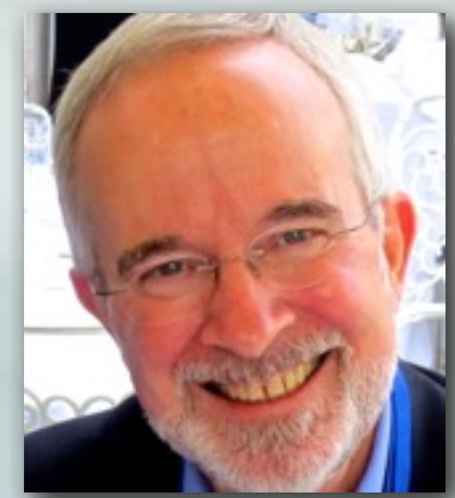
# Wet ‘n Wild

## 40 Years of Hard Lessons About Humidity Control



Mason-Grant CONSULTING

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

# July 1982 - 4:30pm Friday afternoon

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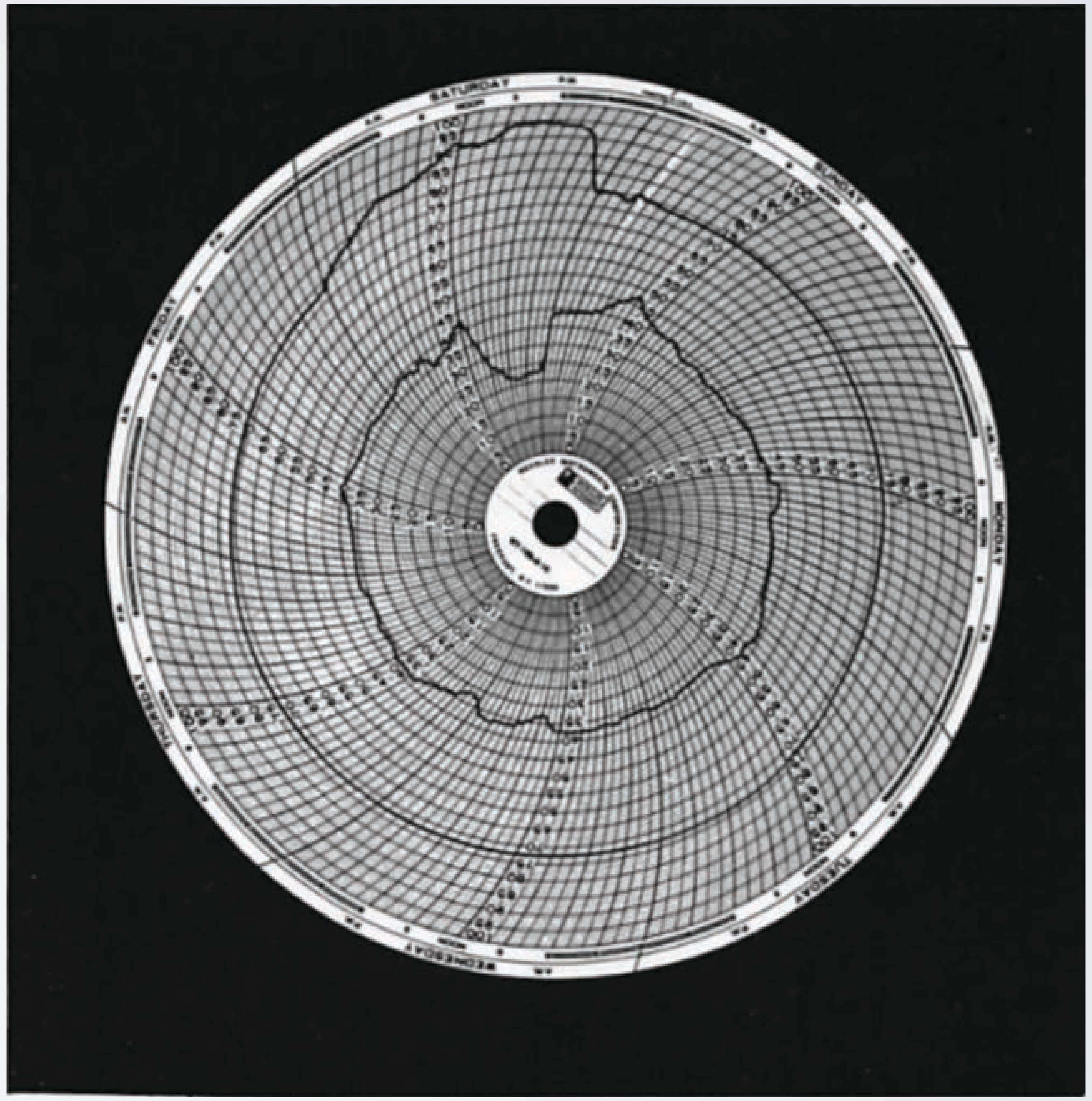

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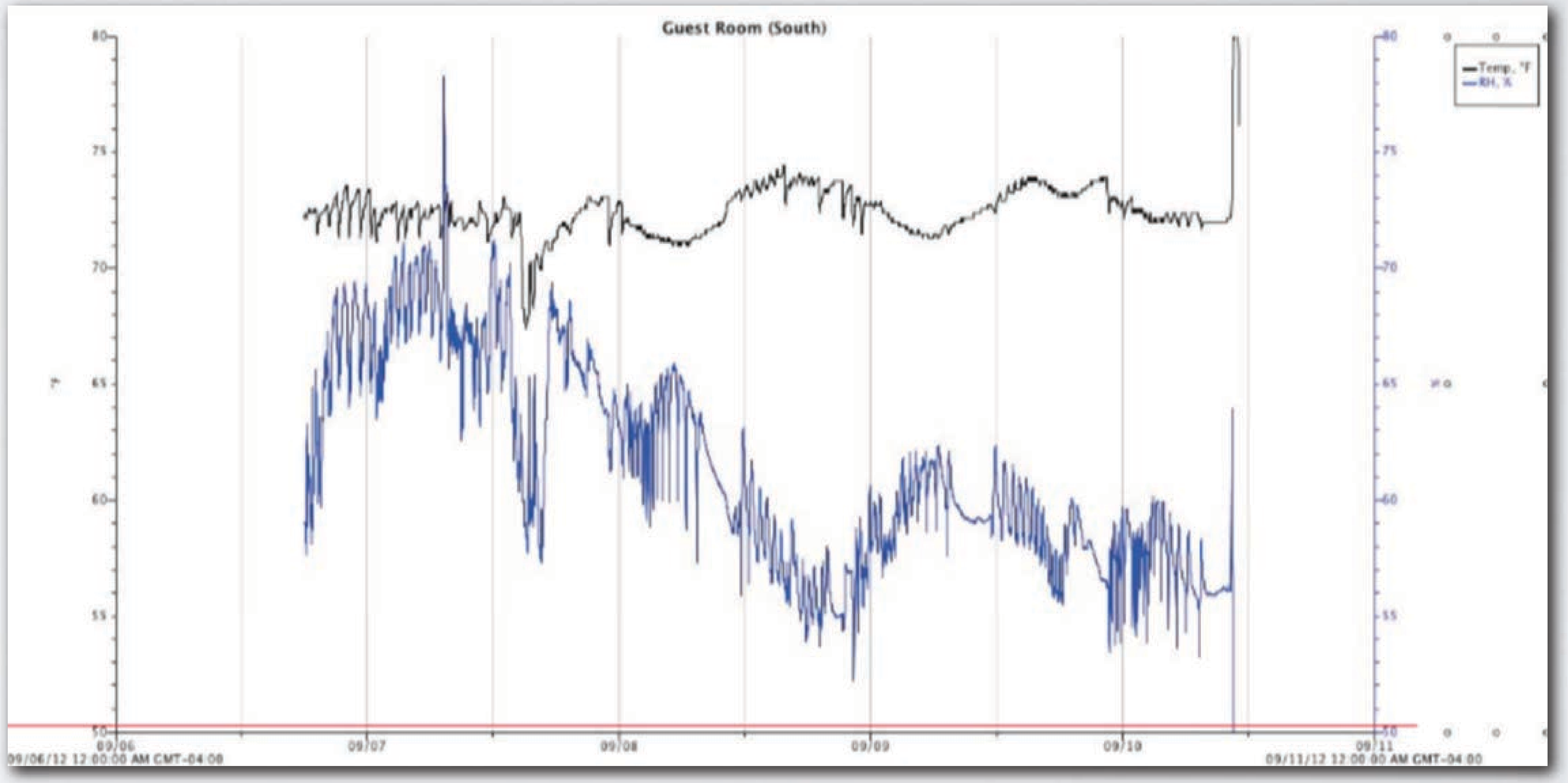

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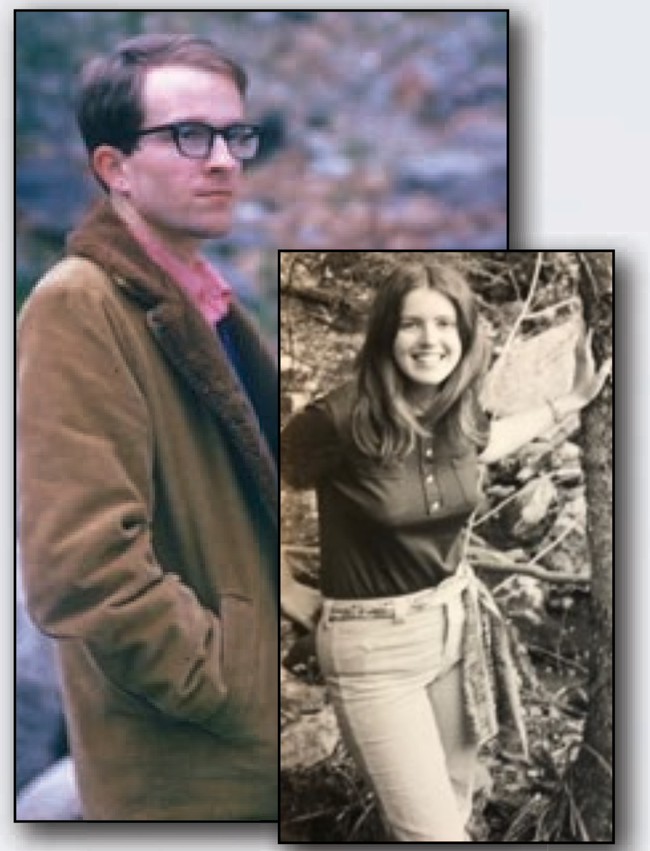
2. **Dry the ventilation air**, using ASHRAE peak dew point design data to size the ventilation dehumidifier.
3. **STOP ventilation + exhausts** when nobody's in the building.
4. **Keep unoccupied buildings DRY (not cool)** by recirculating and operating the ventilation dehumidifier.

# Who IS this guy Harriman?...

## and HOW did he get to BE that way?

1959 - Buffalo, NY
Calasanctius School

1964 - Catalunya, España
Escolápios de Puigcerdá



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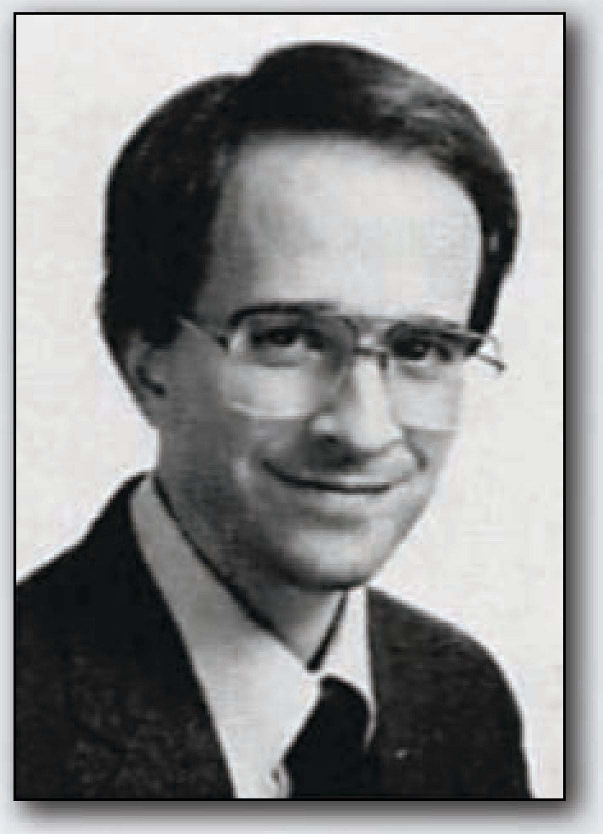

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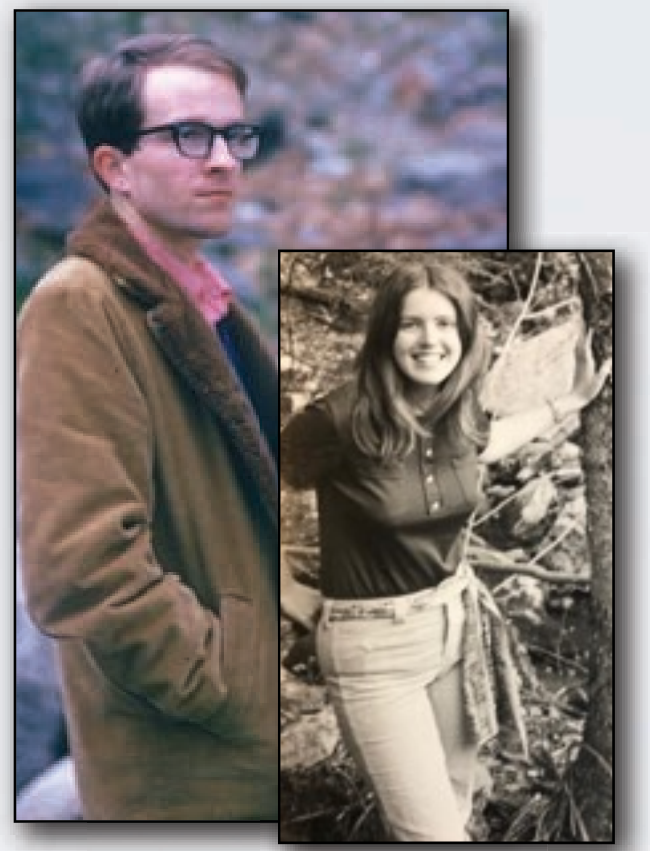

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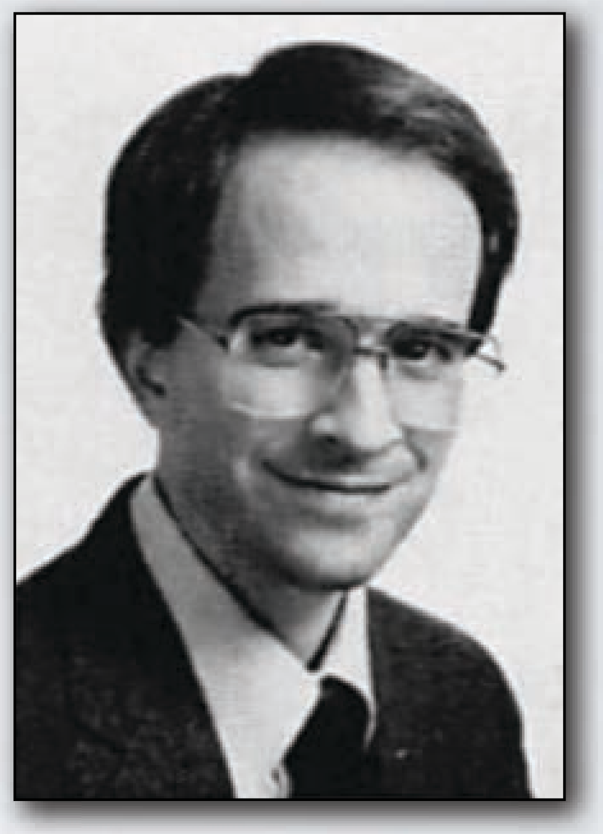

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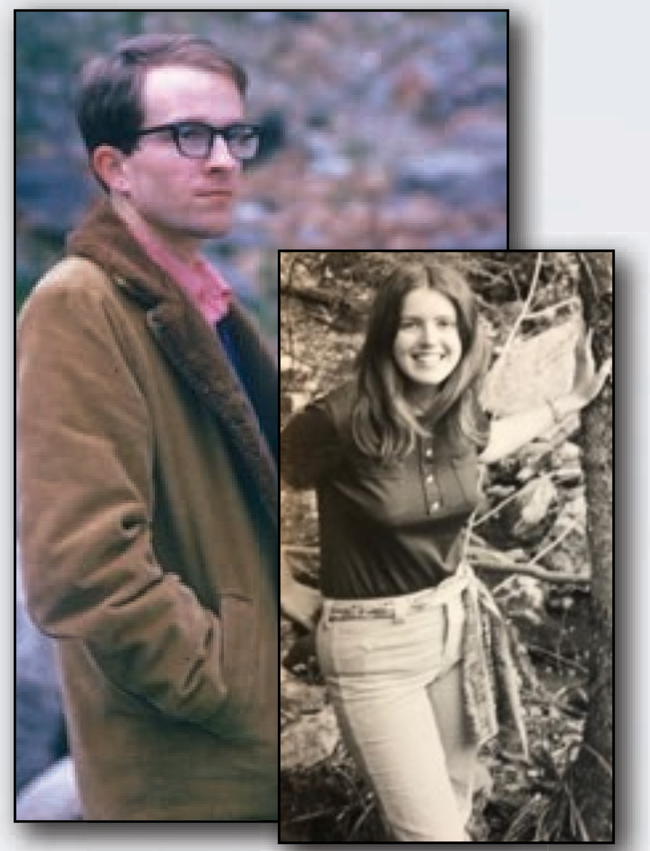

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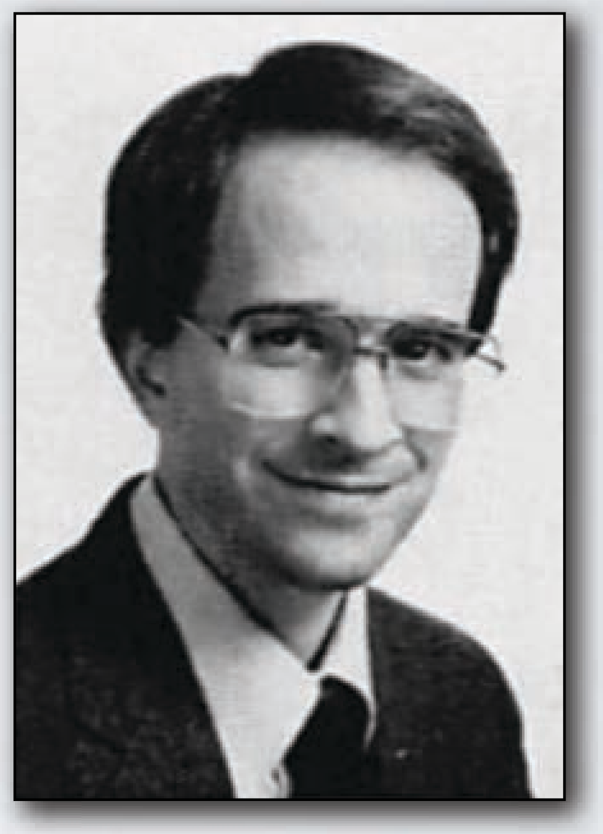

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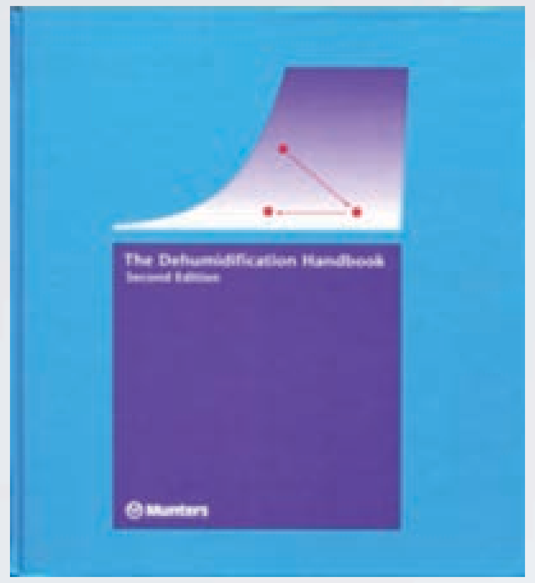
# Books, Articles & Guidance

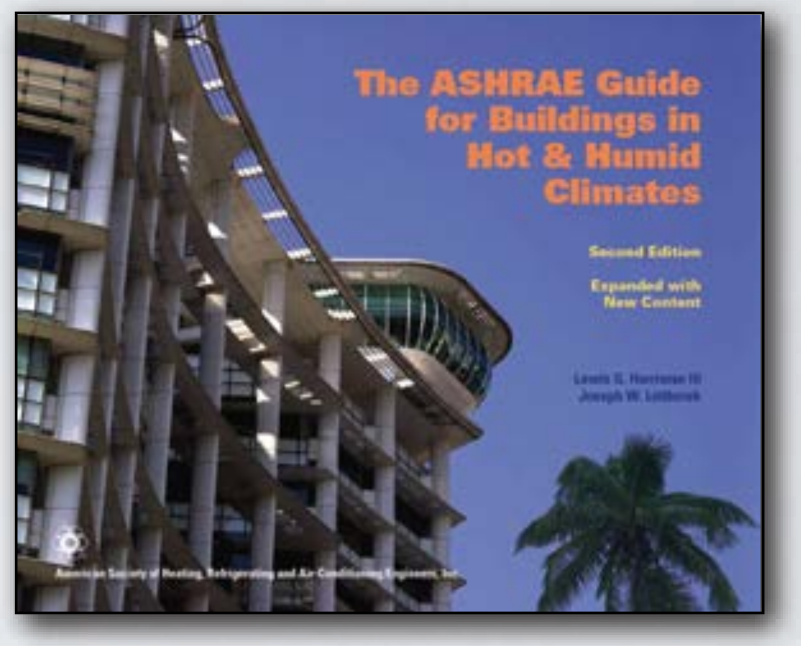

1976-1986 Industrial DH and Heat Recovery




1990 Dehumidification Handbook

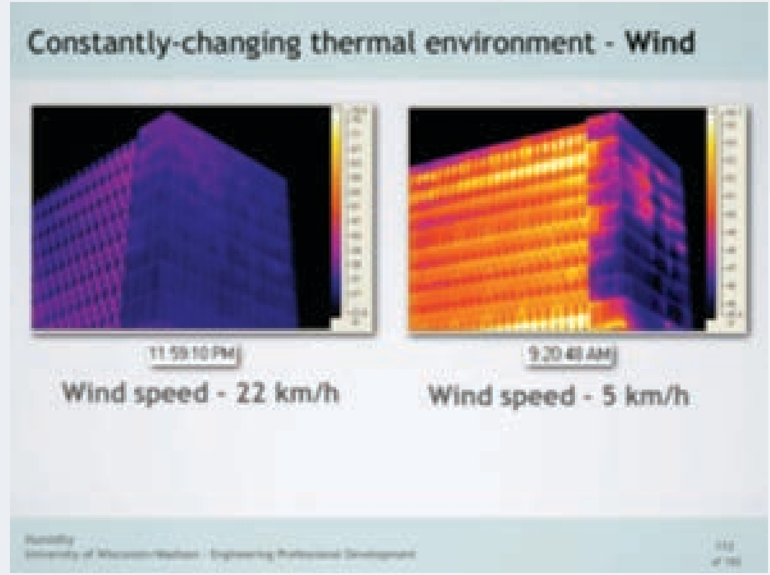

1992 AHMA Hotel Mold Survey


2001 - ASHRAE Humidity Control




2006 - ASHRAE Guide for Buildings


1997 Ventilation (Humidity) Load Index




2002 GSA Building IR Investigation + RIA IR Training


2012 California Home Energy Retrofit


1989-2019 ASHRAE Handbook


2012 - 2018 US EPA Guidance

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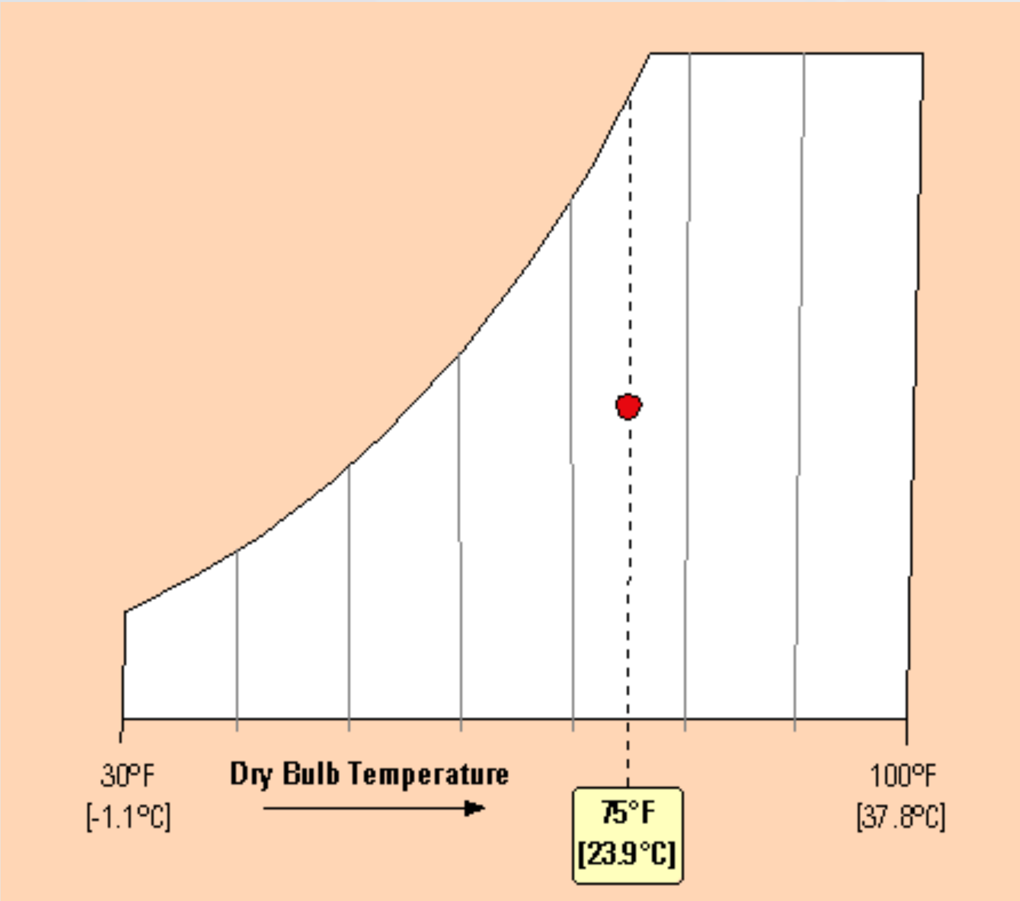


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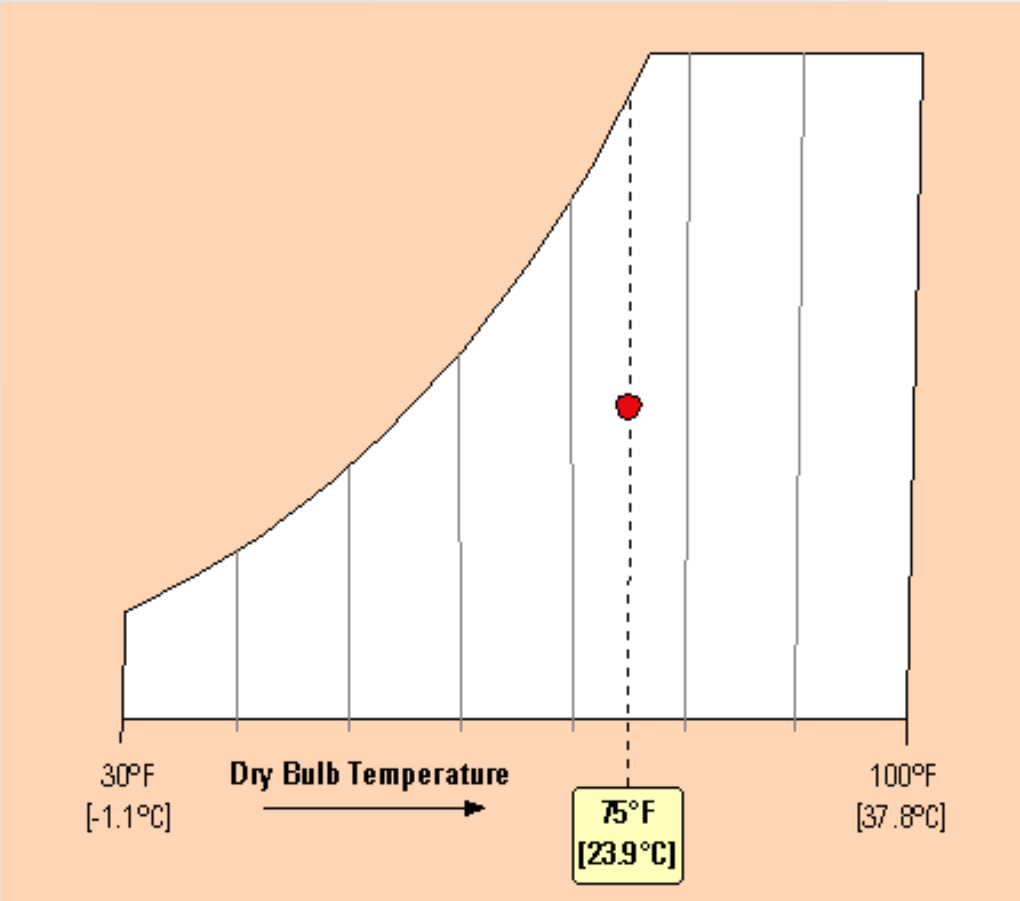


Relative Humidity
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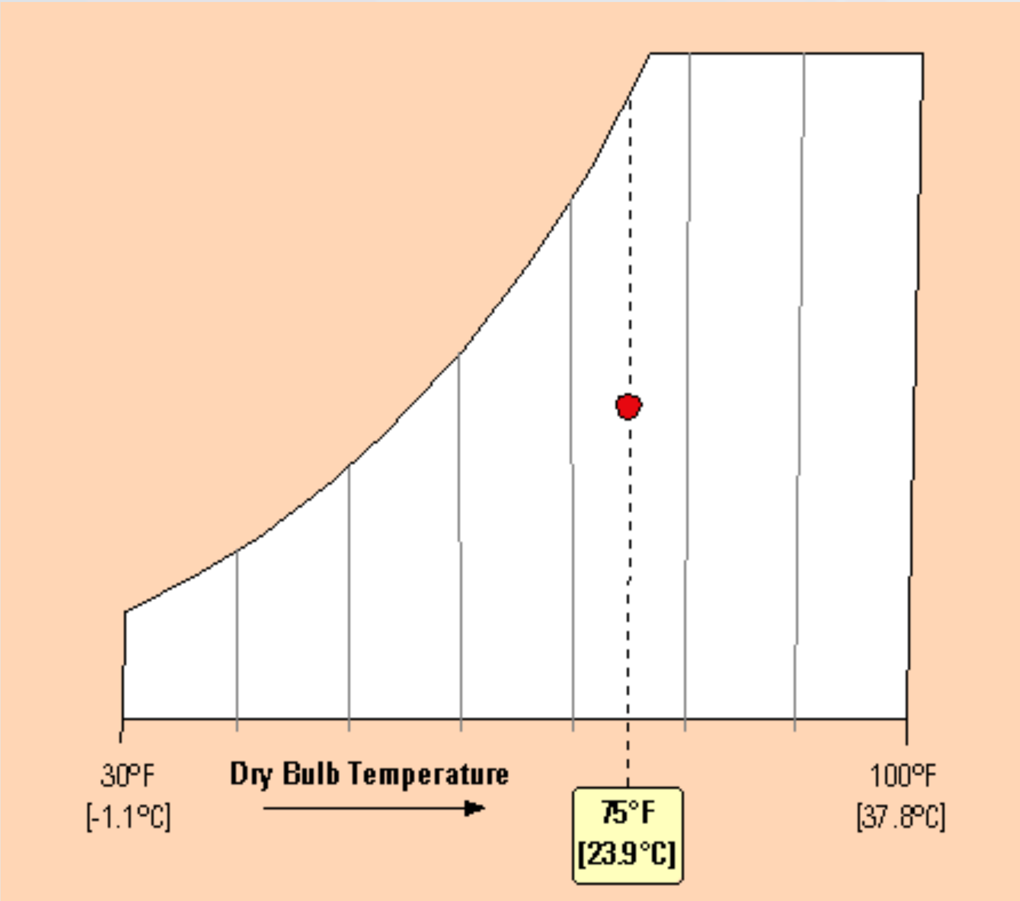


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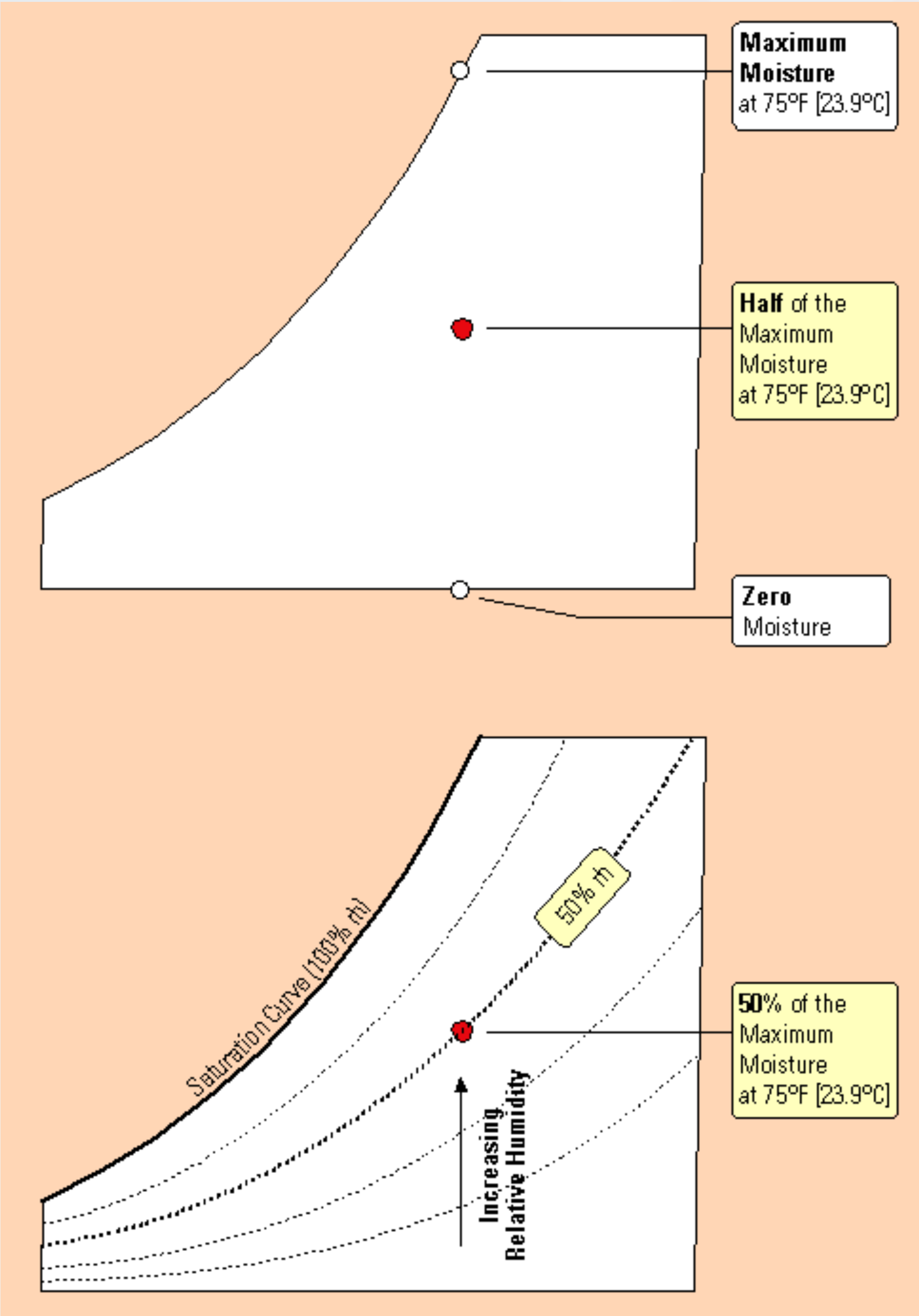

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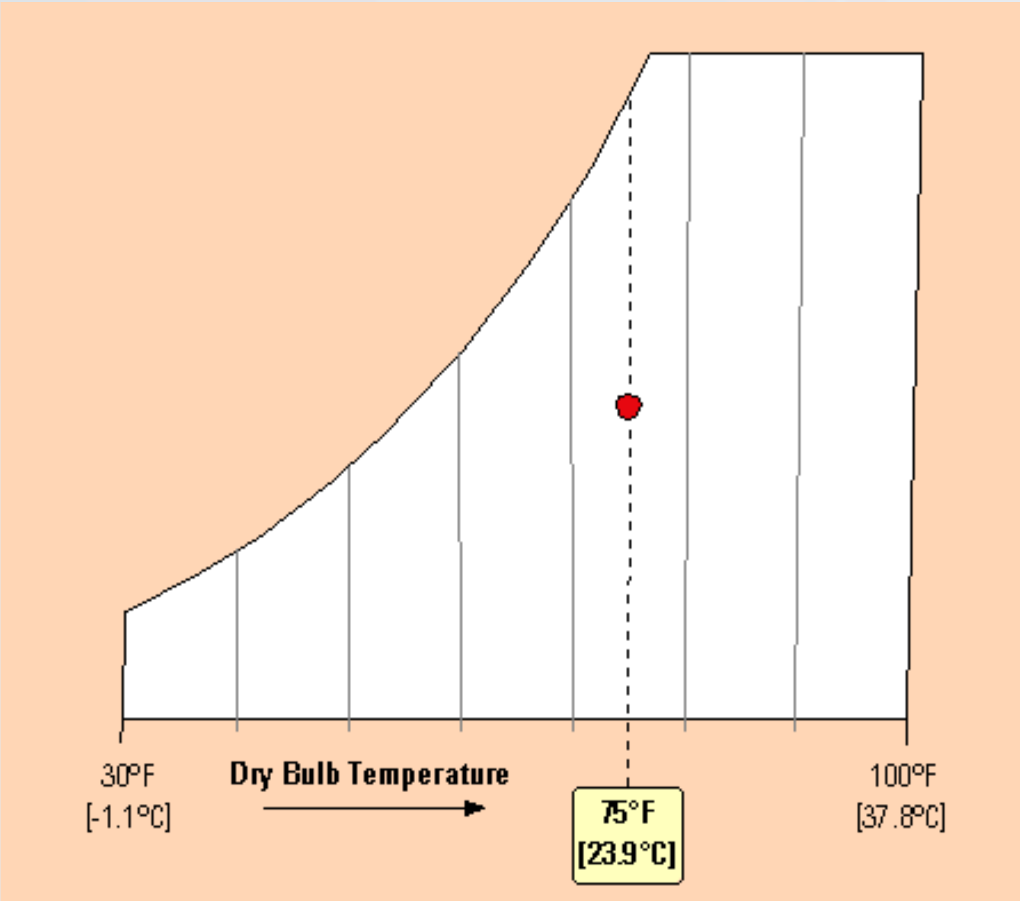


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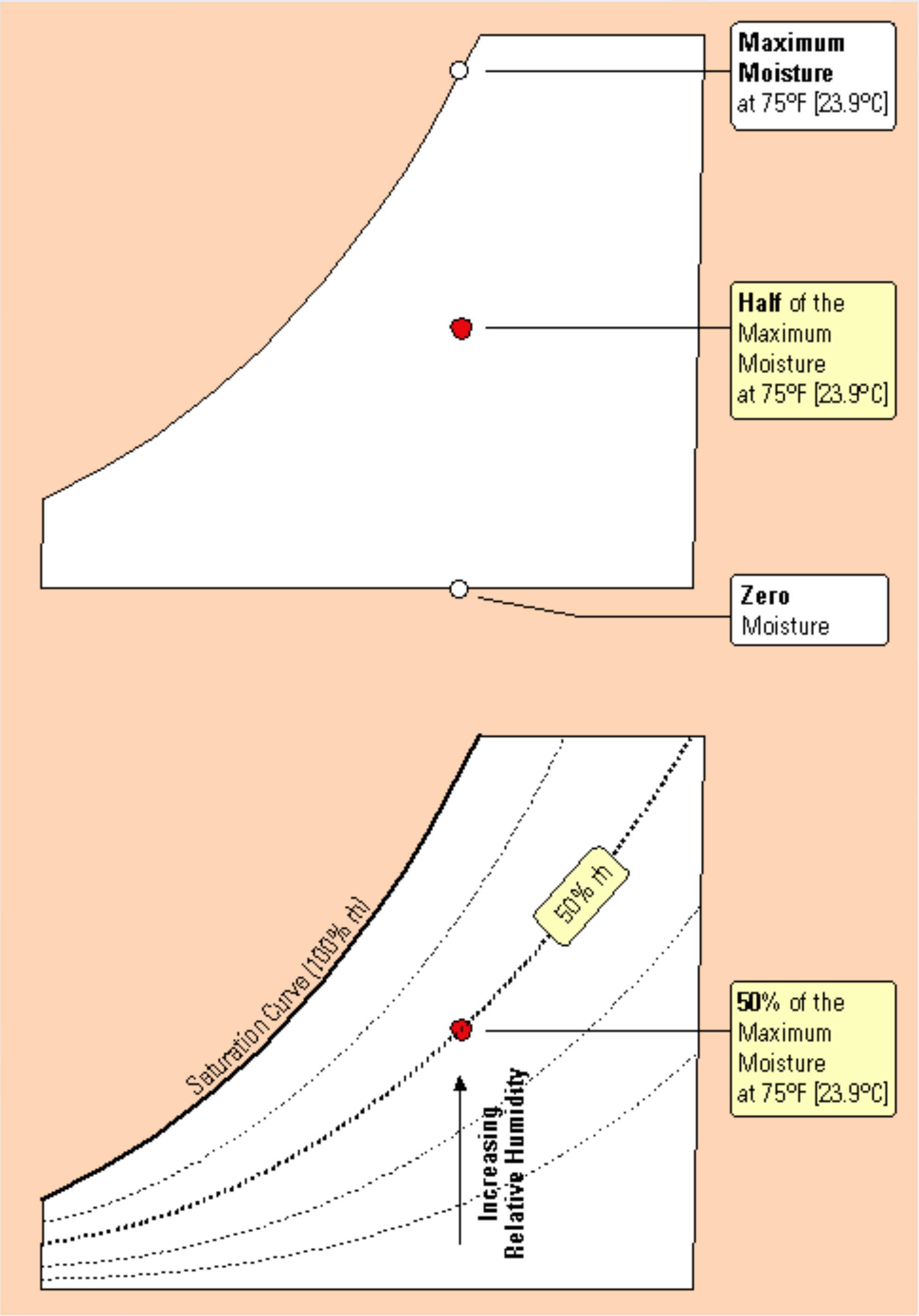


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# Terminology and Units

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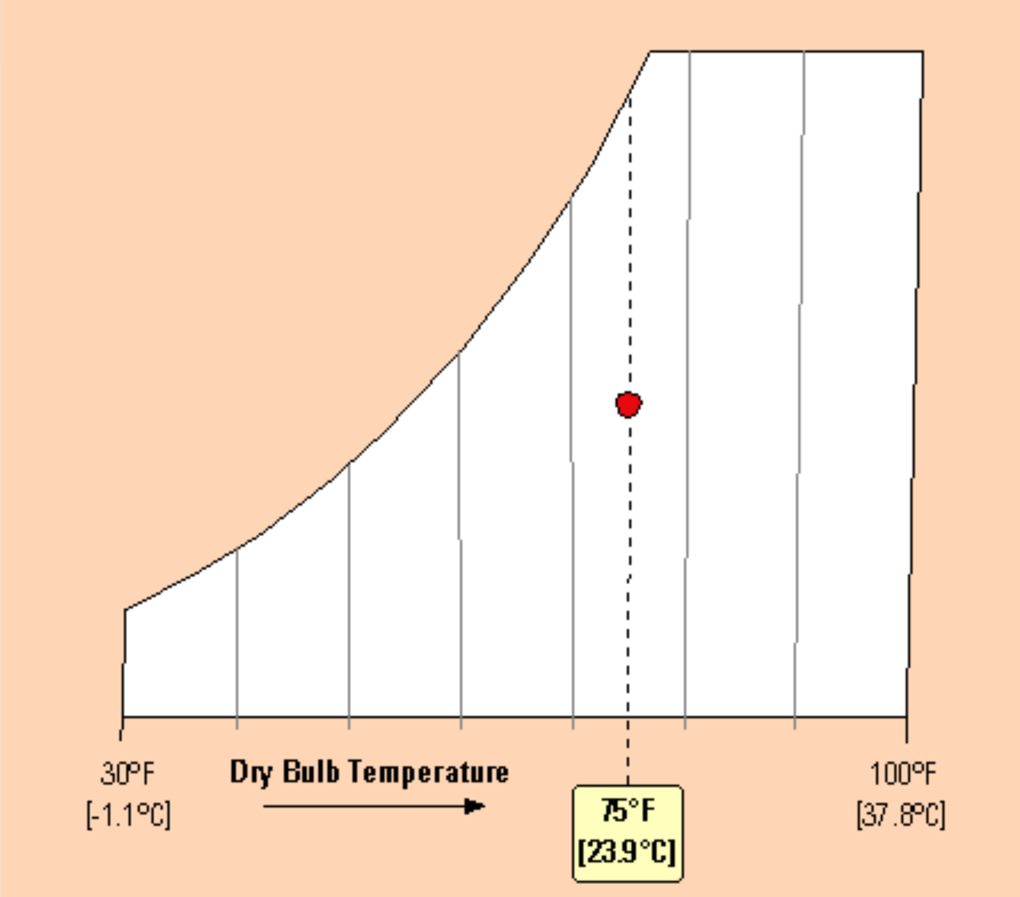


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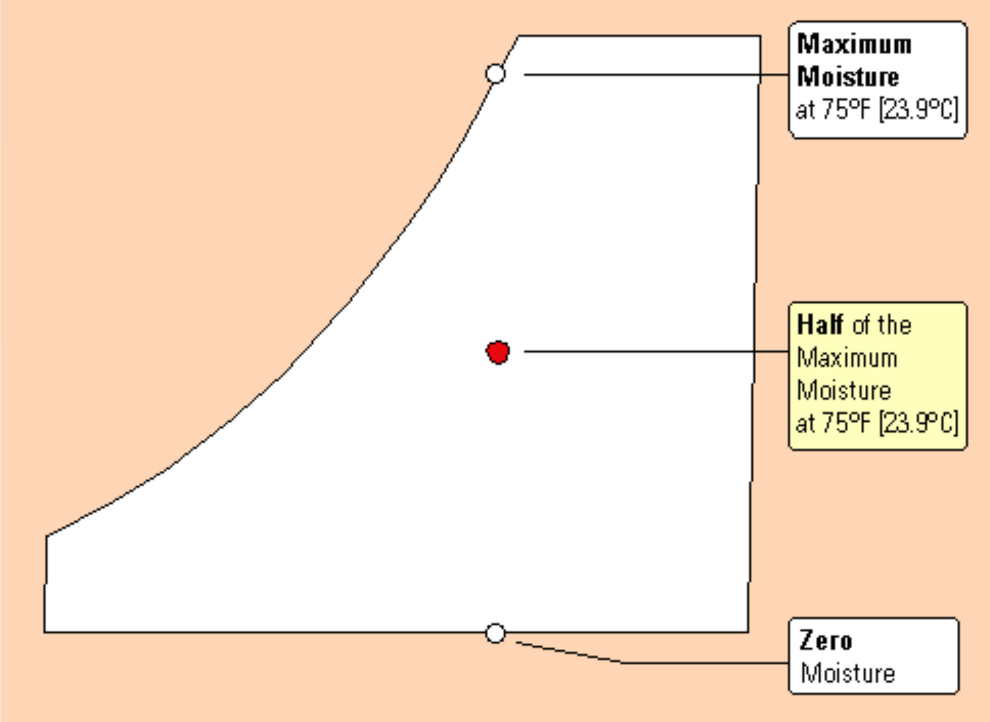


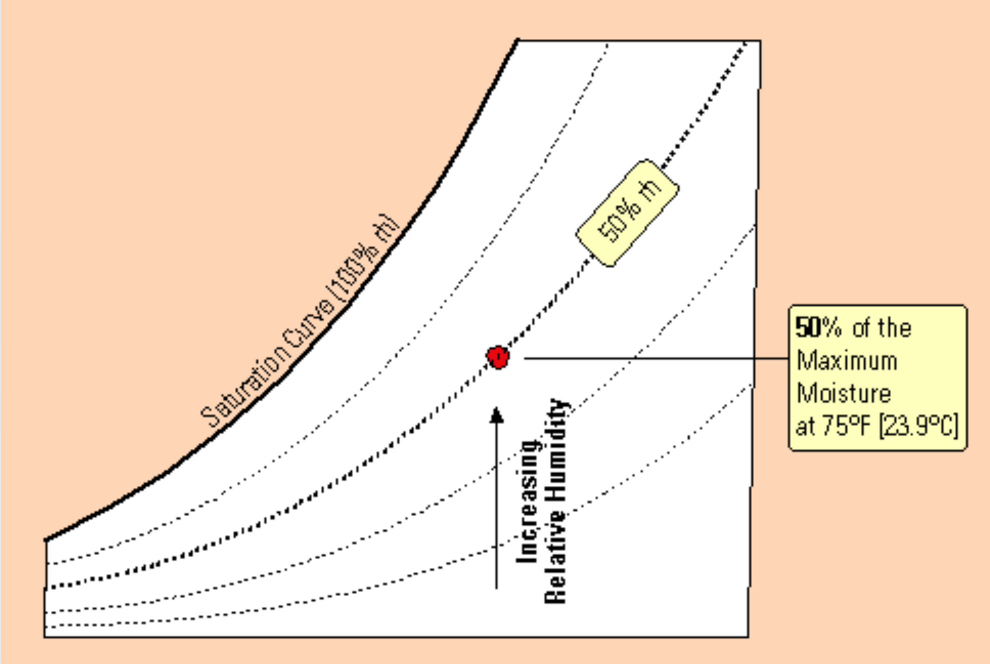


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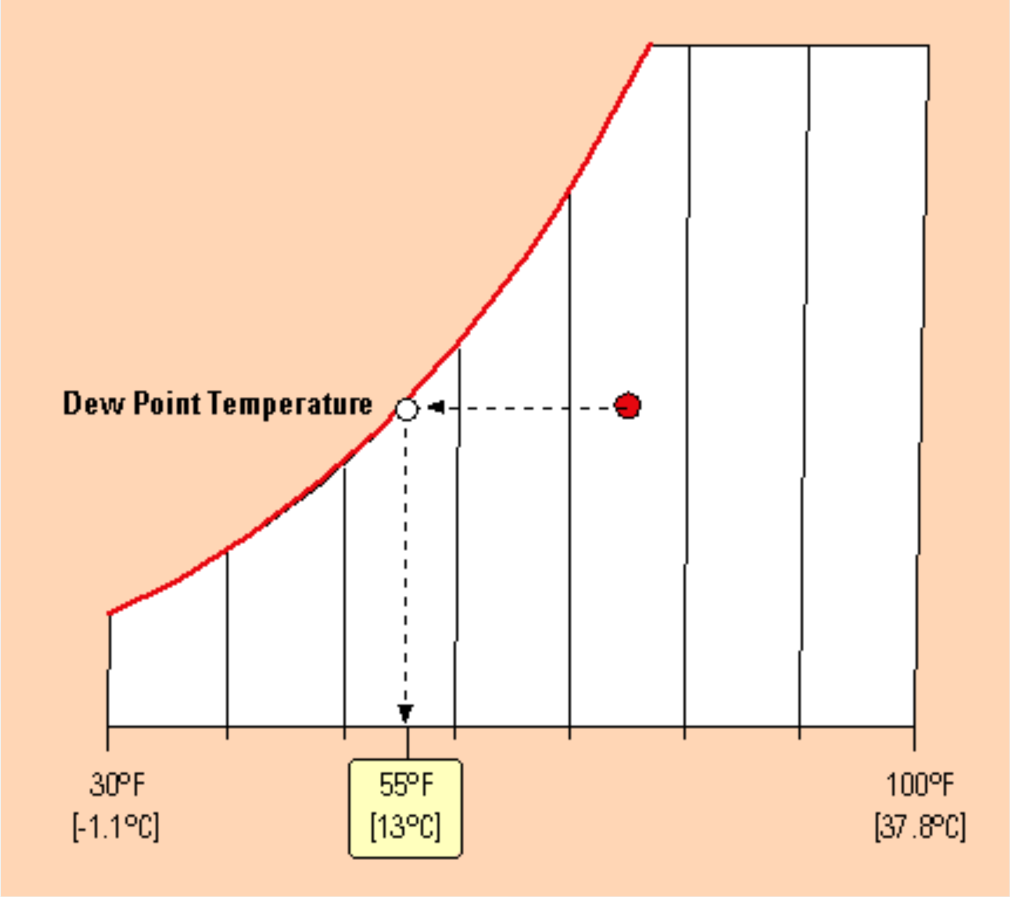


