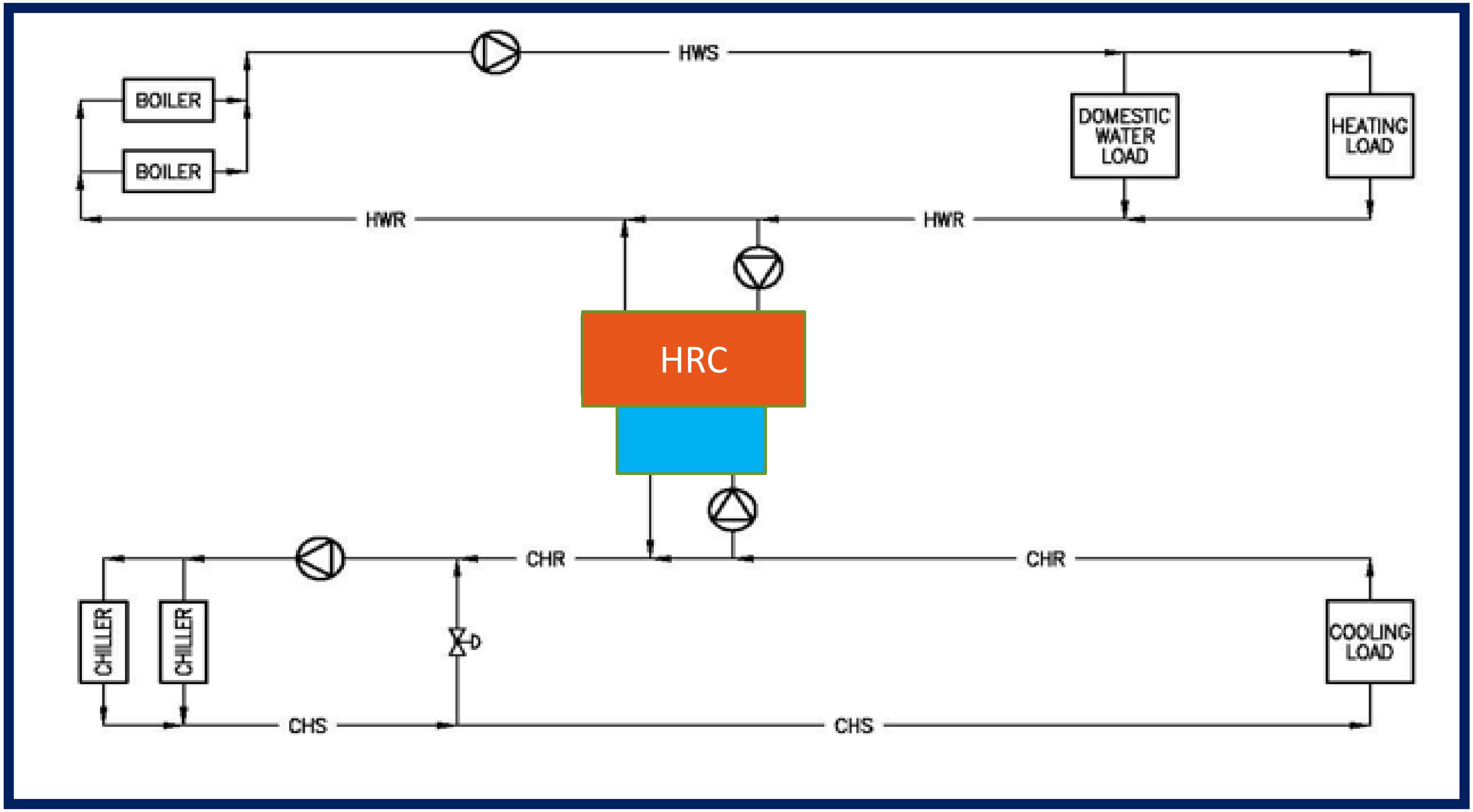
HRC heating = ($0.10/therm) If main chiller is air cooled

HRC Htg/Clg C.O.P. is about 7.7

What is a Heat Recovery Chiller?