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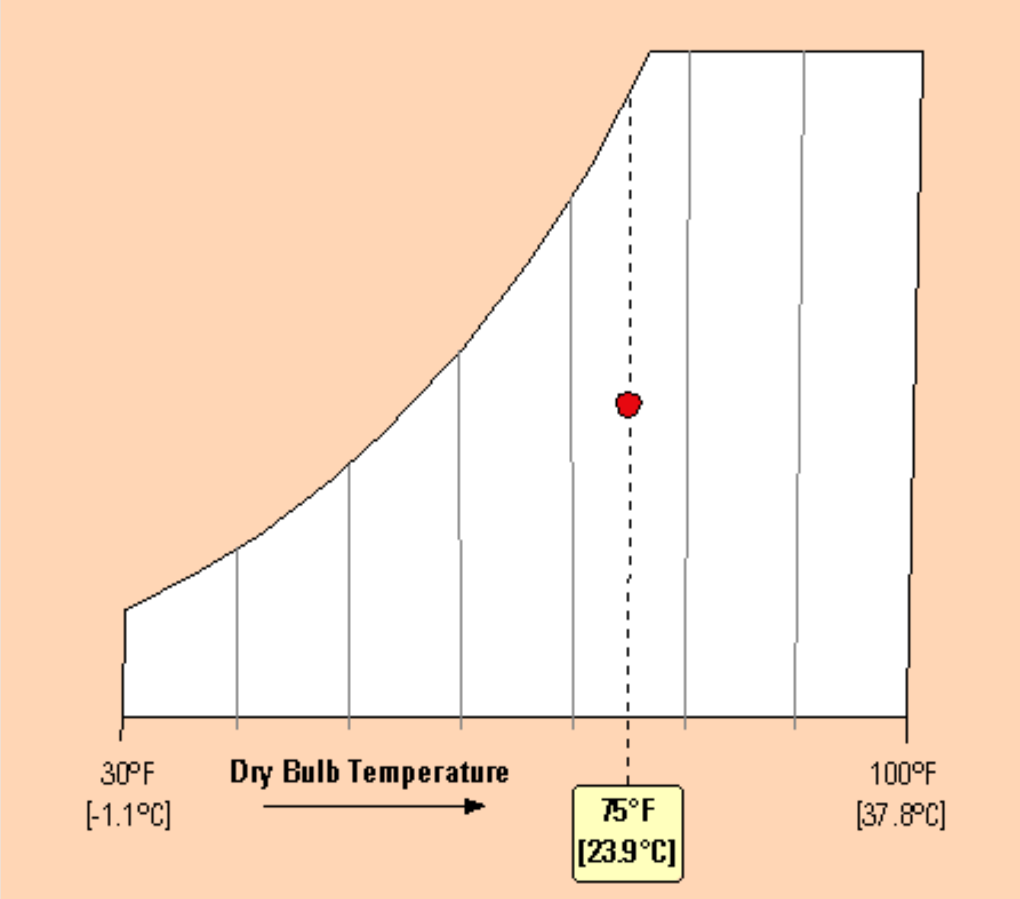


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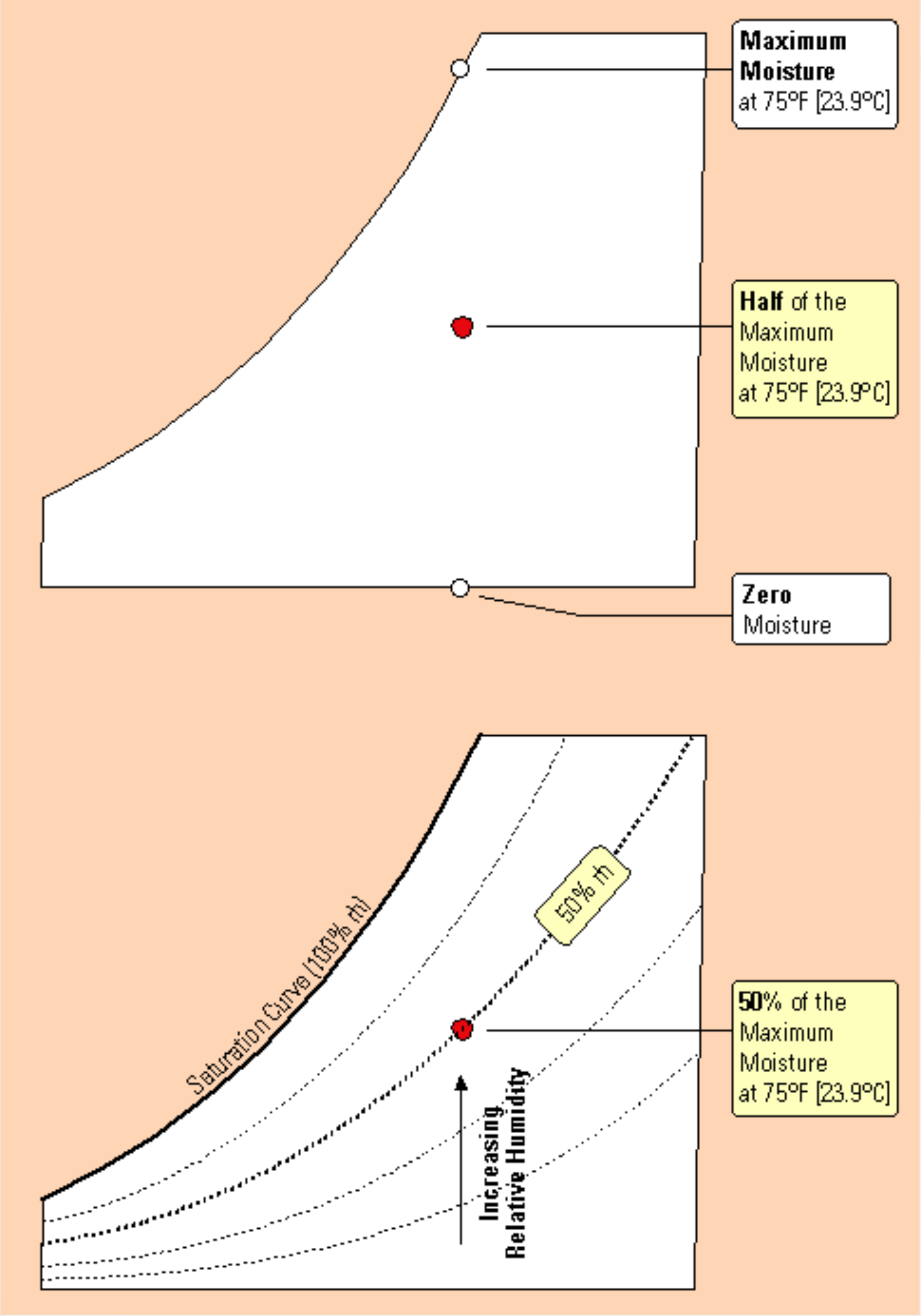


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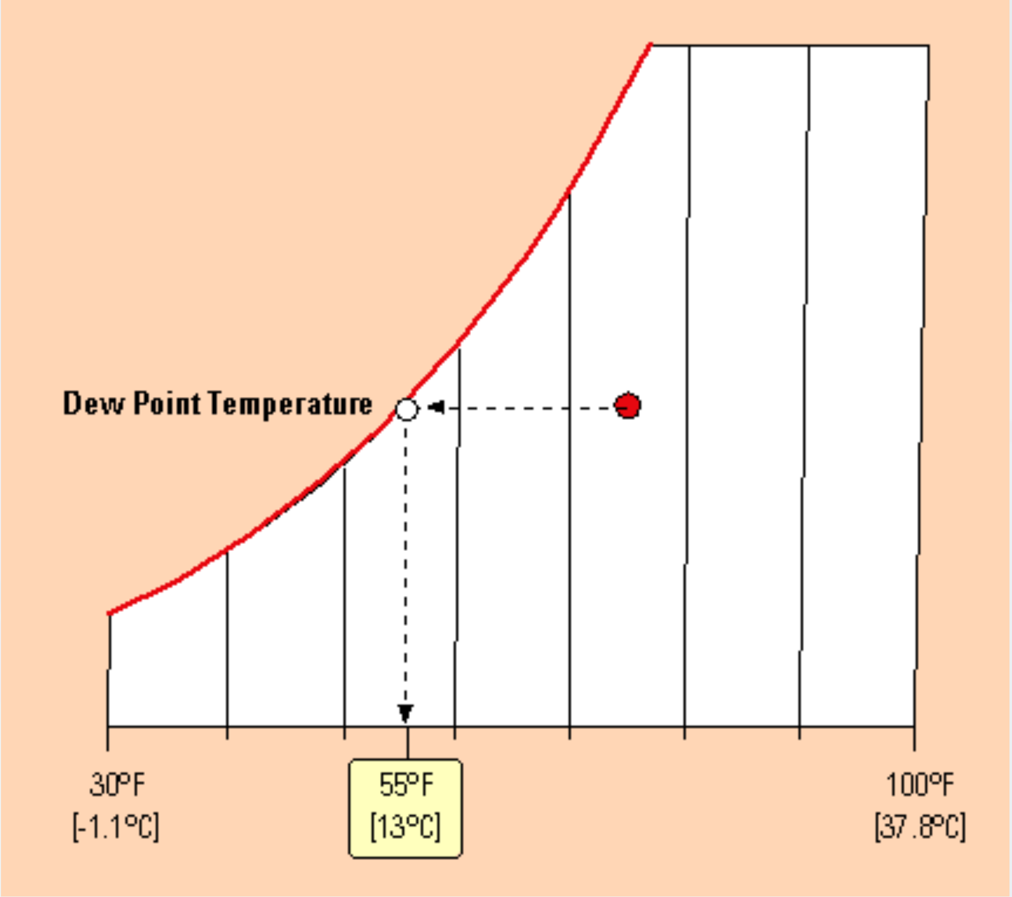


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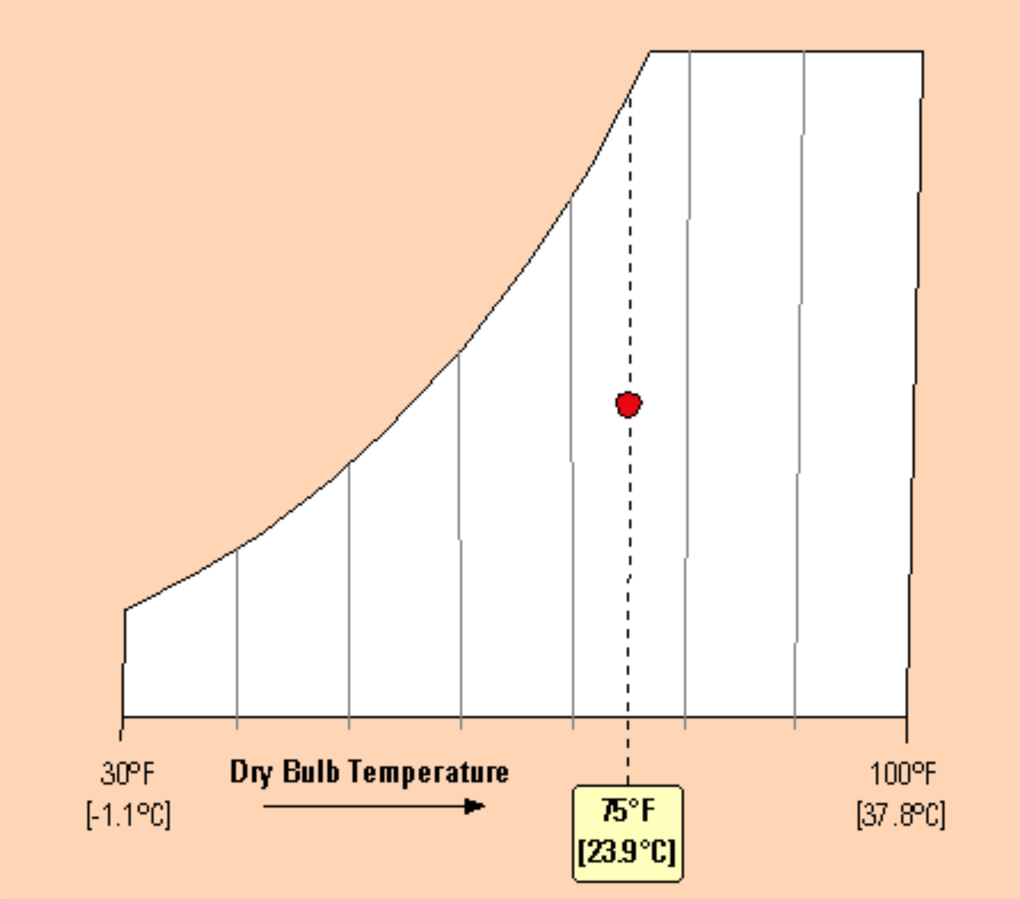


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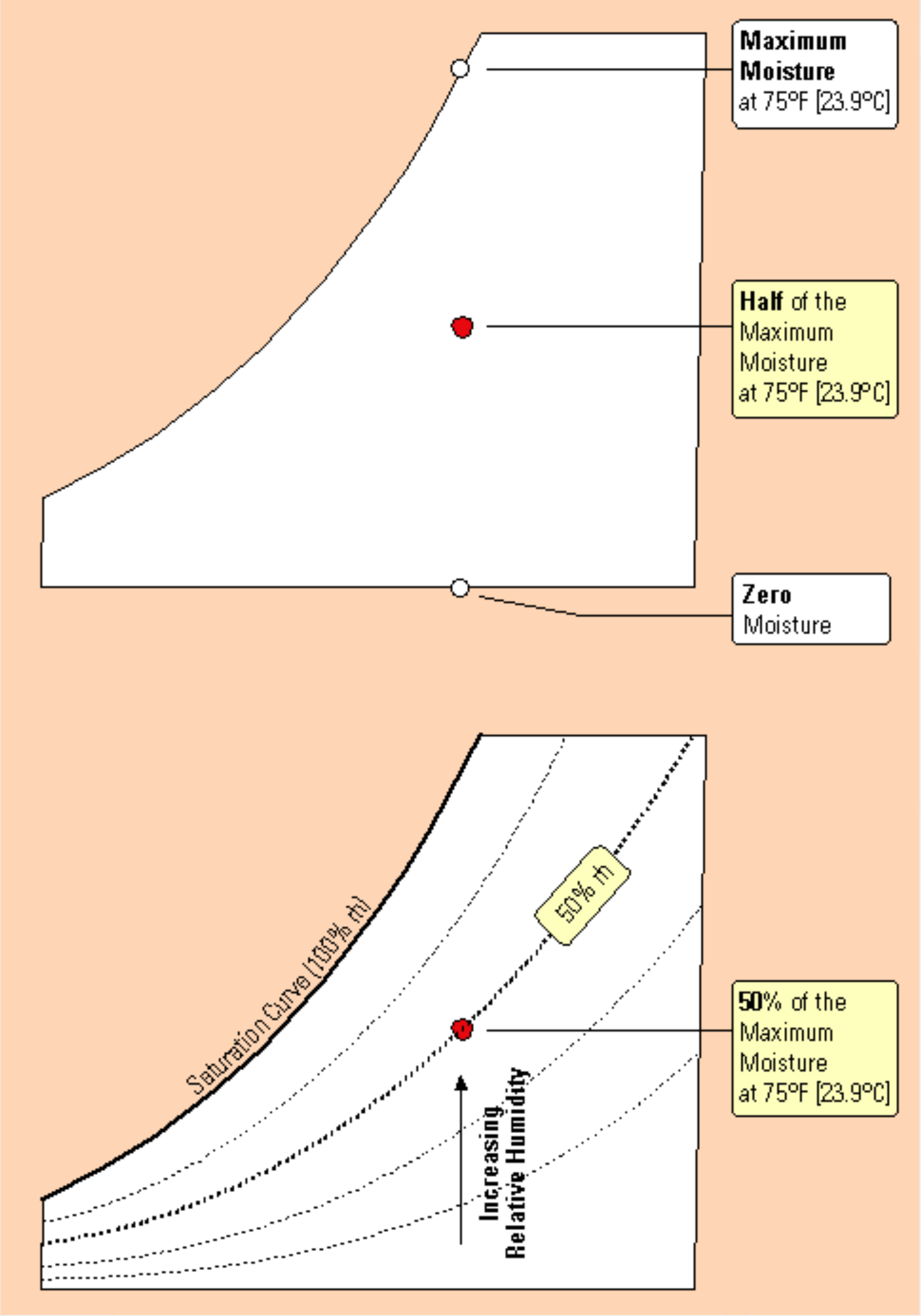


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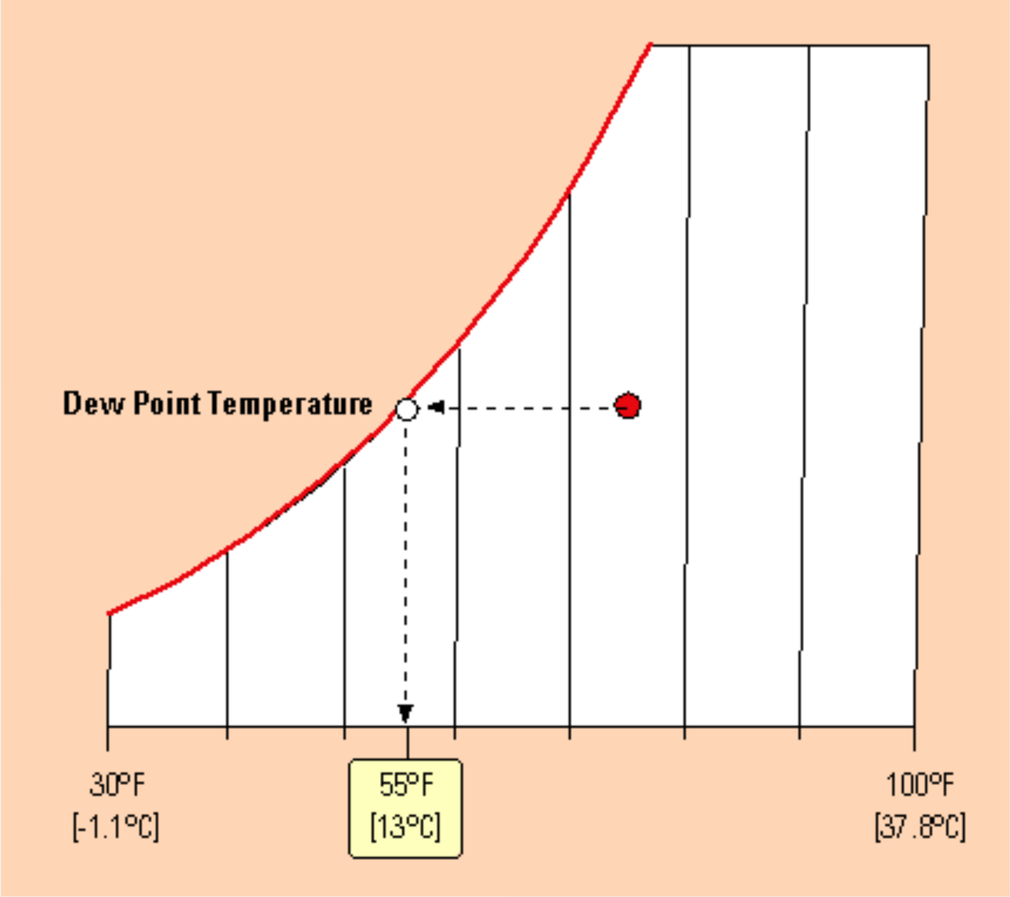


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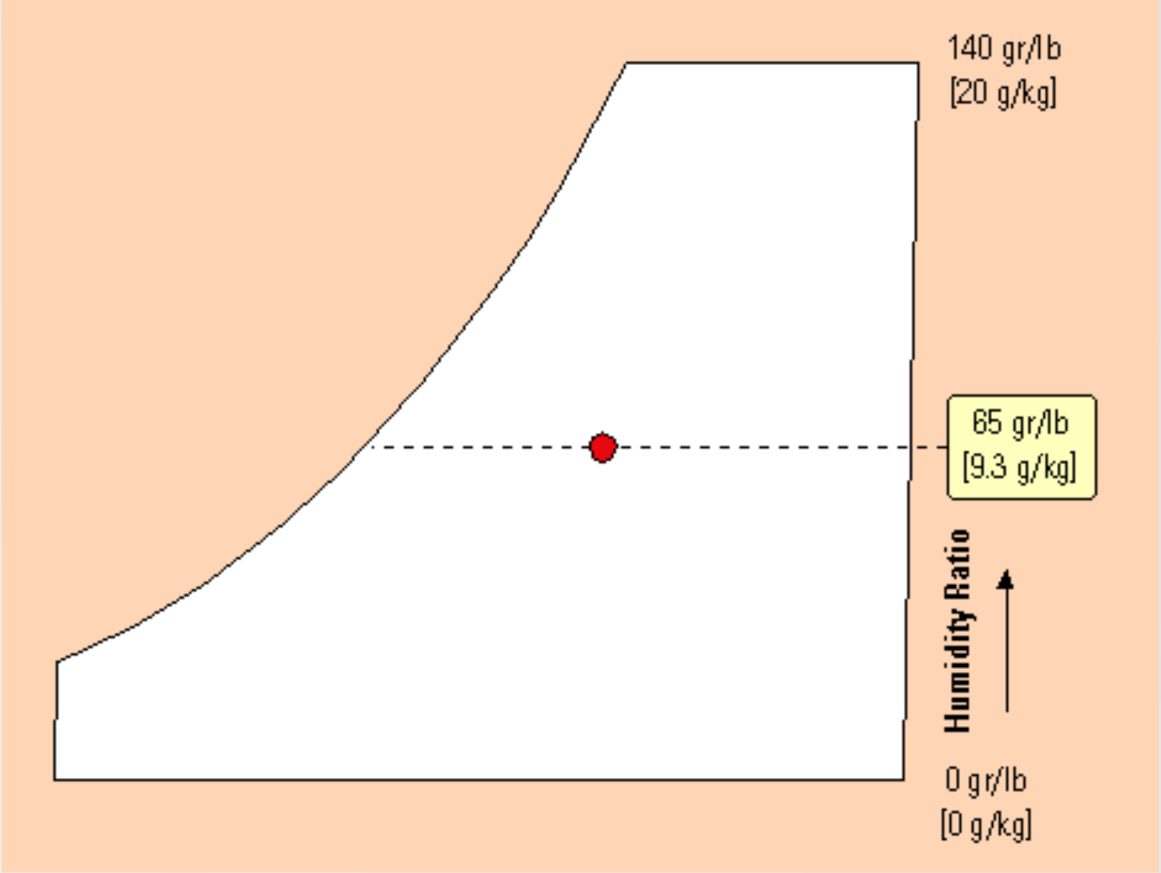

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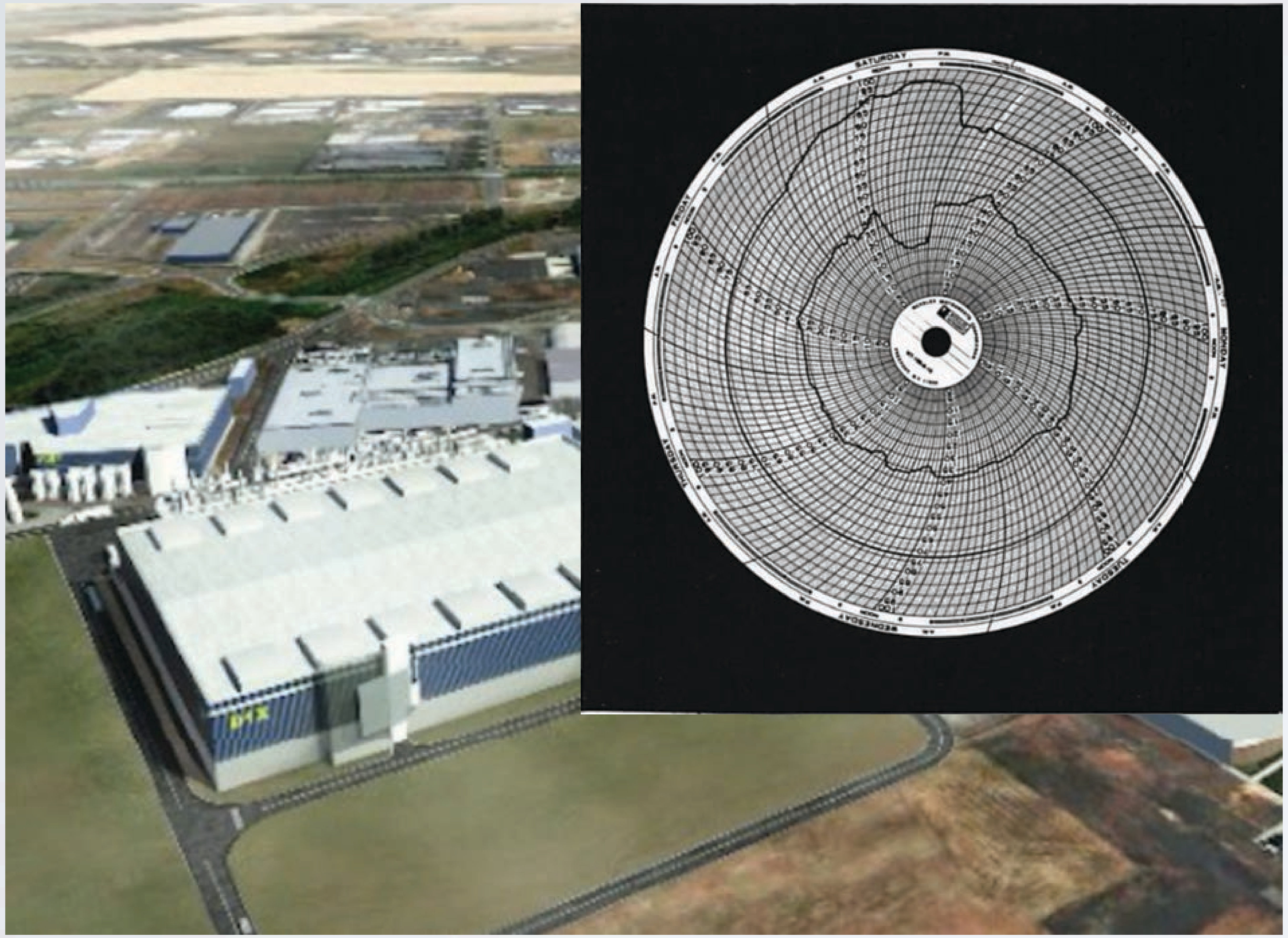

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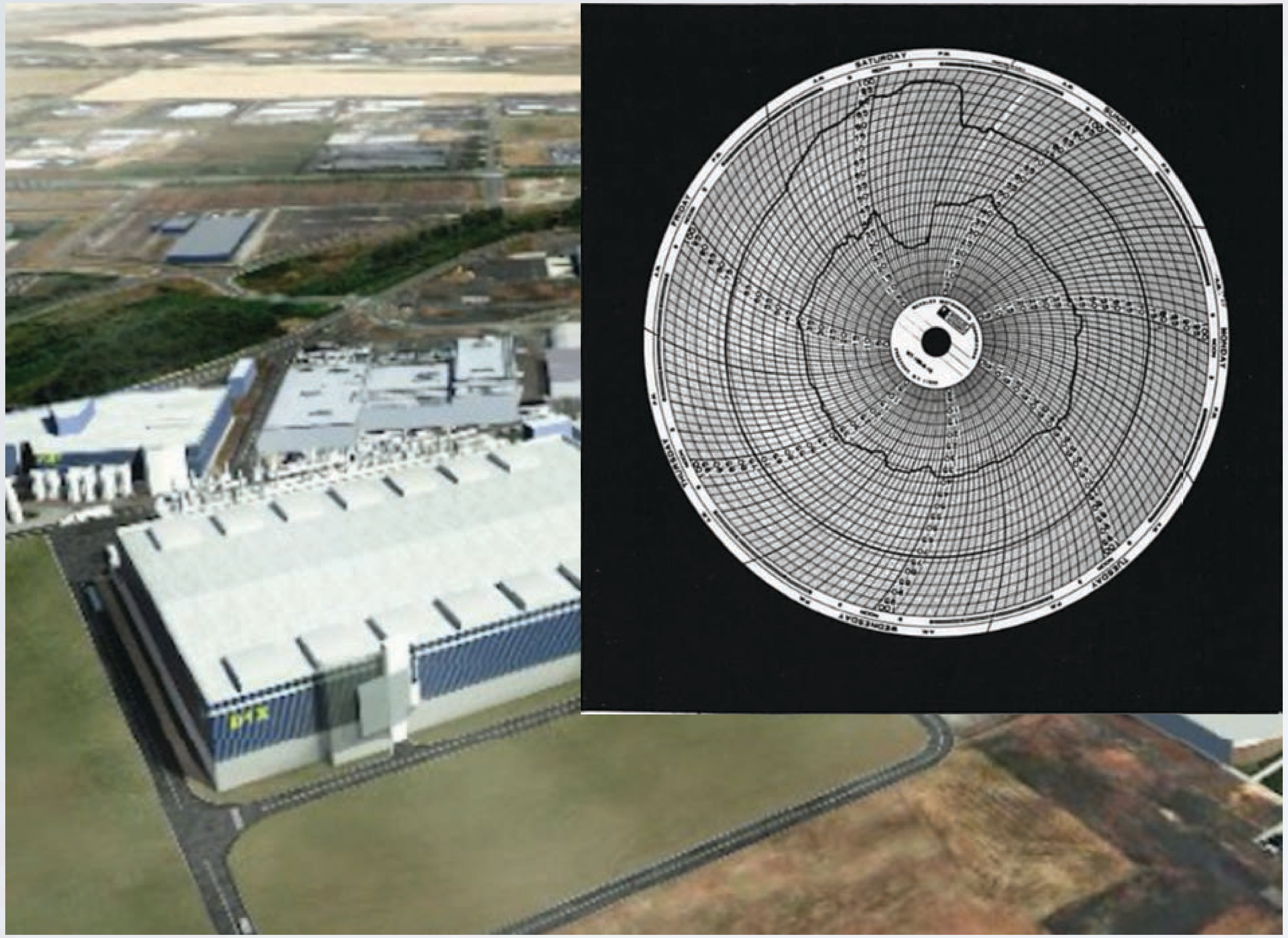

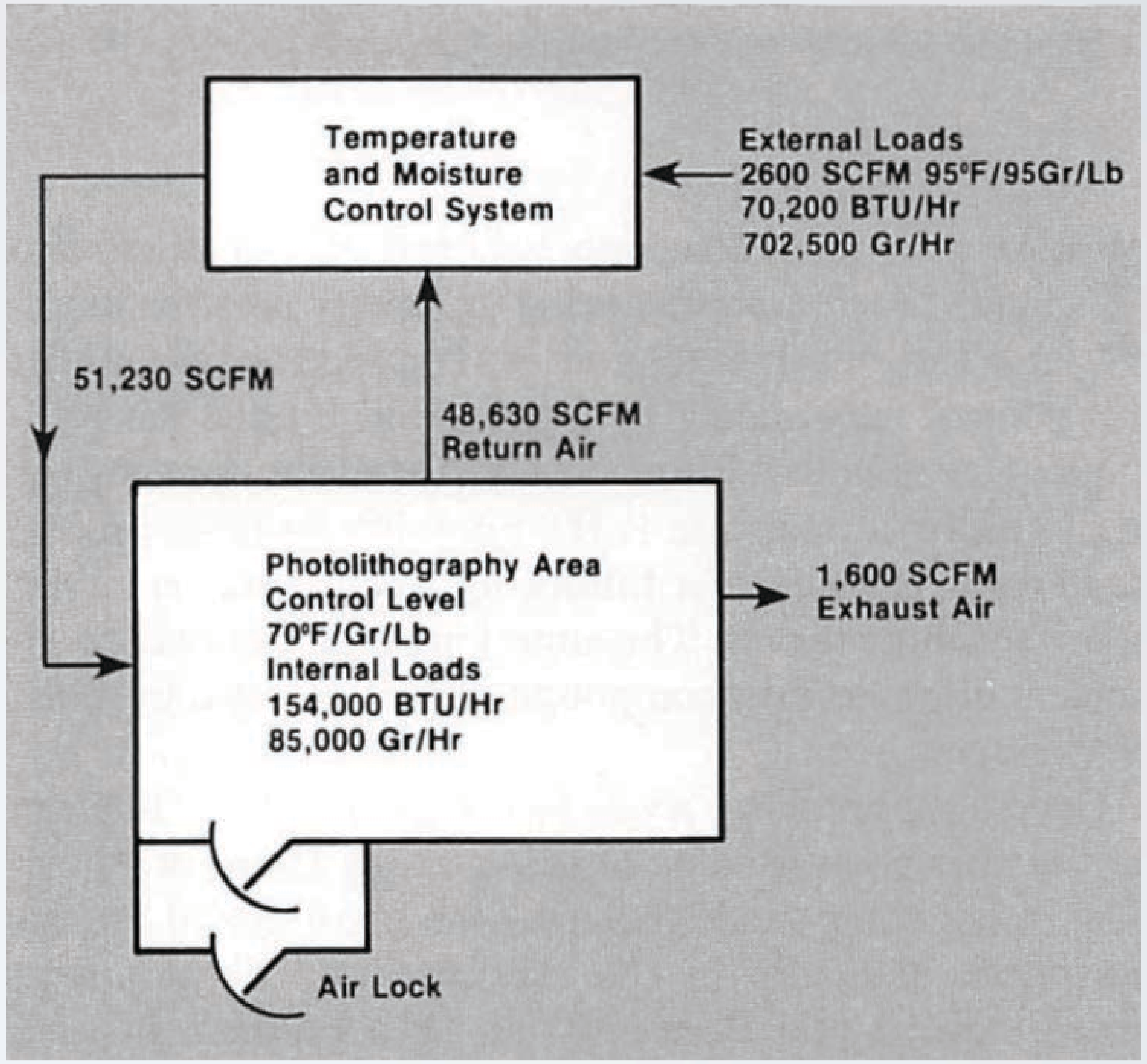

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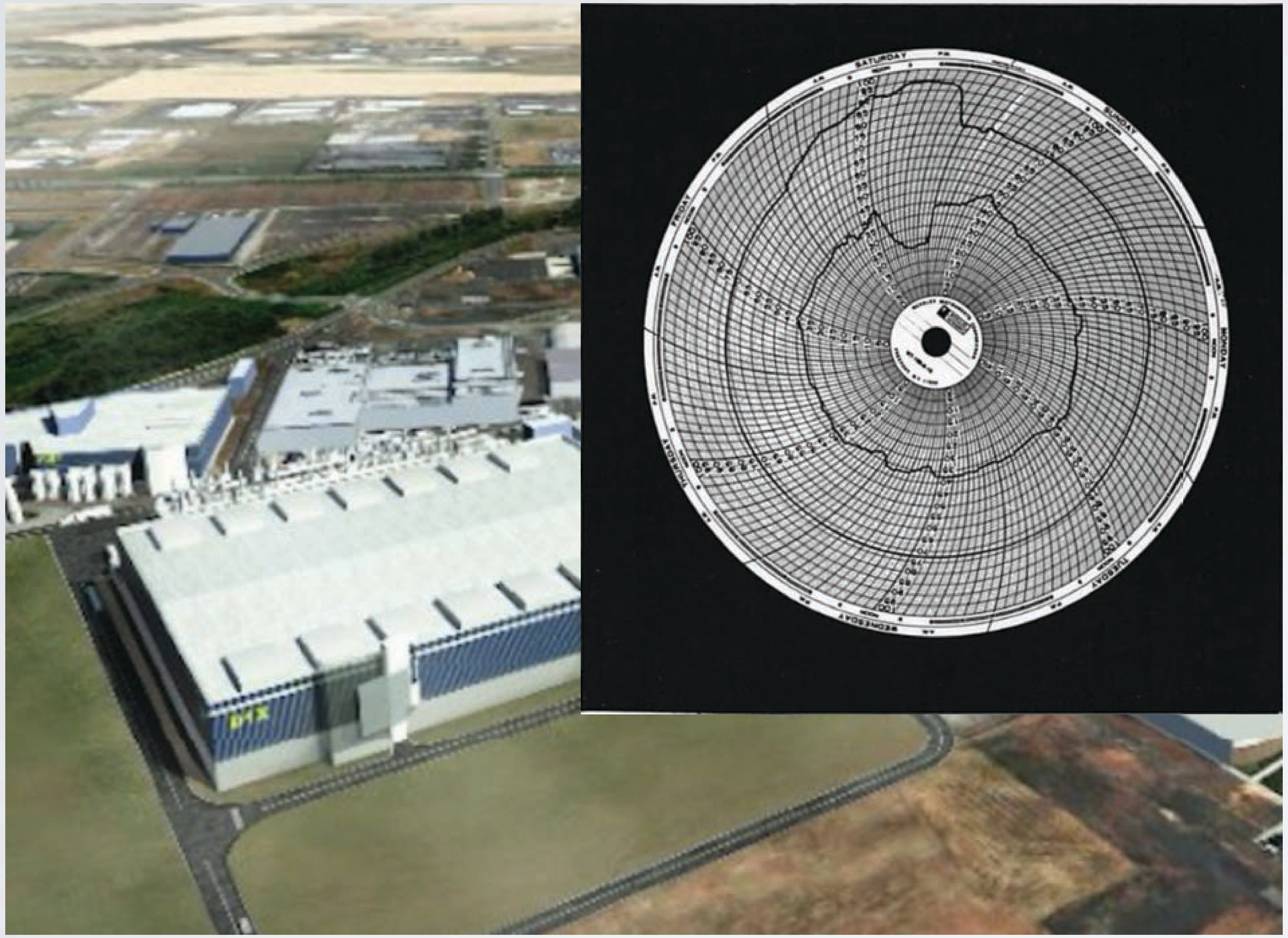

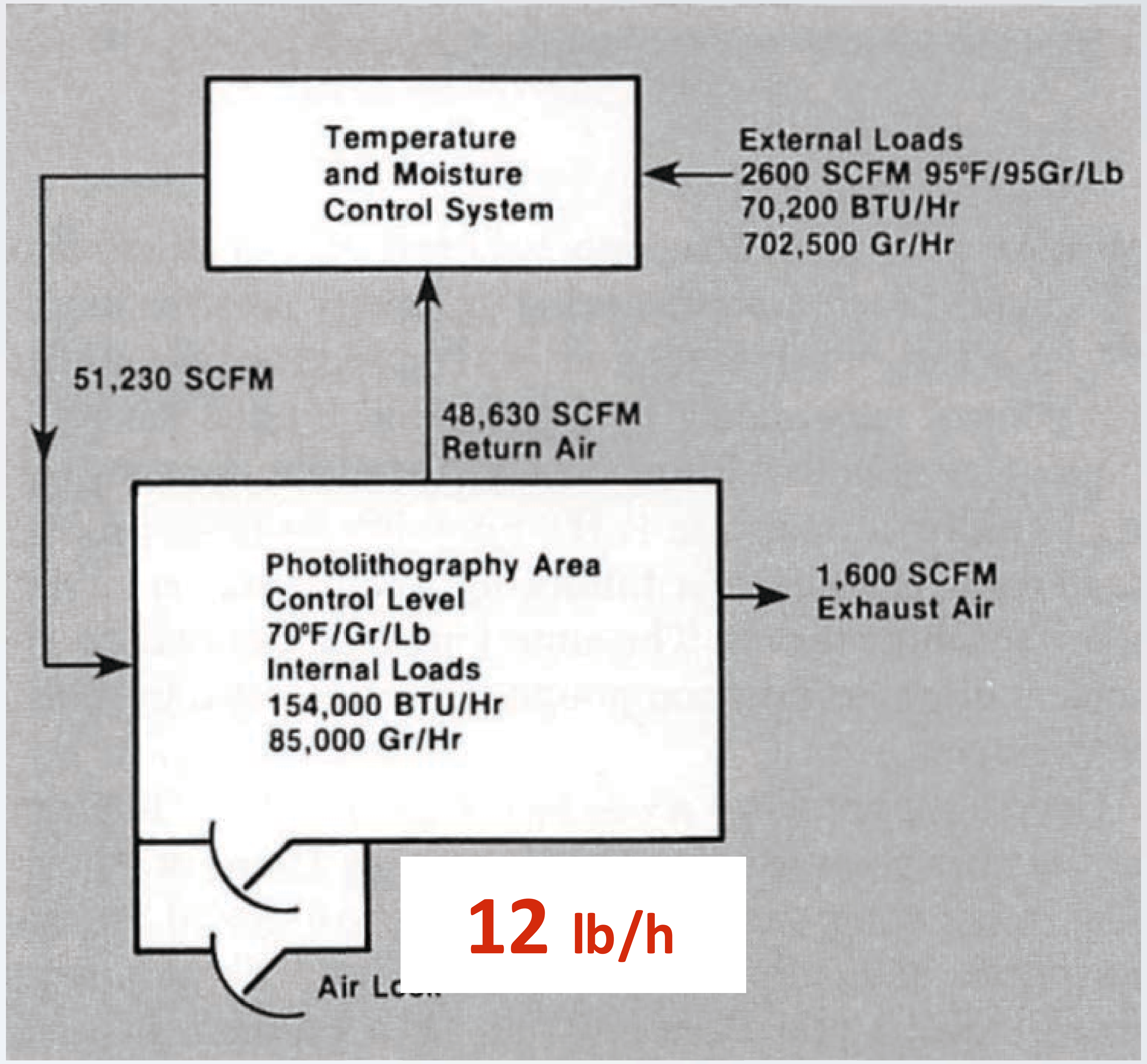

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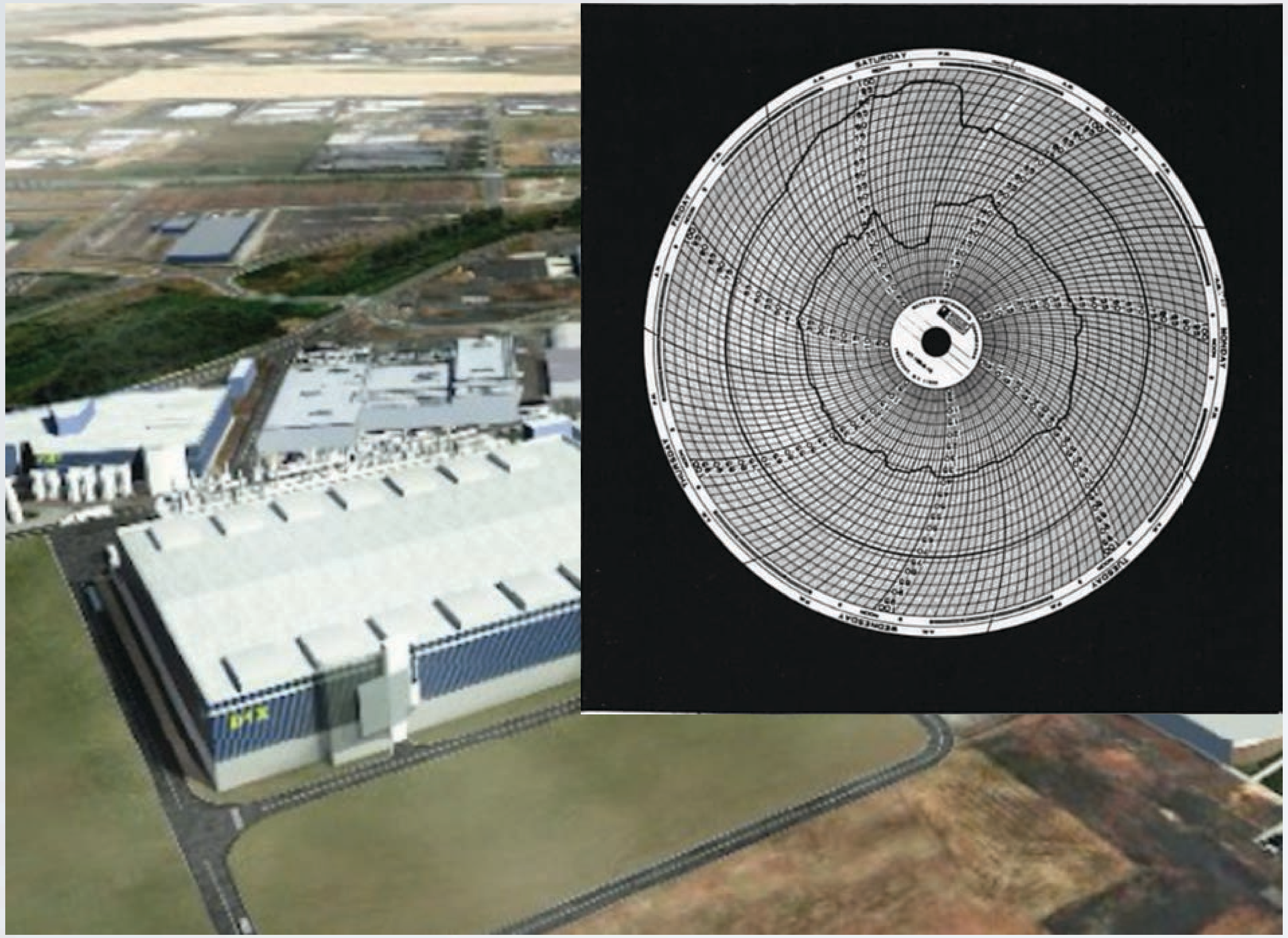

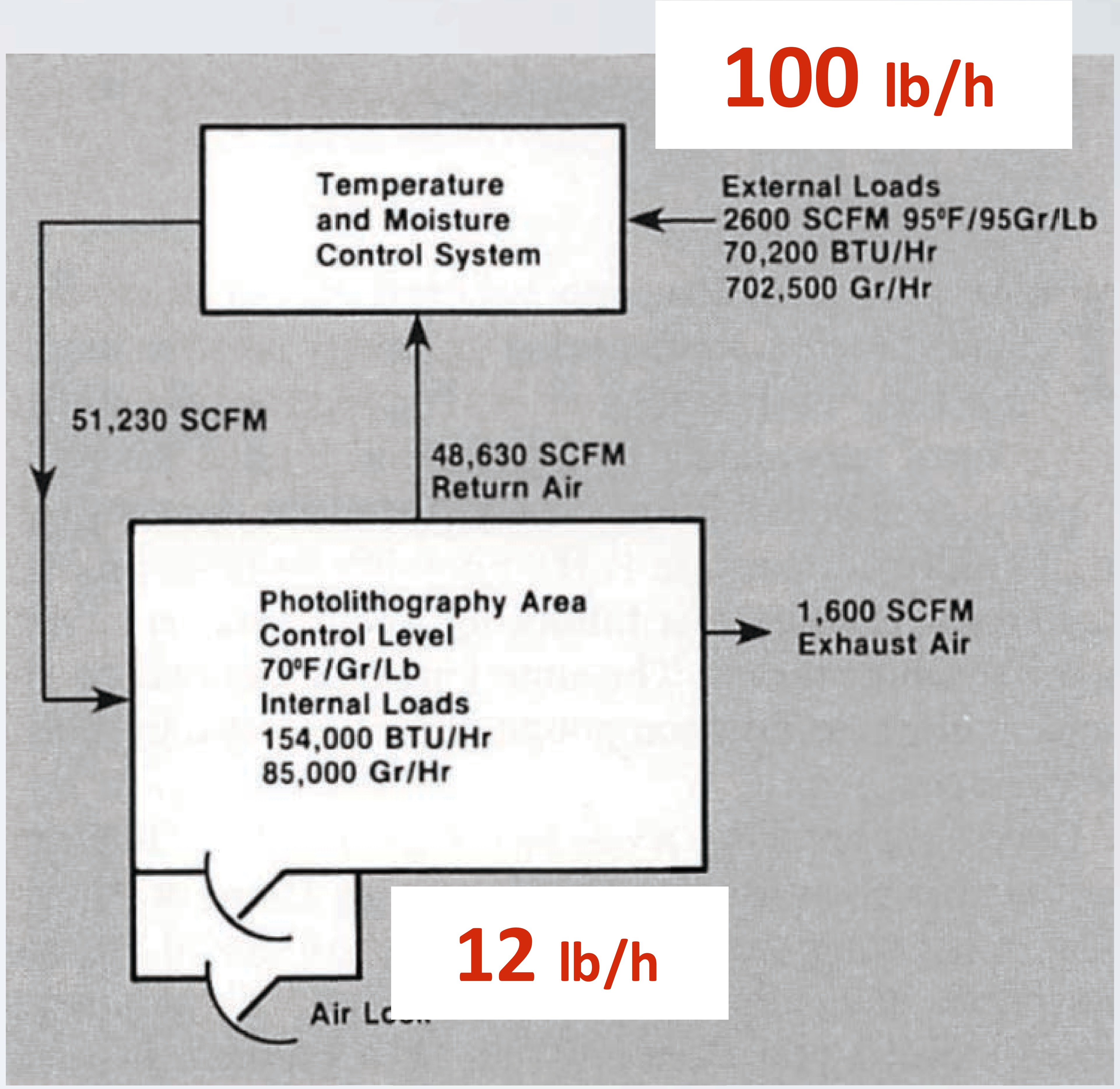

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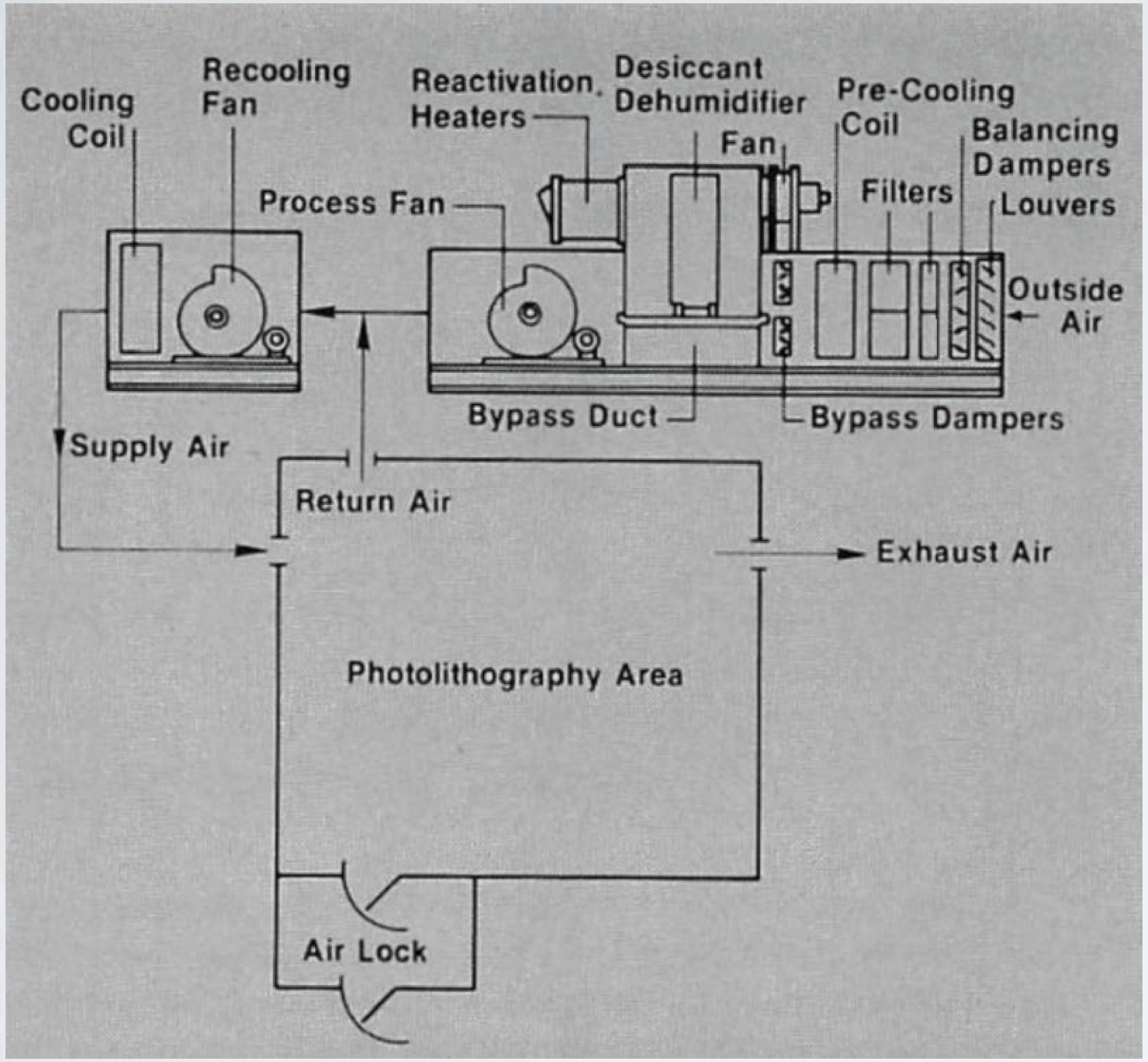

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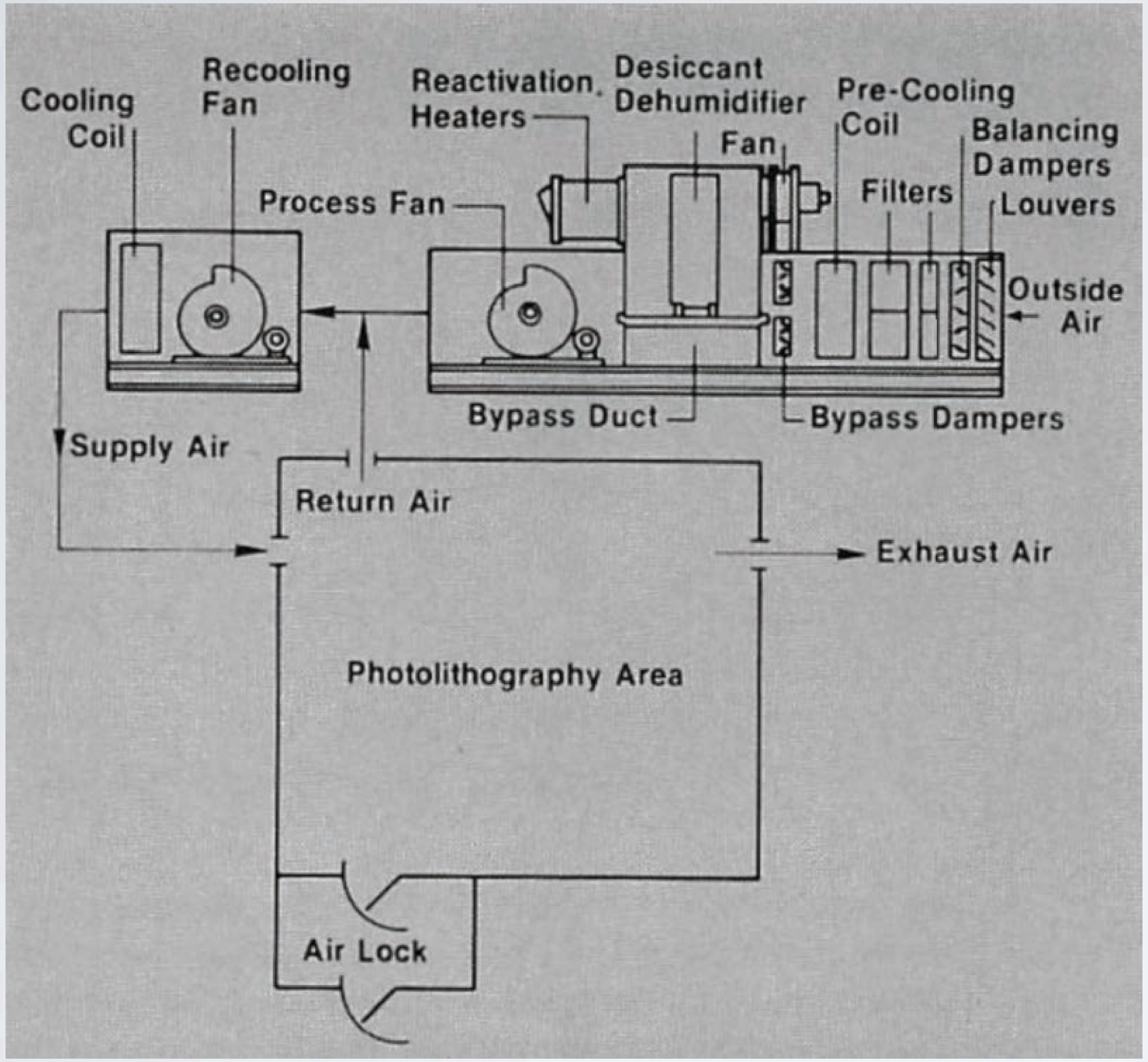


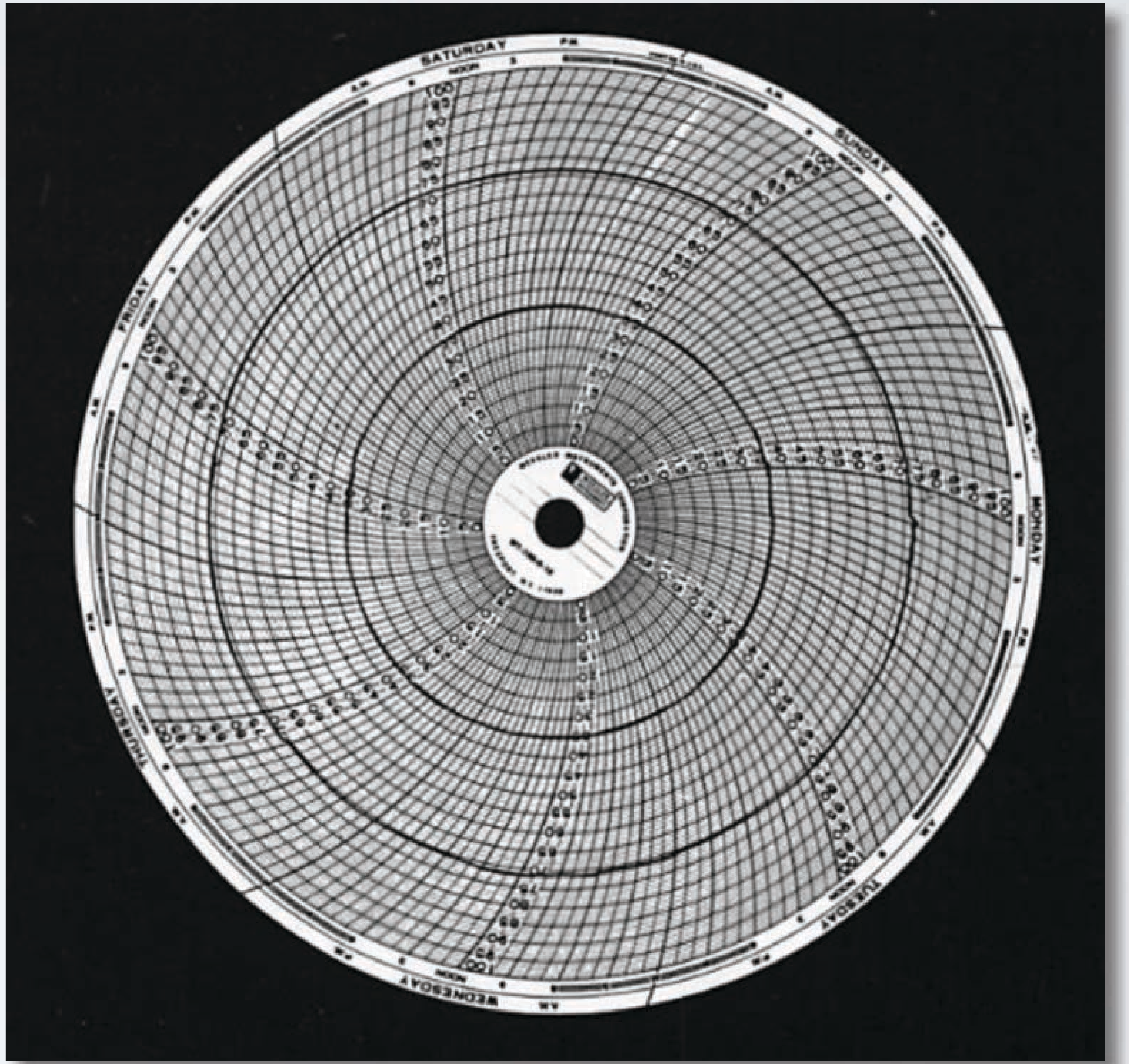

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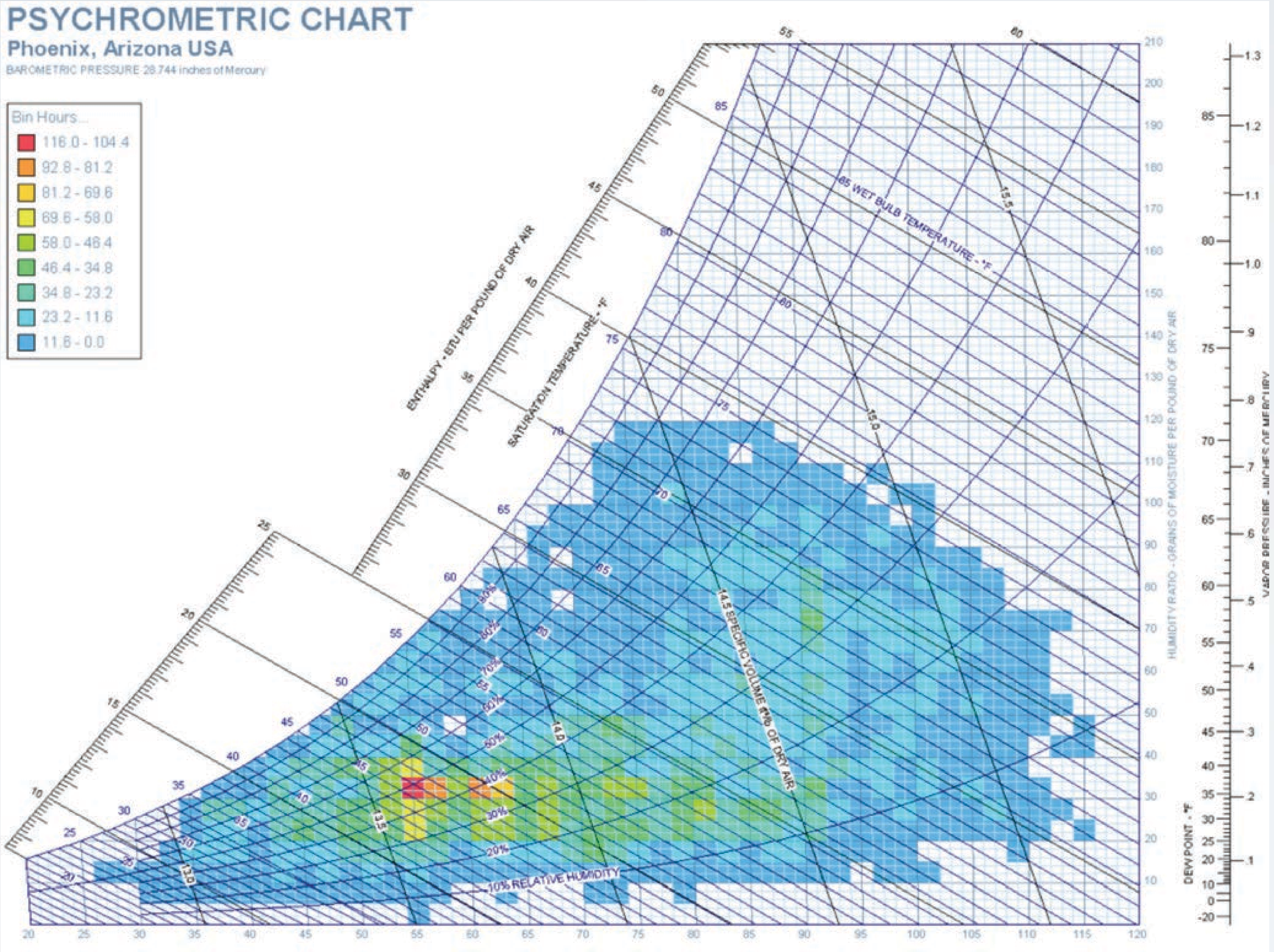

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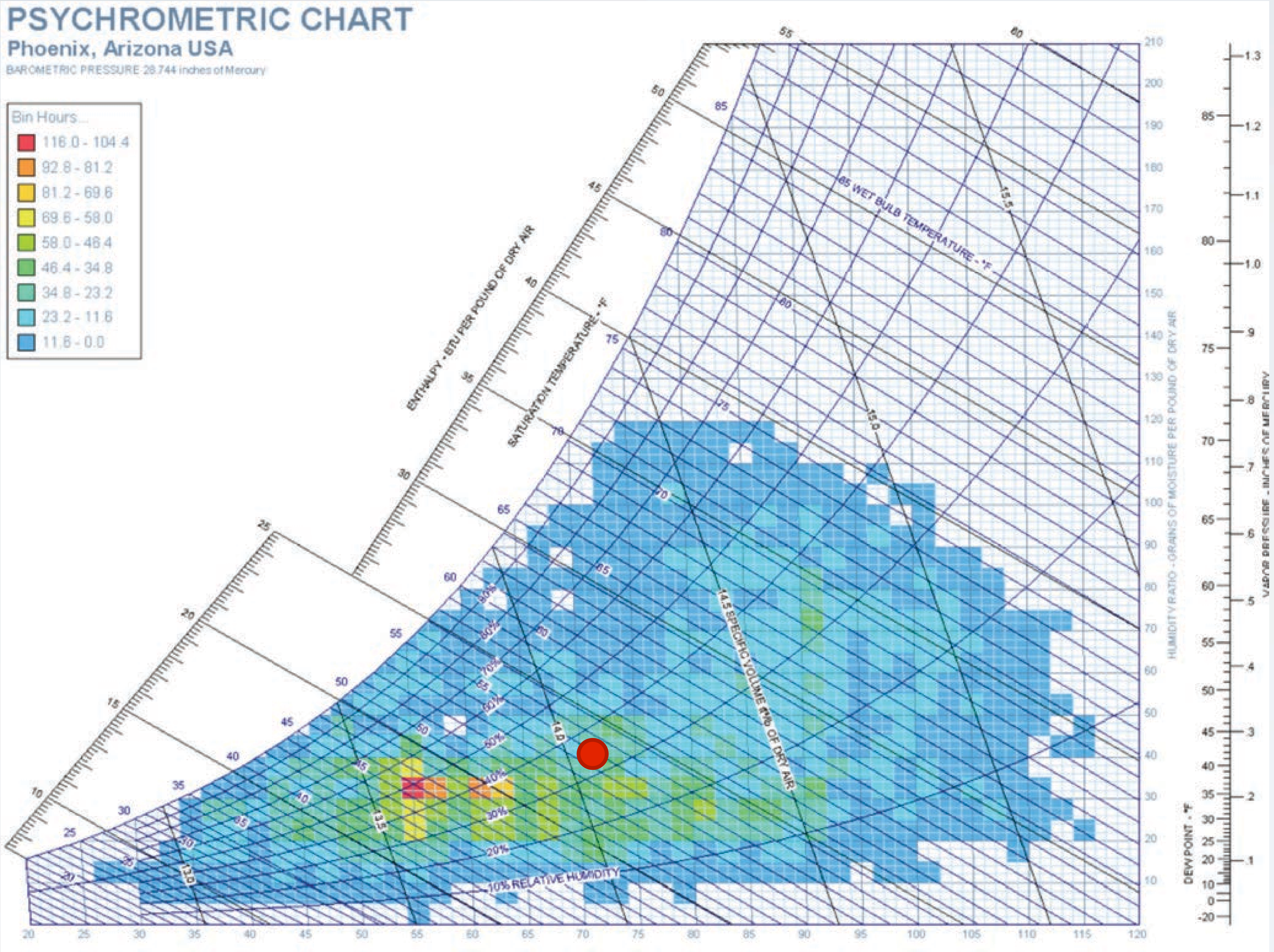

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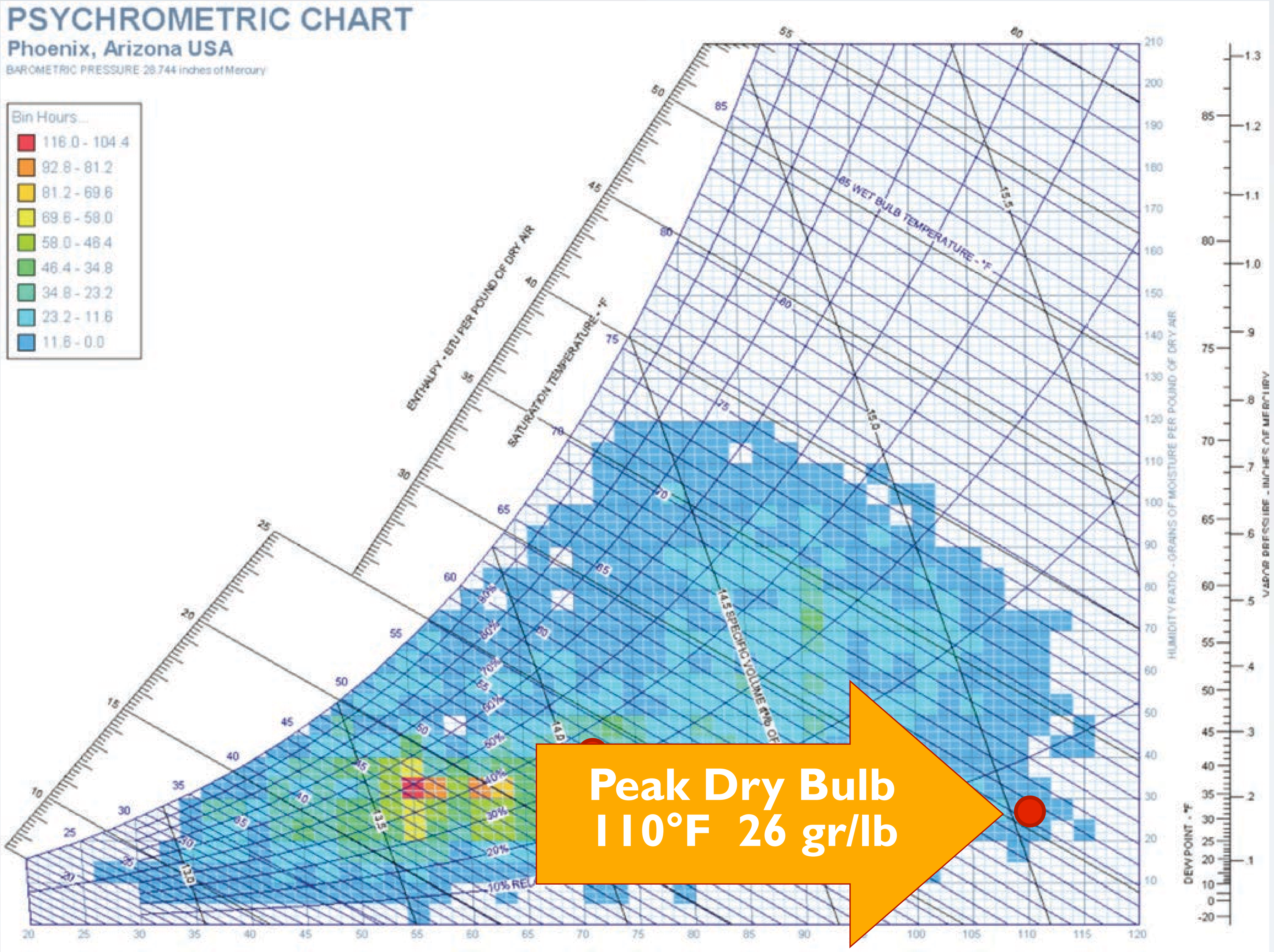

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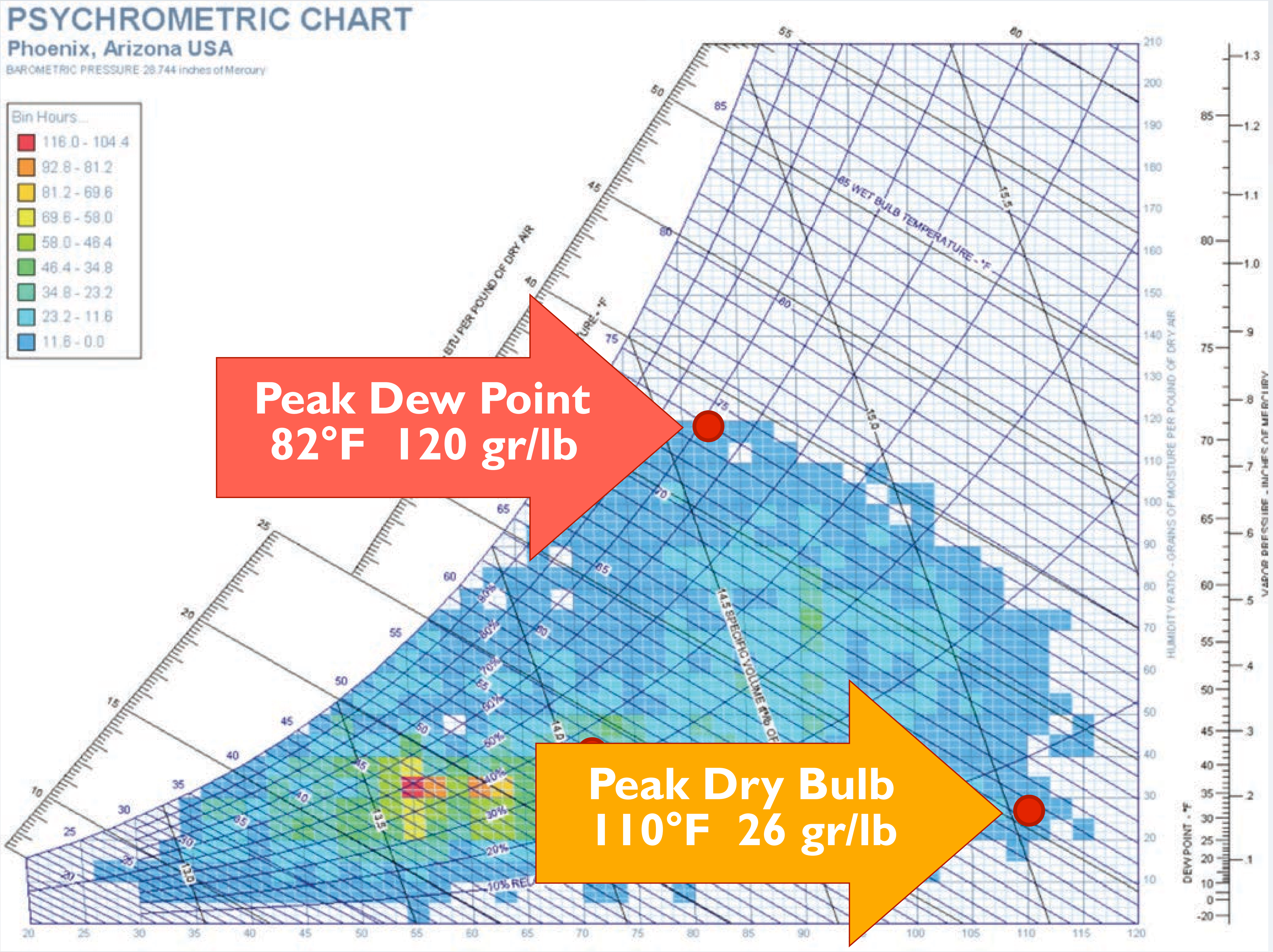

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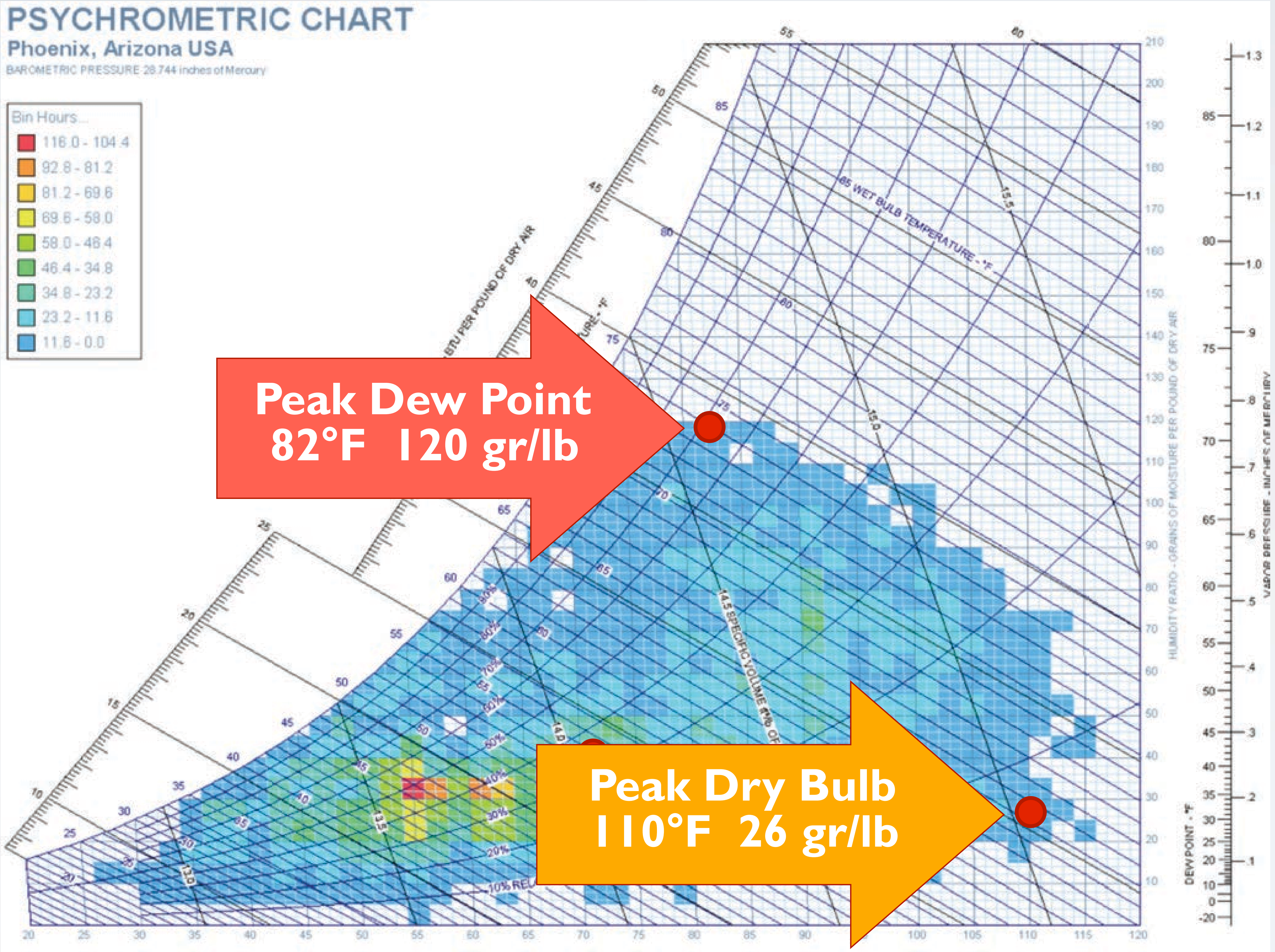


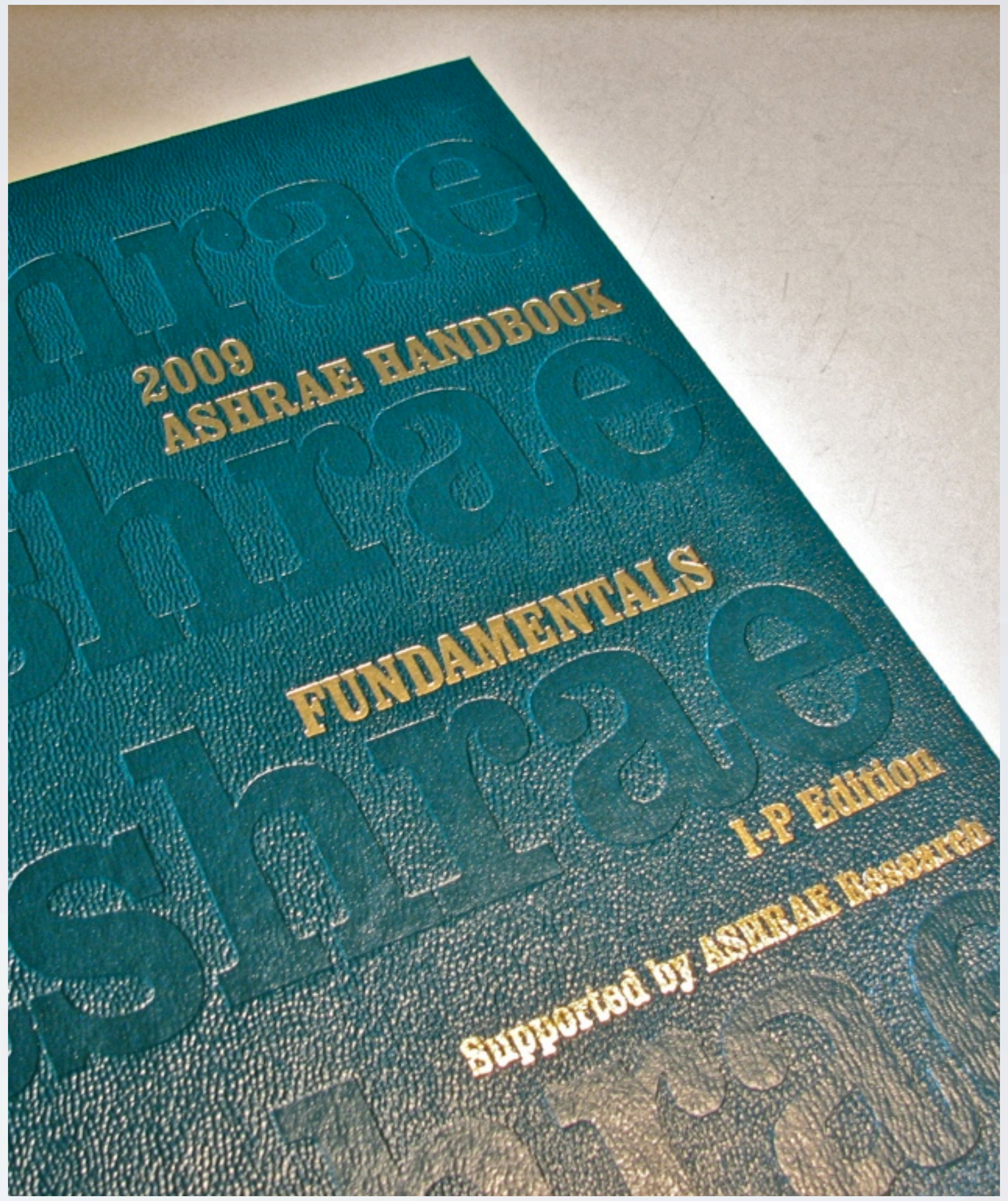

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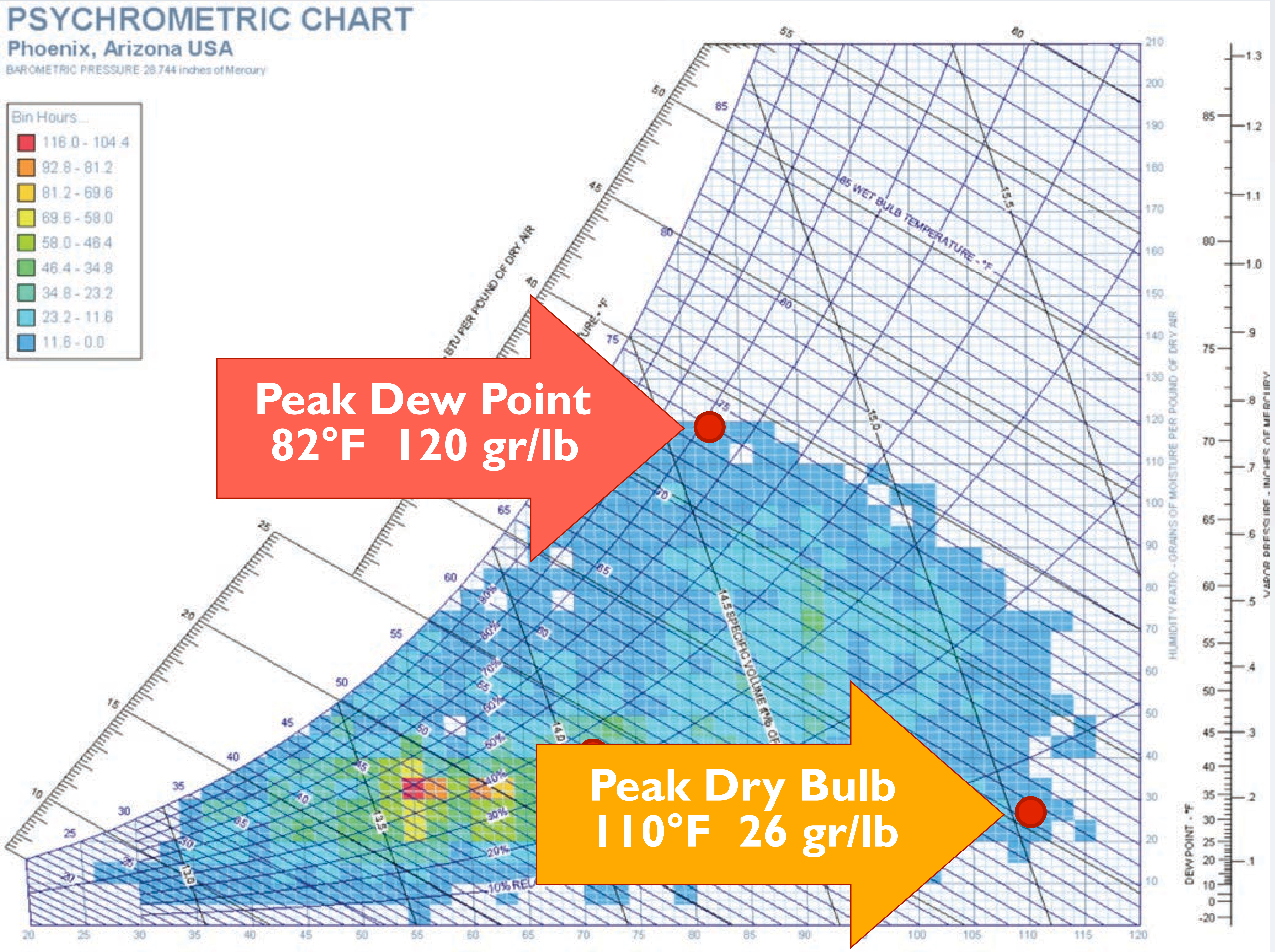



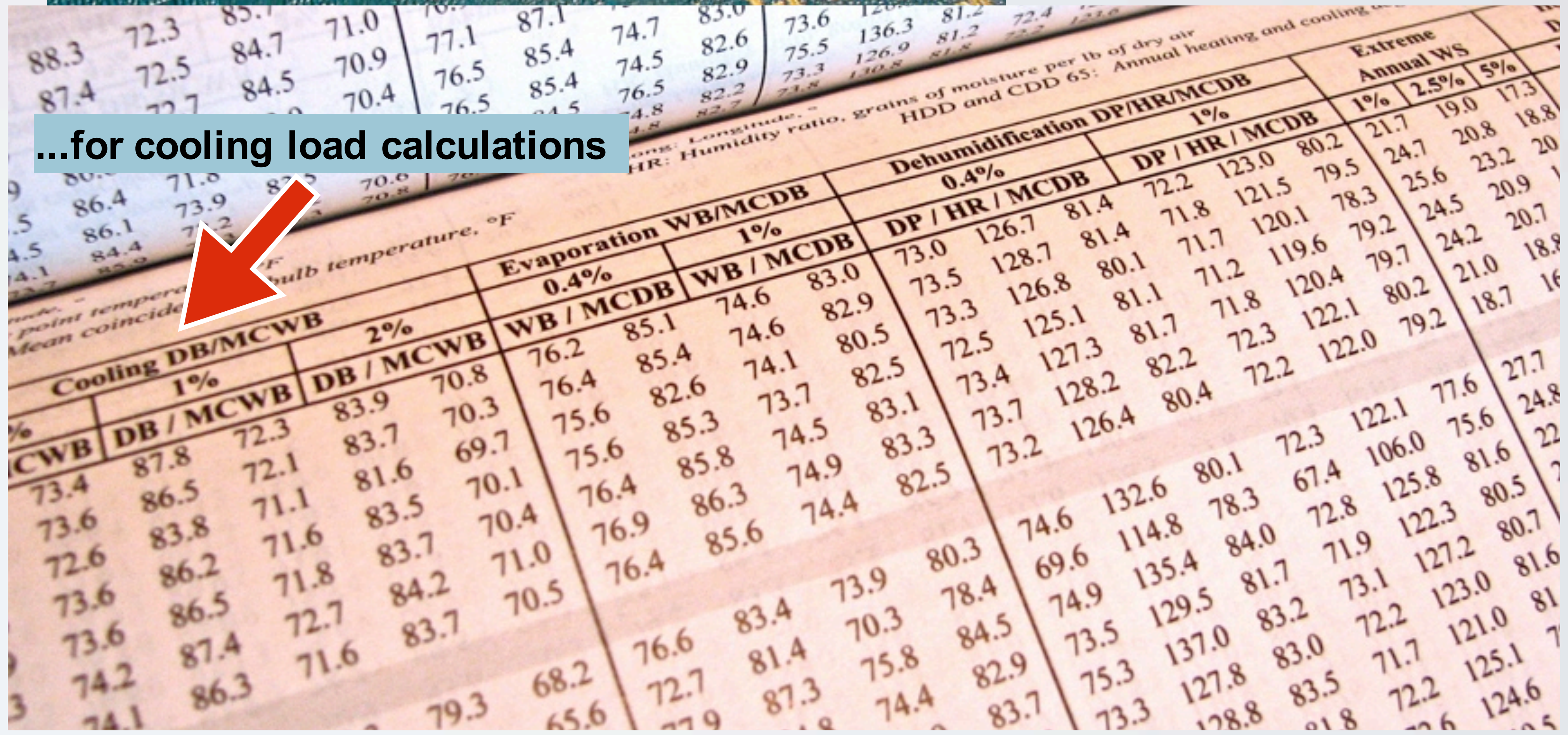

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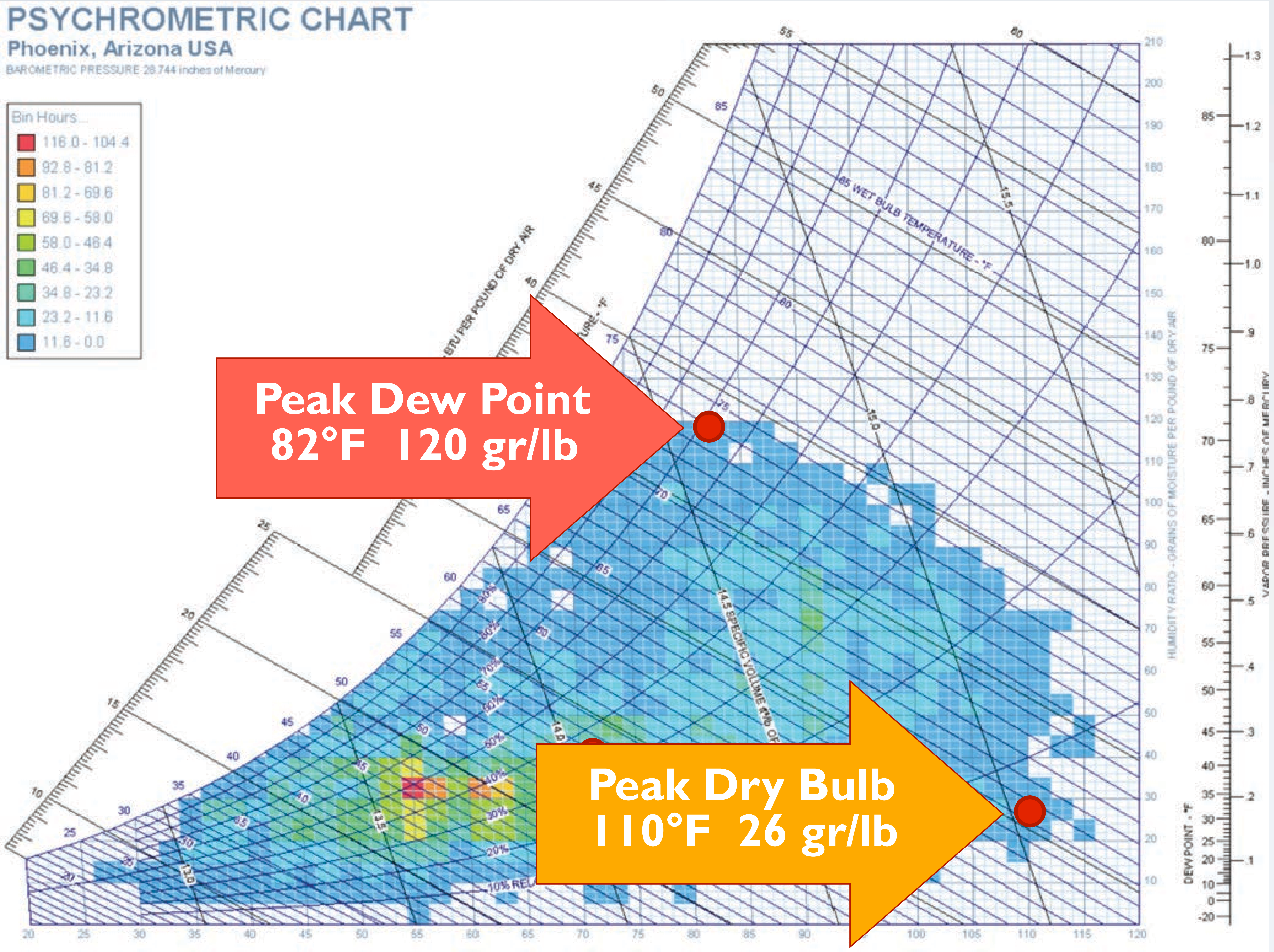
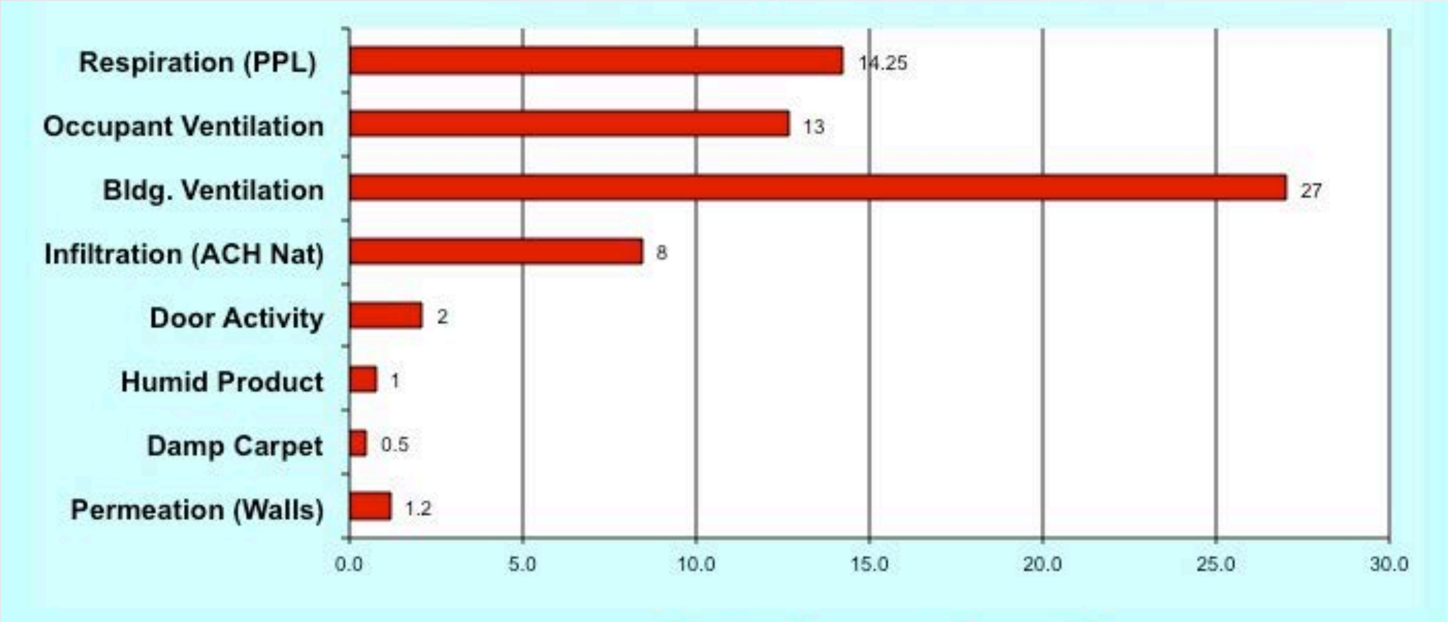



# DH loads at peak dry bulb v. peak dew point

## Small commercial - Retail Store - Cincinnati, OH and Covington, KY

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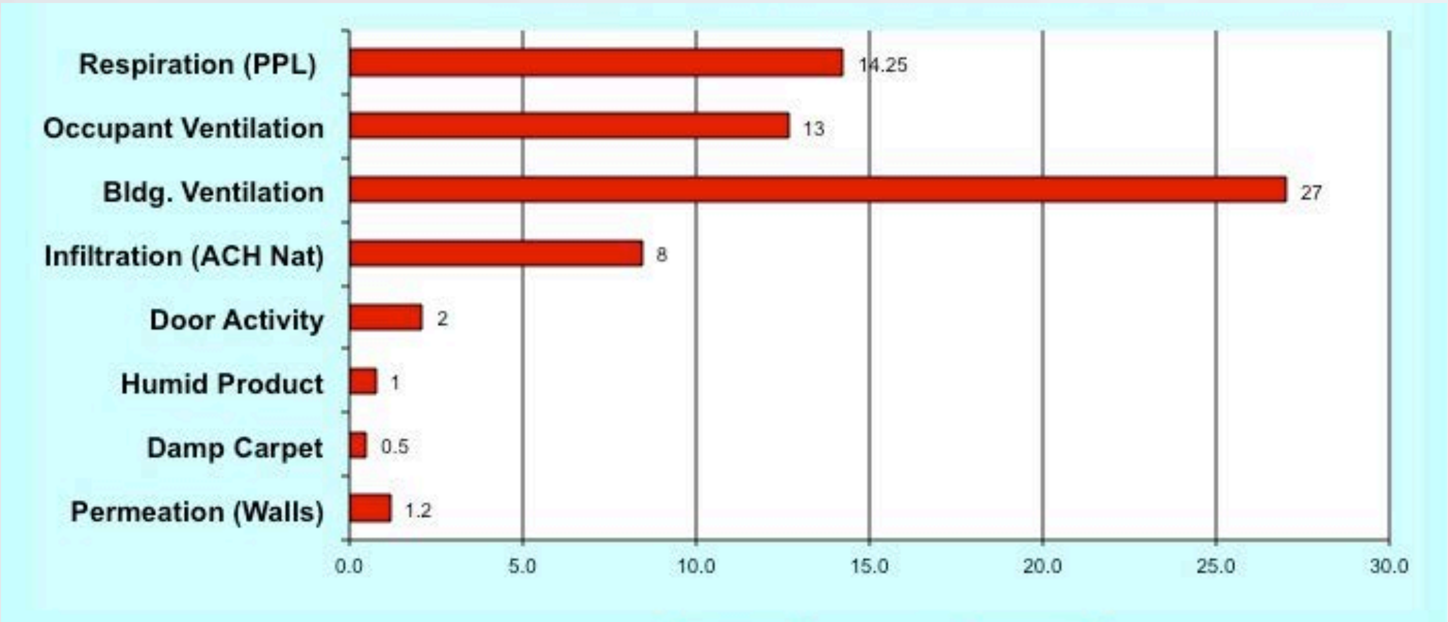


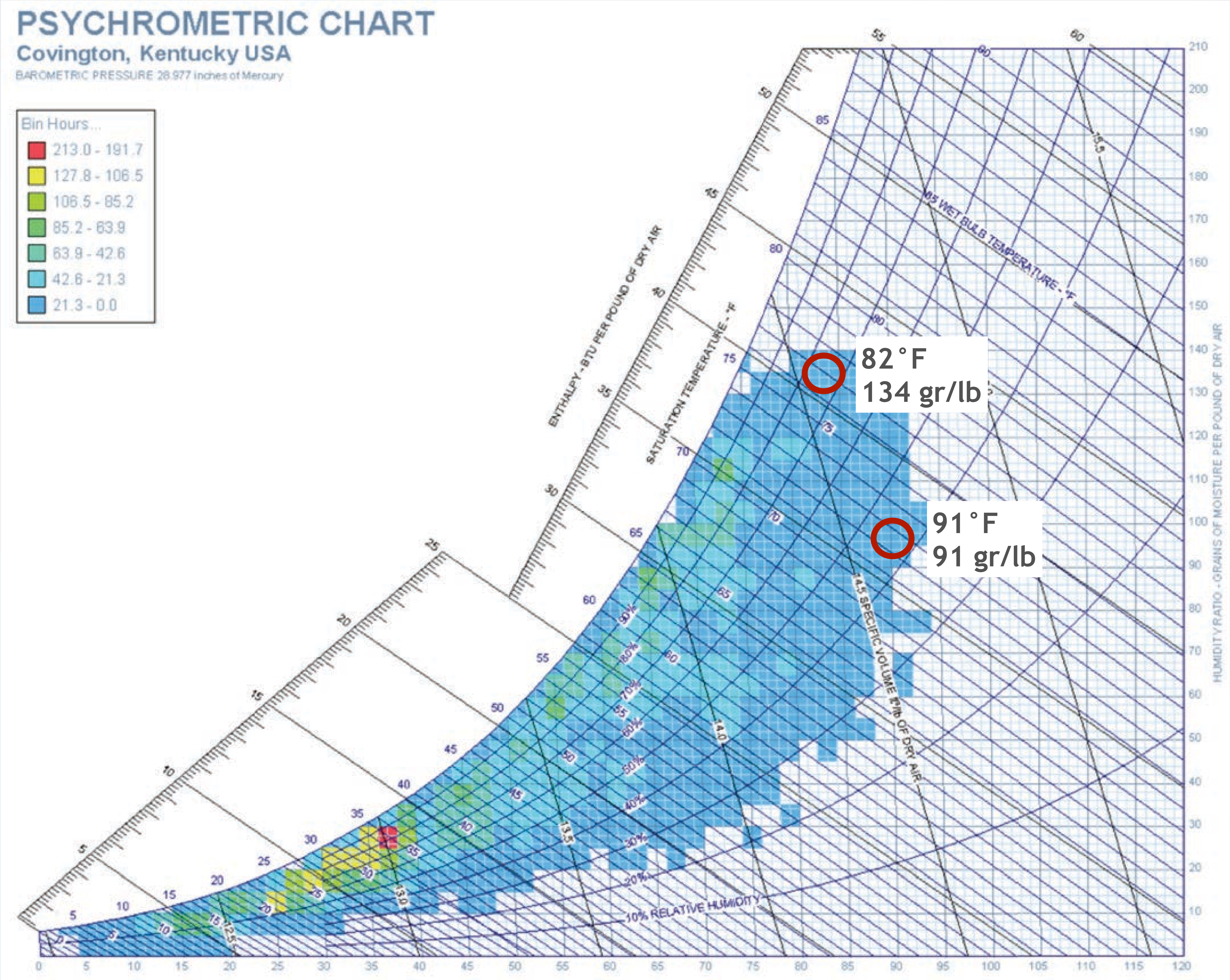

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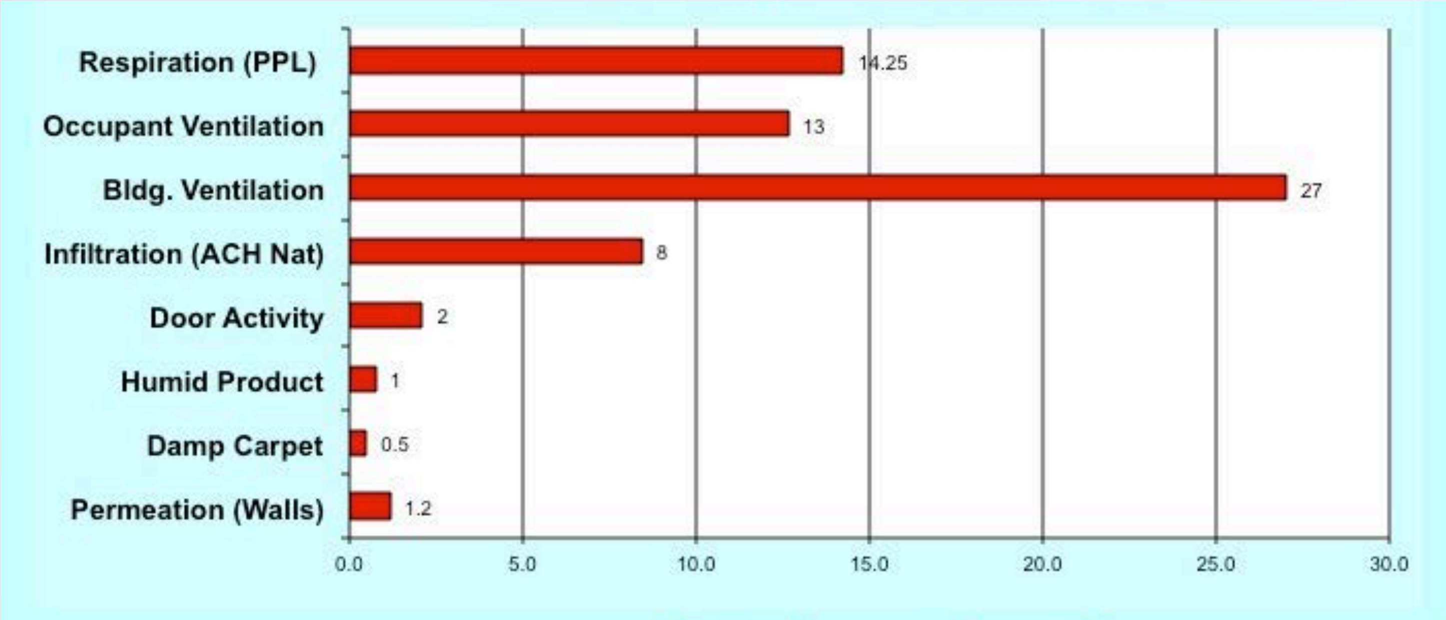