Water cooled chiller

- Elevated condensing temperatures ~ 130F
- Connection to building heating system
- Applicable any time there are concurrent heating and cooling loads
- Saves $$ in any utility rate structure

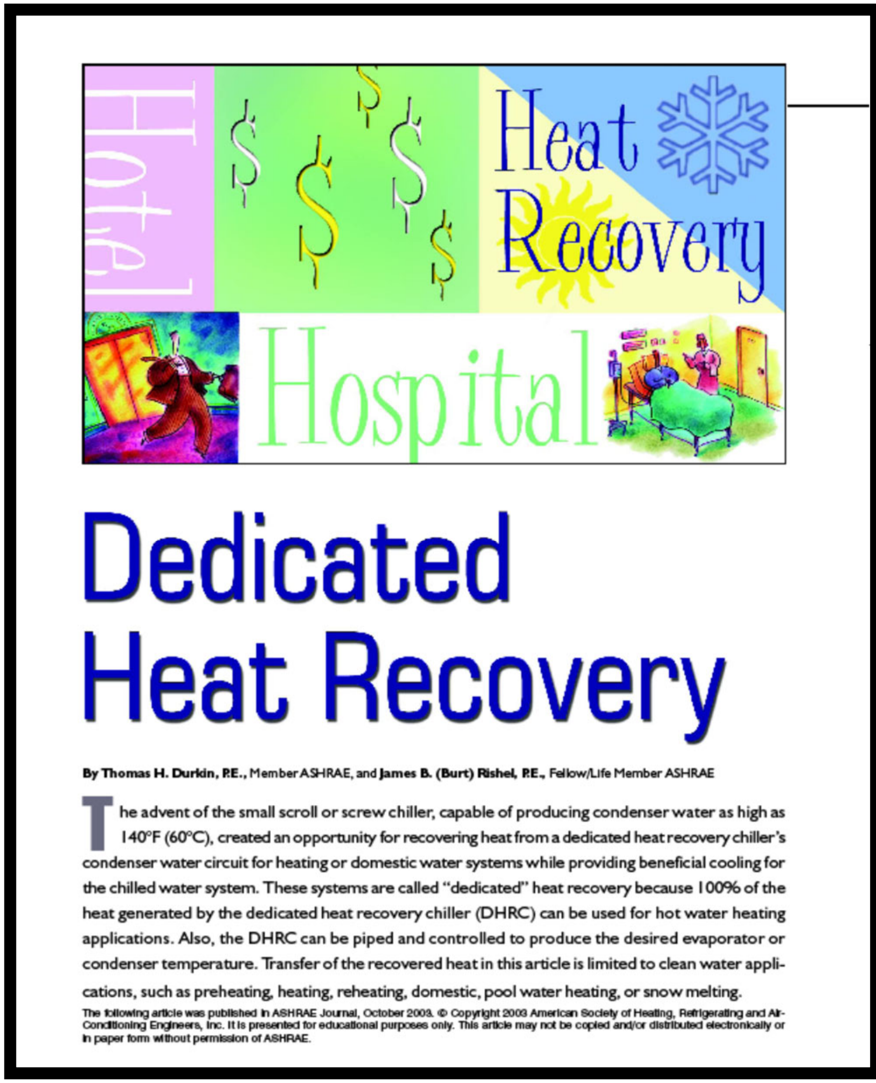


Typically sized for the larger of:

winter cooling load, or

summer heating load.

Caution: don't penalize the entire system for the sake of saving some of the energy.



Dedicated Heat Recovery

By **Thomas H. Durkin, P.E.**, Member ASHRAE, and **James B. (Burt) Rishel, P.E.**, Fellow/Life Member ASHRAE

The advent of the small scroll or screw chiller, capable of producing condenser water as high as 140°F (60°C), created an opportunity for recovering heat from a dedicated heat recovery chiller's condenser water circuit for heating or domestic water systems while providing beneficial cooling for the chilled water system. These systems are called "dedicated" heat recovery because 100% of the heat generated by the dedicated heat recovery chiller (DHRC) can be used for hot water heating applications. Also, the DHRC can be piped and controlled to produce the desired evaporator or condenser temperature. Transfer of the recovered heat in this article is limited to clean water applications, such as preheating, heating, reheating, domestic, pool water heating, or snow melting.