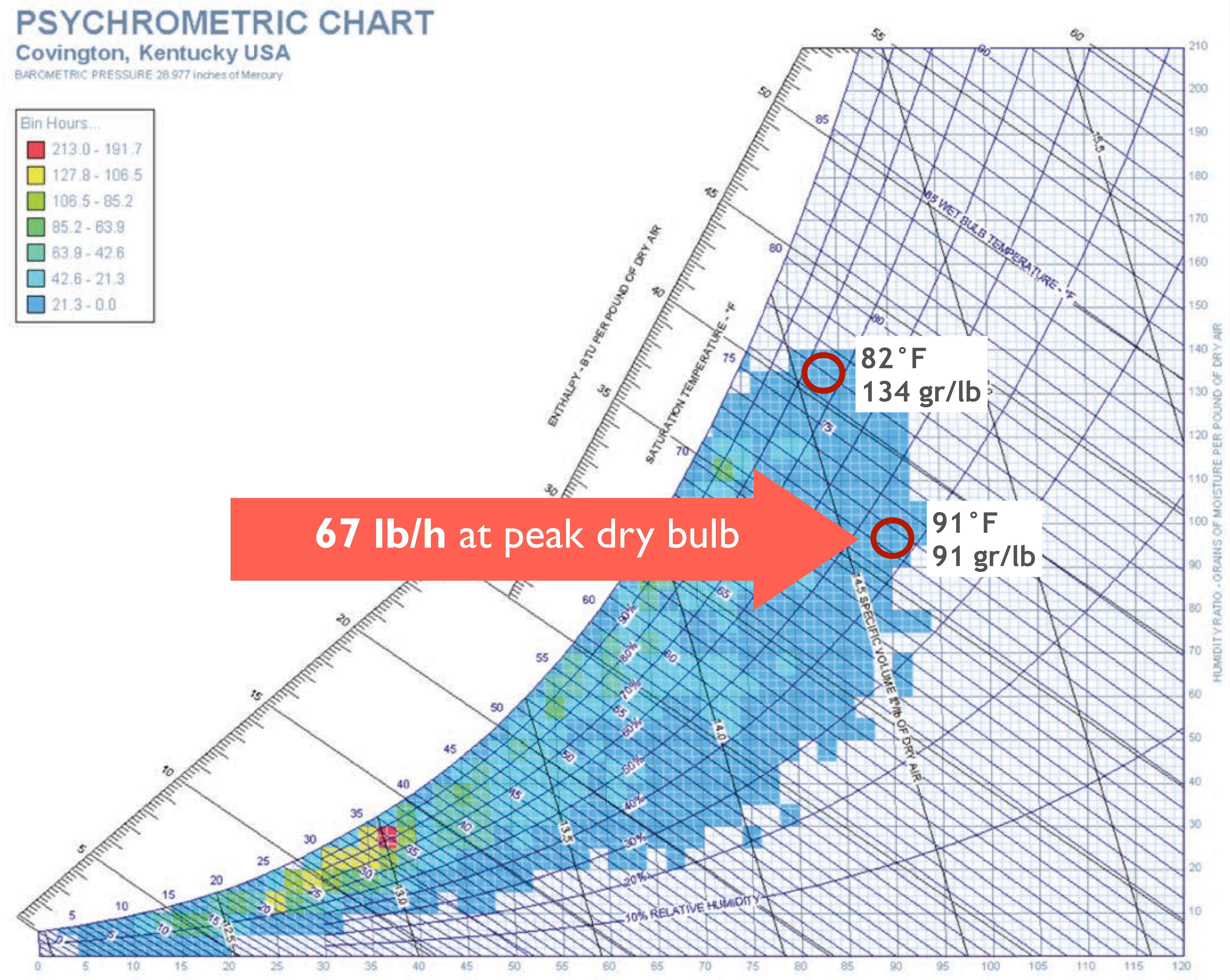

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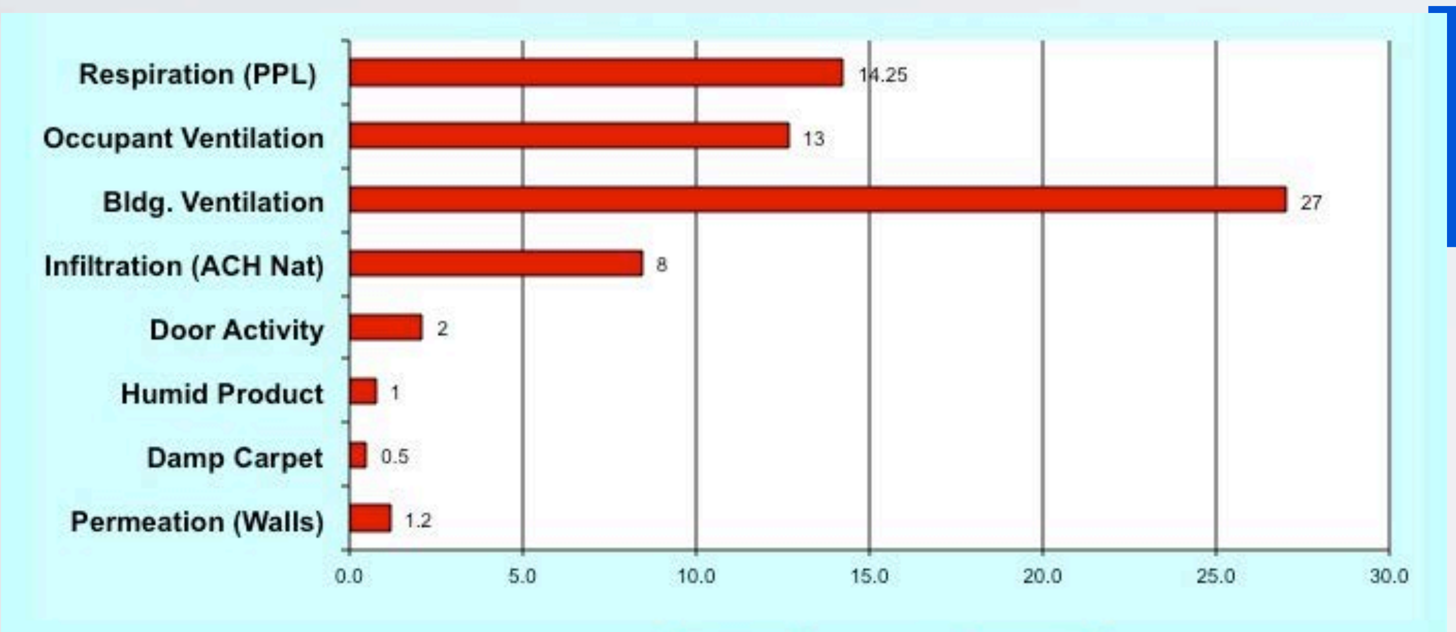


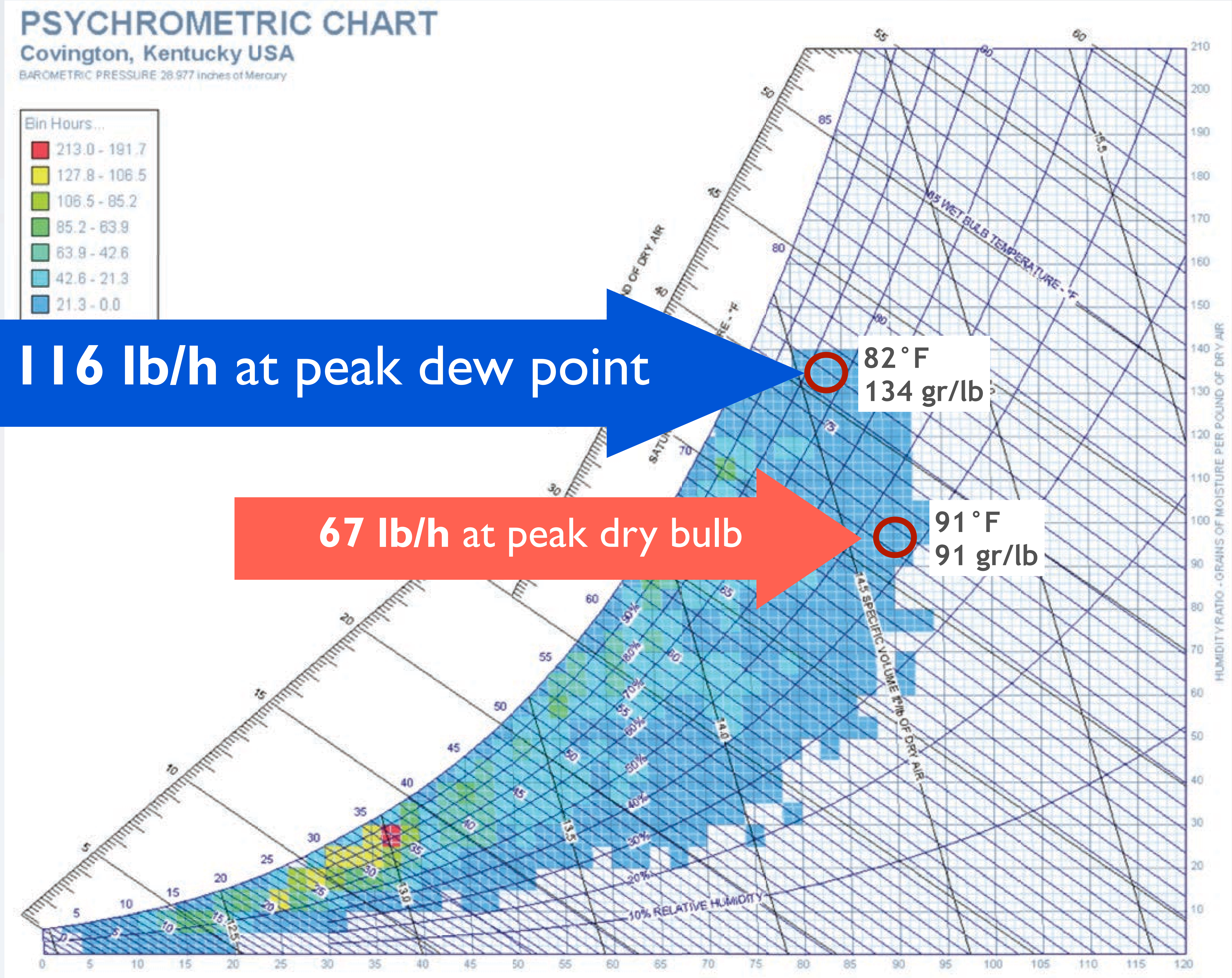

# Residential Case - Chicago

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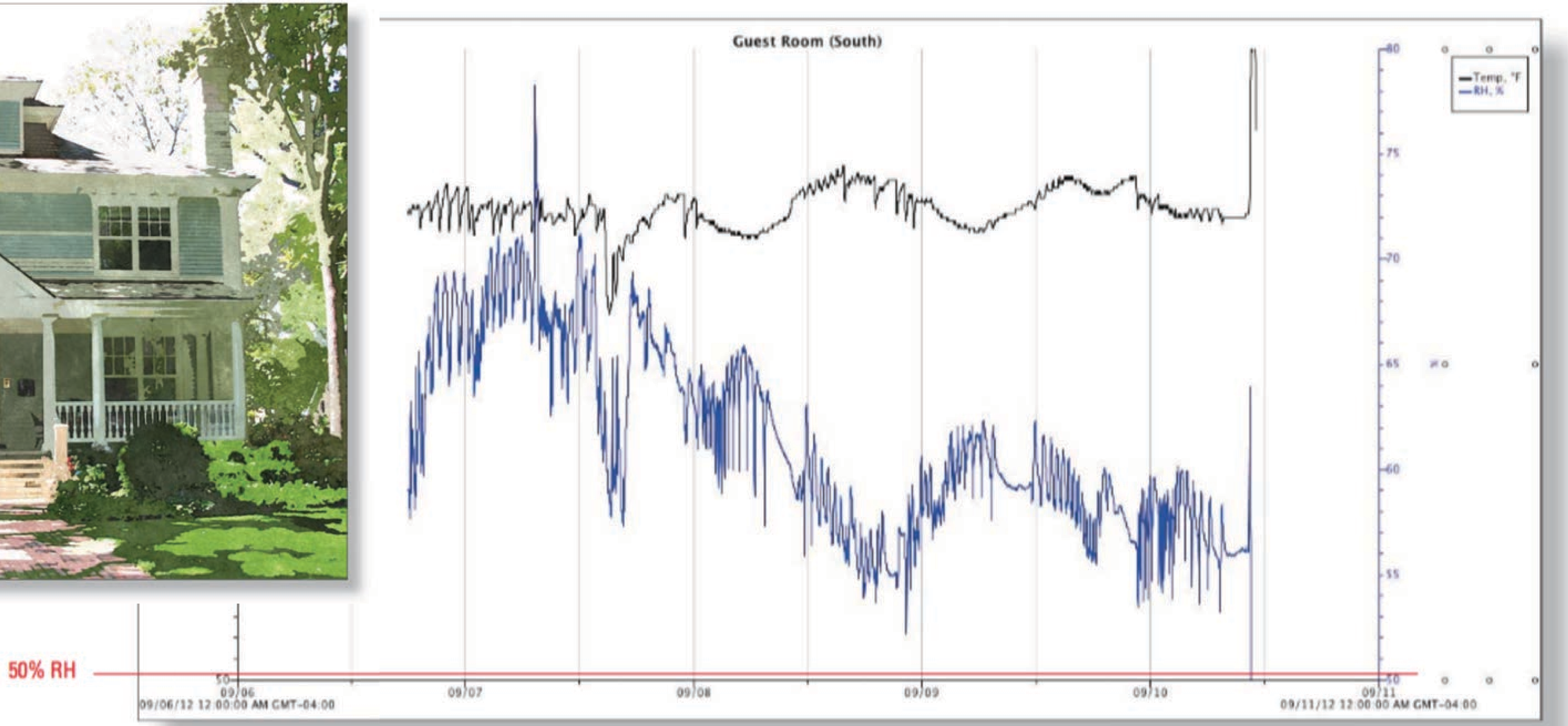

# Tight building! - Nearly zero humid air leaks

Size: 9700 $ft^2$

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Corbett + Grace Lunsford
BuildingPerformanceWorkshop.com

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**Blower door: 2856 $cfm_{50}$**

**ACH (Natural): 0.15**

**ELA: 1.8 ft2**

# Tight houses need ventilation

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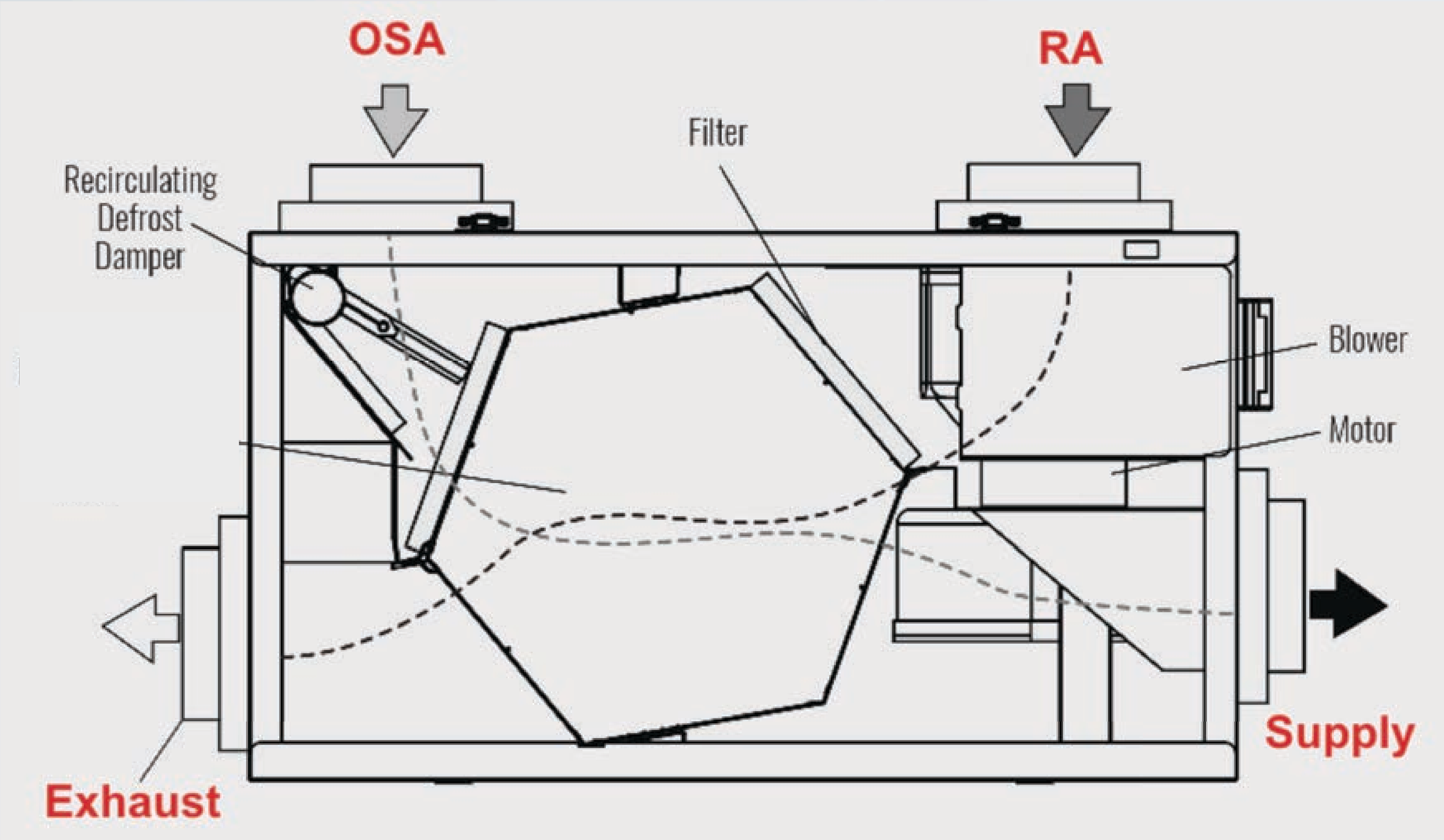


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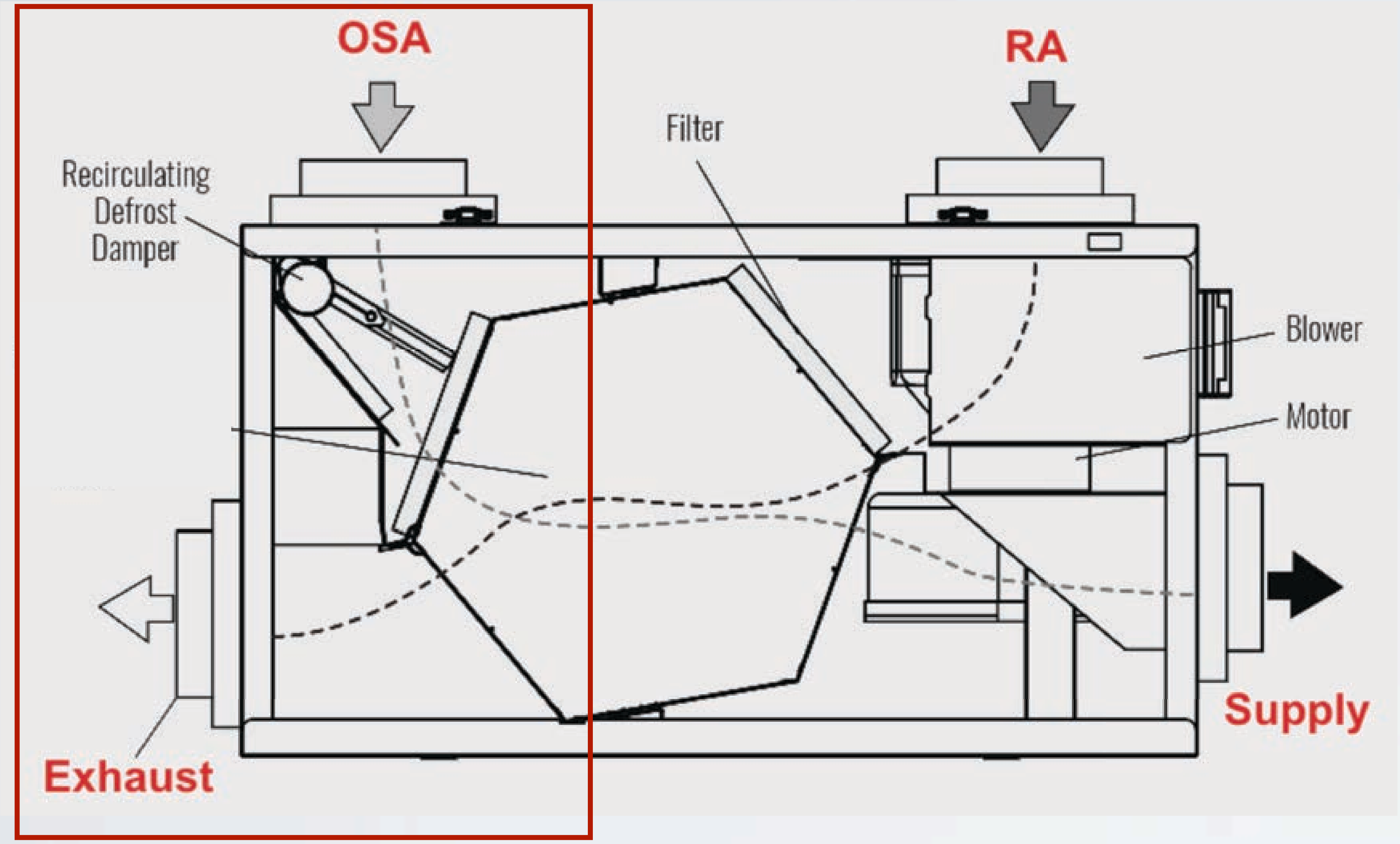


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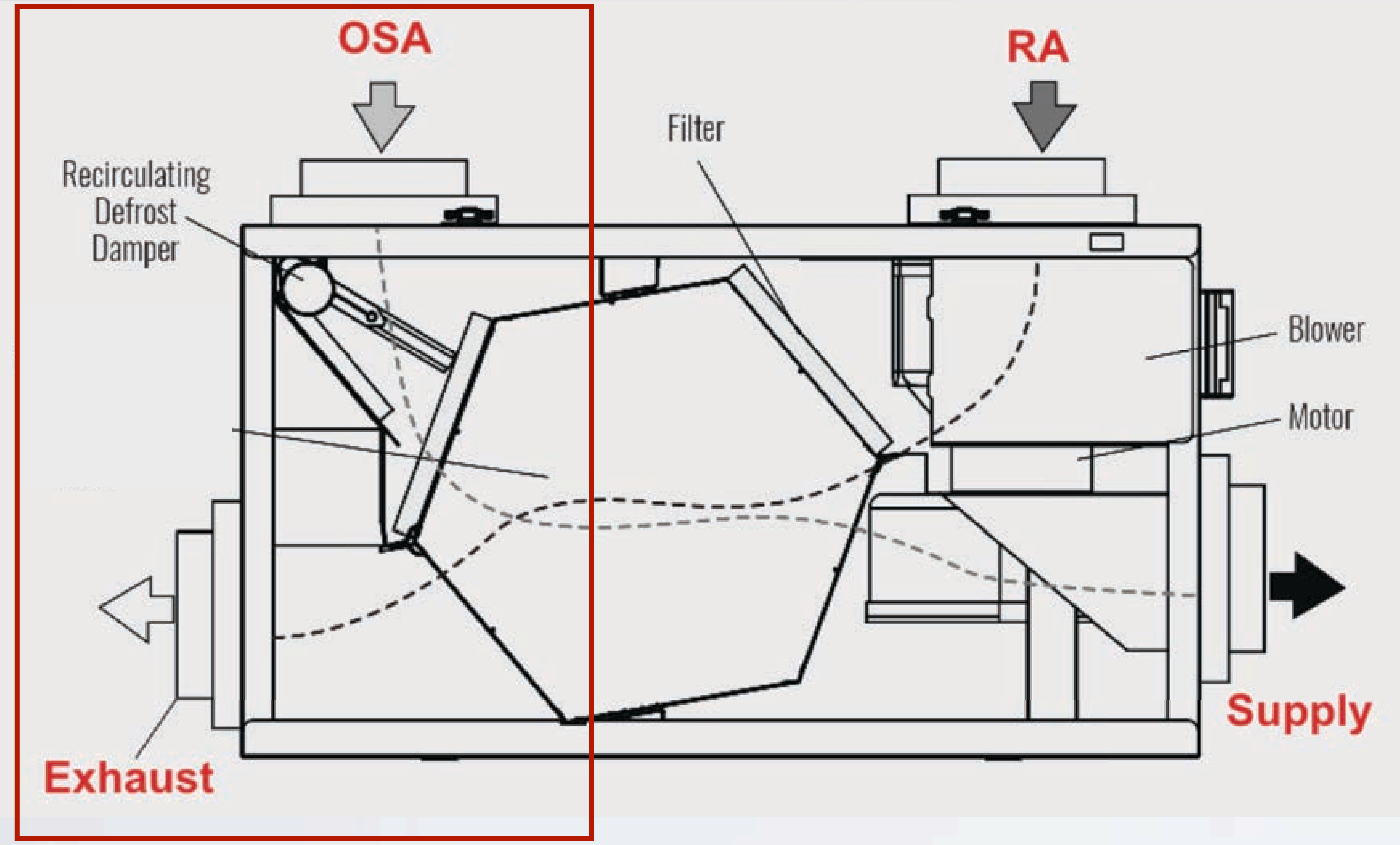


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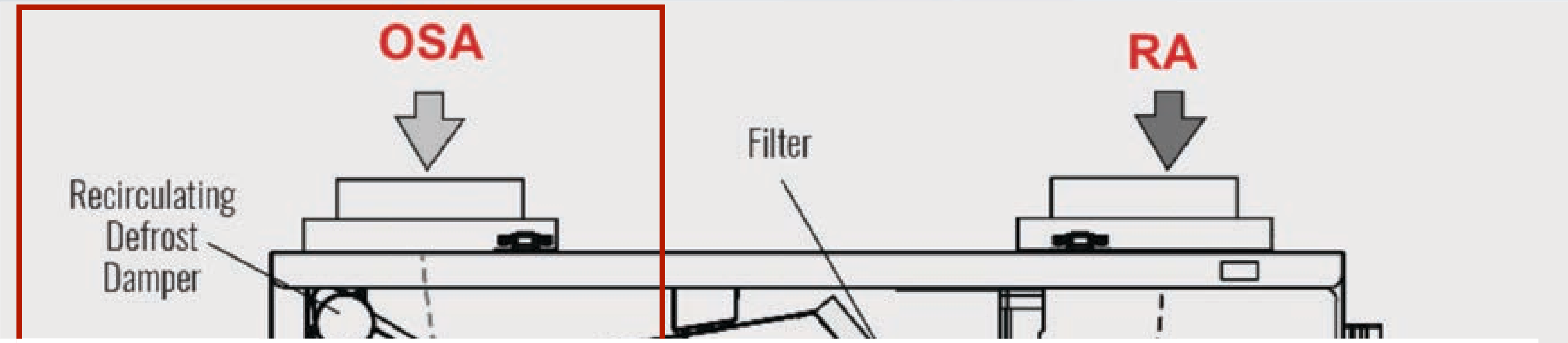



# Why is this tight building so negative?

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## Kitchen exhaust

**11am – 4:00pm**

**948cfm (High)**

**626 (Medium)**

# **In theory** - Extra AC capacity should remove the load...

Size: 9700 $ft^2$

Peak ac load: 7 tons

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**In practice:**

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## In practice:

- Little or no cooling load

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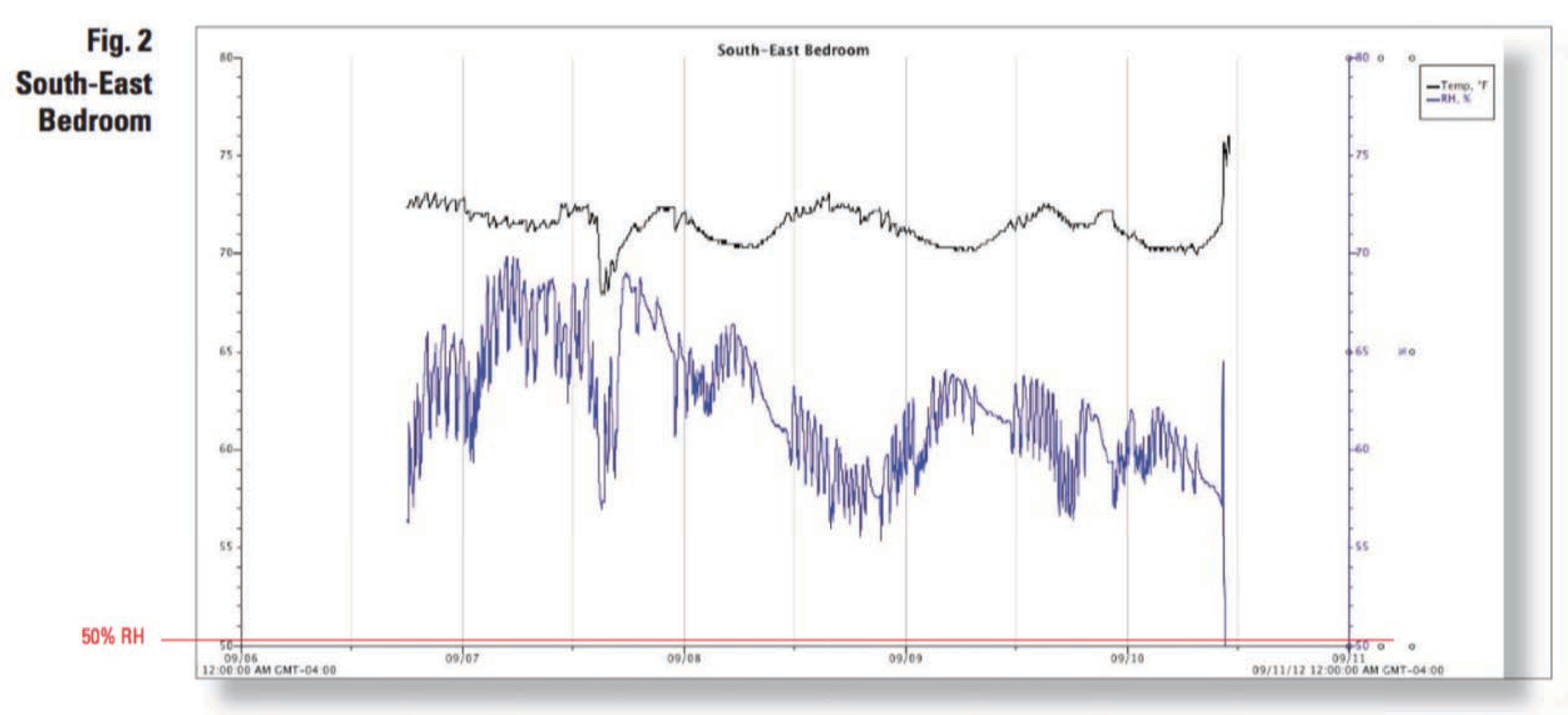


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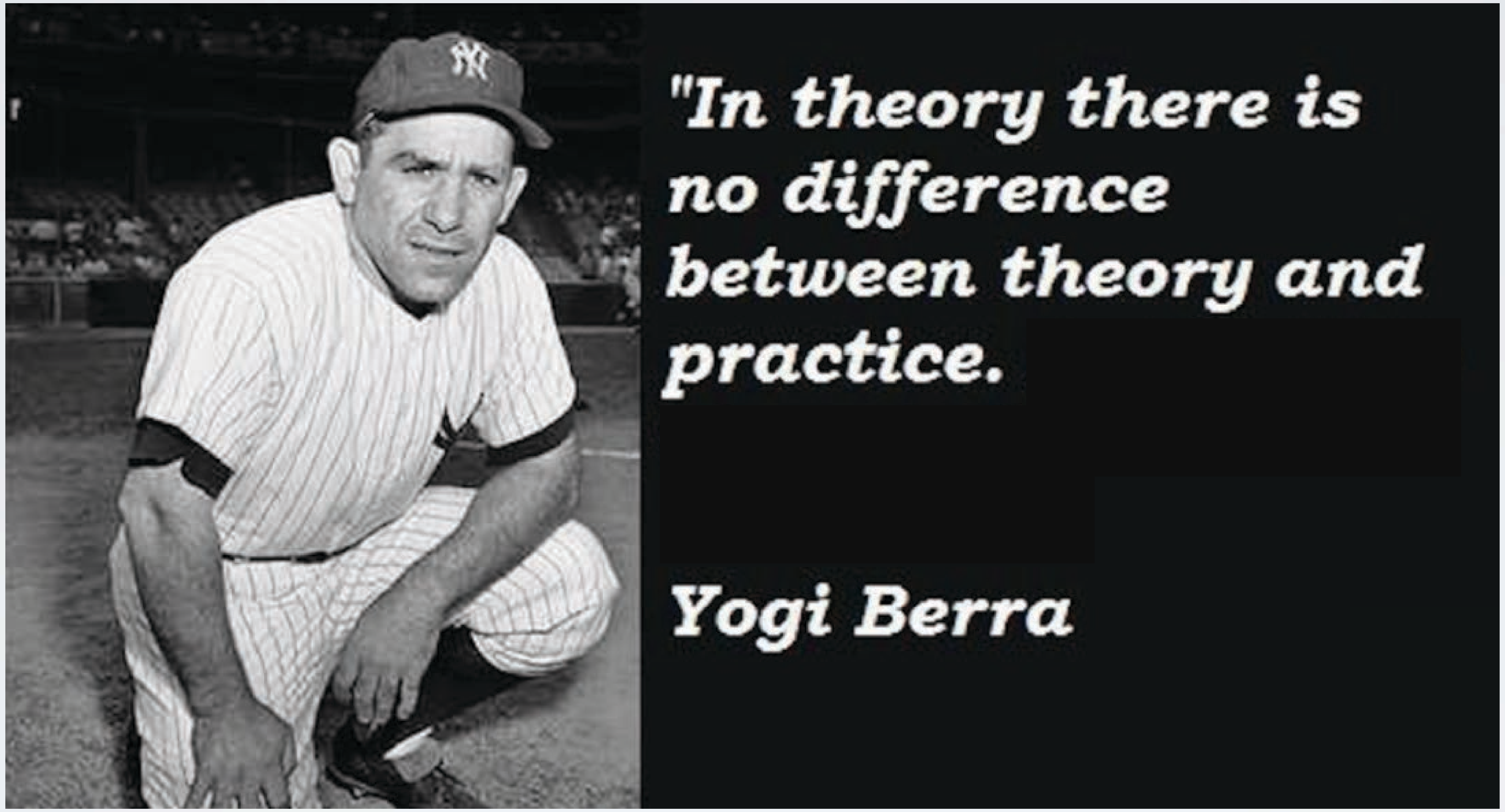
# As the late, great Yogi Berra observed...



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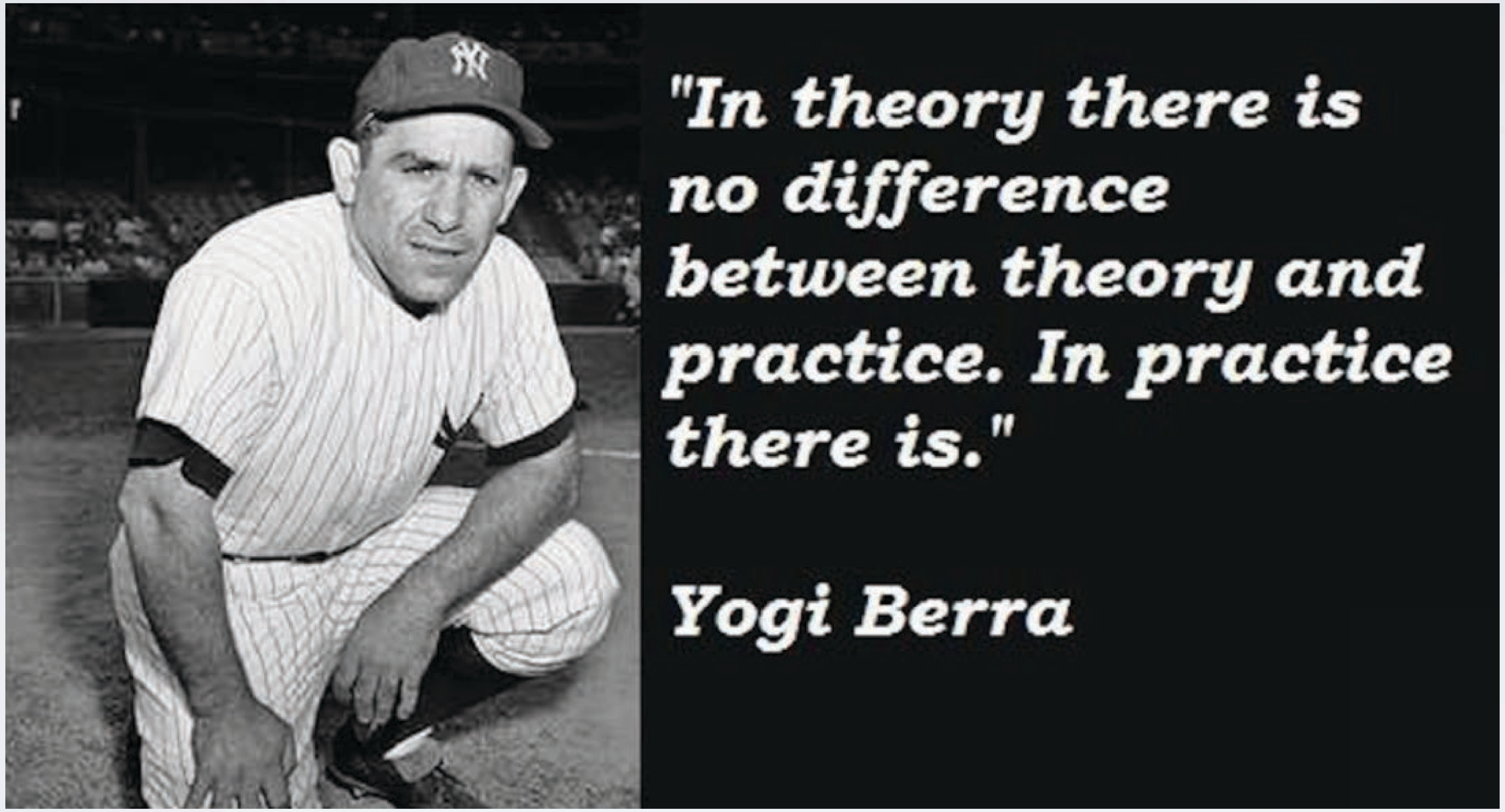
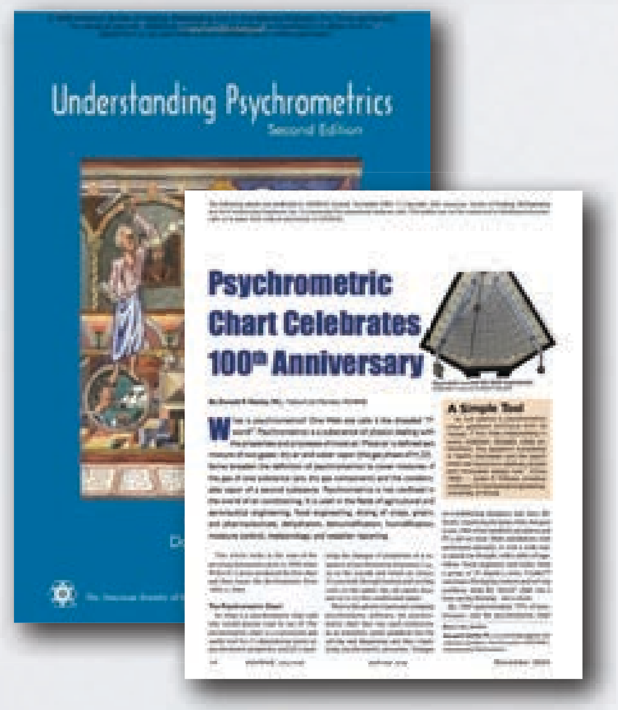


# Don Gatley, P.E. (Senior Summer Camper!)

# Don's Advice: Keep it Simple




## 79 moisture investigations in 25 years

40% hotel and nursing homes
40% apartments, condos, and houses
20% other

**All** except four were caused by building suction and/or excess humidity in ventilation and makeup air:

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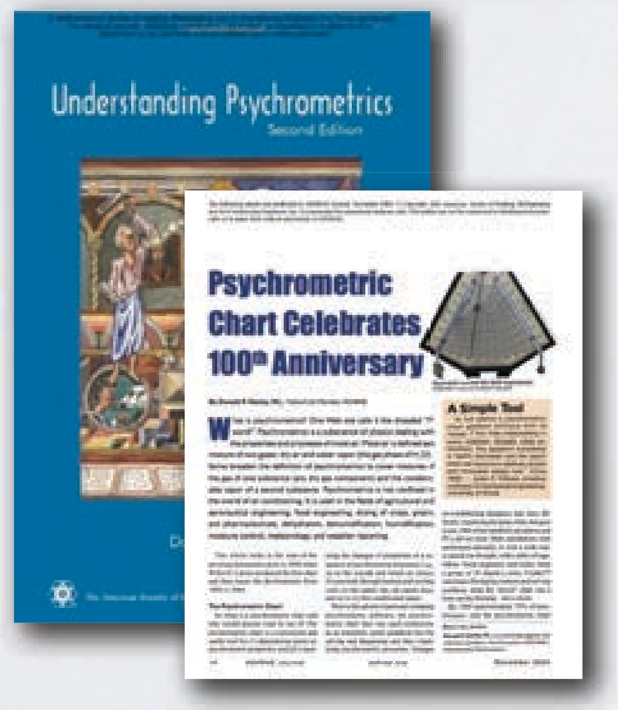


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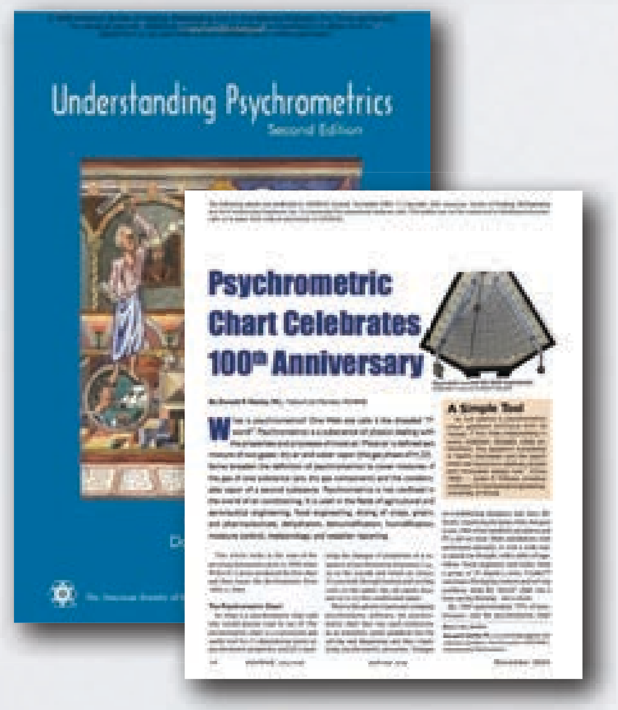


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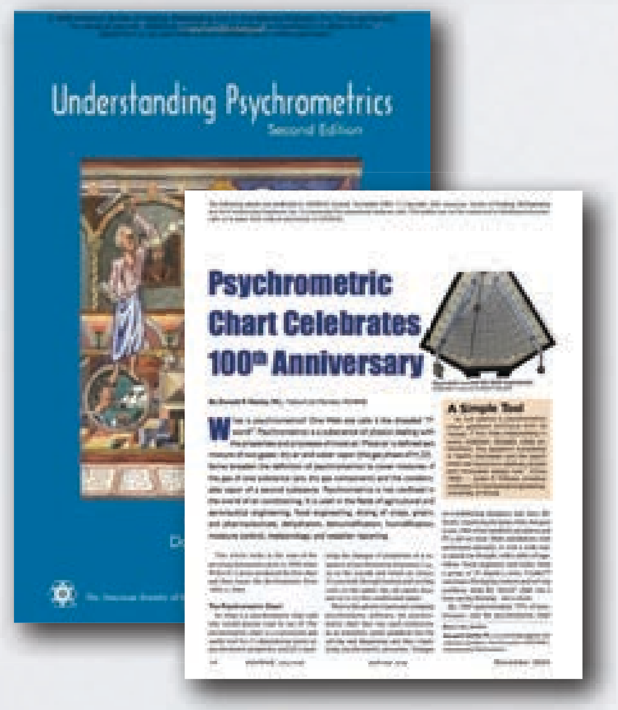
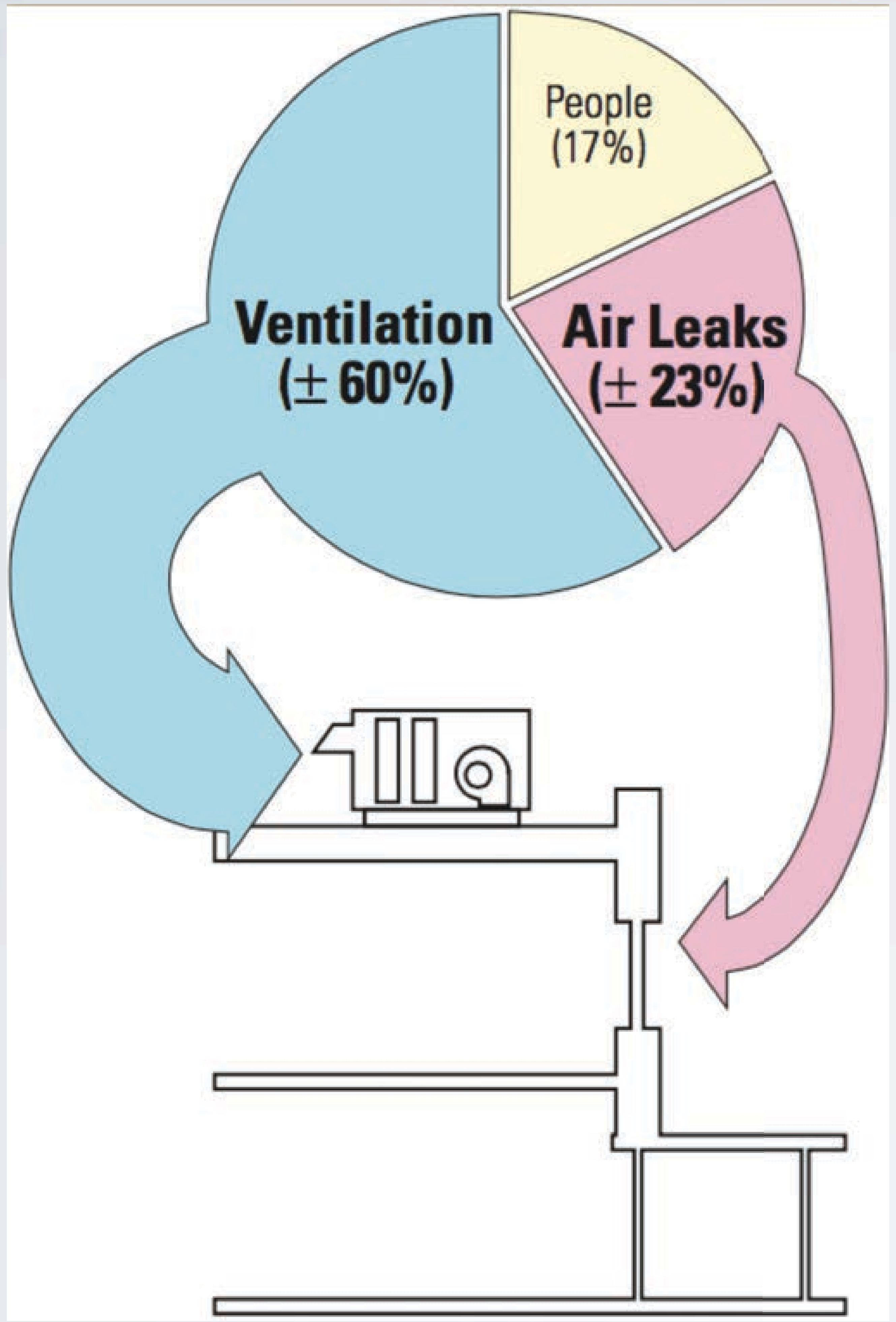



**Don told me: Don't overcomplicate humidity control!** Just make sure that:

1. **The building does not suck, and that…**
2. **Ventilation and makeup air are DRY. (Drier than indoor air)**

# Why dry the ventilation air? - It's the biggest DH load!



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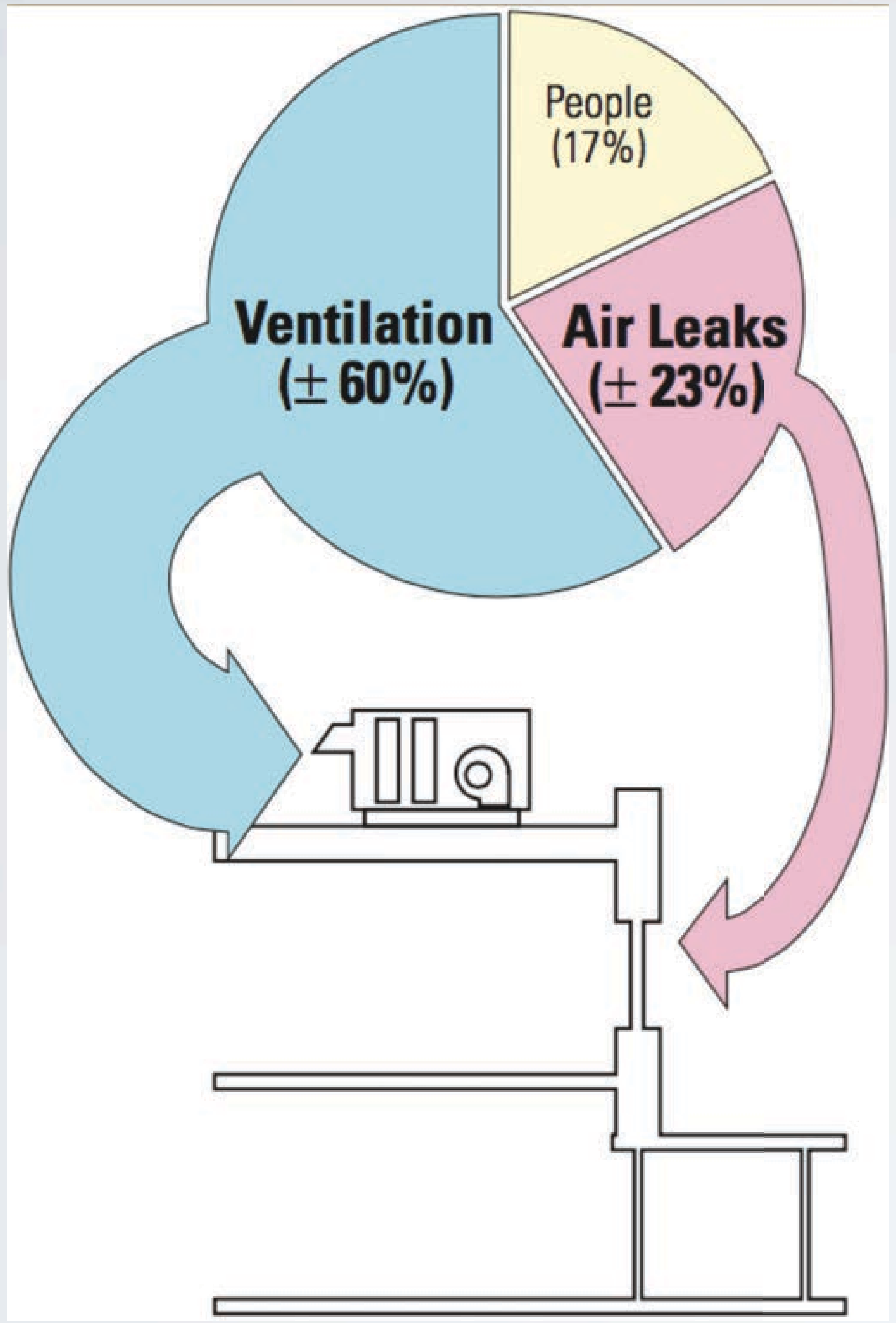


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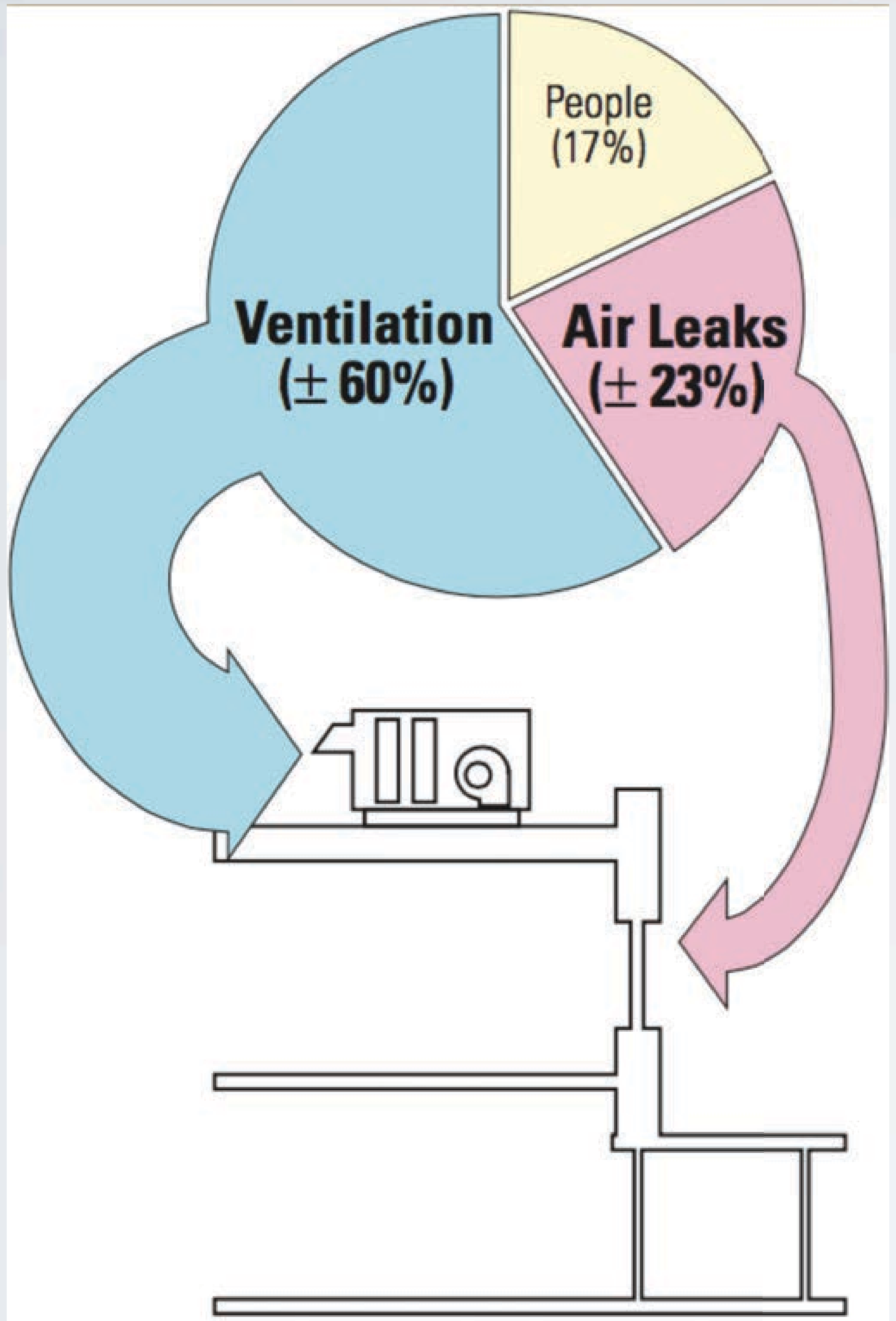


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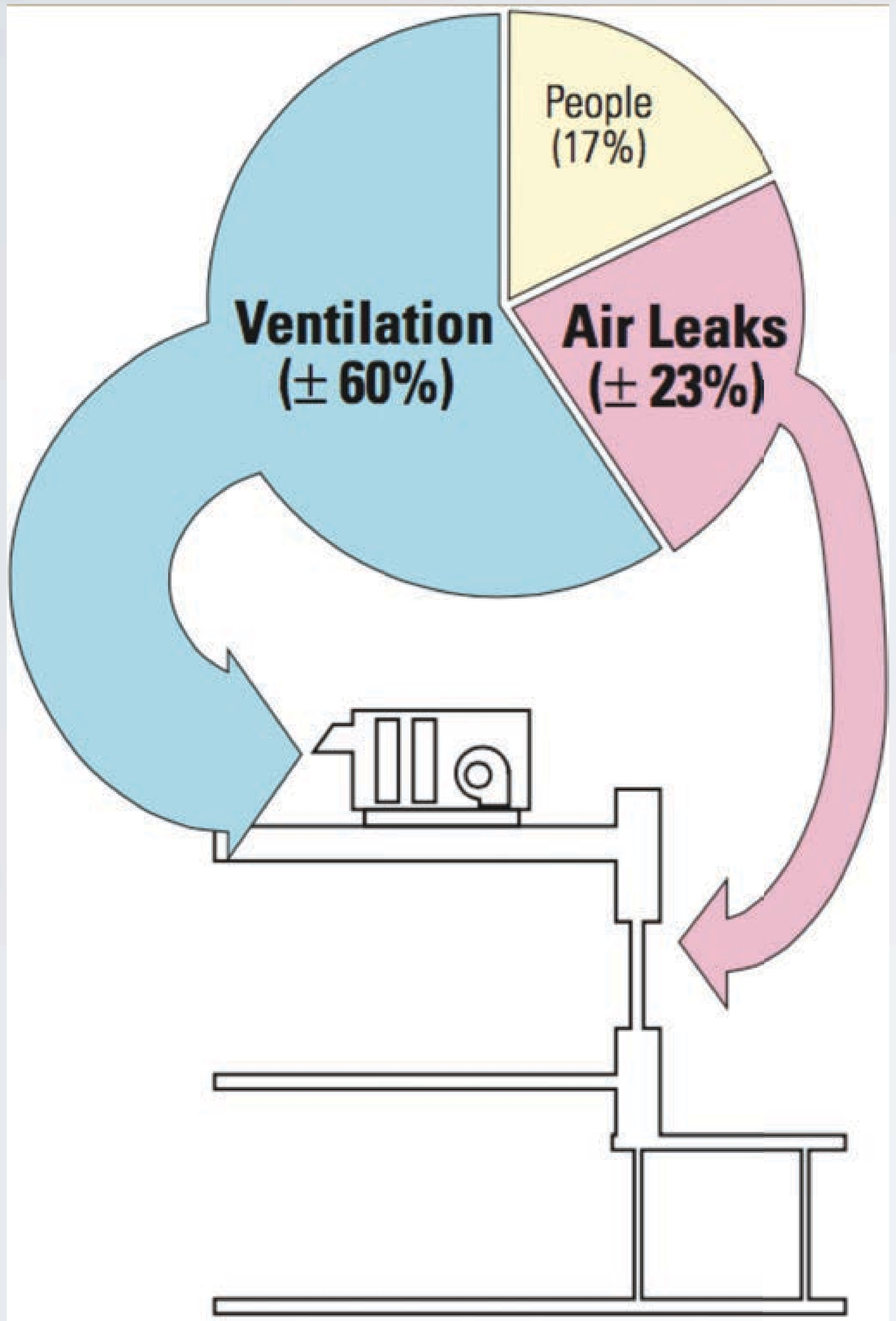


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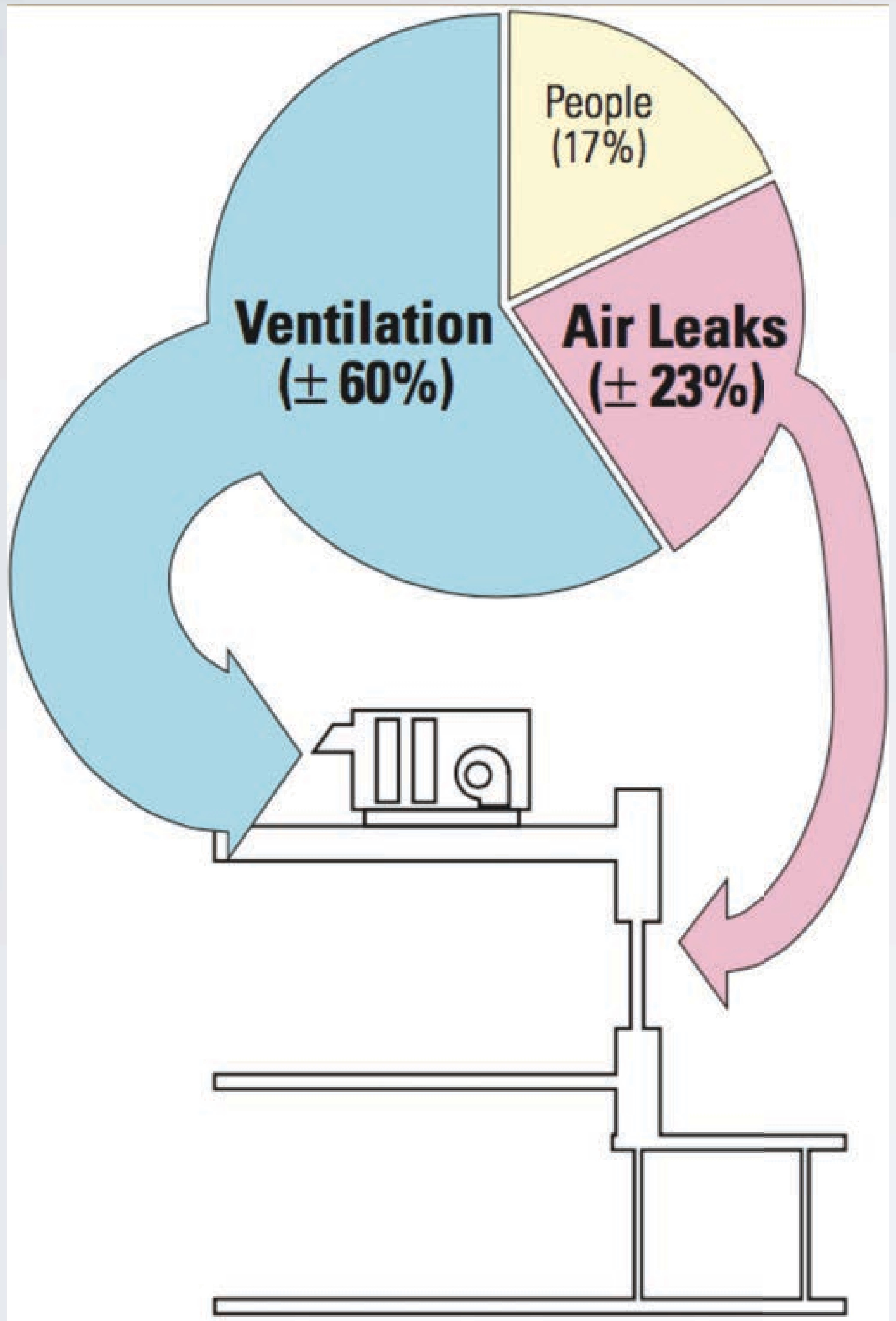


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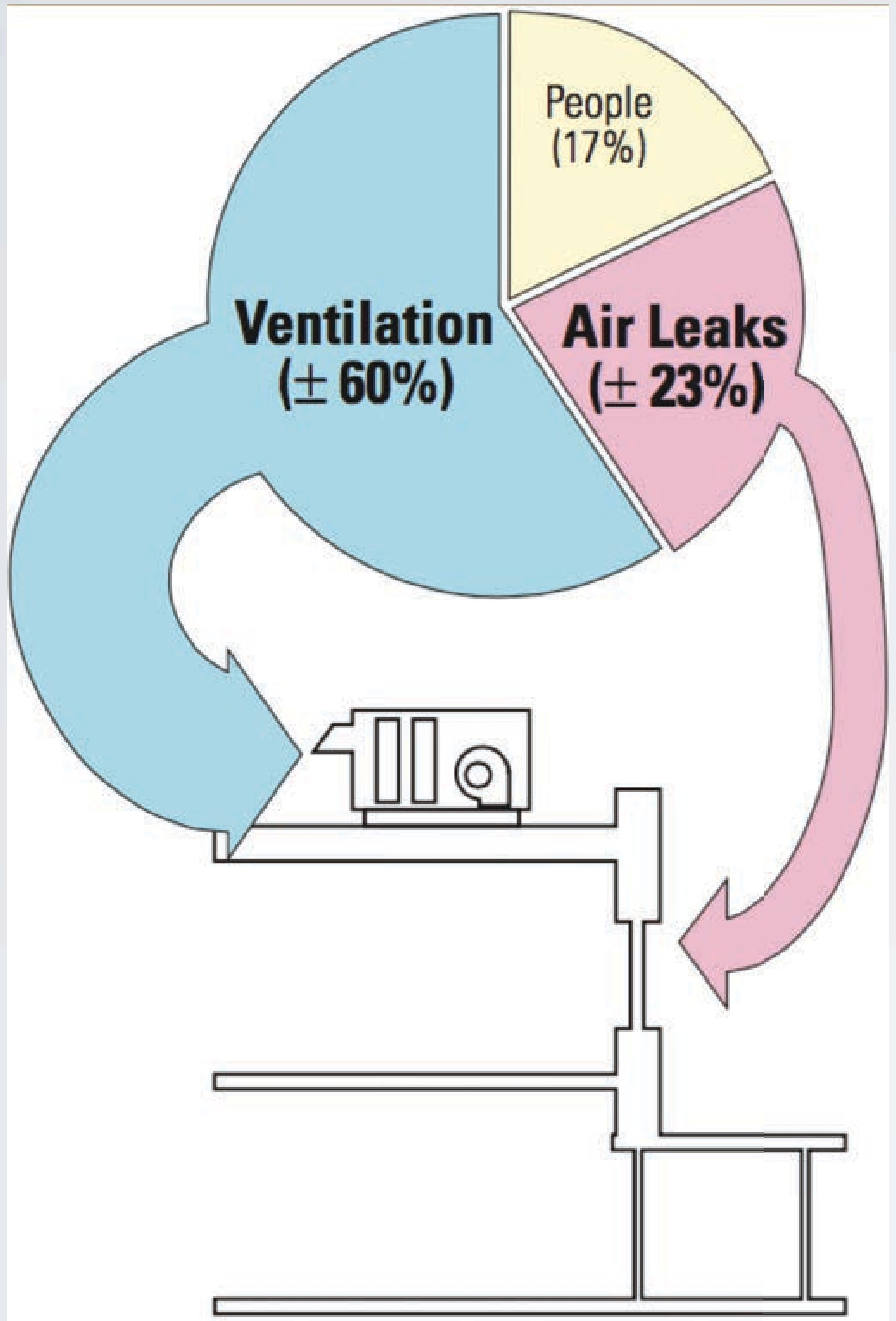


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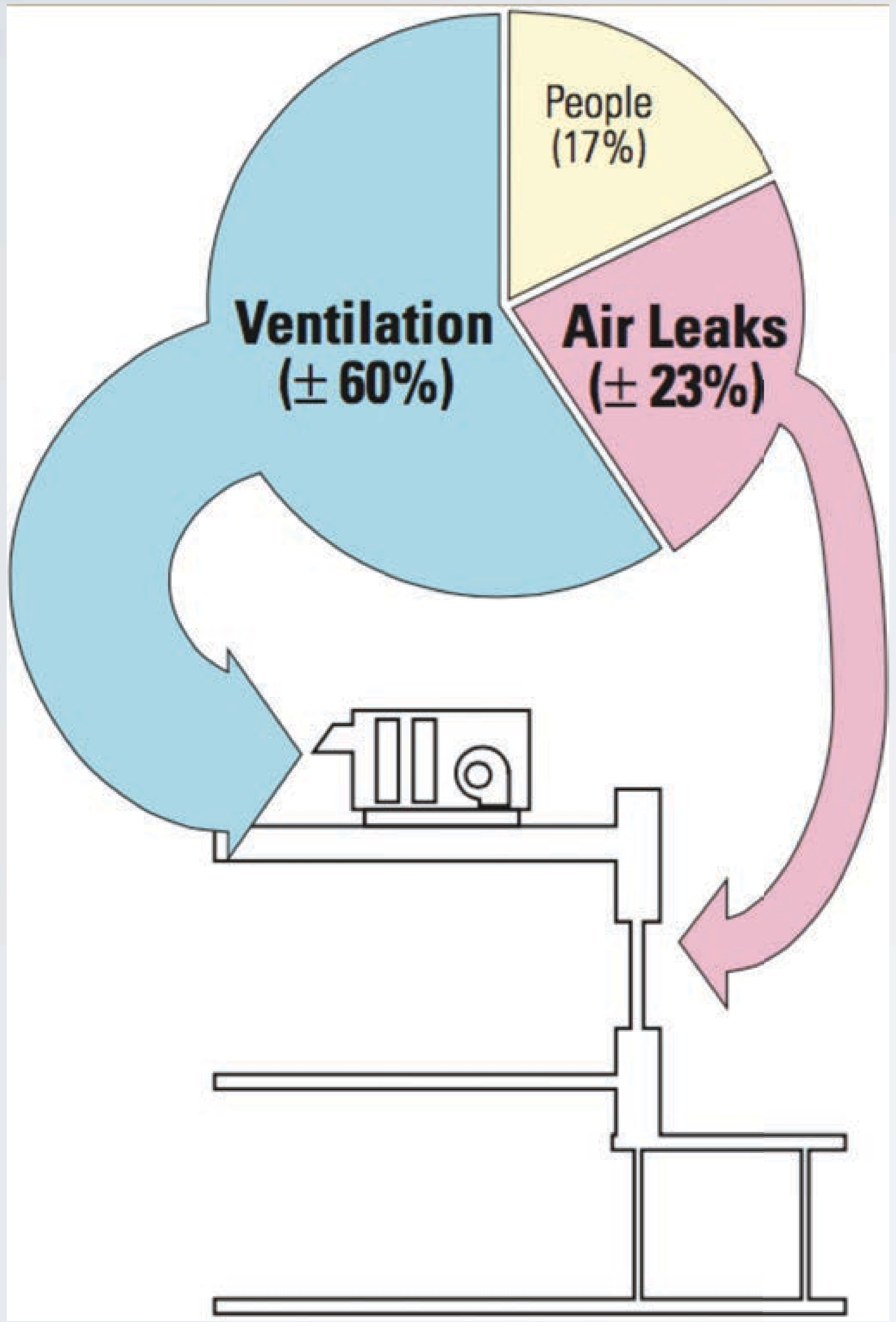


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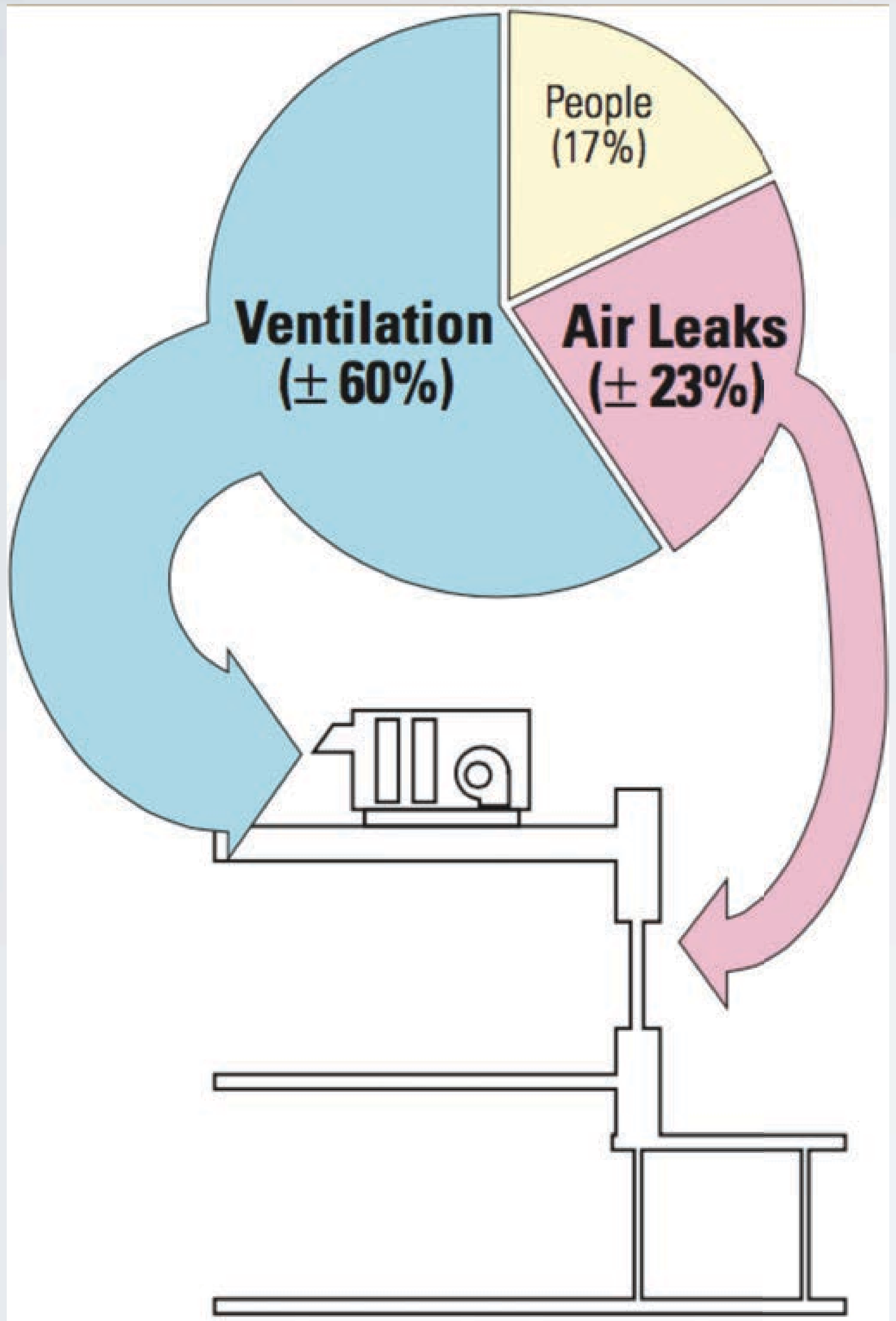


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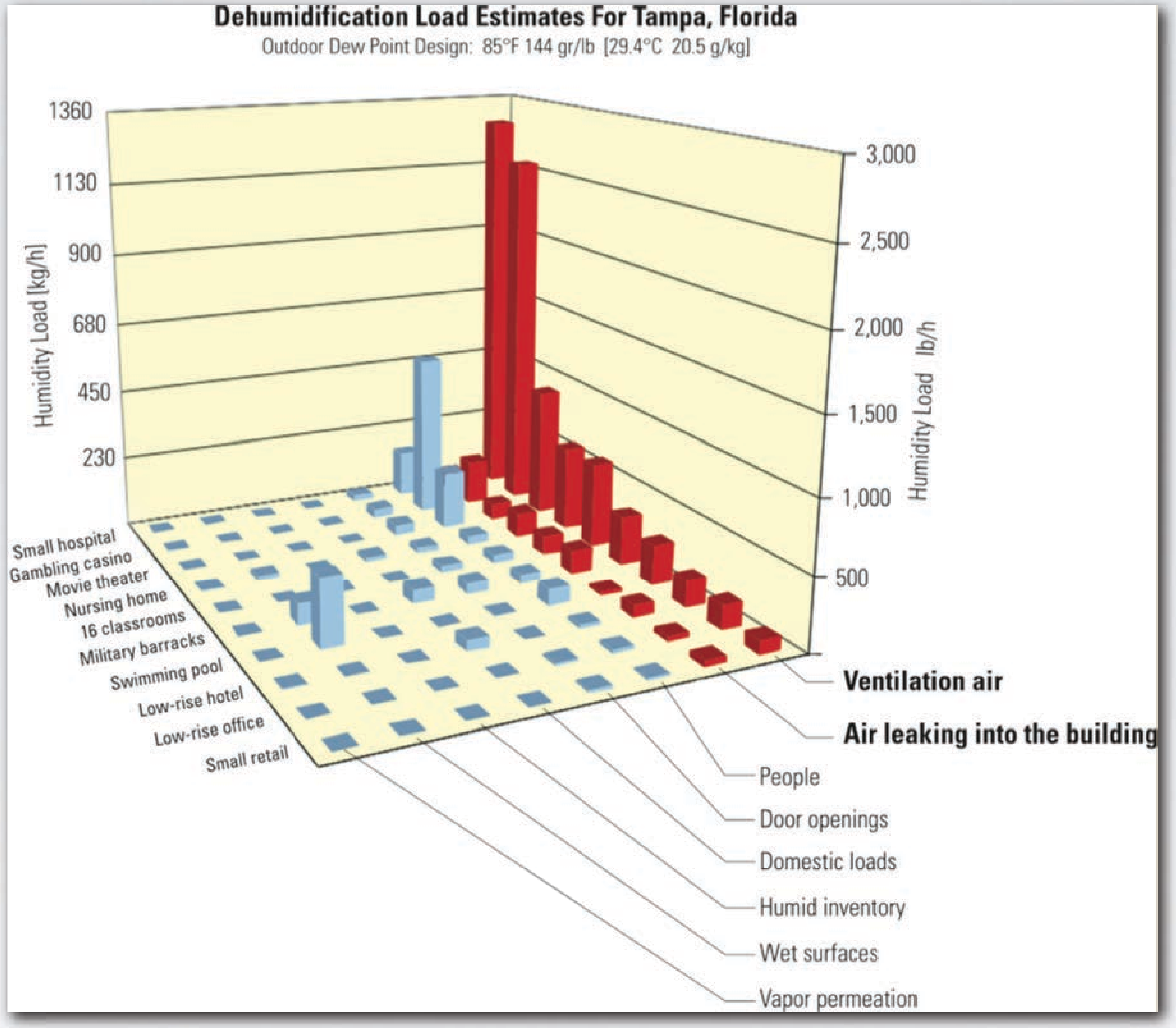
## Sooo.....

- Ventilation is a really big humidity load
- Therefore, we're going to need **dedicated dehumidification to remove the load**

# Peak DH loads - Commercial and institutional buildings



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ASHRAE JOURNAL

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Member ASHRAE
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To assist cooling equipment and meet the challenge of larger ventilation loads, several technologies have succeeded in commercial buildings. Newer technologies such as subcool/reheat and heat pipe reheat show promise. These increase latent capacity of cooling-based systems by reducing their sensible capacity. Also, desiccant wheels have traditionally provided deeper-drying capacity by using thermal energy in place of electrical power to remove the latent load.[2]

Regardless of what mix of technologies is best for a particular application, there is a need for a more effective way of thinking about the cooling loads created by ventilation air. It is clear from the literature that all-too-frequently, HVAC systems do not perform well unless the ventilation air loads have been effectively addressed at the original design stage.[3,4] This article proposes an engineering shorthand, an annual load index for ventilation air. This index will aid in the complex process of improving the ability of HVAC systems to deal efficiently

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with the amount of fresh air the industry has deemed useful for maintaining comfort in buildings.[5]

The proposed "ventilation load index" (VLI) is the total load generated by one cubic foot per minute of fresh air brought from the weather to space-neutral conditions over the course of one year. It consists of two numbers, separating the load into its dehumidification and cooling components: latent ton-hours per cfm per year and sensible ton-hours per cfm per year. For example, a ventilation air load index of 6.7 + 1.1 means that the total annual latent load is 6.7 ton-hours per cfm, and the annual sensible load is 1.1 ton-hours per cfm.

The "VLI" is proposed in the same spirit that led to the use of the "degree-day" as shorthand for expressing heating and cooling loads on the envelope of a building, or the SEER as a means of expressing the relative efficiency of cooling equipment over time. Those engineering shorthand values reduce great complexity to simple terms. Although they cannot replace detailed examination of the phenomena they represent, they allow rapid comparisons between similar items. In the same way, the ventilation load index allows for quick comparisons between loads in different geographic locations.

### *Latent vs. Sensible Ton-hours per SCFM per Year*

To calculate the index for a given location, one must compare the temperature and humidity levels in the weather to the temperature and humidity in the conditioned space. Then a calculation is made for every hour of the year. One must also decide what values to use for "space-neutral" temperature and humidity set points to compare with the weather conditions.

In calculating the indexes contained in this article, "space-neutral" conditions are defined as 75°F (24°C), 50% rh (65 gr/lb [39 g/.45 kg]). One could equally choose different set points for specialty applications, but 75°F (24°C), 50% rh seems to represent values consistent with human comfort research findings. This set point is at the middle of the combined summer and winter comfort zones with respect to dry bulb temperature

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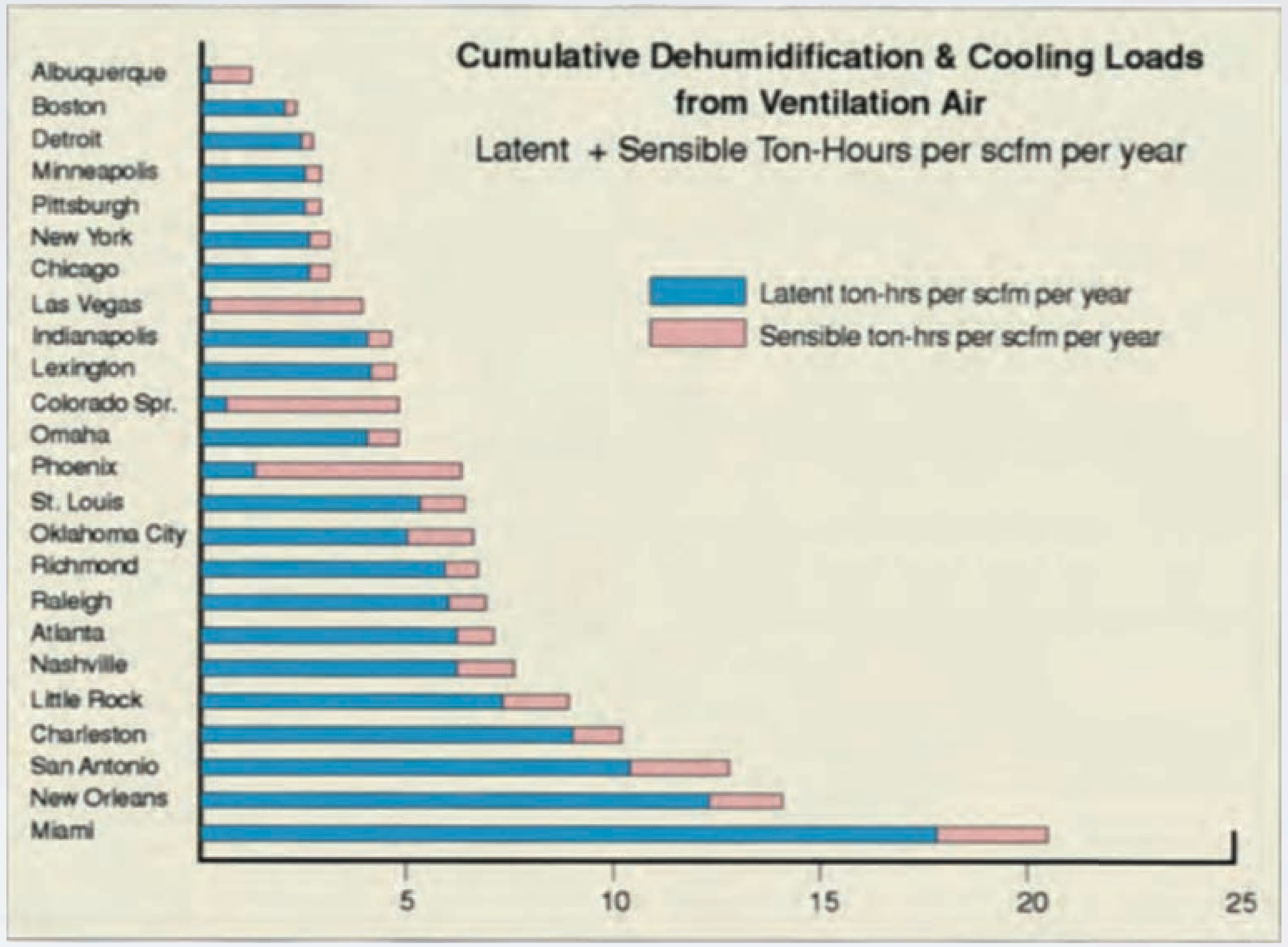

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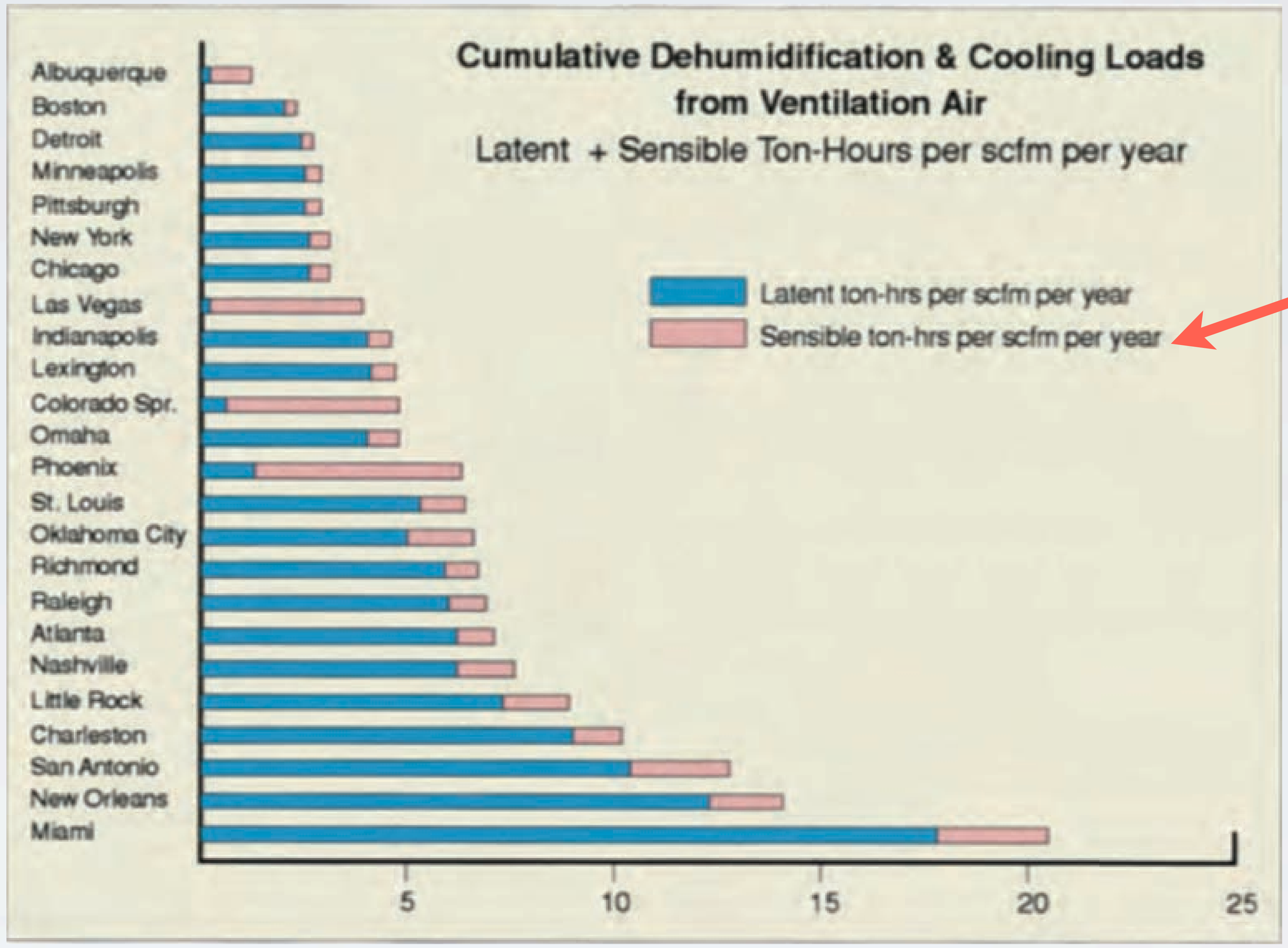
November 1997 ASHRAE Journal 37




Cooling

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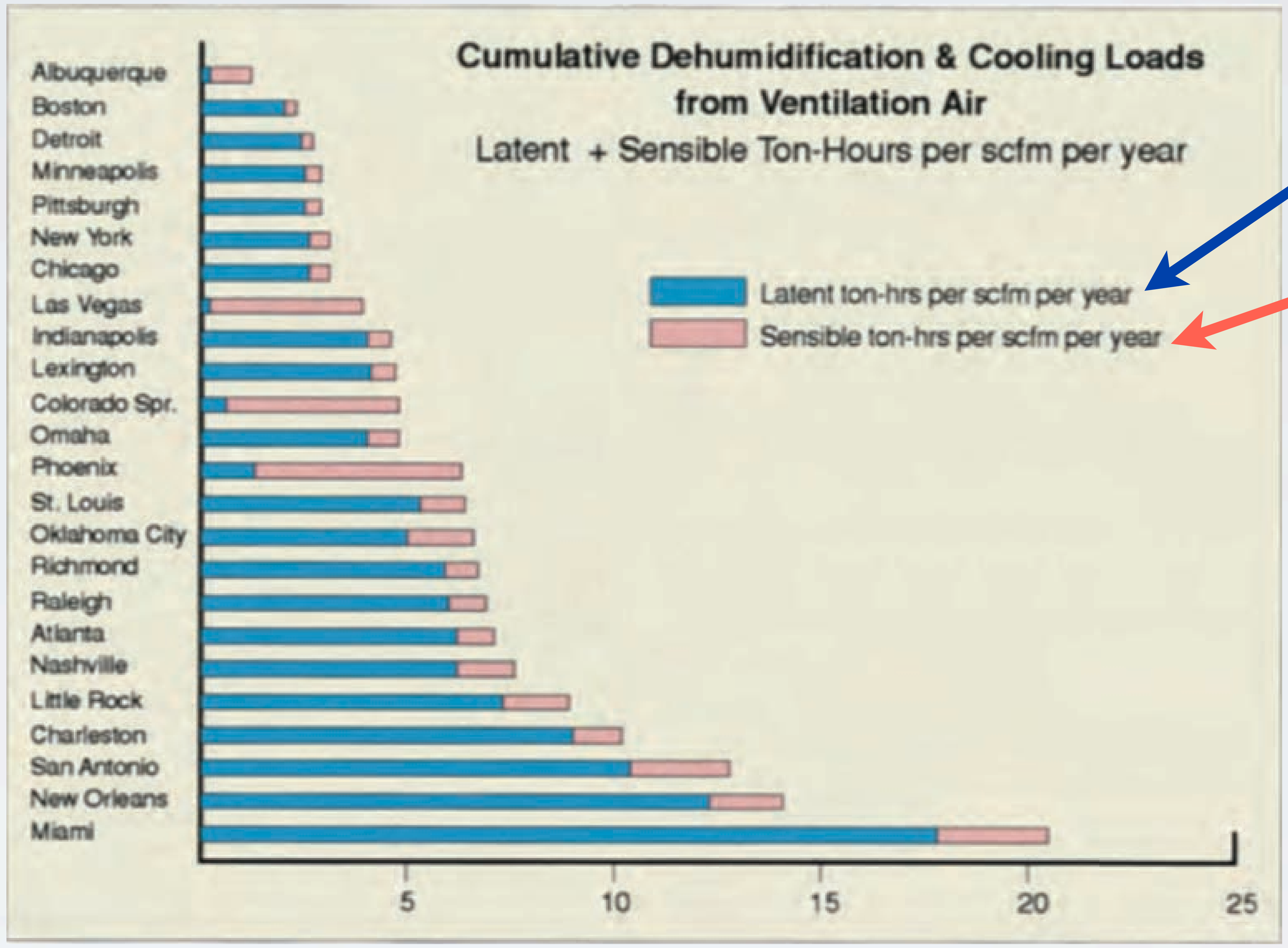


Dehumidification

Cooling

# The **ANNUAL** ventilation **DH load** is much larger than the ventilation **cooling** load

ASHRAE JOURNAL

## Dehumidification and Cooling Loads From Ventilation Air

By Lewis G. Harriman III
Member ASHRAE
Dean Plager
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To assist cooling equipment and meet the challenge of larger ventilation loads, several technologies have succeeded in commercial buildings. Newer technologies such as subcool/reheat and heat pipe reheat show promise. These increase latent capacity of cooling-based systems by reducing their sensible capacity. Also, desiccant wheels have traditionally provided deeper-drying capacity by using thermal energy in place of electrical power to remove the latent load.[2]

Regardless of what mix of technologies is best for a particular application, there is a need for a more effective way of thinking about the cooling loads created by ventilation air. It is clear from the literature that all-too-frequently, HVAC systems do not perform well unless the ventilation air loads have been effectively addressed at the original design stage.[3,4] This article proposes an engineering shorthand, an annual load index for ventilation air. This index will aid in the complex process of improving the ability of HVAC systems to deal efficiently with the amount of fresh air the industry has deemed useful for maintaining comfort in buildings.[5]

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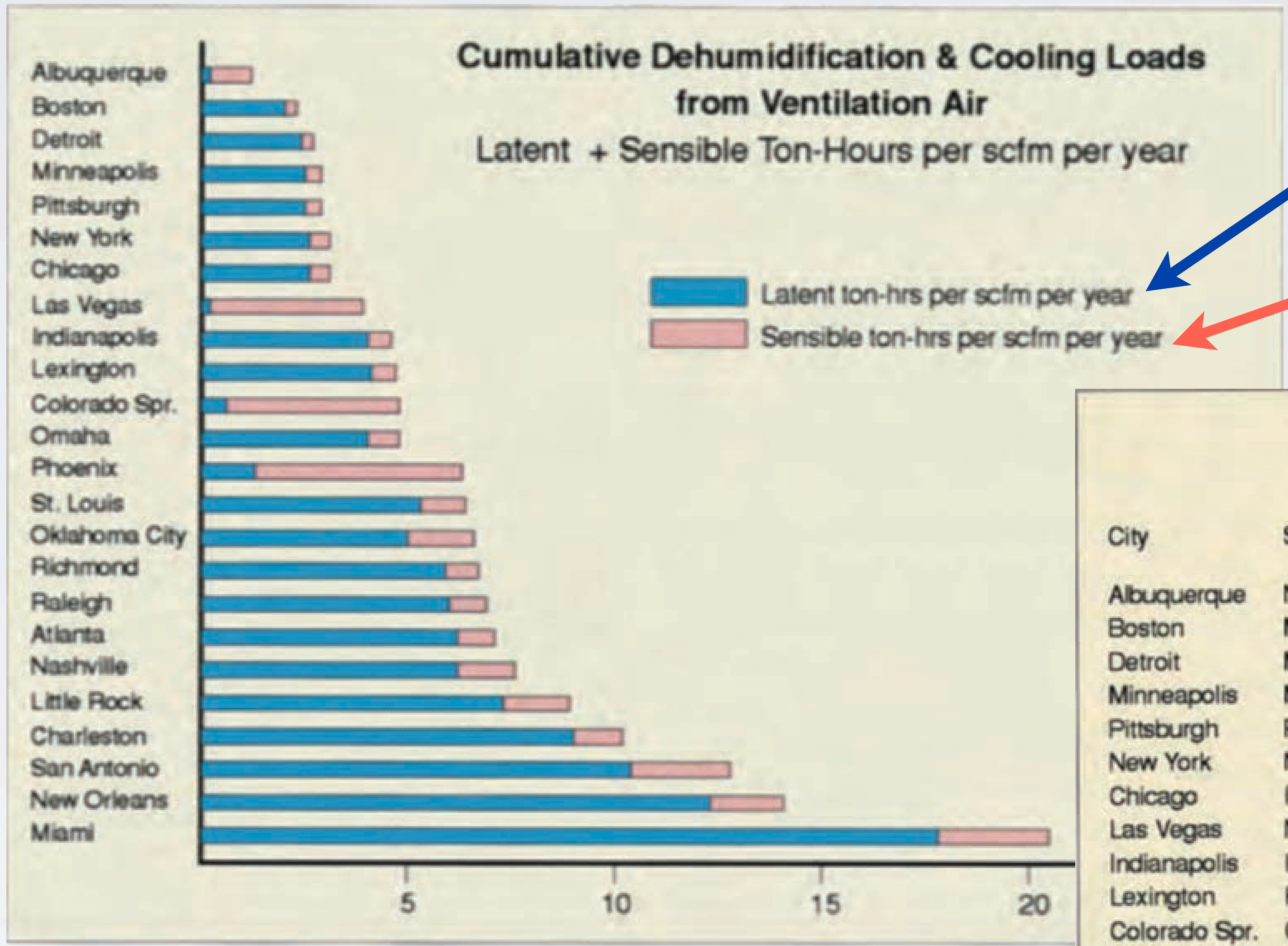


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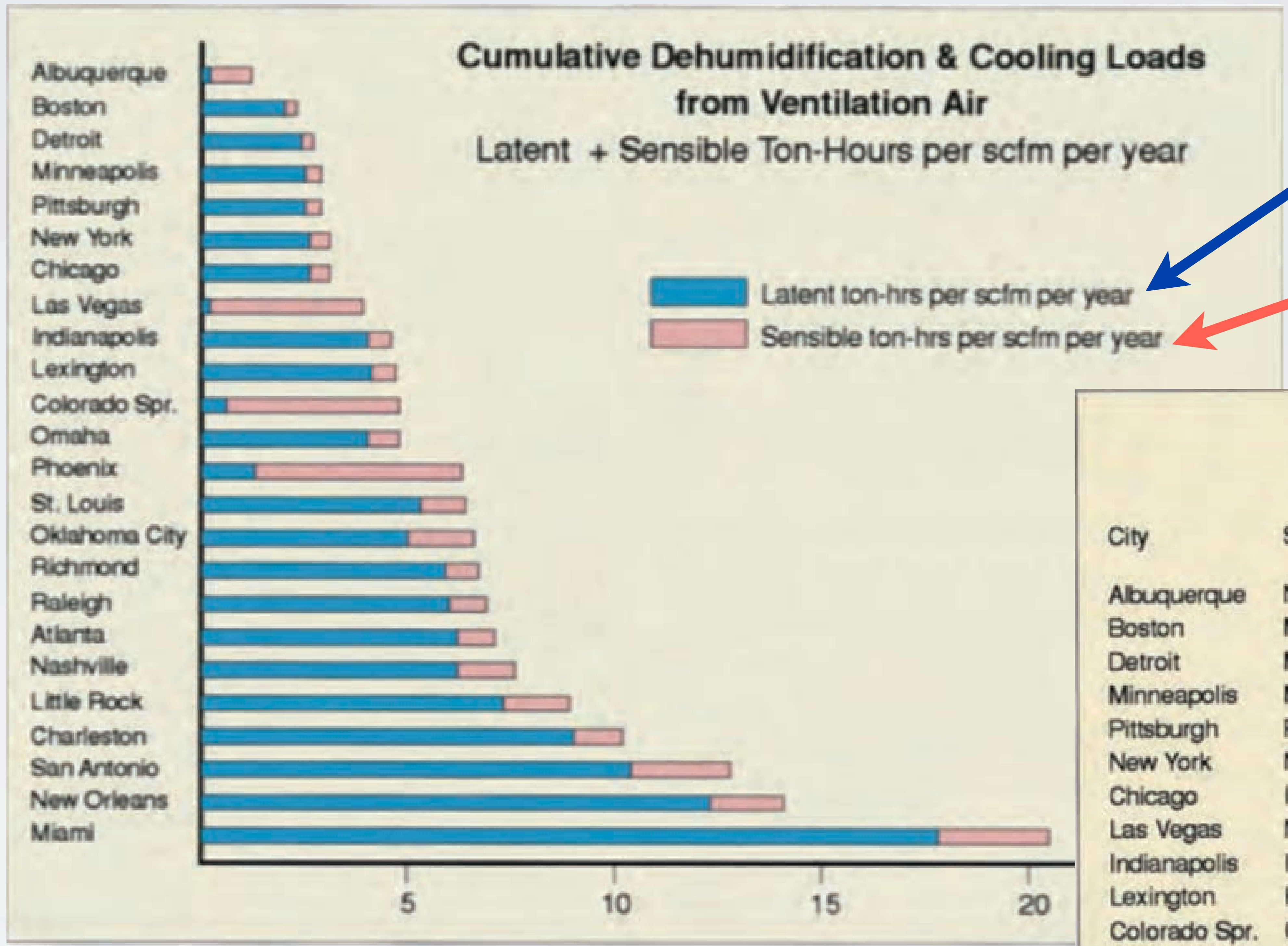