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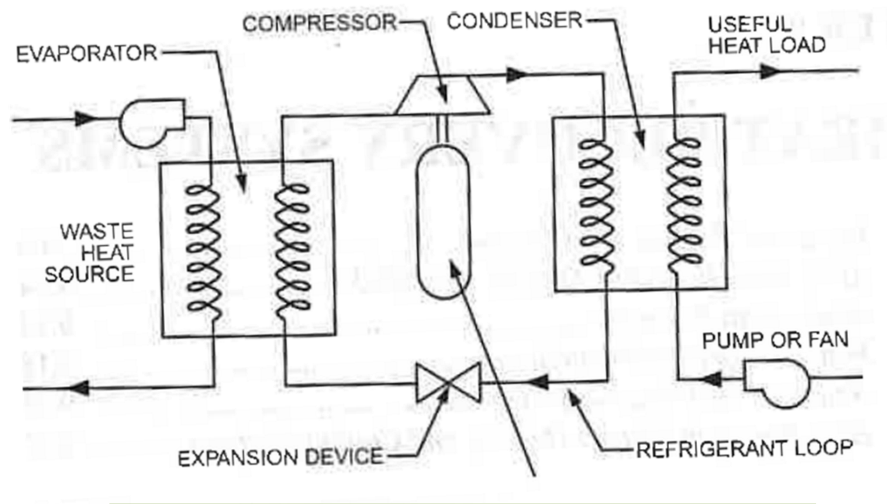
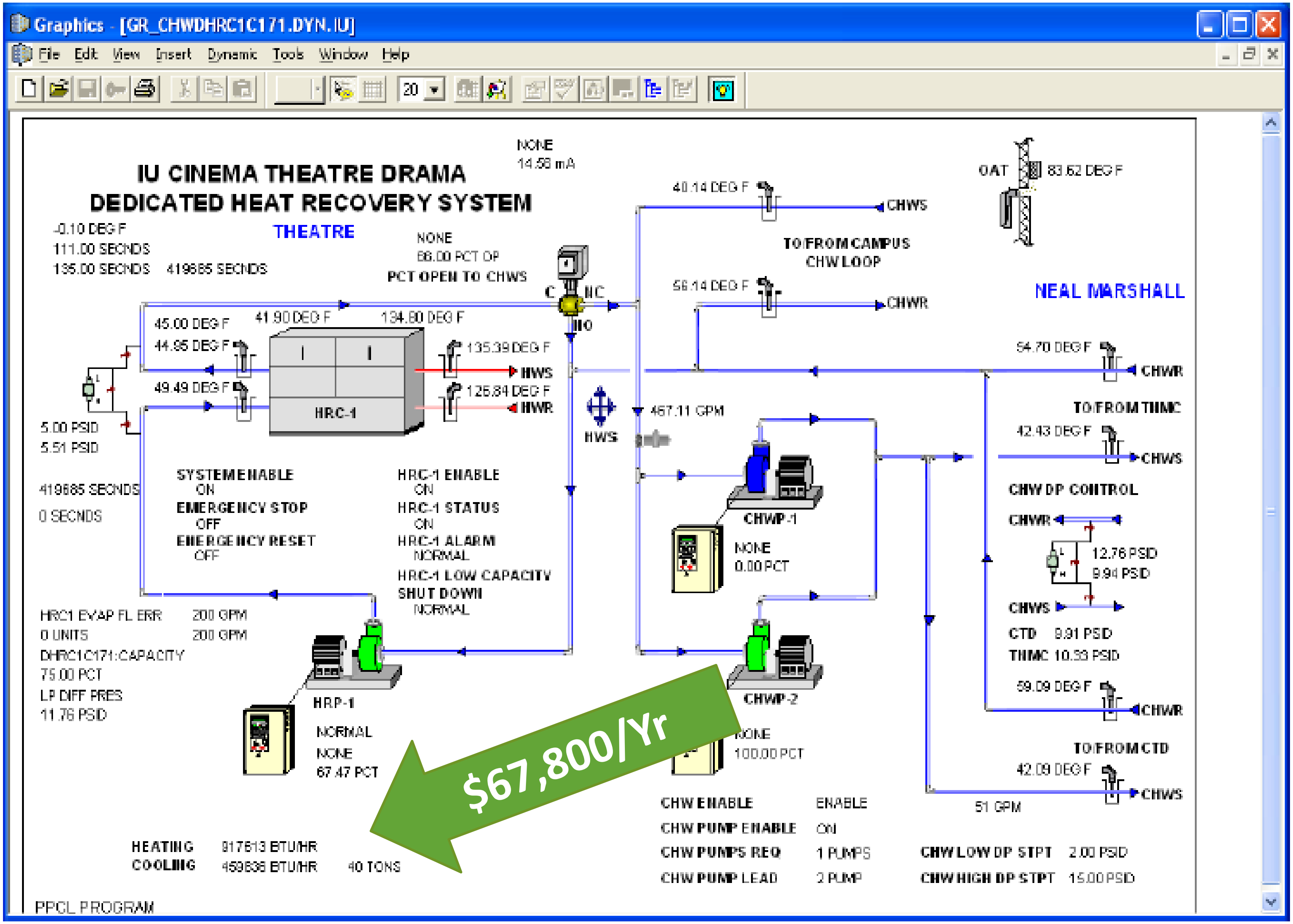
October 2003



2020 Systems Handbook Chapters 9 and 43



Bid as an alternate: payback = 2.3 Yrs

One of four performance spaces in CTD. Murals are historic from 1930's by Thomas Hart Benton

Tom’s Rules of Heat Recovery

1. Never compromise IAQ, occupant comfort or humidity control.
2. Don’t spend more to save energy than energy is worth.
3. Try to engineer the need for heat recovery out of a project.
4. Anything goes…BTUs = BTUs.