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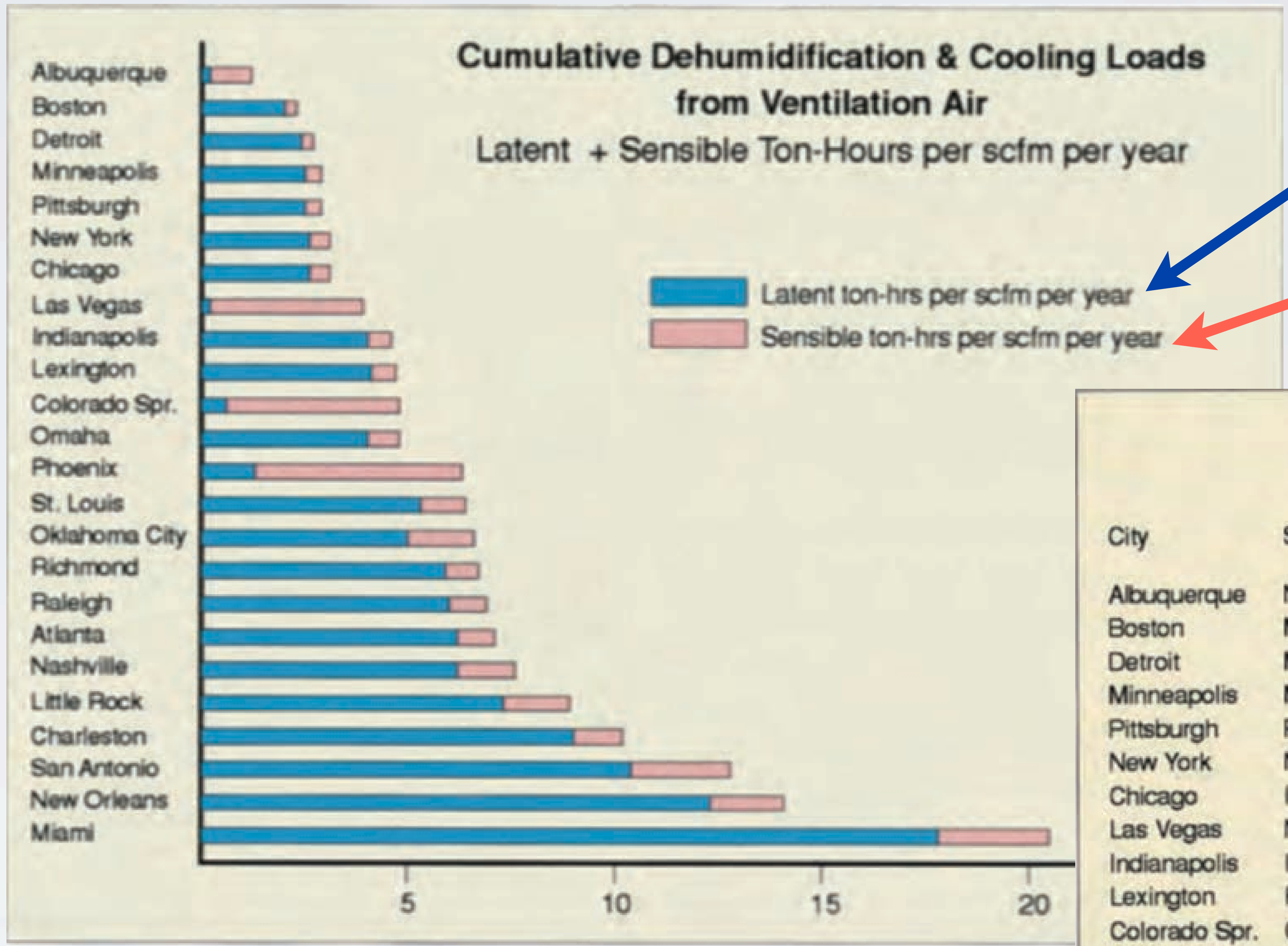


Dehumidification

Cooling

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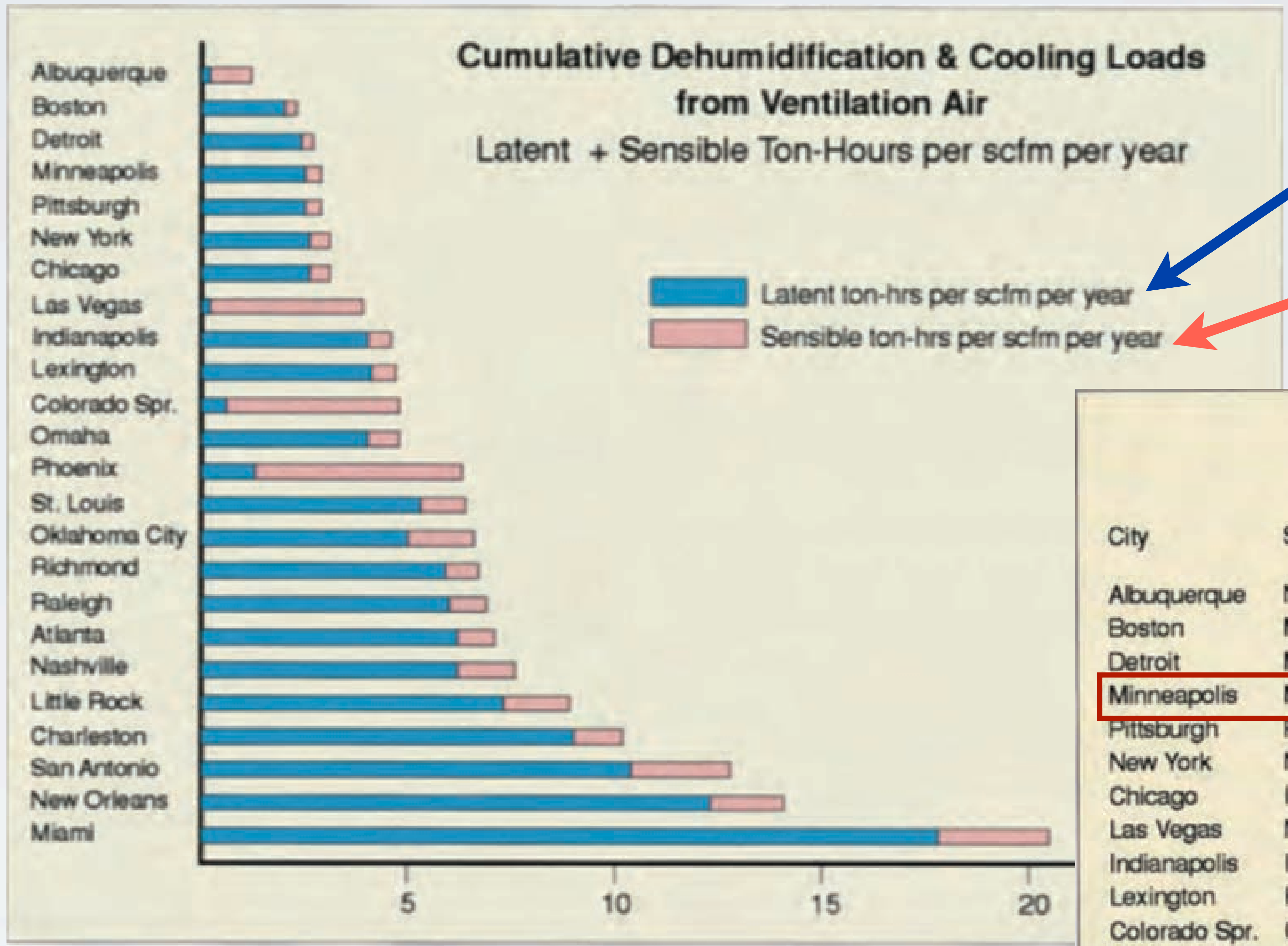


Dehumidification

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# **Non-ventilated** new houses - South Florida

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**4,240 ft$^2$ 5 Bedrooms + 5 Bathrooms**

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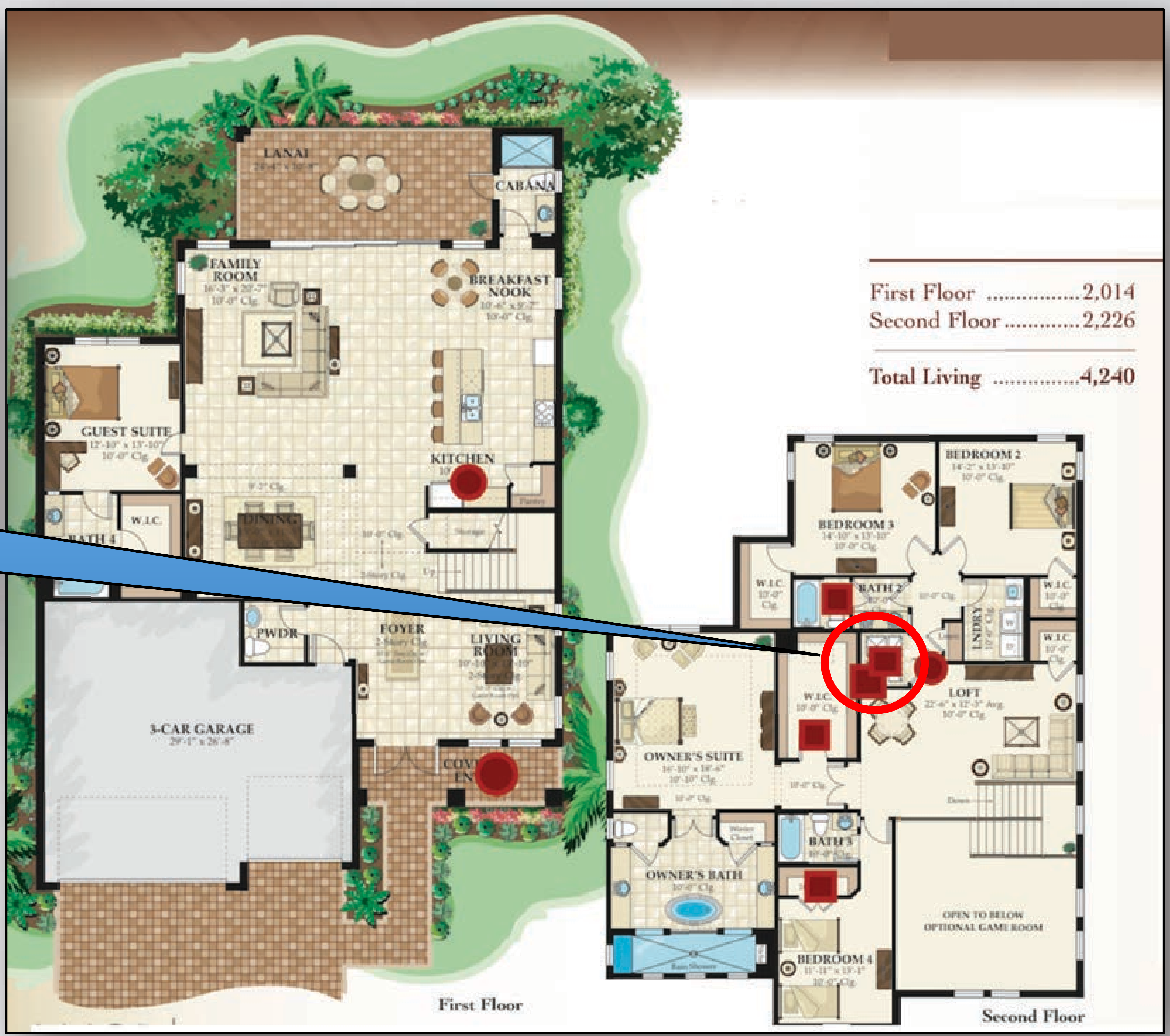
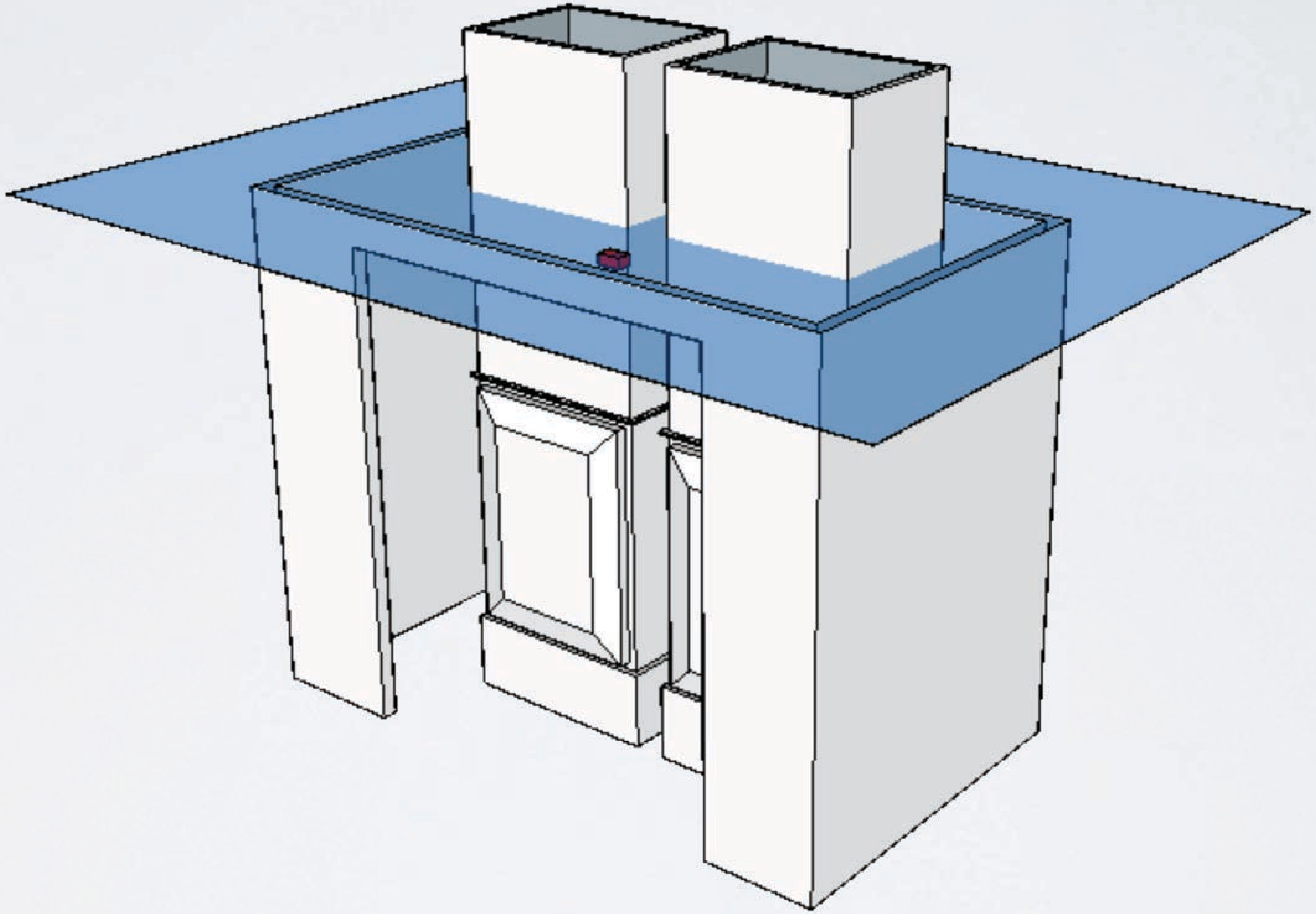
**4,240 ft$^2$ 5 Bedrooms + 5 Bathrooms**

Mechanical closet located on the 2nd floor



# Measuring dehumidification in real time



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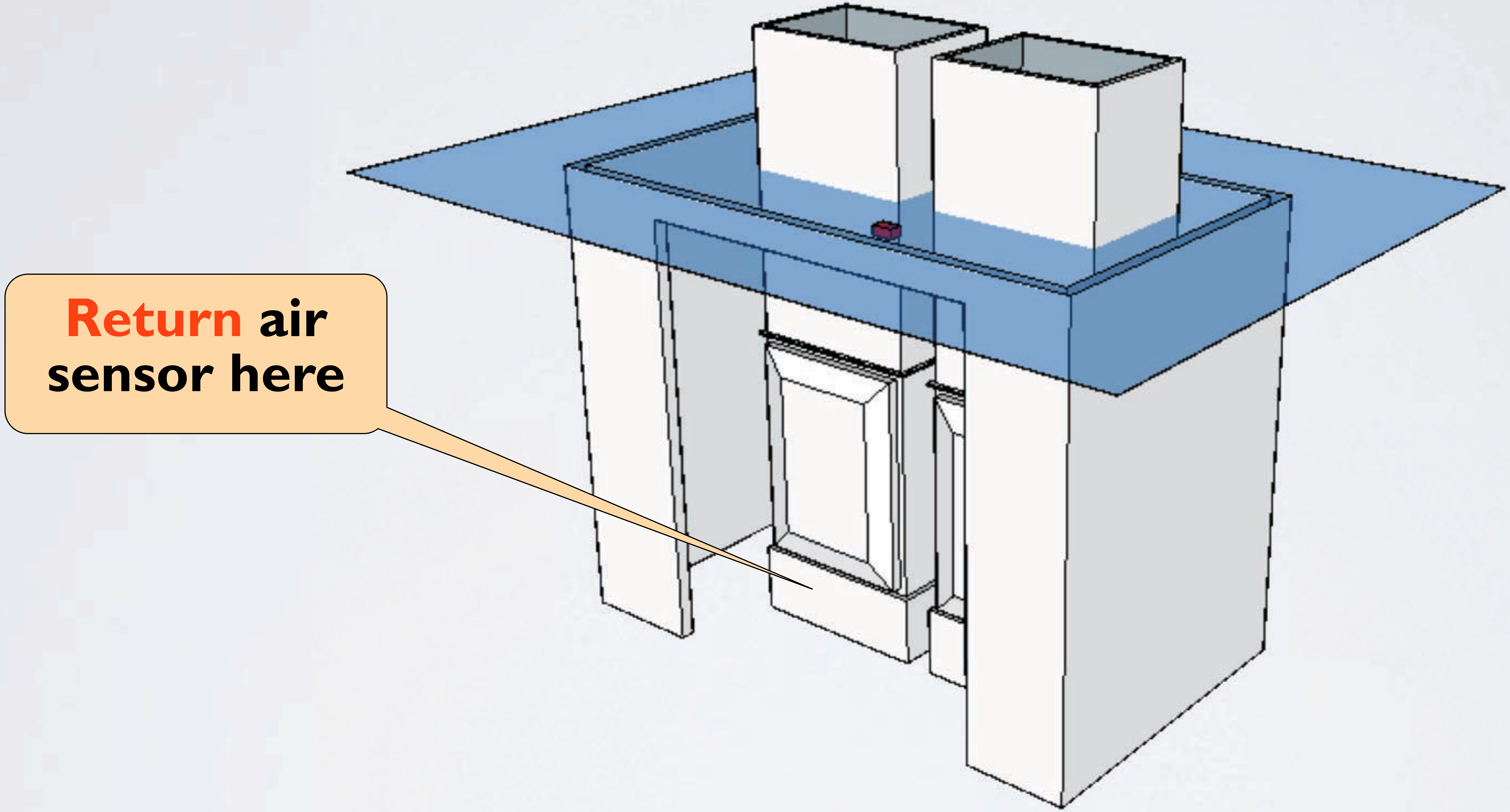

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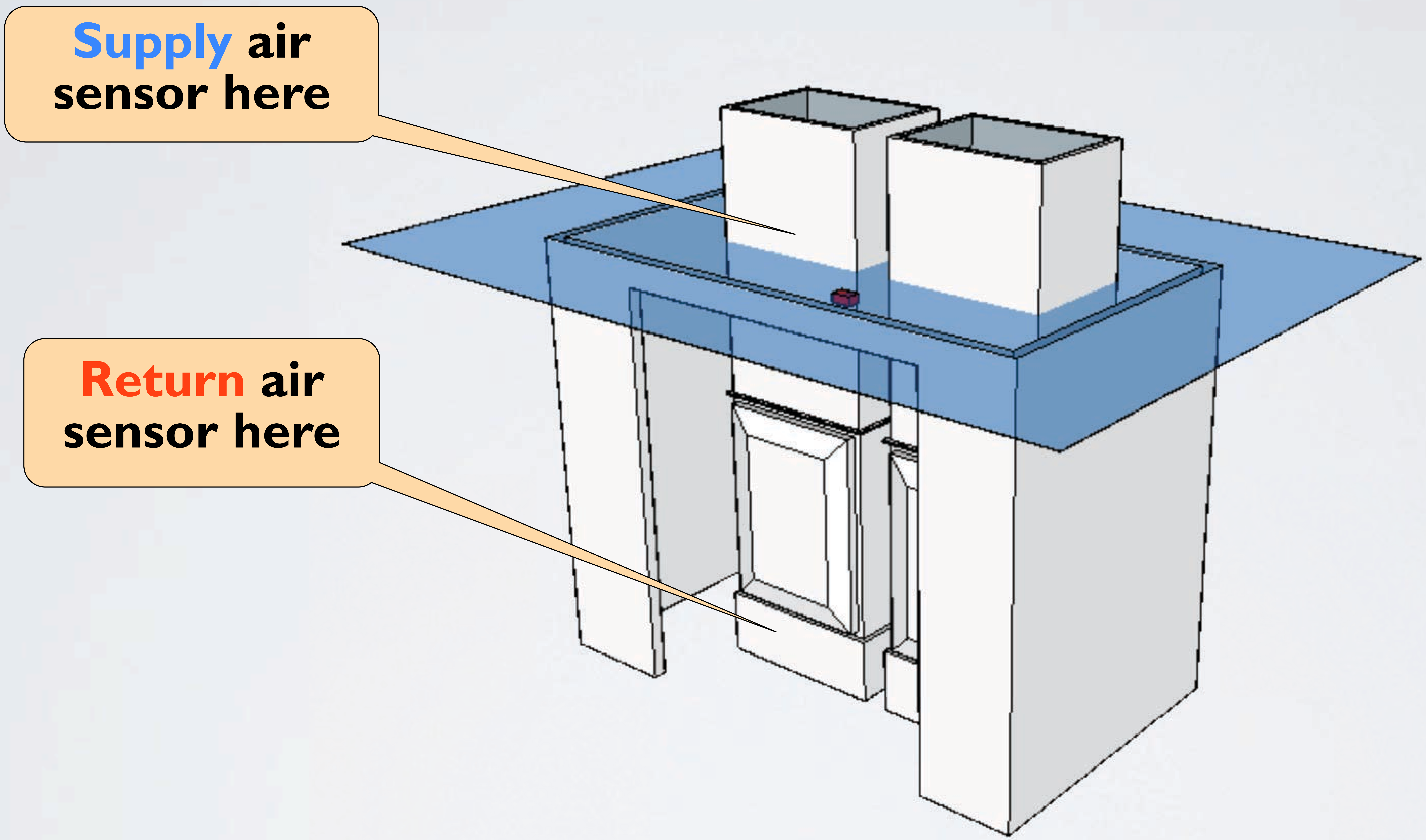
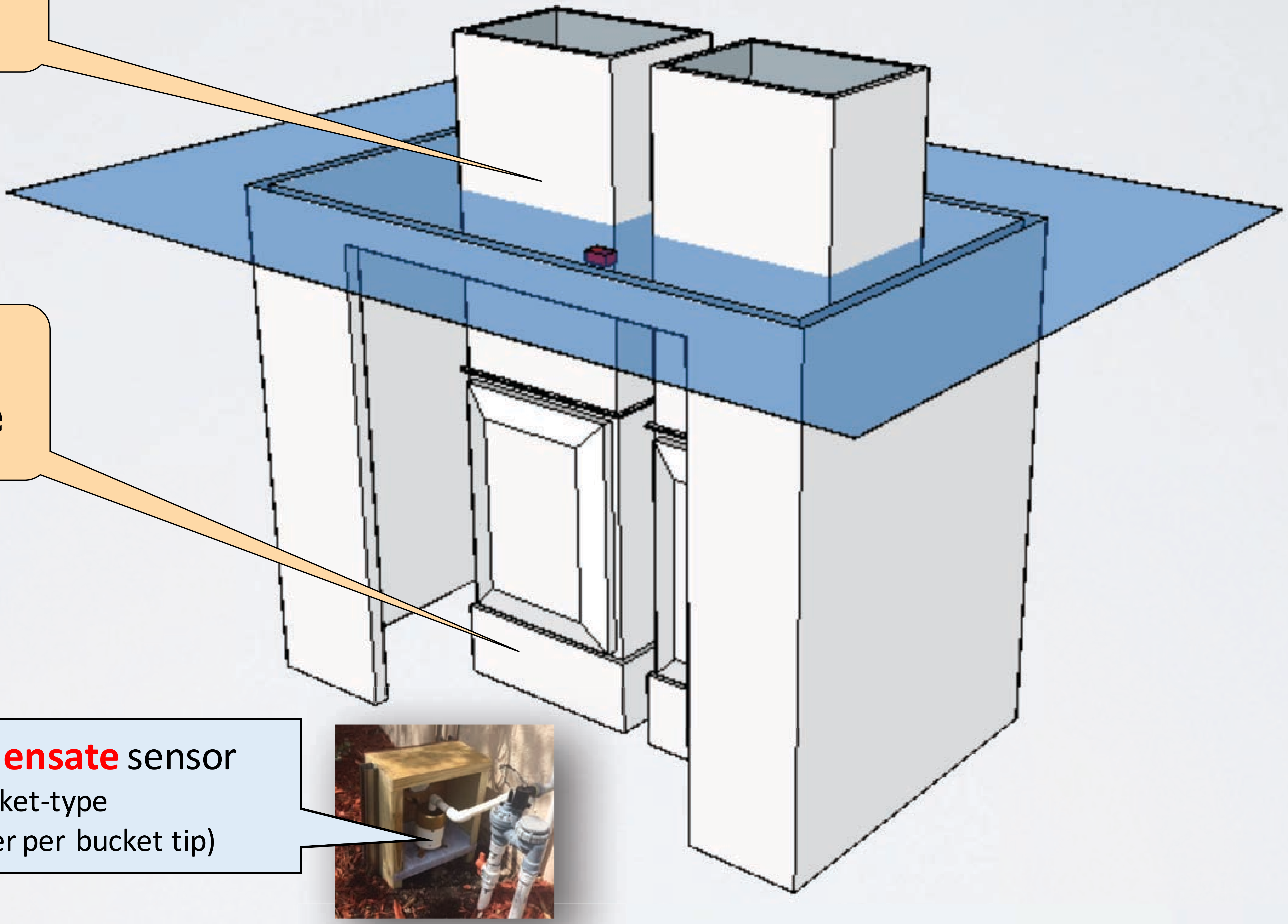


# Measuring dehumidification in real time

**Supply air sensor here**

**Return air sensor here**



Outdoors - **Condensate** sensor
Tipping-bucket-type
(0.00474 lb of water per bucket tip)

# Wireless sensor-transmitter
# Air Temperature + Dew Point

# Wireless sensor-transmitter
# Air Temperature + Dew Point

Wireless sensor
(8-yr lithium battery)

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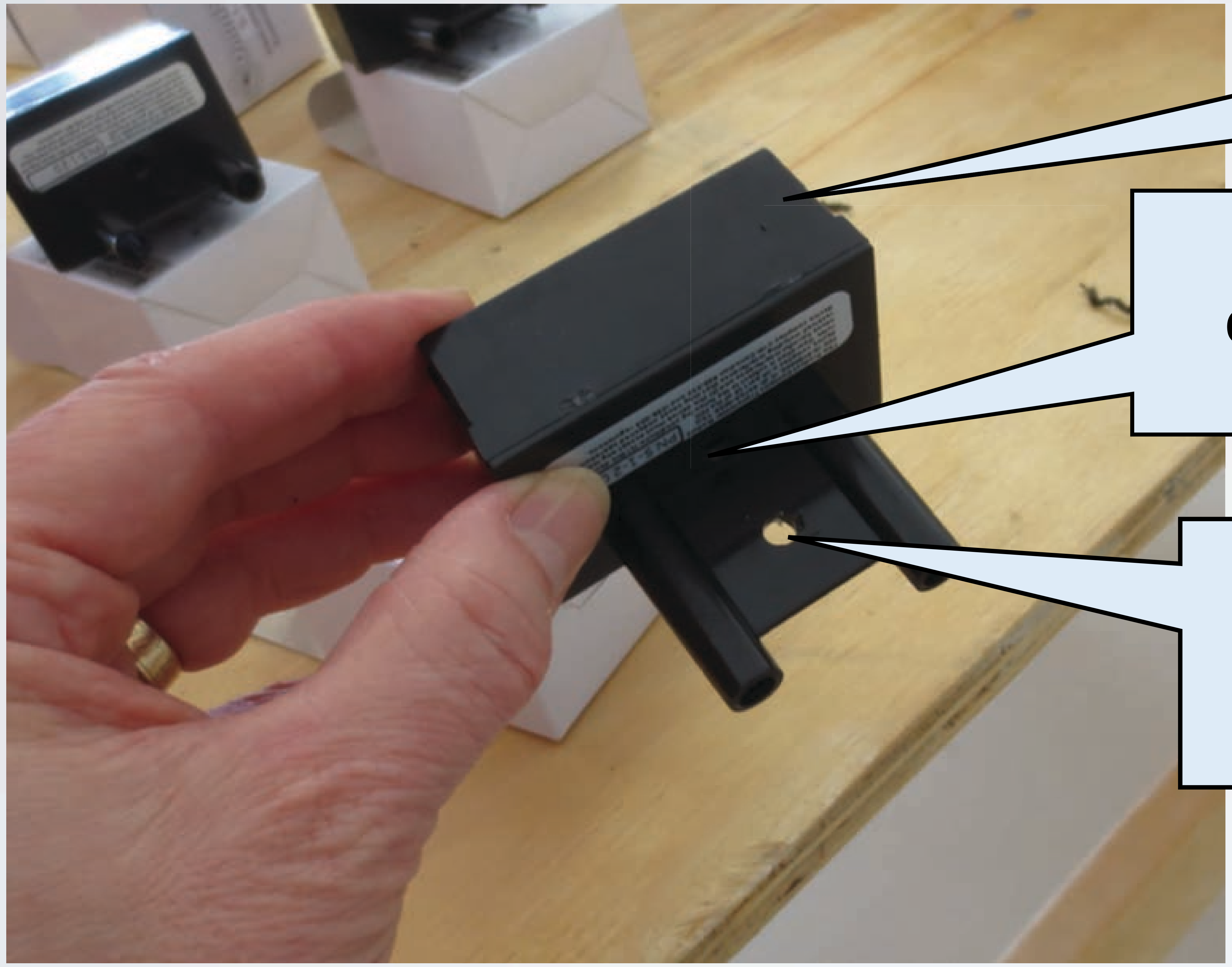
Sensor on the circuit board is exposed to air on the underside
Air Temp + RH

# Wireless sensor-transmitter
# Air Temperature + Dew Point



Wireless sensor
(8-yr lithium battery)

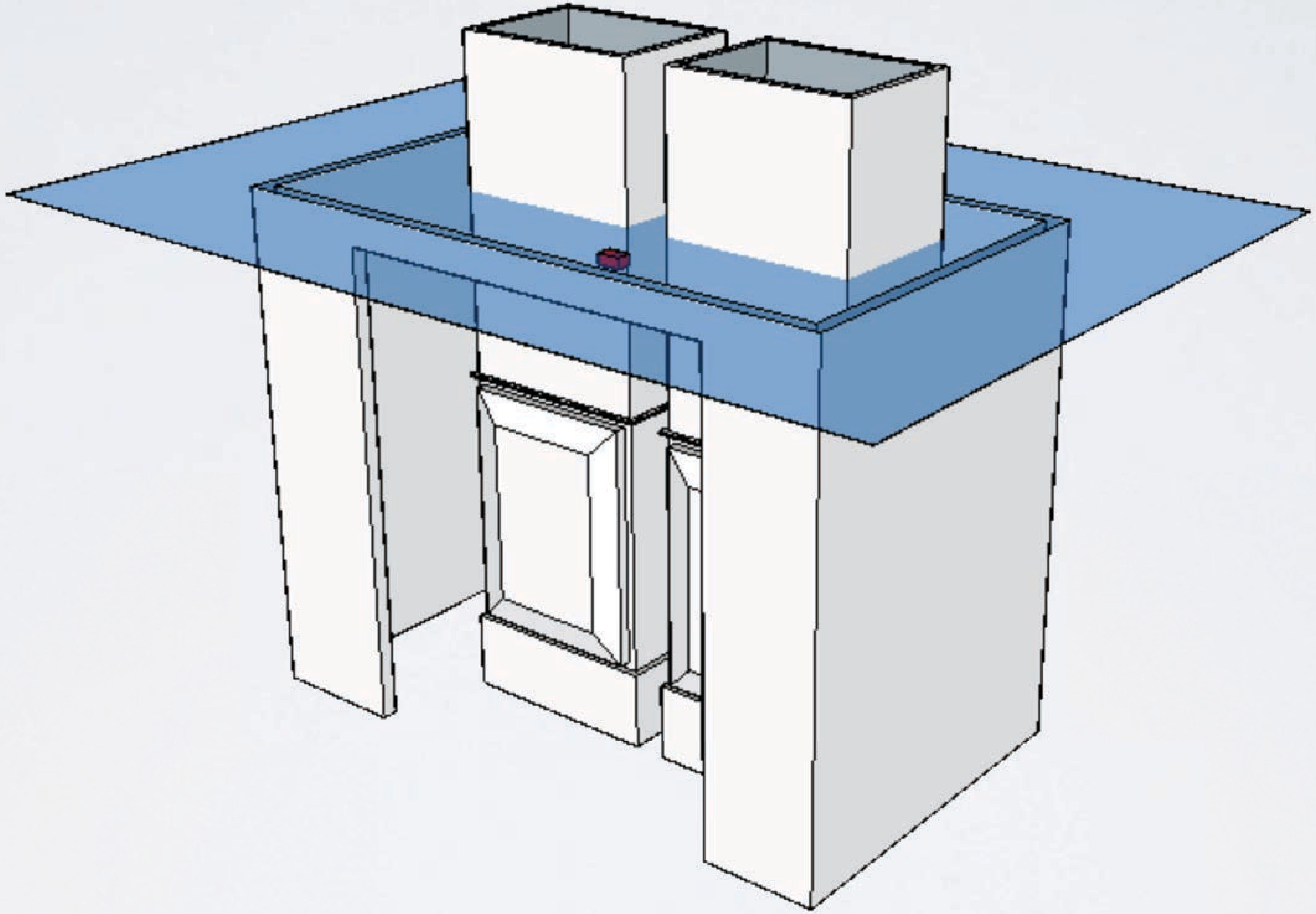
Sensor on the circuit board is exposed to air on the underside
Air Temp + RH

Sensor hangs from a wire hook on the inside of the air ducts

# Measuring real-time dehumidification
# Tipping-bucket rain gauge and wireless pulse-counter

# Measuring real-time dehumidification
# Tipping-bucket rain gauge and wireless pulse-counter

# Important fact! To make air **DRY**...
# ..the **supply dew point must be lower** than the return.



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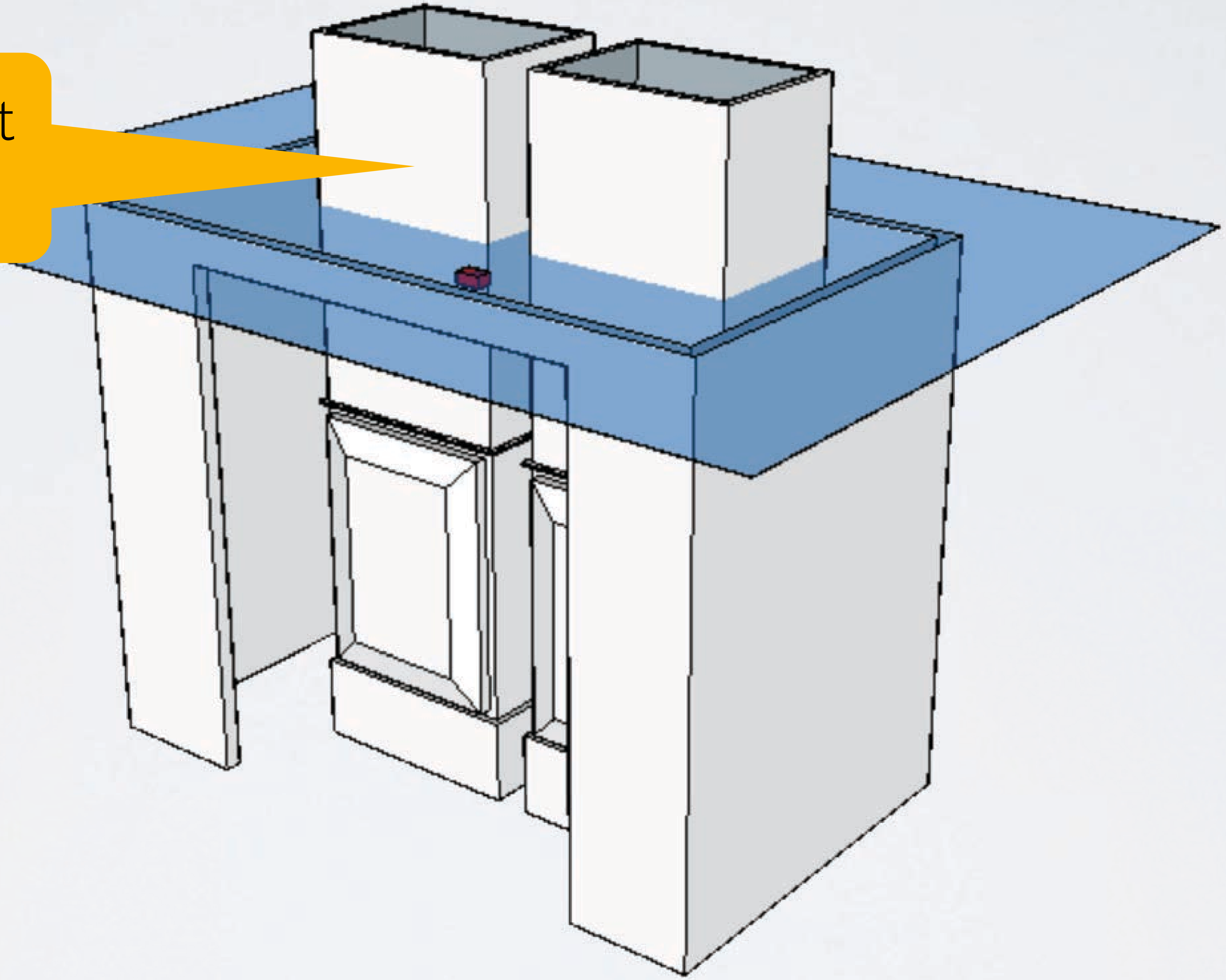
Supply air dew point must be **lower** than...



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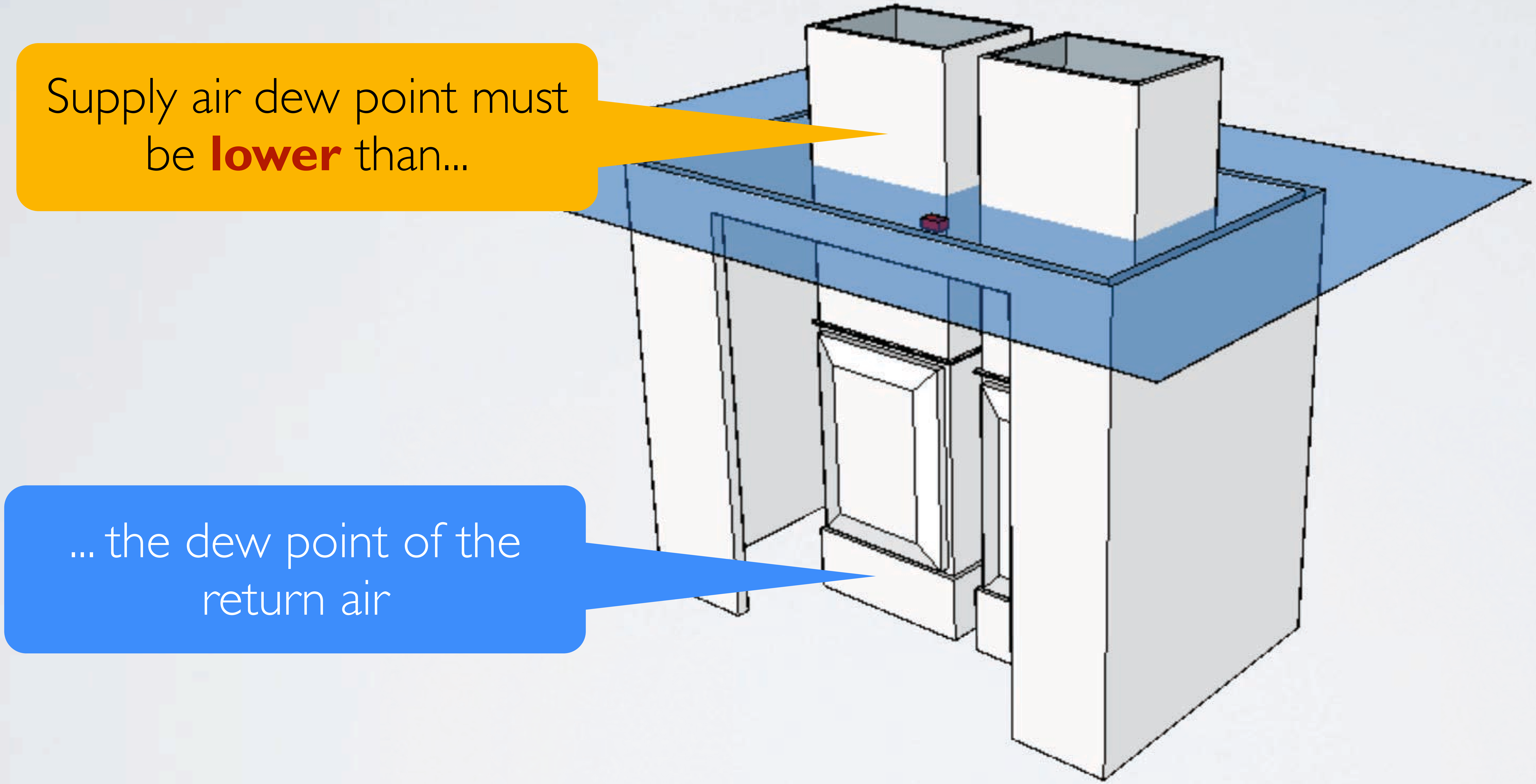
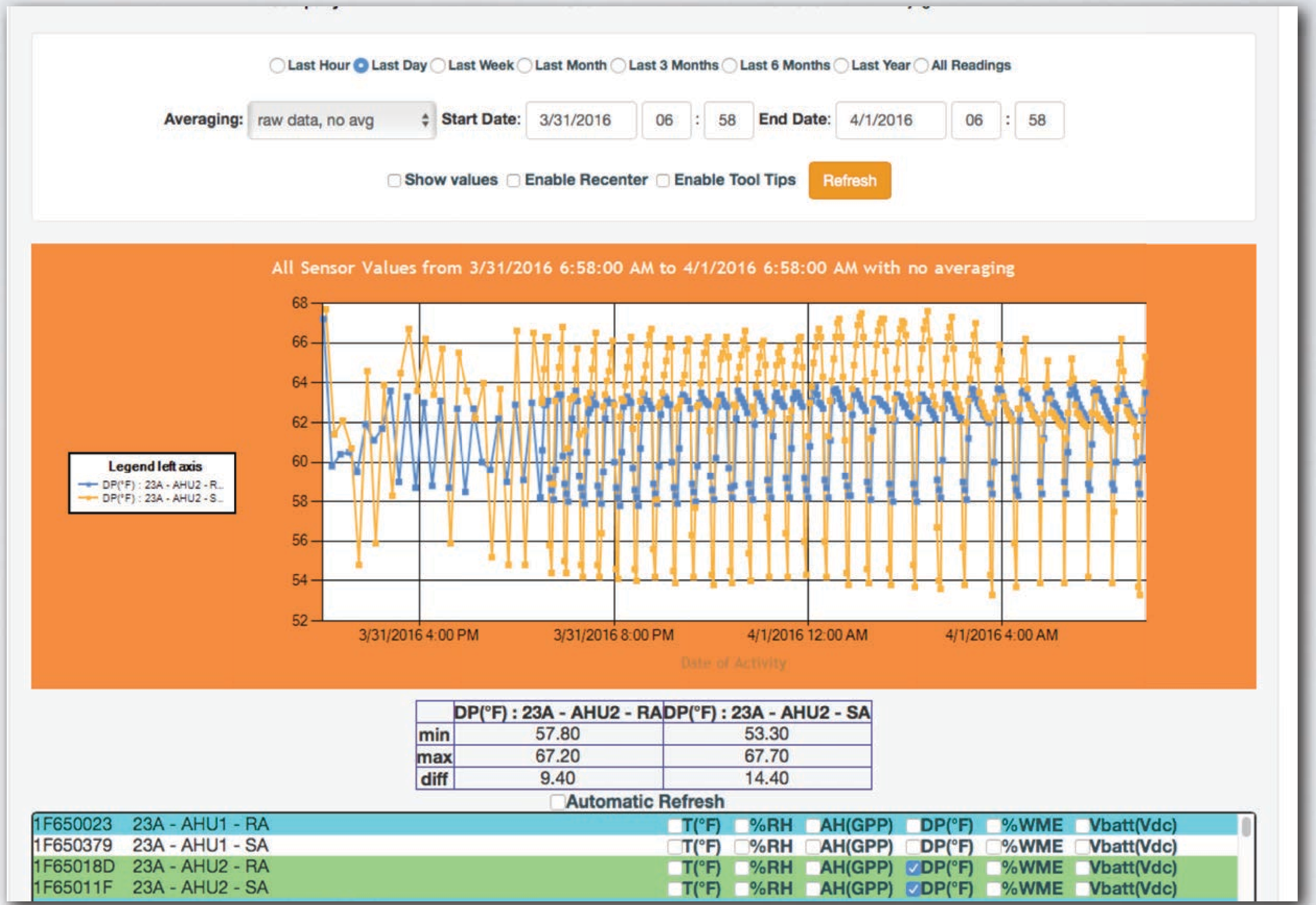


# Real-time dew points
# Return (**Blue**) v. Supply (**Yellow**)



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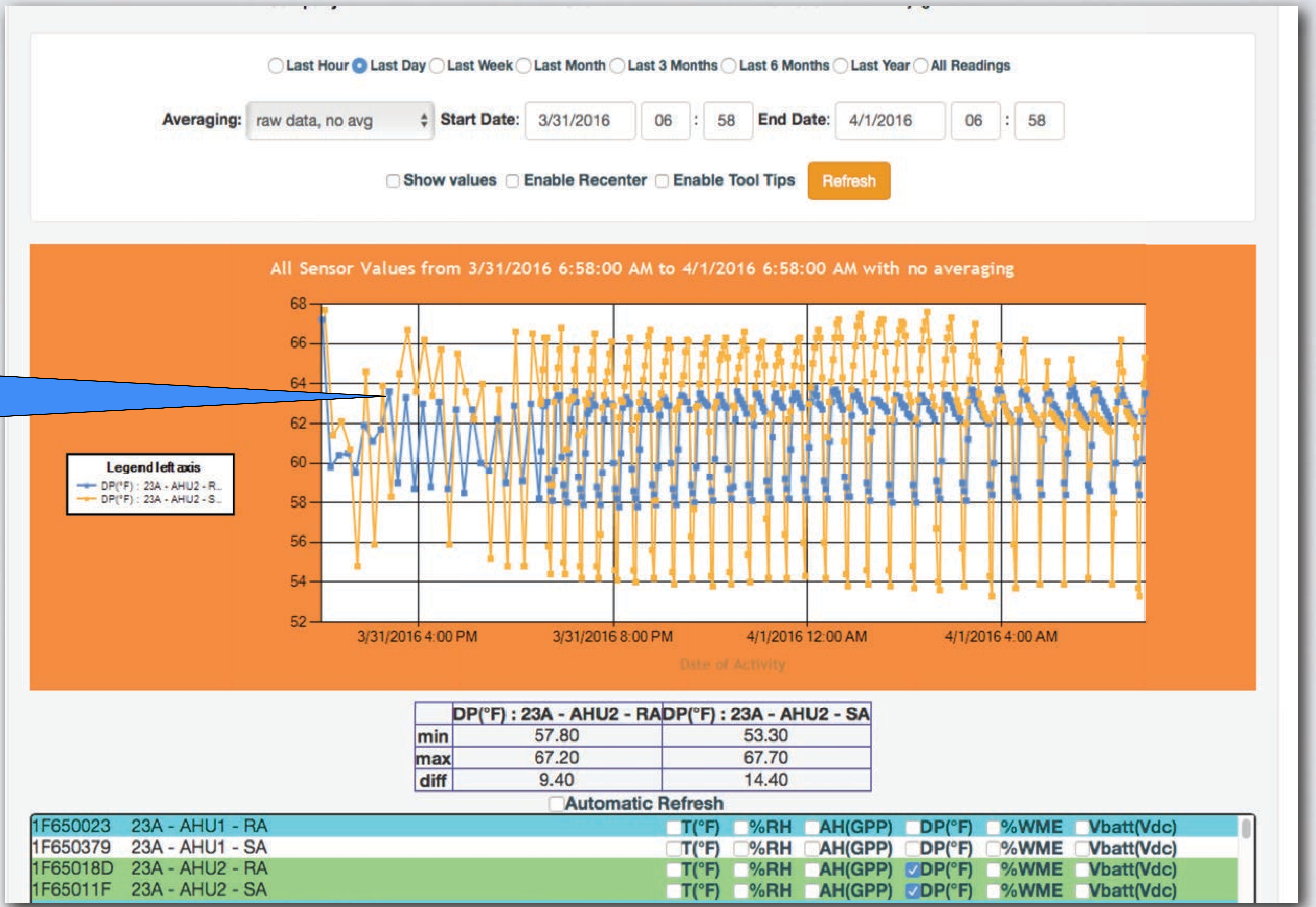
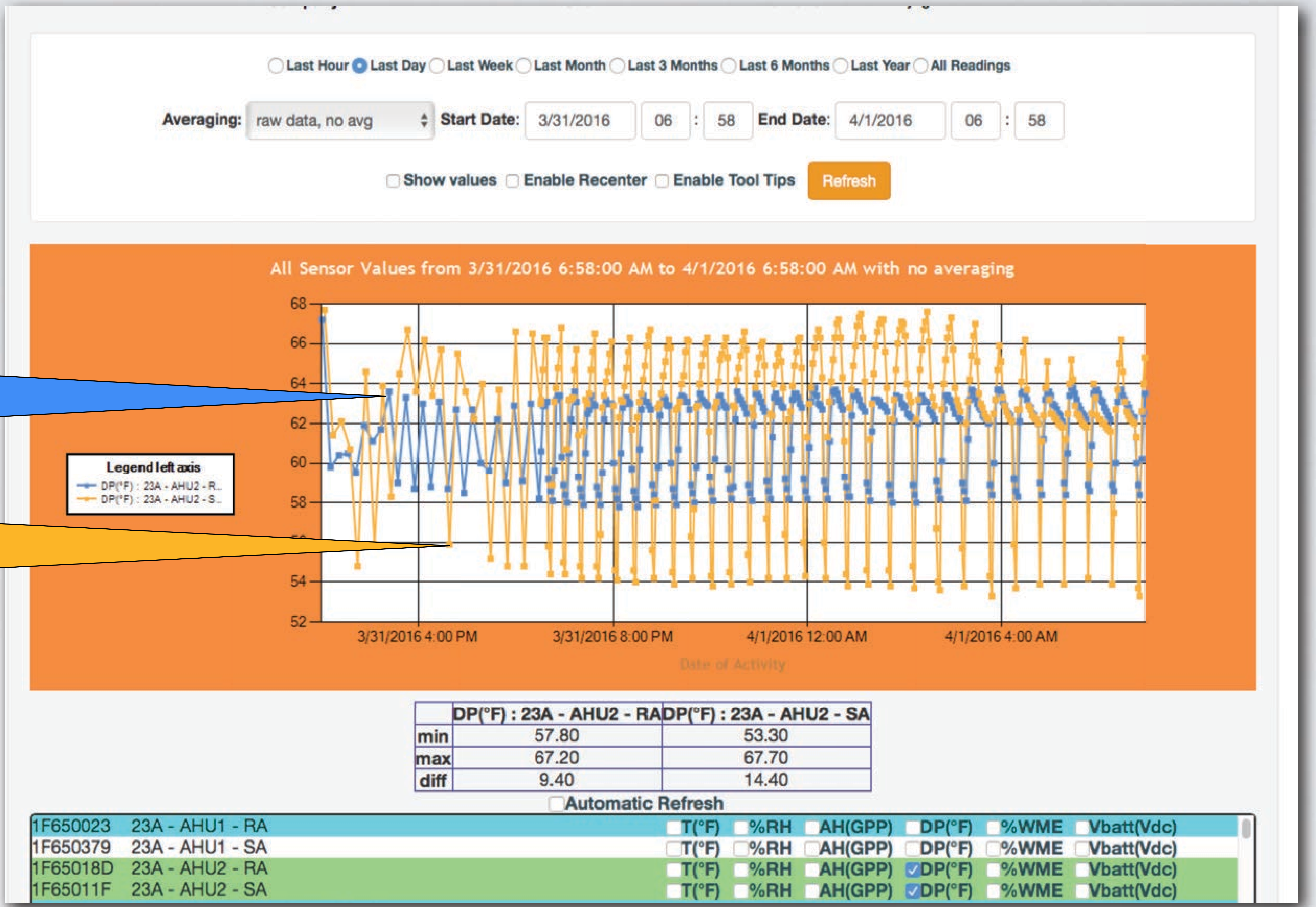


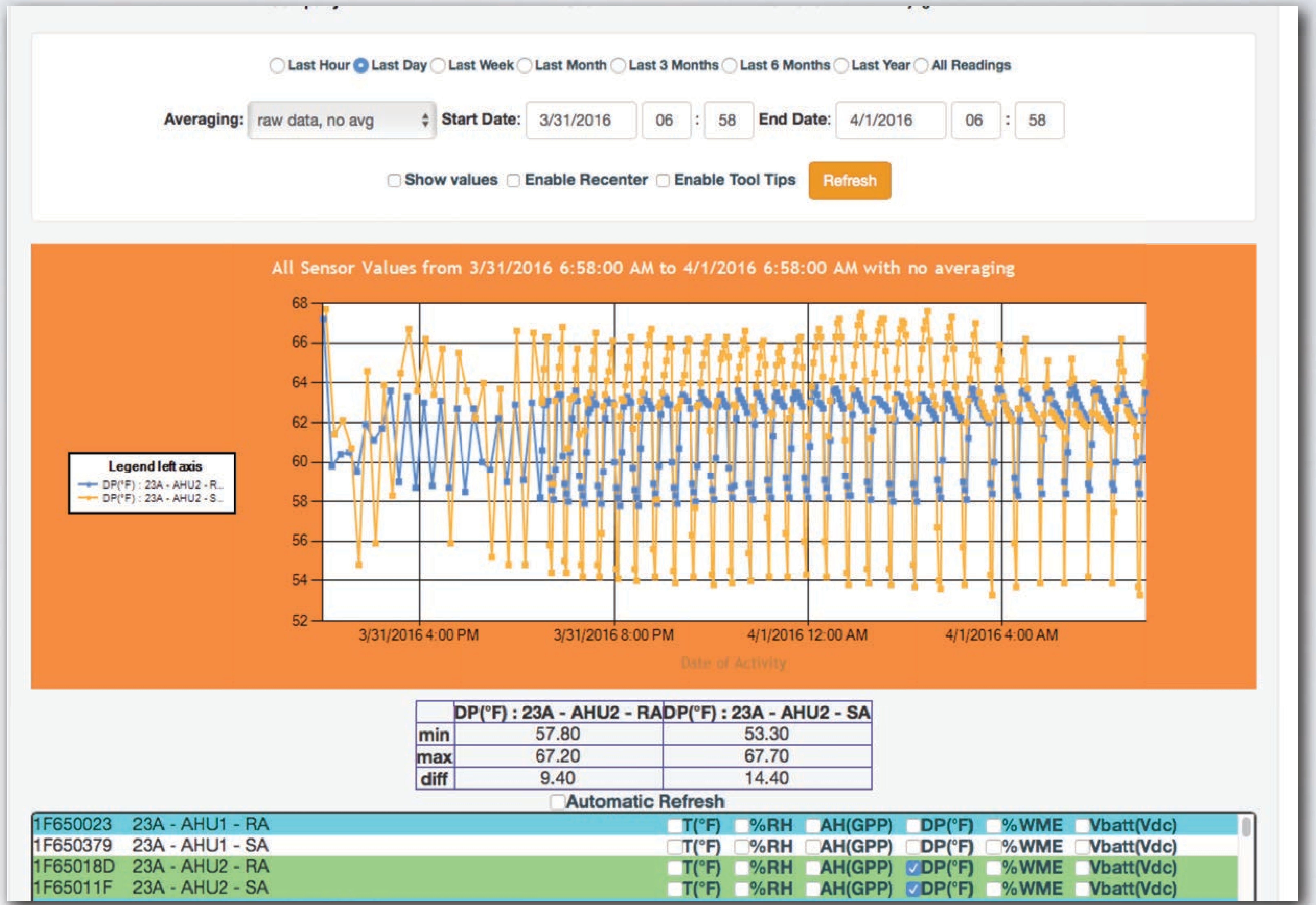
# Real-time dew points
# Return (**Blue**) v. Supply (**Yellow**)

**Return Air In**

**Supply Air Out**



# Cooling systems do NOT always dry the air!



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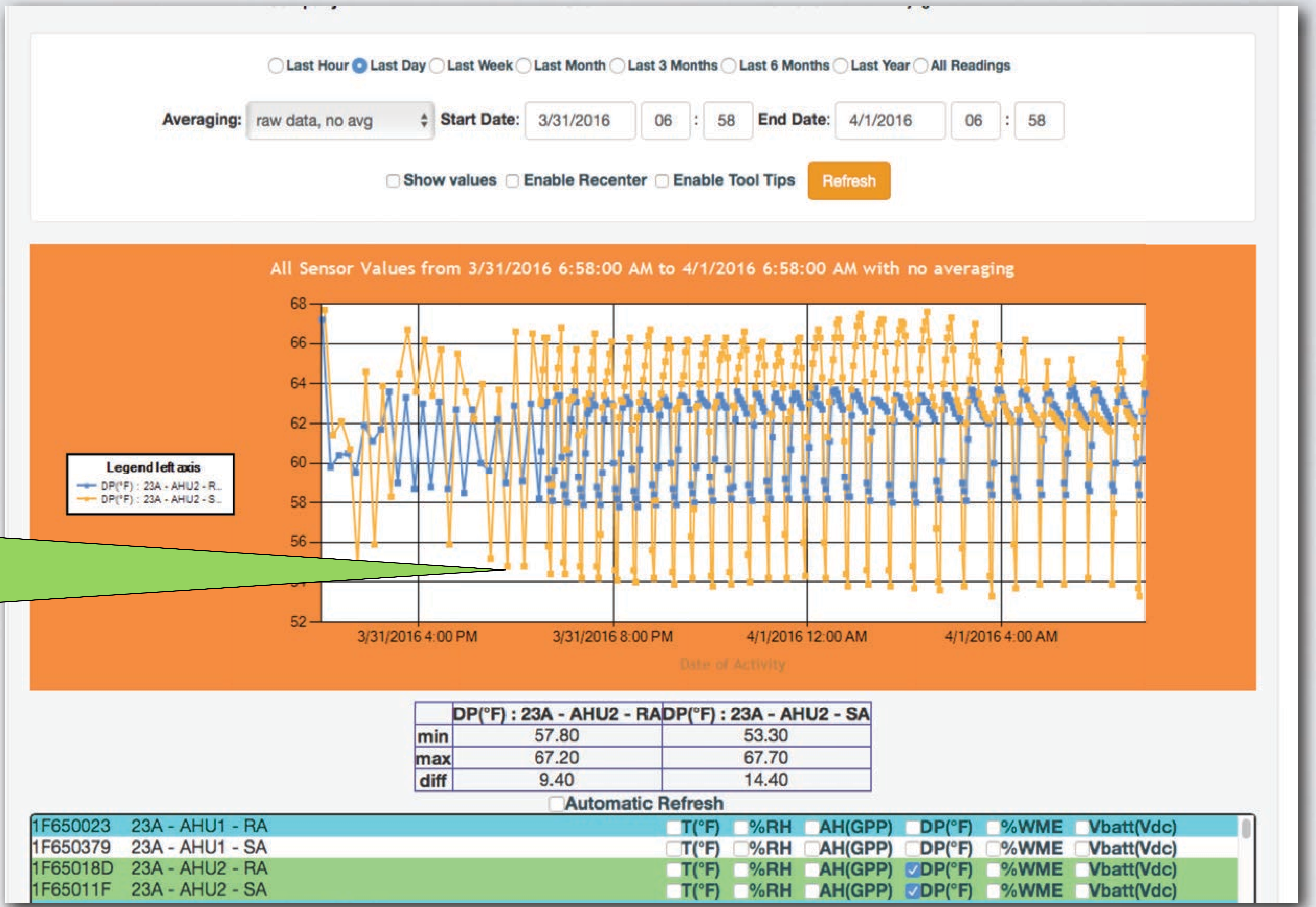
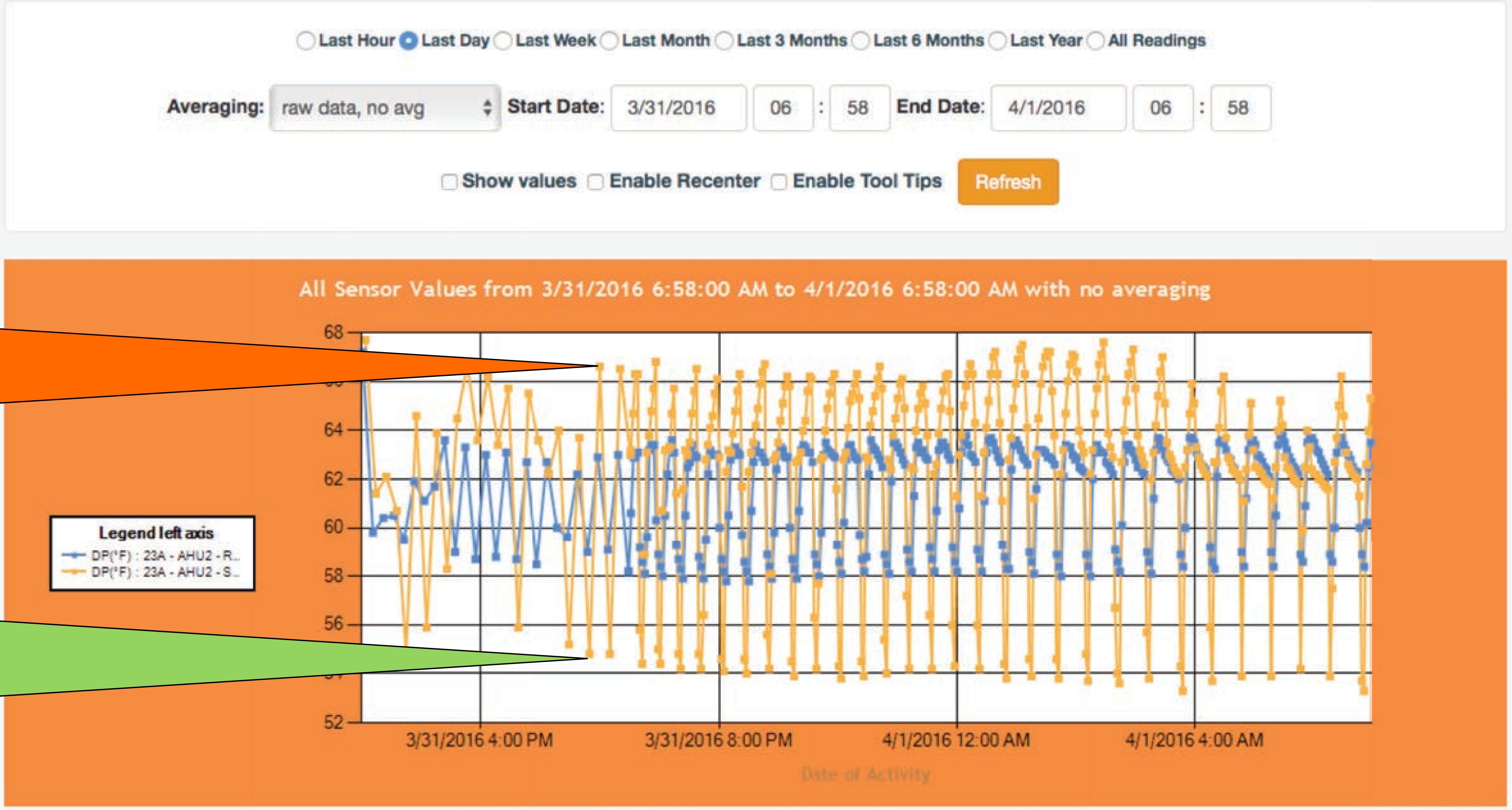



Compressor ON
Supply air is being
**DE-HUMIDIFIED**

# Cooling systems do NOT always dry the air!

Compressor OFF
Supply air is being
**HUMIDIFIED**

Compressor ON
Supply air is being
**DE-HUMIDIFIED**

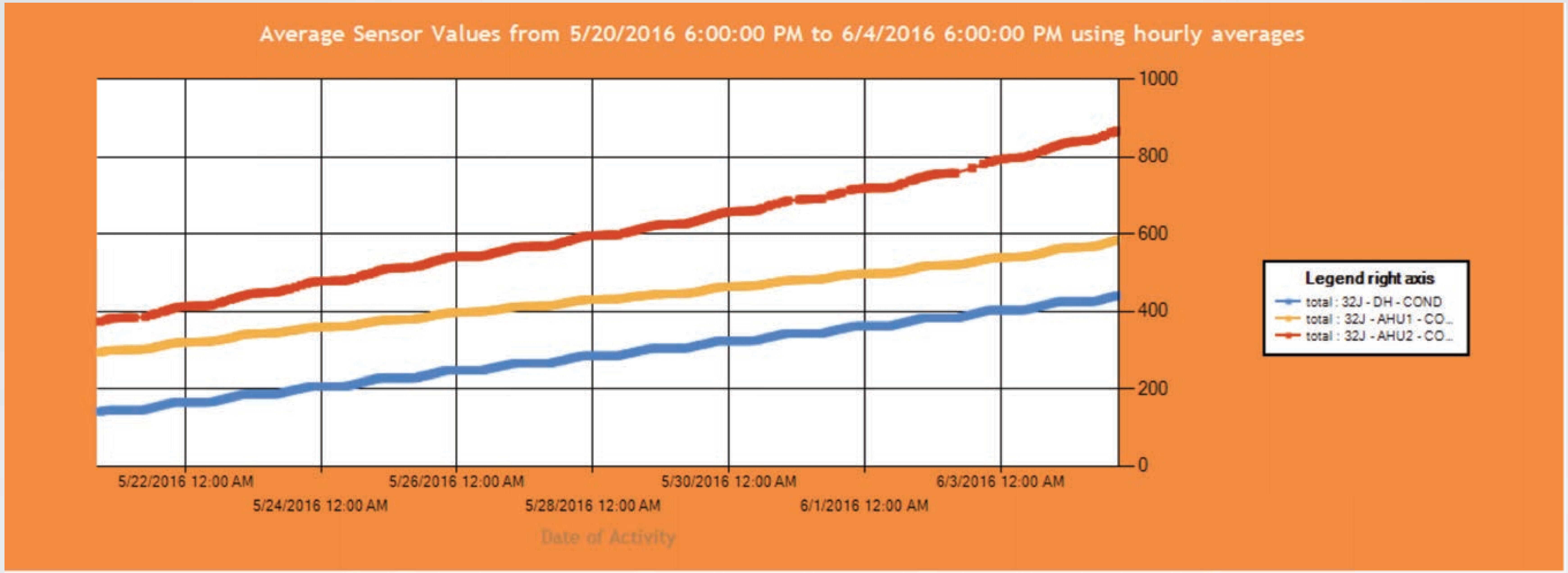



| | DP(°F) : 23A - AHU2 - RA | DP(°F) : 23A - AHU2 - SA |
|---|---|---|
| min | 57.80 | 53.30 |
| max | 67.20 | 67.70 |
| diff | 9.40 | 14.40 |

Automatic Refresh

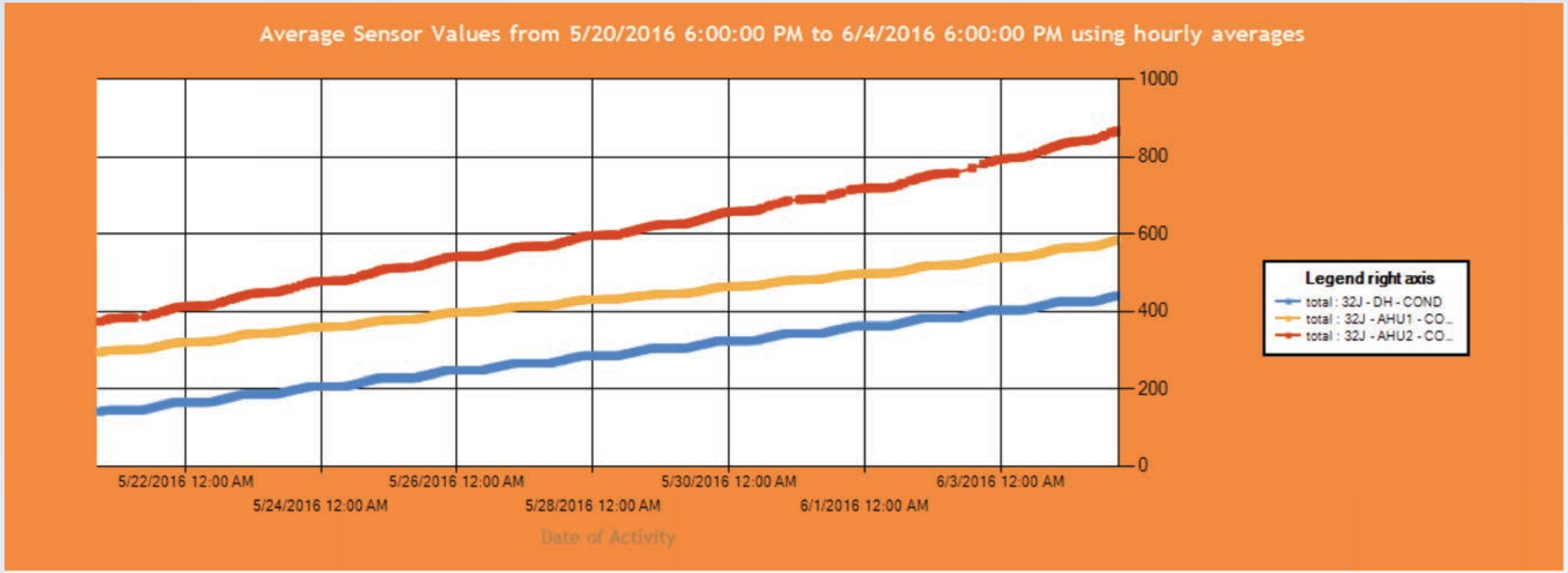
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1F650023 | 23A - AHU1 - RA | T(°F) | %RH | AH(GPP) | DP(°F) | %WME | Vbatt(Vdc) |
| 1F650379 | 23A - AHU1 - SA | T(°F) | %RH | AH(GPP) | DP(°F) | %WME | Vbatt(Vdc) |
| 1F65018D | 23A - AHU2 - RA | T(°F) | %RH | AH(GPP) | ☑DP(°F) | %WME | Vbatt(Vdc) |
| 1F65011F | 23A - AHU2 - SA | T(°F) | %RH | AH(GPP) | ☑DP(°F) | %WME | Vbatt(Vdc) |

# Still.. cooling is not bad... if it's **SMALL and runs a lot**




| | total : 32J - DH - COND | total : 32J - AHU1 - COND | total : 32J - AHU2 - COND |
|---|---|---|---|
| min | 140.70 | 293.00 | 372.90 |
| max | 440.20 | 583.80 | 865.40 |
| diff | 299.50 | 290.80 | 492.50 |

# Still.. cooling is not bad… if it's **SMALL and runs a lot**

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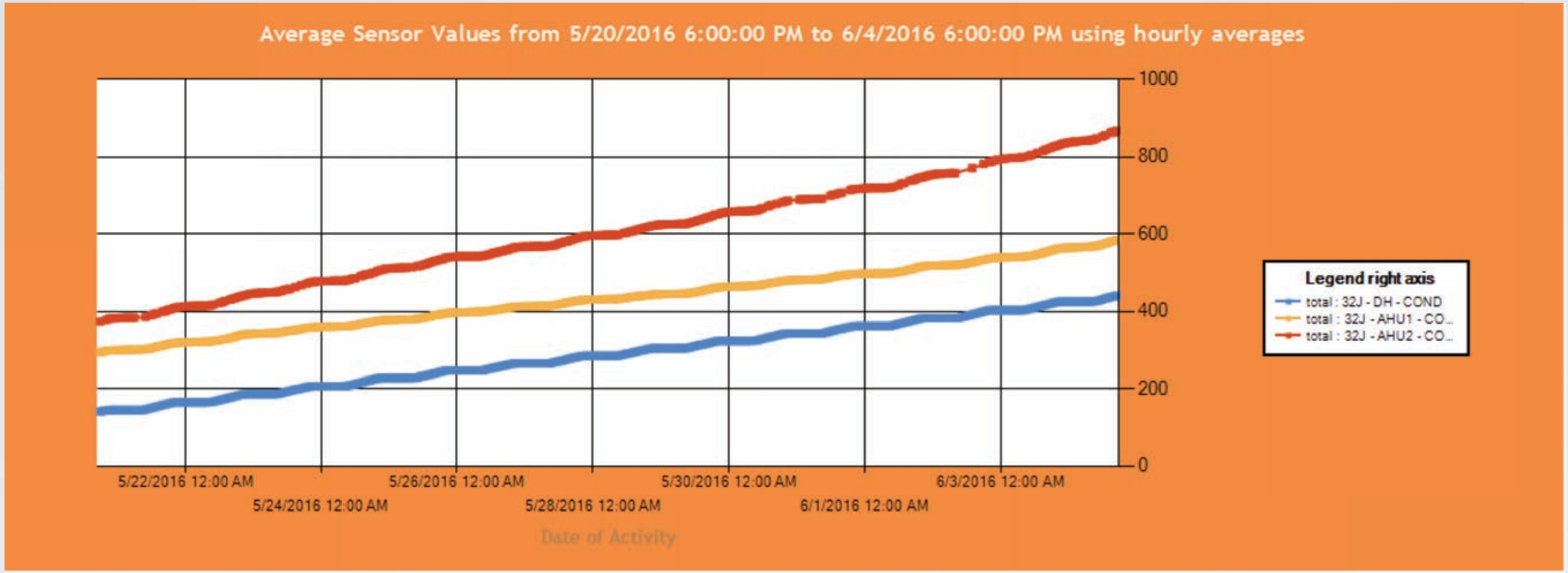
|---|---|---|---|
| min | 140.70 | 293.00 | 372.90 |
| max | 440.20 | 583.80 | 865.40 |
| diff | 299.50 | 290.80 | 492.50 |

AHU-2
**492 lbs** of water removed

# Still.. cooling is not bad... if it's **SMALL and runs a lot**

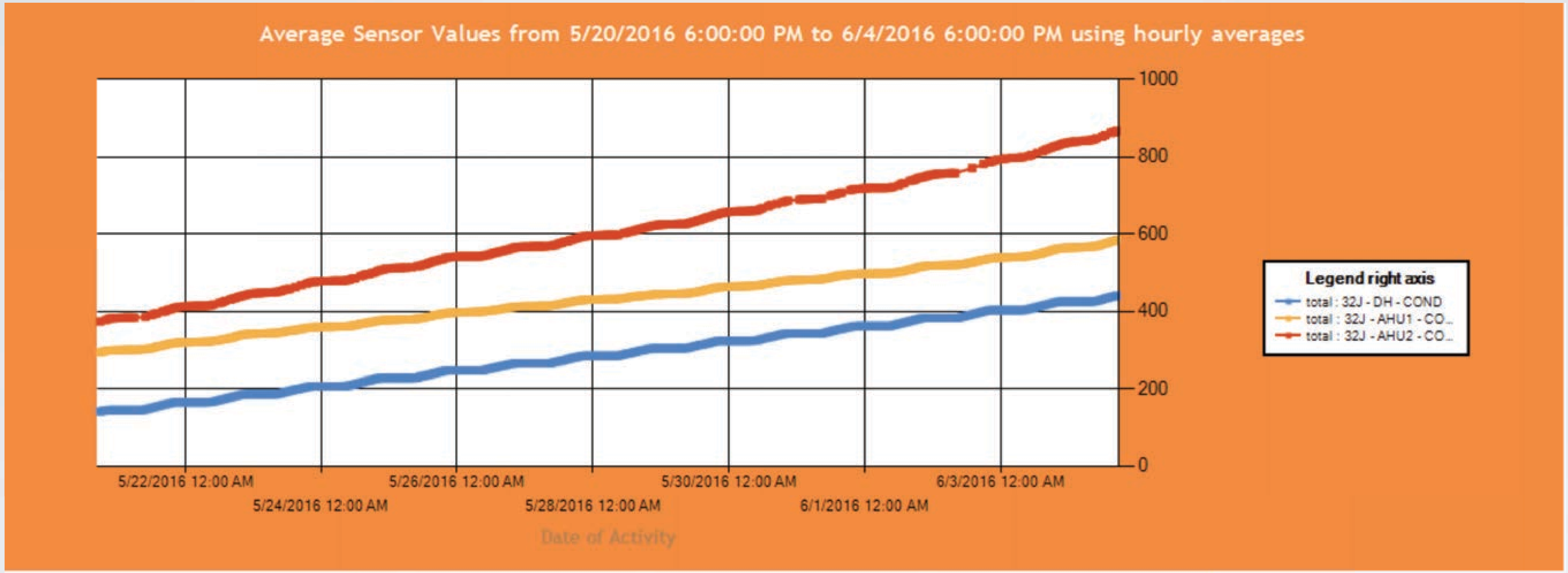



| | total : 32J - DH - COND | total : 32J - AHU1 - COND | total : 32J - AHU2 - COND |
|---|---|---|---|
| min | 140.70 | 293.00 | 372.90 |
| max | 440.20 | 583.80 | 865.40 |
| diff | 299.50 | 290.80 | 492.50 |

AHU-1
**290 lbs** of water removed

AHU-2
**492 lbs** of water removed

# Still.. cooling is not bad... if it's **SMALL and runs a lot**

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| min | 140.70 | 293.00 | 372.90 |
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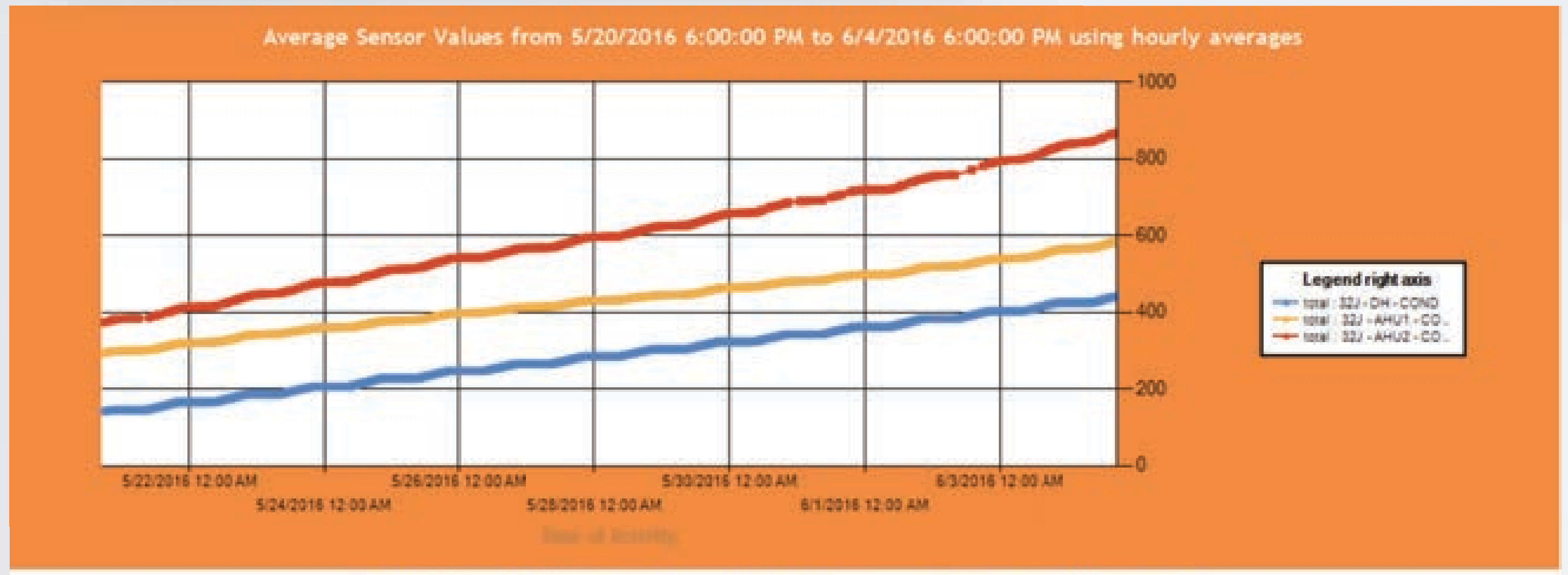
Supplemental DH Unit
**300 lbs** of water removed

AHU-1
**290 lbs** of water removed

AHU-2
**492 lbs** of water removed

# But whoa!.. Total DH load in this **NON**-ventilated house?

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| diff | 299.50 | 290.80 | 492.50 |

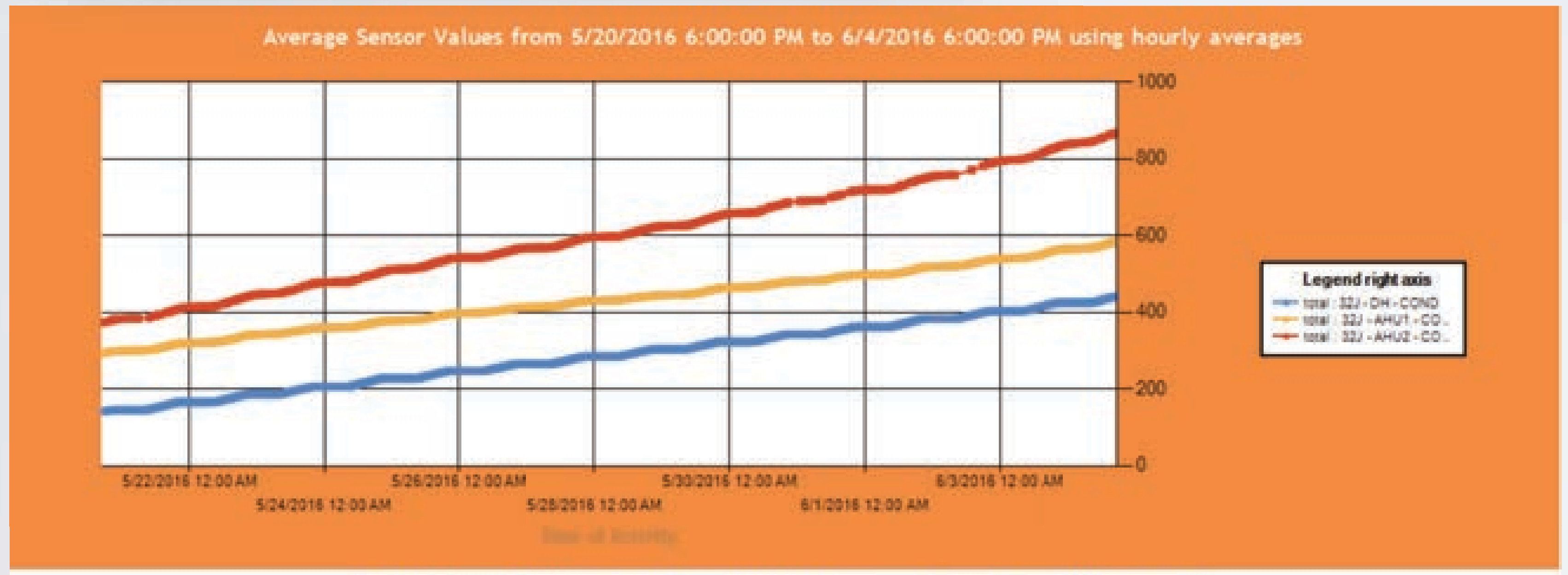
Supplemental DH Unit
**300 lbs** of water
removed

AHU-1
**290 lbs** of water
removed

AHU-2
**492 lbs** of water
removed

# But whoa!.. Total DH load in this **NON**-ventilated house?

Over 12 days:

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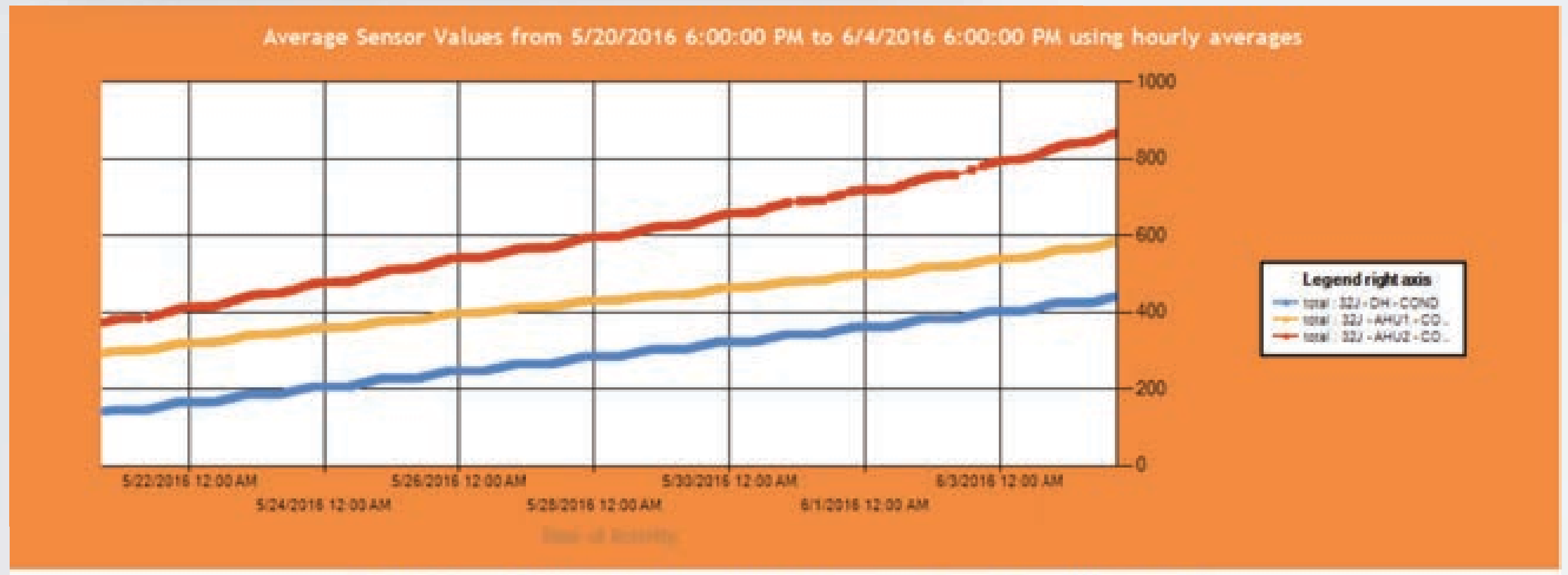


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| min | 140.70 | 293.00 | 372.90 |
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Supplemental DH Unit **300 lbs** of water removed

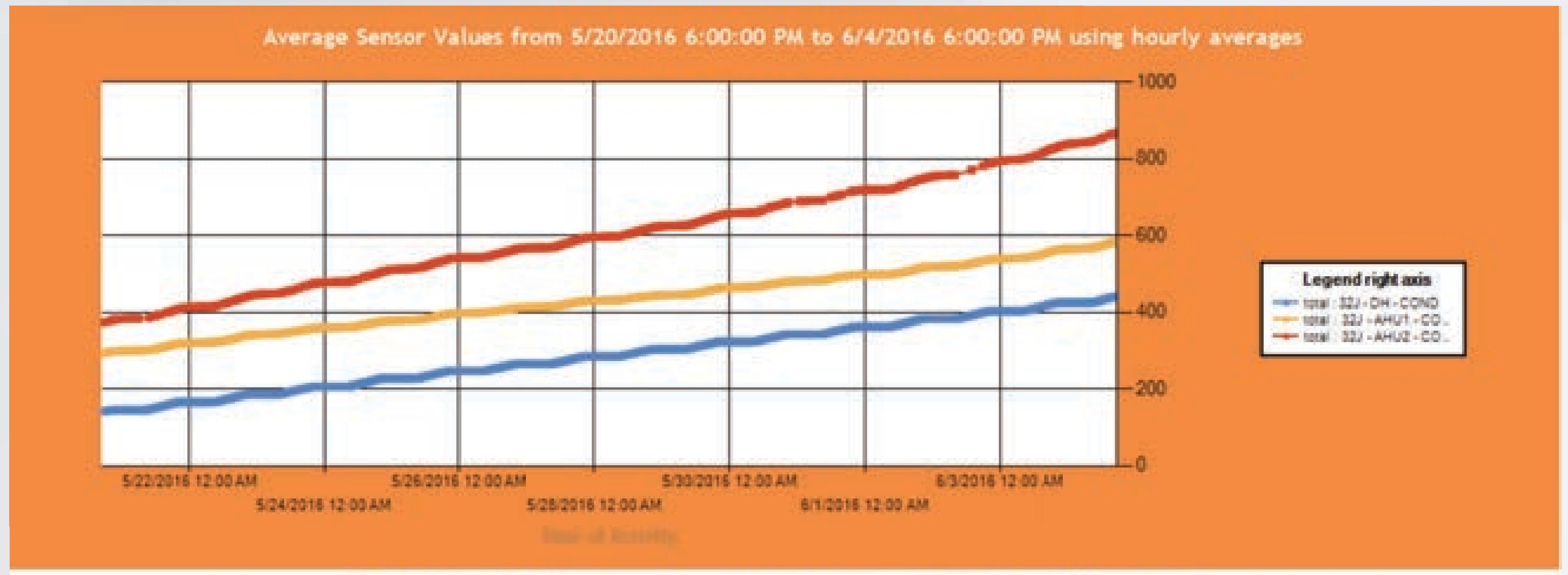
AHU-1 **290 lbs** of water removed

AHU-2 **492 lbs** of water removed

Over 12 days:

AHU1 = 290 lbs

# But whoa!.. Total DH load in this **NON**-ventilated house?

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Supplemental DH Unit
**300 lbs** of water removed

AHU-1
**290 lbs** of water removed

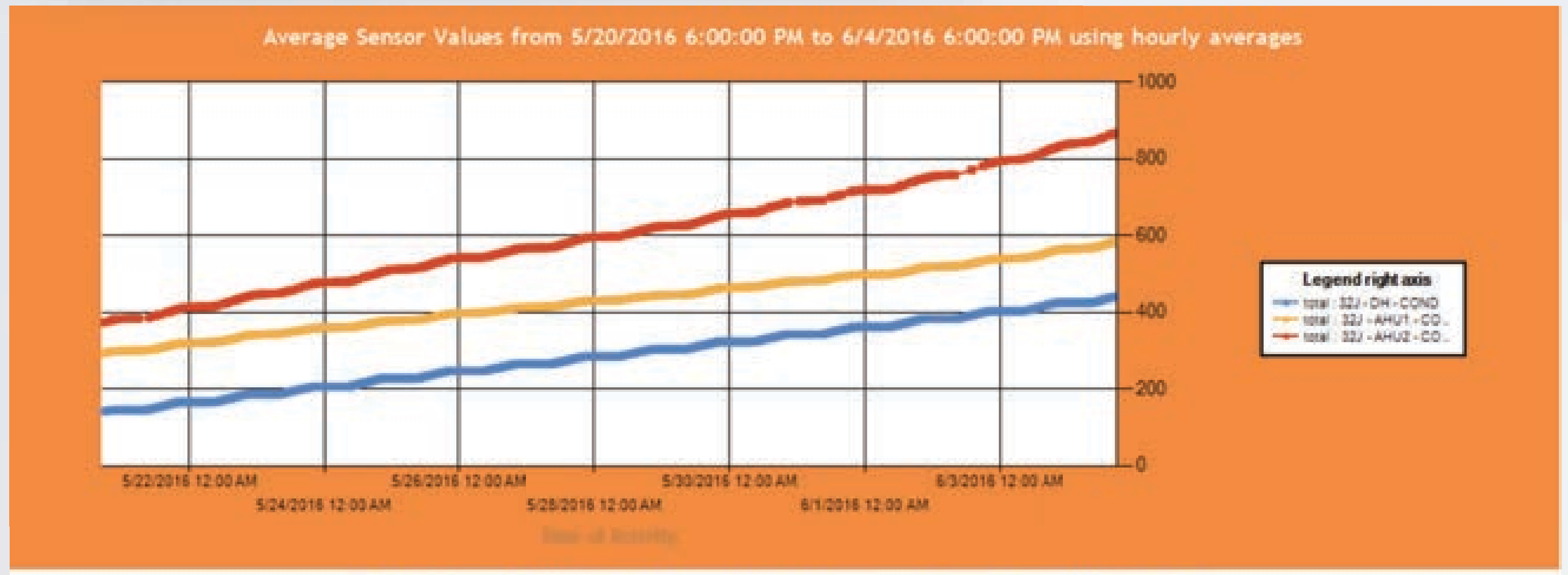
AHU-2
**492 lbs** of water removed

Over 12 days:

AHU1 = 290 lbs

AHU2 = 492 lbs

# But whoa!.. Total DH load in this **NON**-ventilated house?

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Over 12 days:

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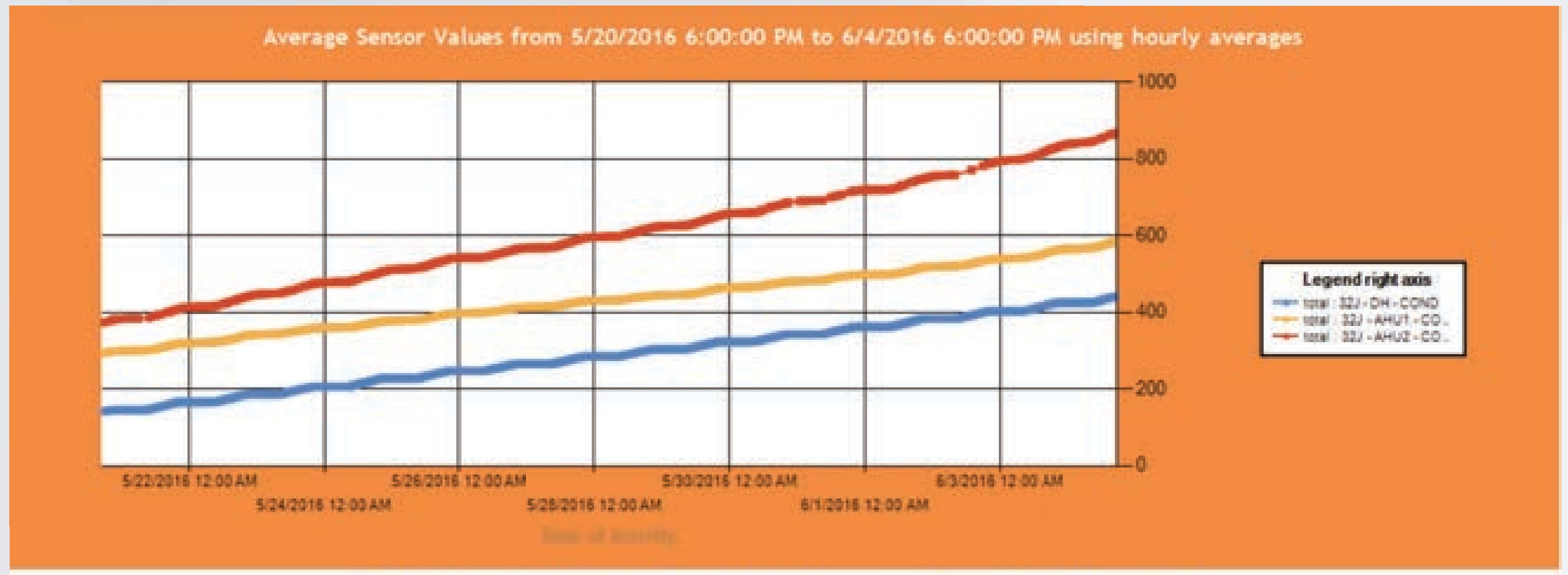
AHU2 = 492 lbs

DH = 300 lbs

# But whoa!.. Total DH load in this **NON**-ventilated house?

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**300 lbs** of water removed

AHU-1
**290 lbs** of water removed

AHU-2
**492 lbs** of water removed

Over 12 days:

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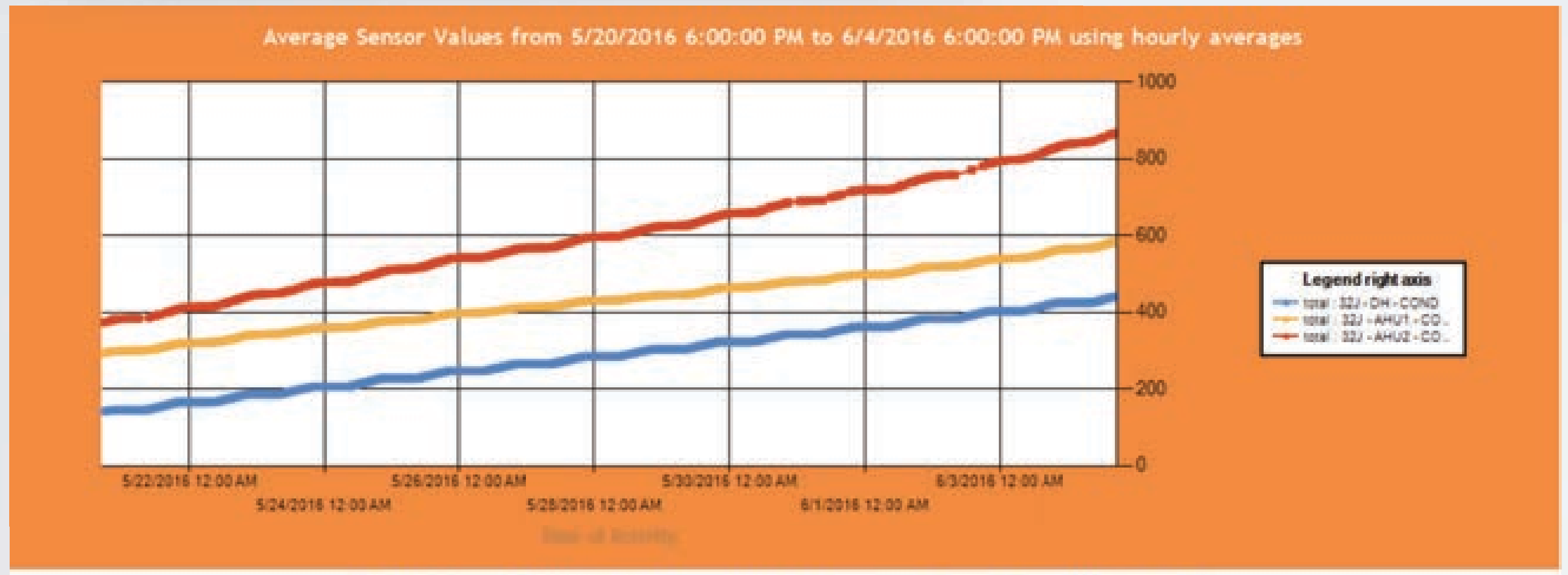
AHU2 = 492 lbs

DH = 300 lbs

Total = 1082 lbs

# But whoa!.. Total DH load in this **NON**-ventilated house?

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Supplemental DH Unit **300 lbs** of water removed

AHU-1 **290 lbs** of water removed

AHU-2 **492 lbs** of water removed

Over 12 days:

AHU1 = 290 lbs

AHU2 = 492 lbs

DH = 300 lbs

Total = 1082 lbs

**Daily DH Load = 90 lbs**

# How about houses that are not that large?....

| Summer DH Loads During Three 3-day periods | | | |
|---|---|---|---|
| **Lot and Model** | **Whole-house Daily DH Load** lb $H_2O$ / 24 hours | **Normalized Daily DH Load** Lb $H_2O$ • $ft^2$ of living space | Hourly DH Load **lb/h** |
| Lot 21H - 2-Story | 55.1 | 0.021 | 2.3 |
| Lot 8J - 1-Story | 54.9 | 0.020 | 2.3 |
| Lot 1T - 2-Story | 64.0 | 0.015 | 2.7 |
| Lot 32J - 2-Story | 78.9 | 0.019 | 3.3 |
| Lot 35G - 2-Story | 84.3 | 0.020 | 3.5 |
| Lot 43G - 2-Story | 94.7 | 0.022 | 3.9 |
| Lot 3H - 1-Story | 53.0 | 0.016 | 2.2 |

Values are based on average condensate during nine days, measured over three sets of three 24-hour periods. Dates of these three periods vary by house, because houses did not have condensate data available at all times.