BTUs = BTUs

One shower = 4.4 Tons of Cooling

BTUs = BTUs

Turn **Gray** BTUs into **Green** BTUs

Or

Heat your buildings with BTUs from that were being rejected at the condensing units or relief vents.

They're your BTUs, you bought them.

Don't just throw them away.

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
- 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

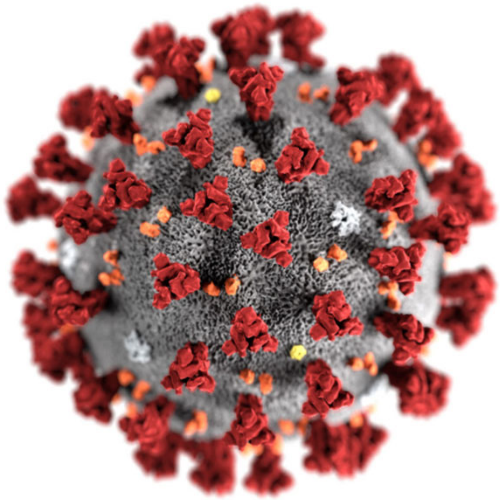
All are correct

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
  - Don't create a humidity problem by exceeding the capacity of your cooling coils
- Better filtration…MERV-13
  - Will capture most virus

CDC Infection Control Pyramid

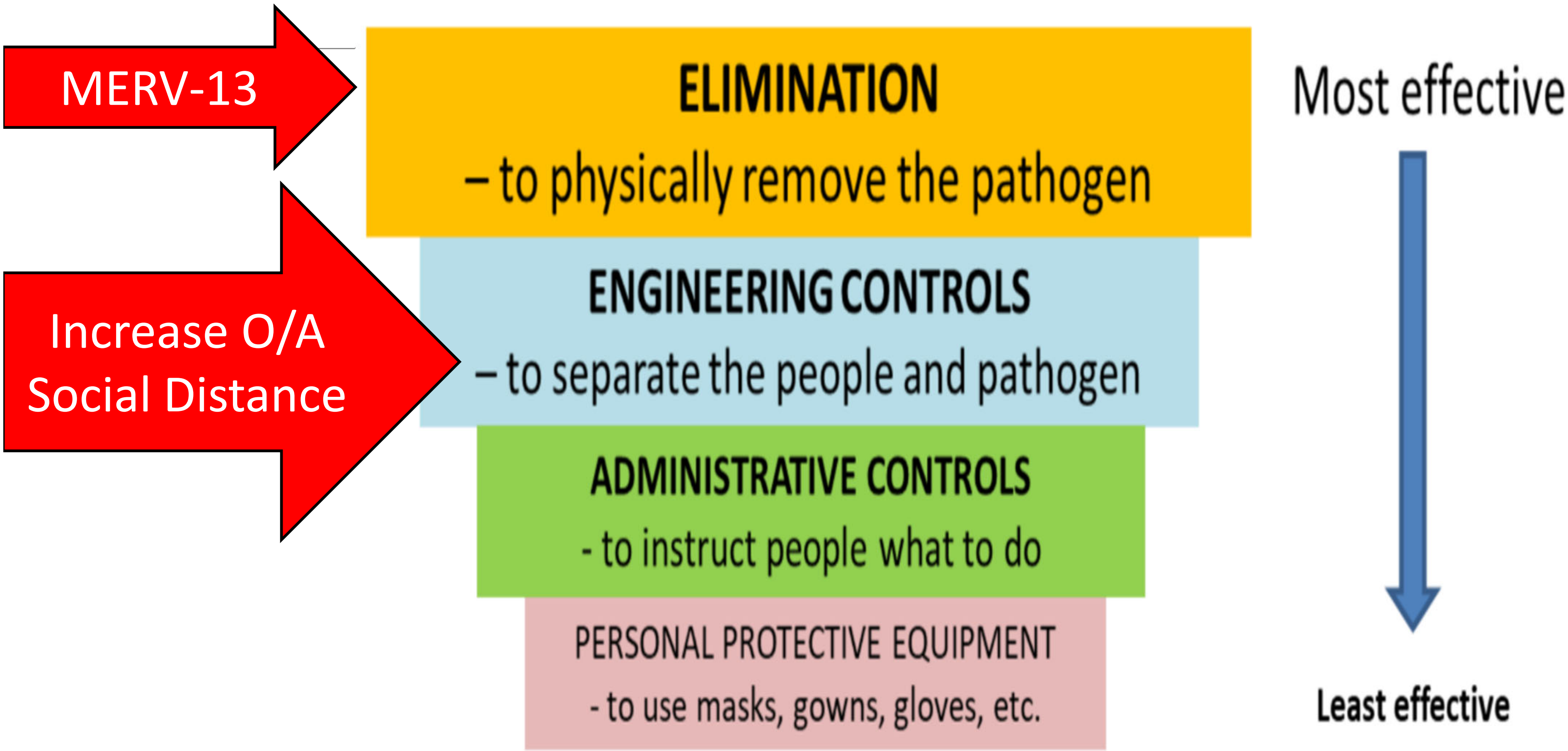
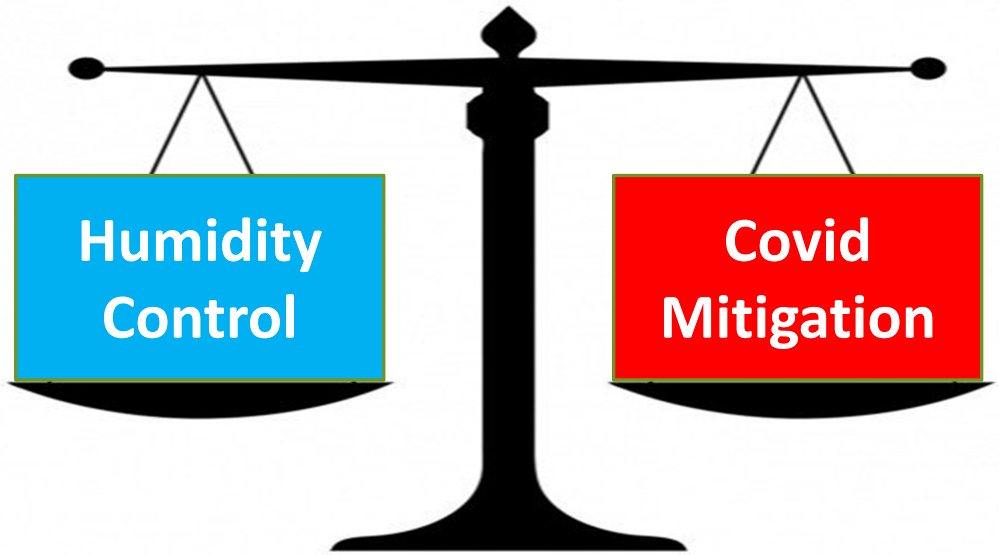


Figure 3. Traditional infection control pyramid adapted from the US Centers for Disease Control[xxxiii].

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. 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.

Questions?

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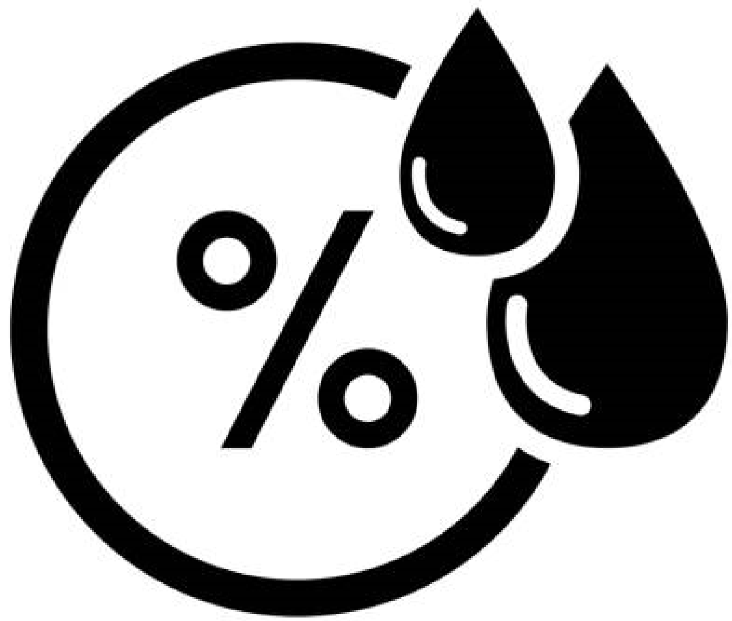

Humidity Control

Your No. 1 IAQ Liability