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# Now **add ventilation** in South Florida (ASHRAE Std 62.1-2017)

| Measured DH Loads PLUS ASHRAE Std 62.2 Ventilation (Florida) | | | |
|---|---|---|---|
| **Lot, living space and bedrooms** | **Current Measured DH Load** lb $H_2O$ / 24 hours | **New 62.2 Ventilation DH Load** Lb $H_2O$ /24 hrs 75° dpt Outdoors vs. 55°F dpt Indoors | Total current + new ventilation DH Loads Lb $H_2O$ /24 hrs |
| Lot 21H - 1-Story 2677 ft², 3 bedrooms | 55.1 | 113.7 | **168.8** |
| Lot 8J - 1-Story 2677 ft², 3 bedrooms | 54.9 | 113.7 | **168.6** |
| Lot 1T - 2-Story 4240 ft², 5 bedrooms | 64.0 | 177.8 | **241.8** |
| Lot 32J - 2-Story 4240 ft², 5 bedrooms | 78.9 | 177.8 | **256.7** |
| Lot 35G - 2-Story 4240 ft², 5 bedrooms | 84.3 | 177.8 | **262.1** |
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| Lot 3H - 1-Story 3318 ft², 4 bedrooms | 53.0 | 141.6 | **194.6** |

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| Measured DH Loads PLUS ASHRAE Std 62.2 Ventilation (Florida) | | | |
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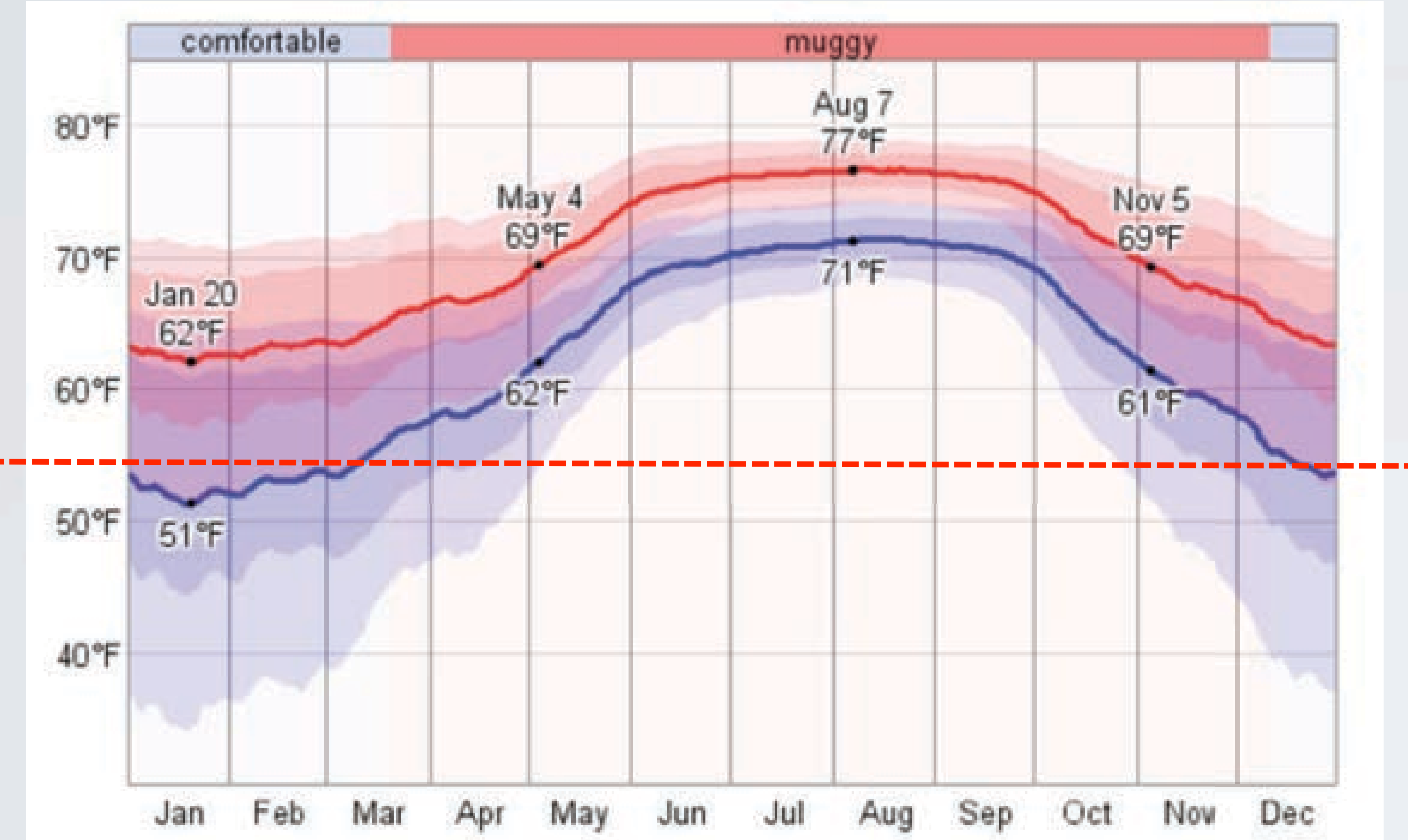
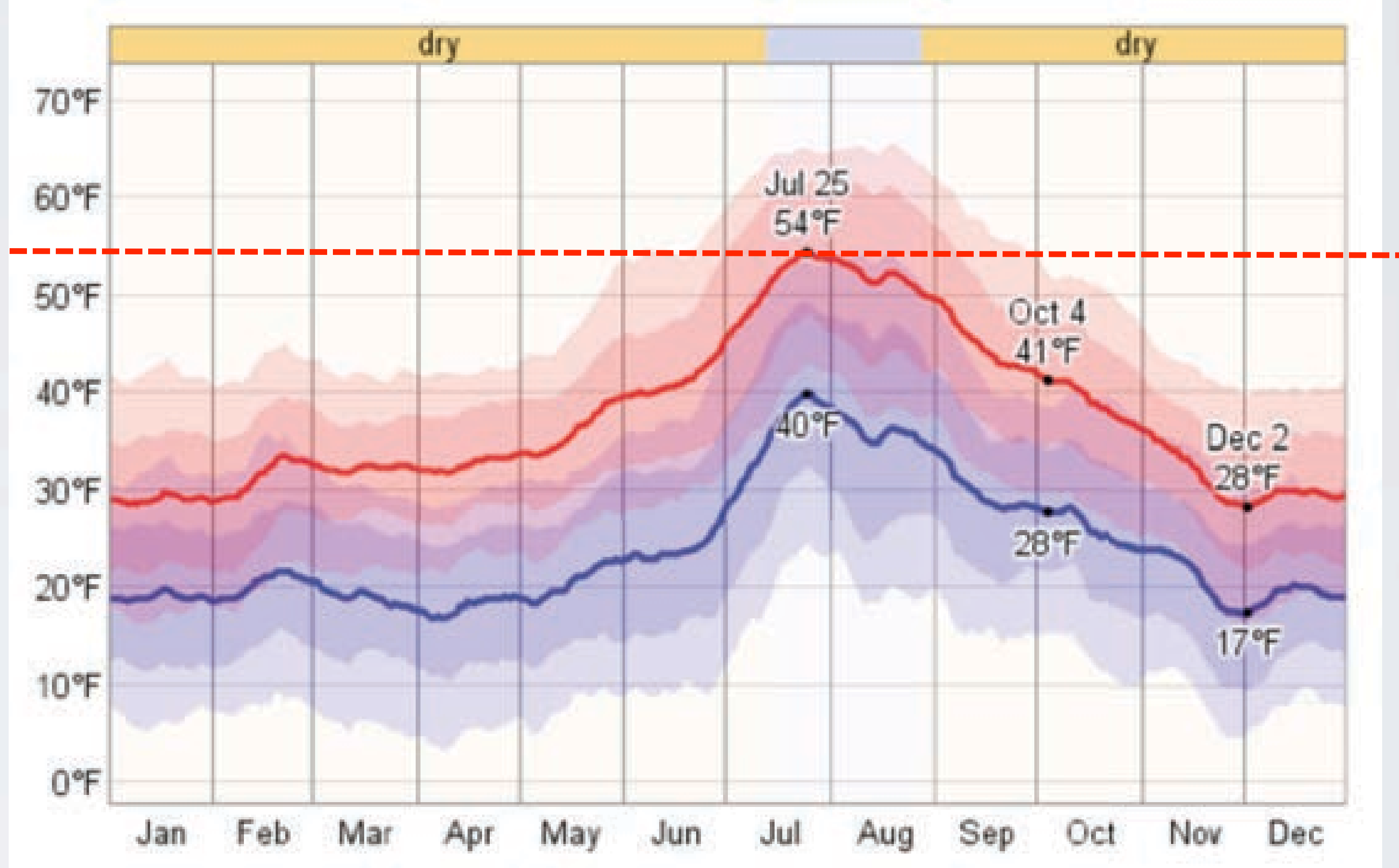
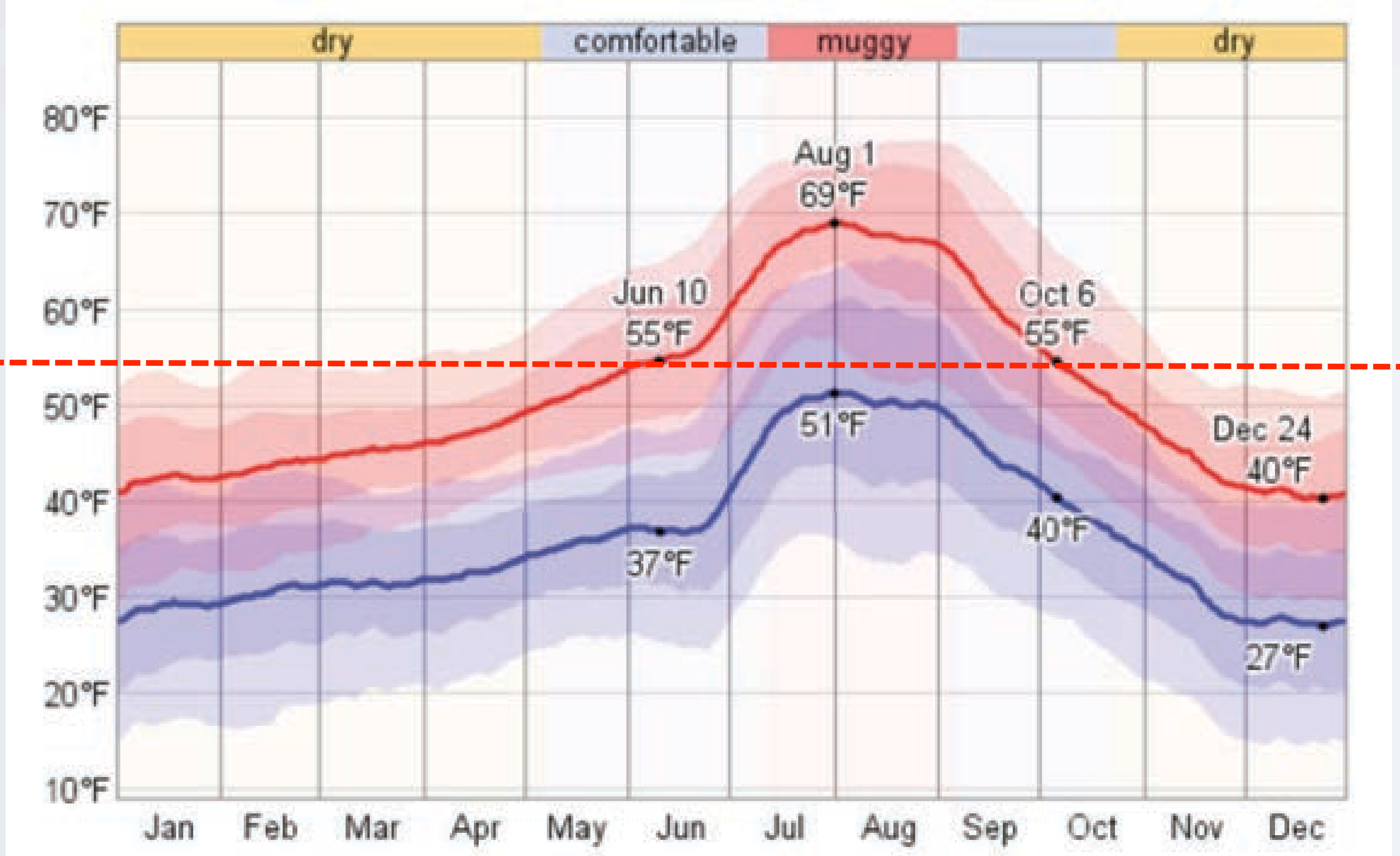
# Geography dictates the **annual hours** of ventilation DH load



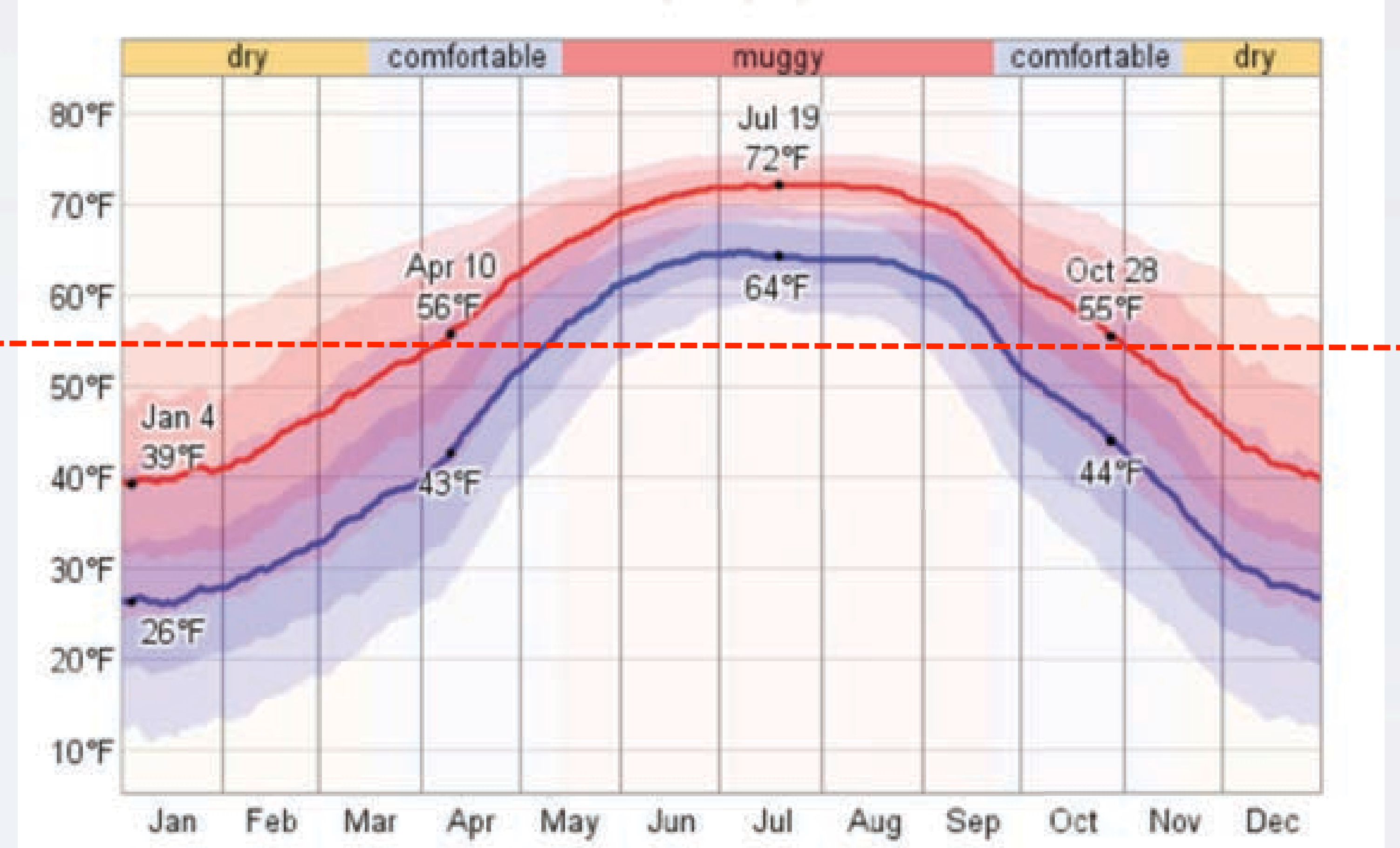

South Florida




Las Vegas

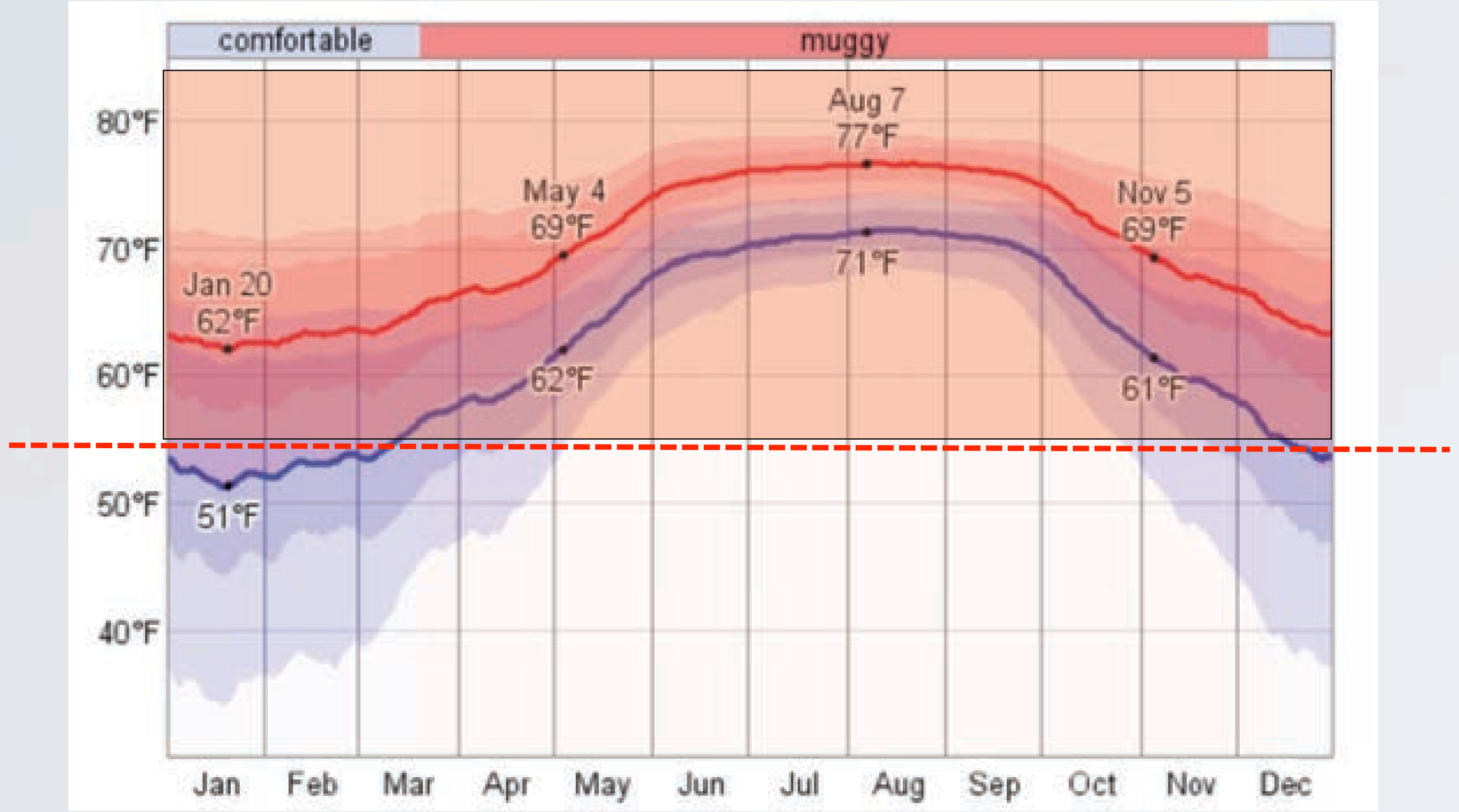



Imperial, CA

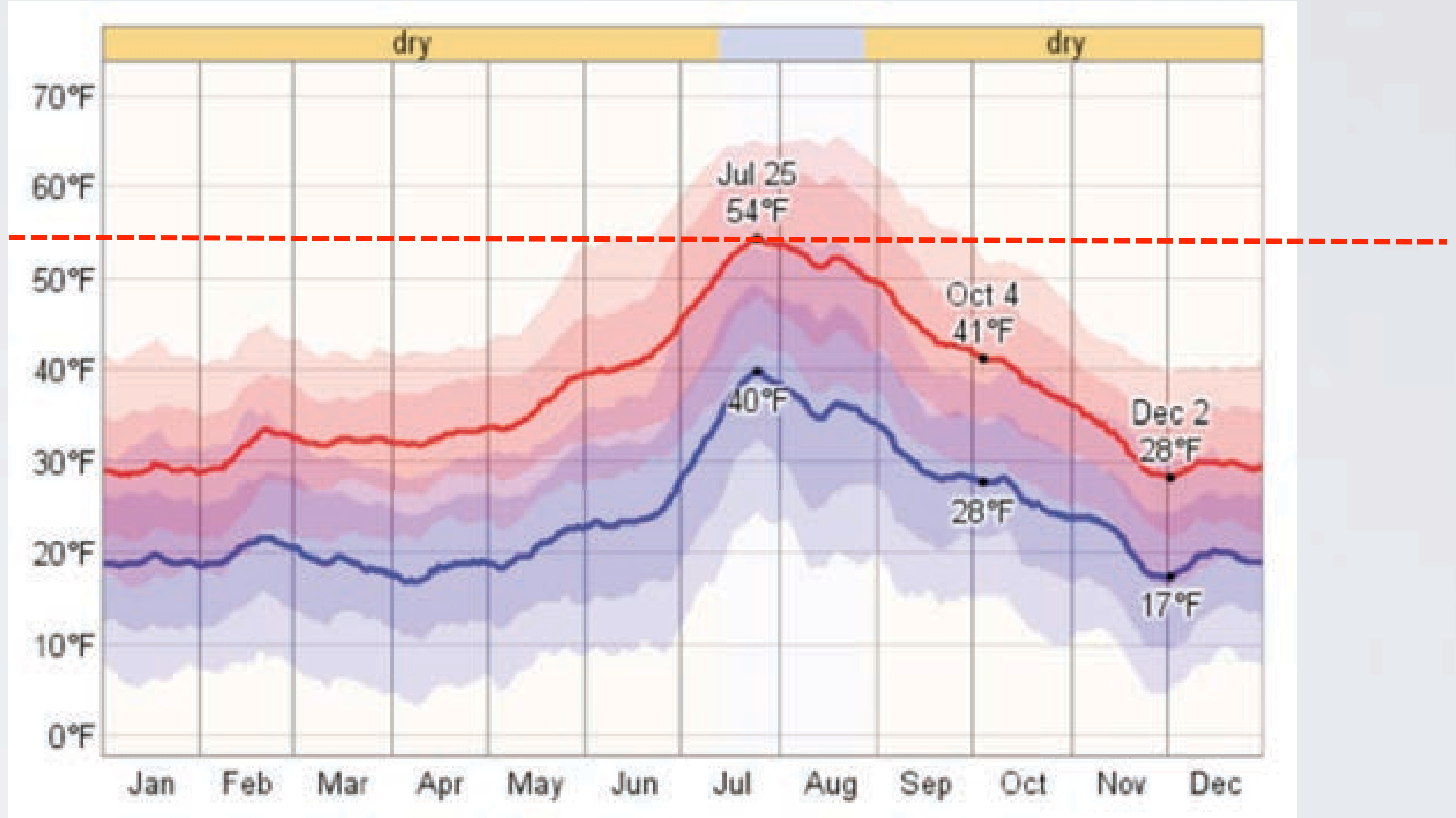



Dallas, TX

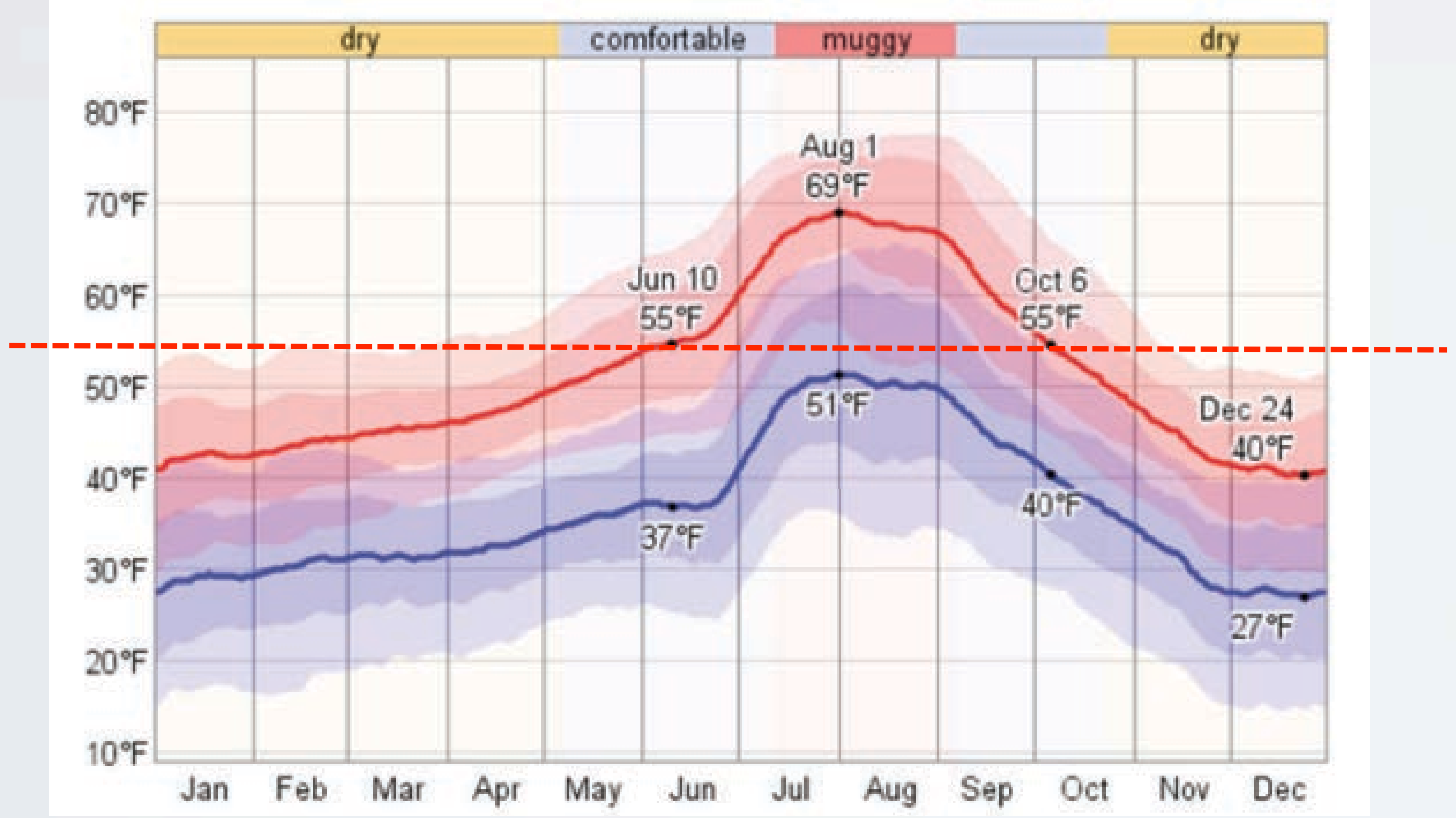
# Geography dictates the **annual hours** of ventilation DH load




South Florida




Las Vegas

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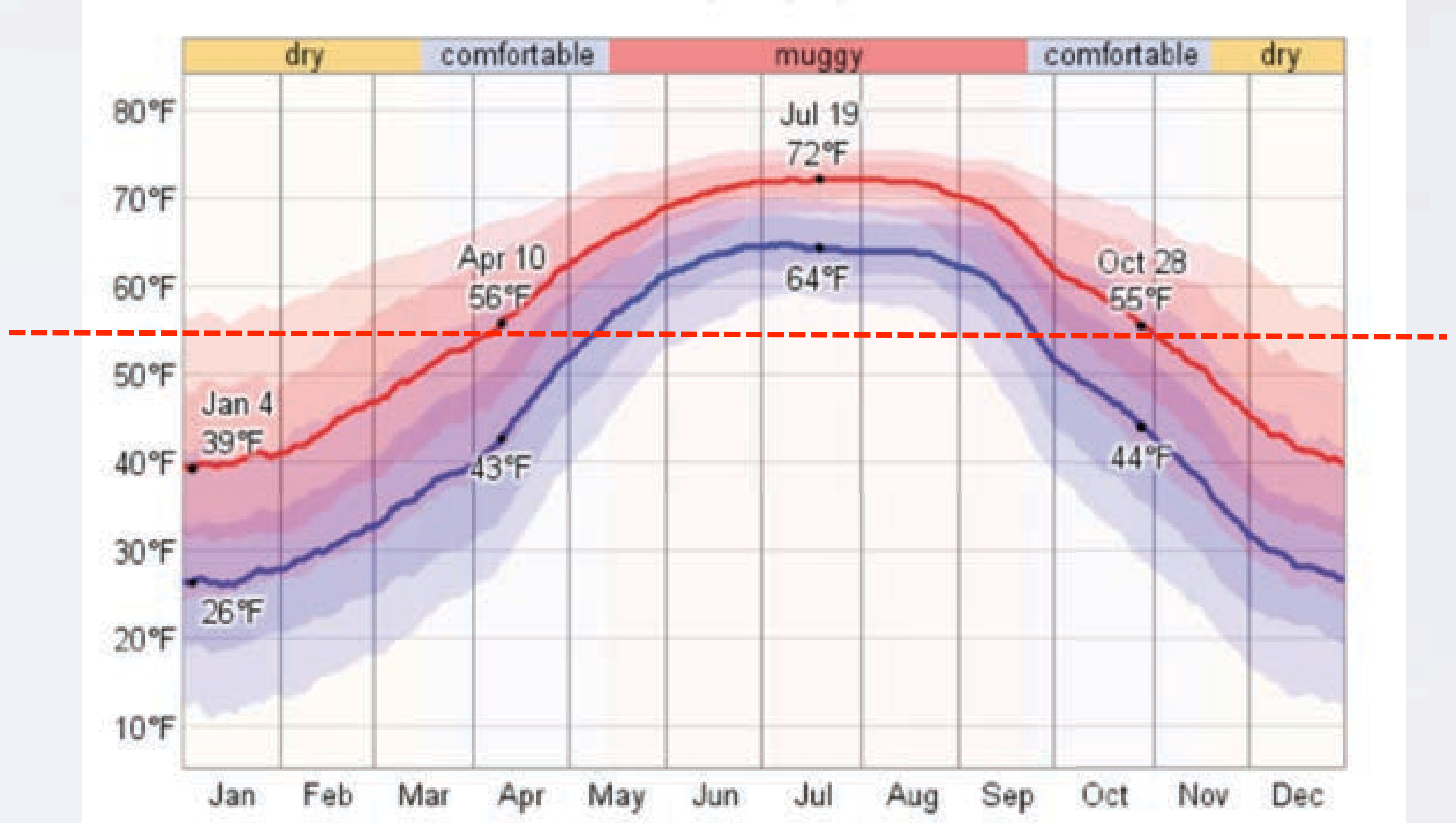


Dallas, TX

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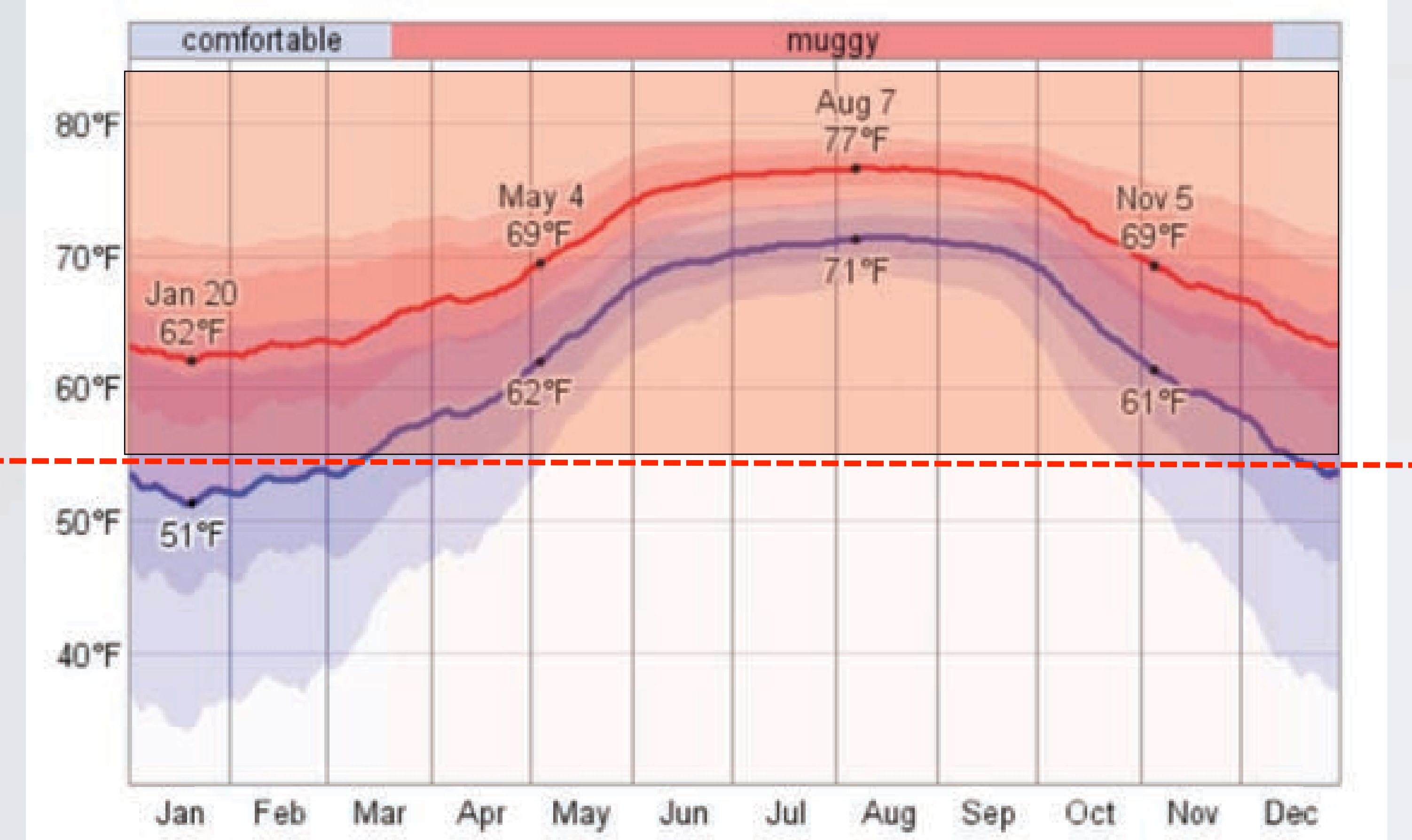
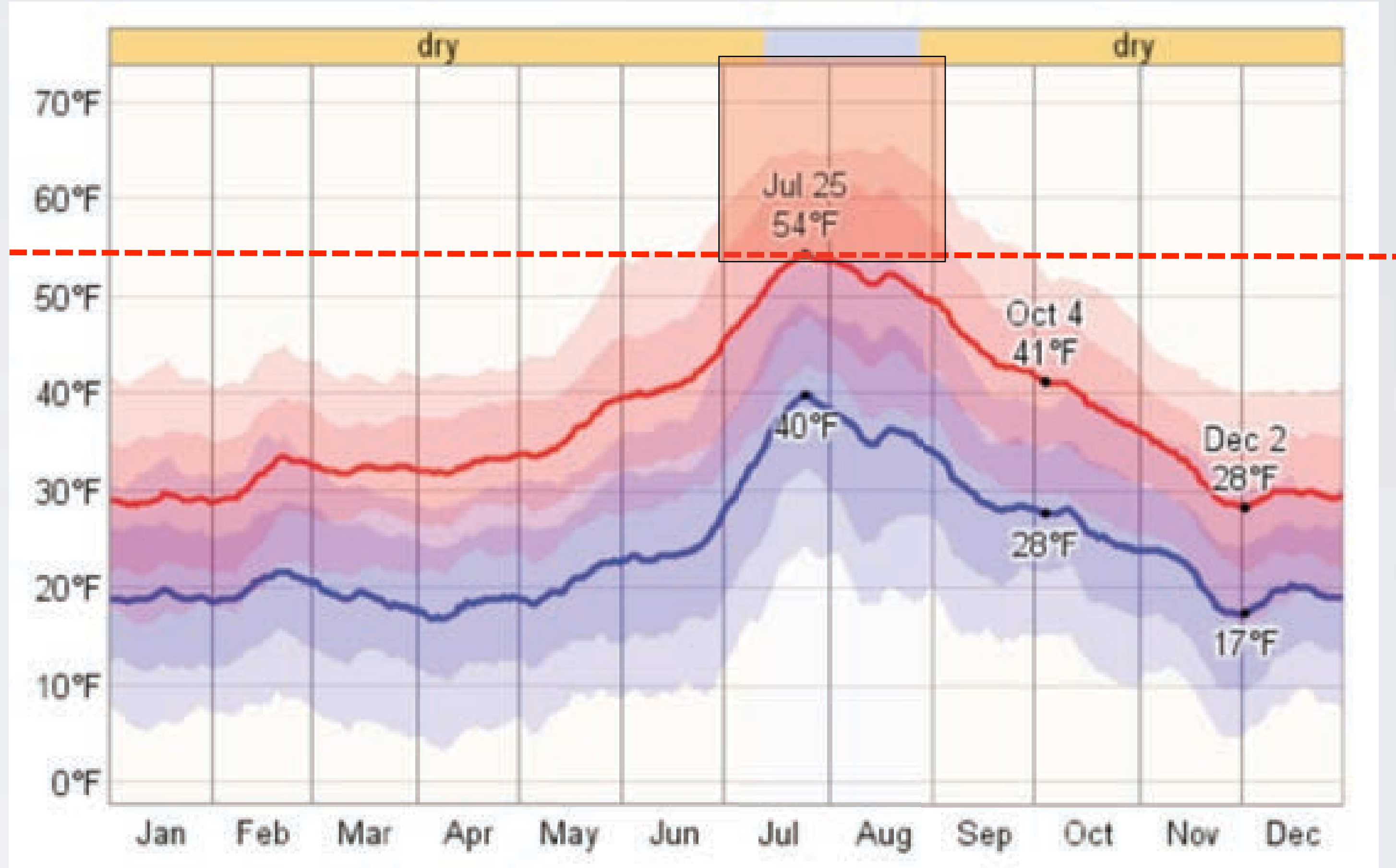
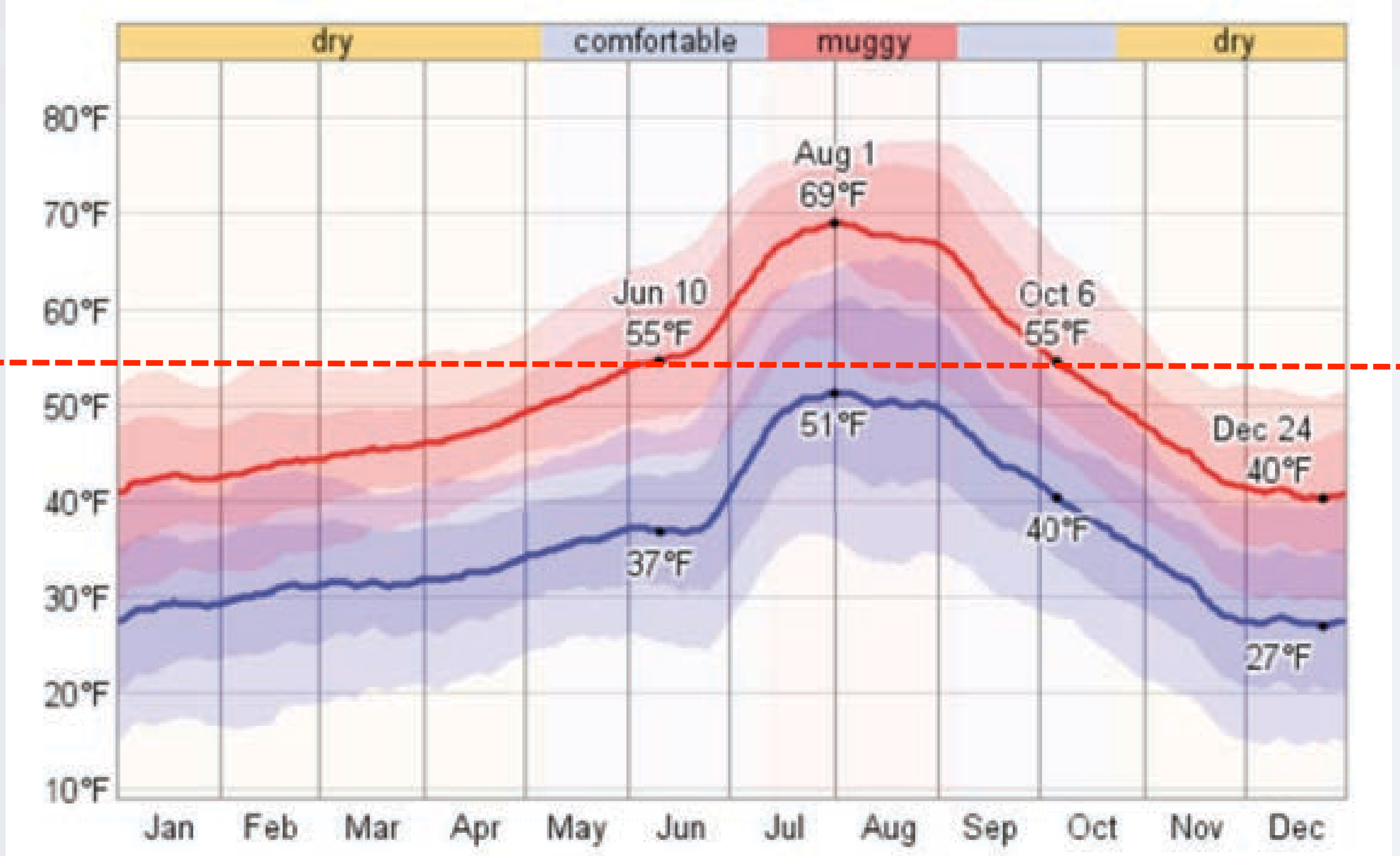


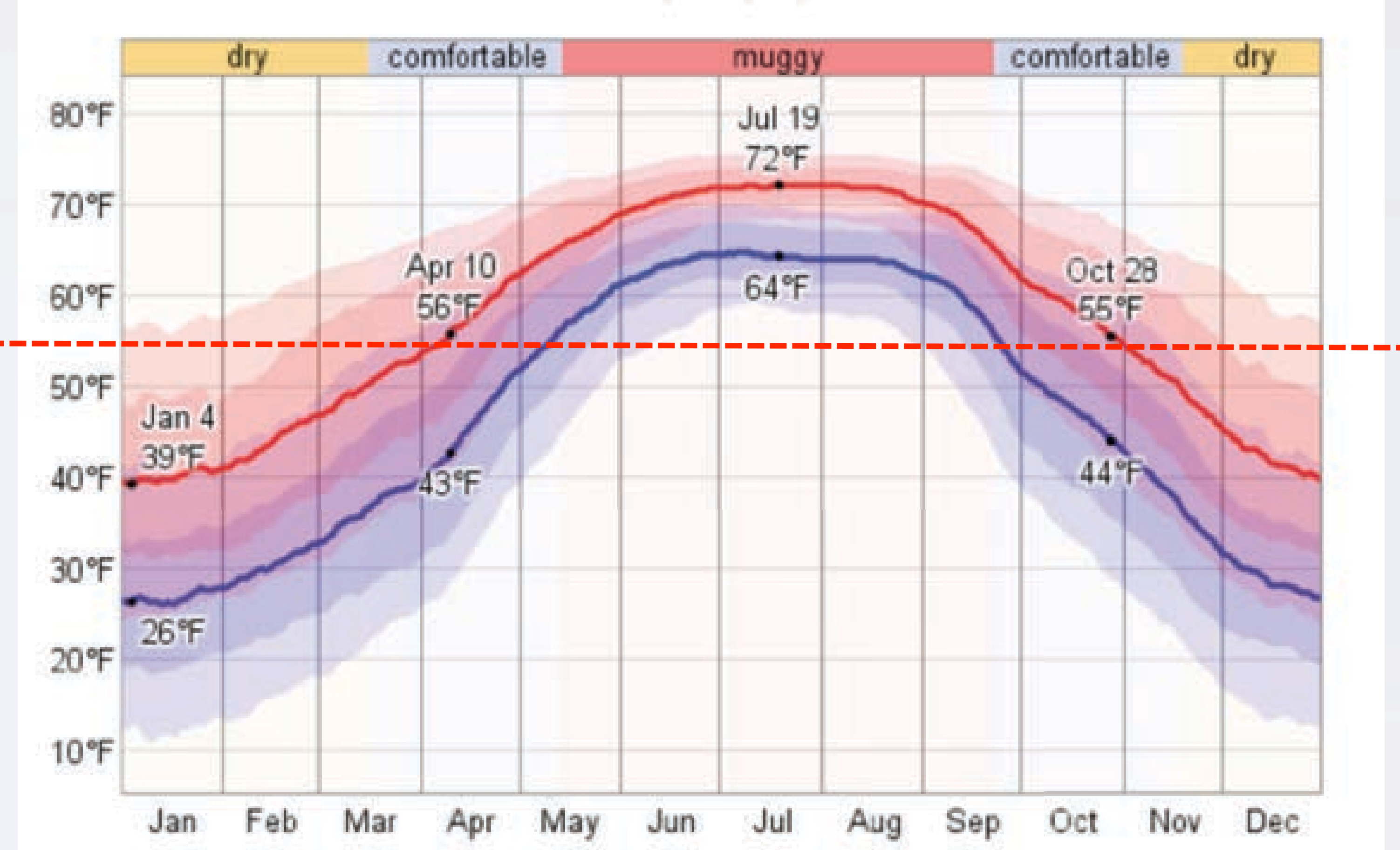

**South Florida**




**Las Vegas**

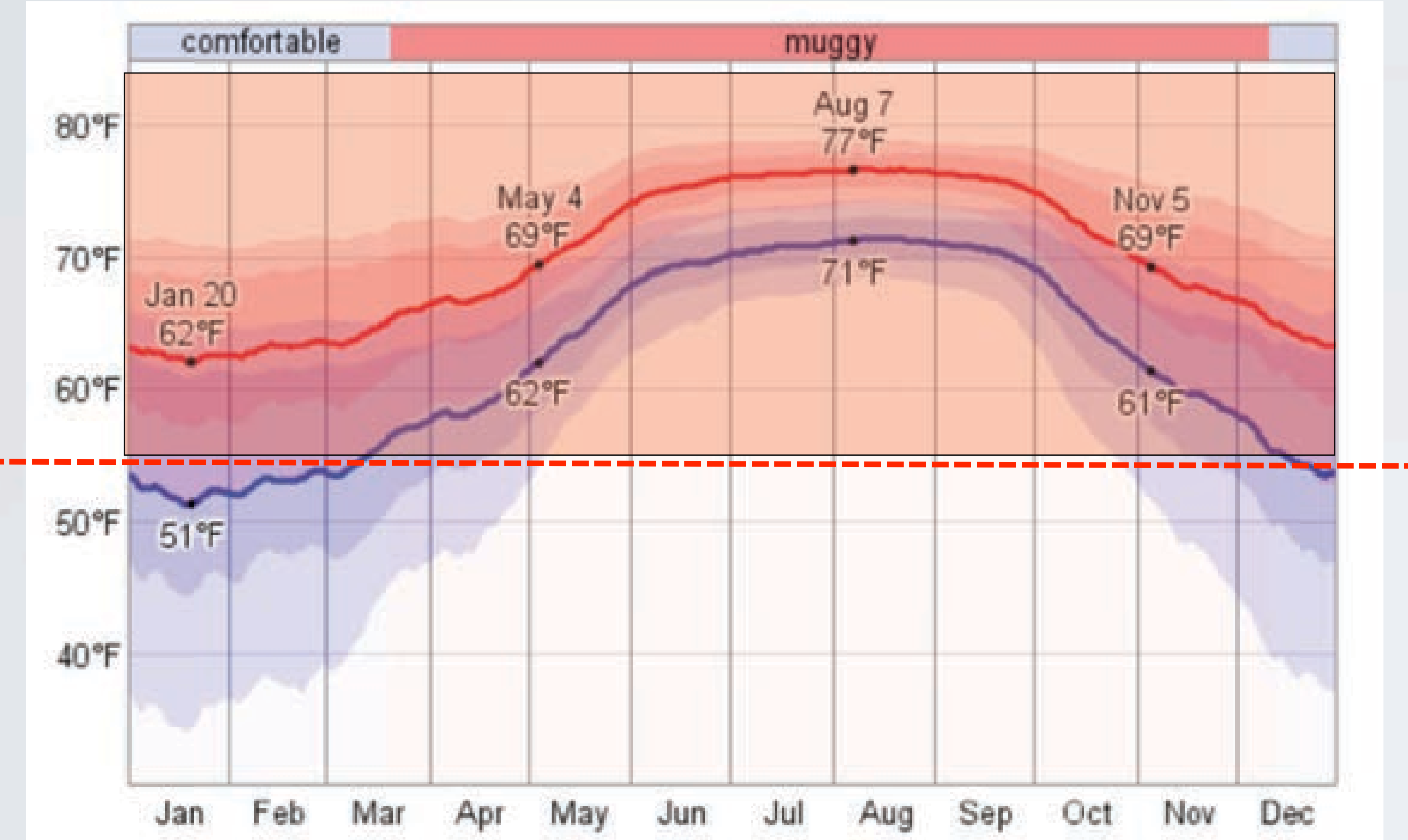



**Imperial, CA**

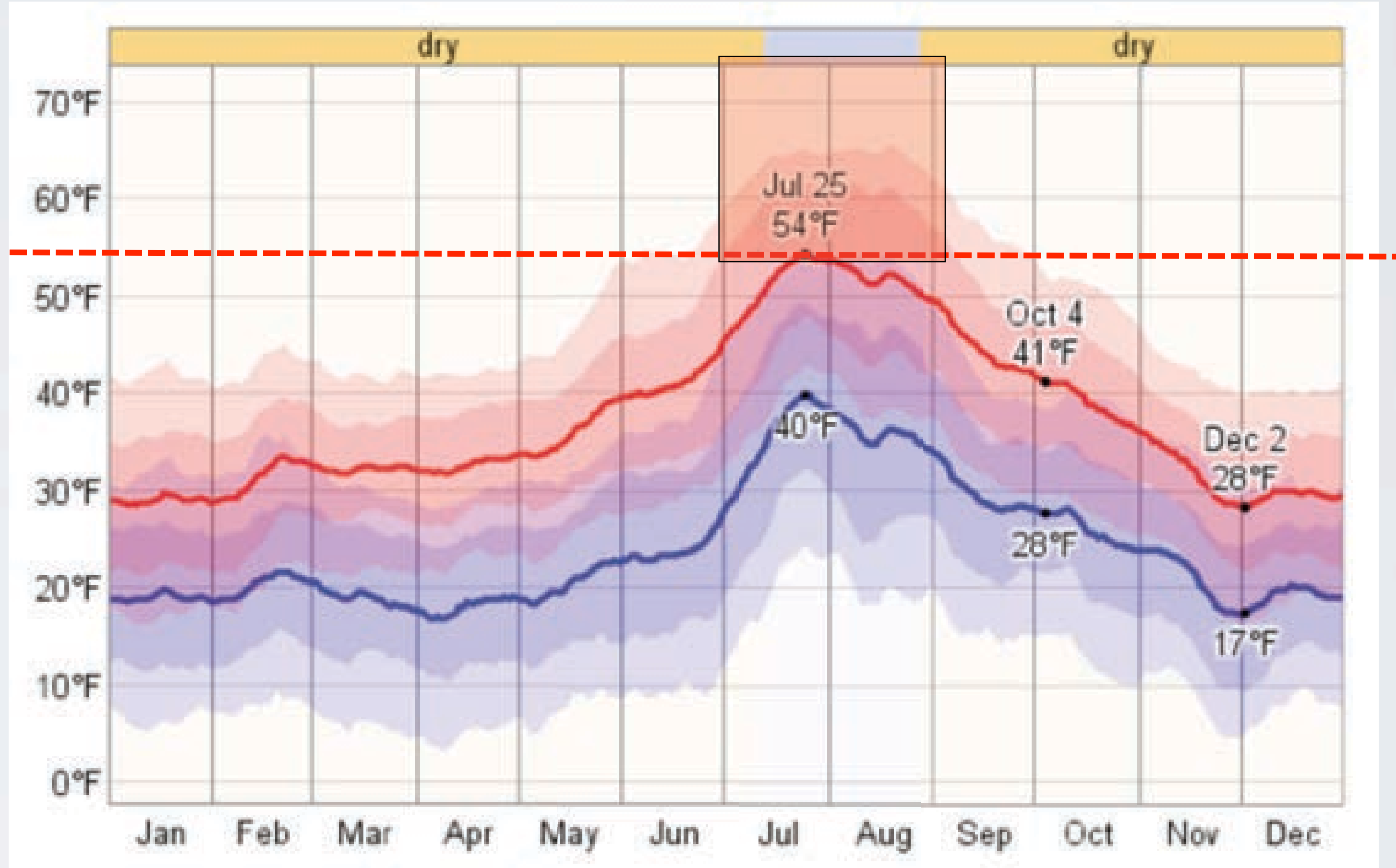



**Dallas, TX**

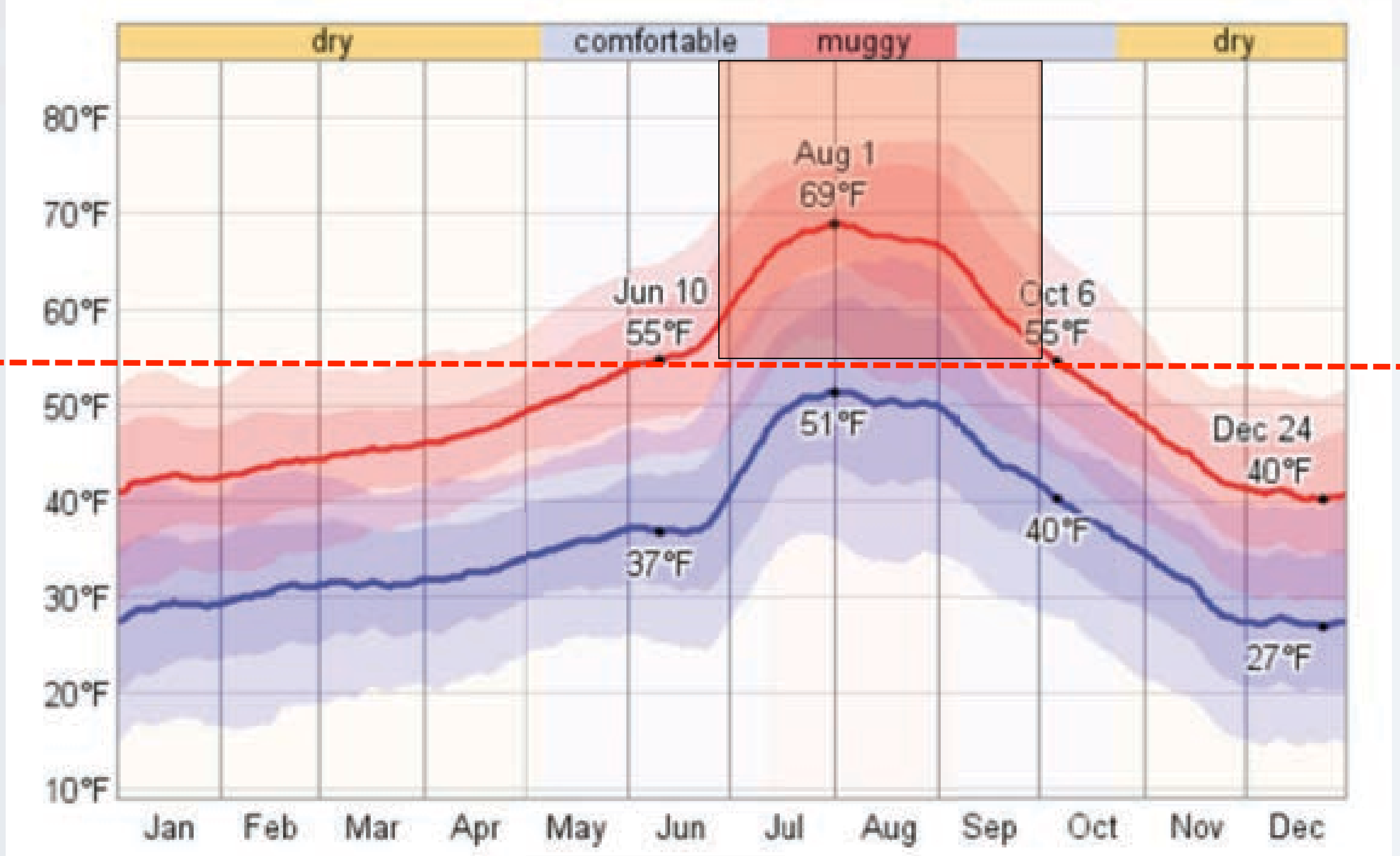
# Geography dictates the **annual hours** of ventilation DH load




South Florida




Las Vegas

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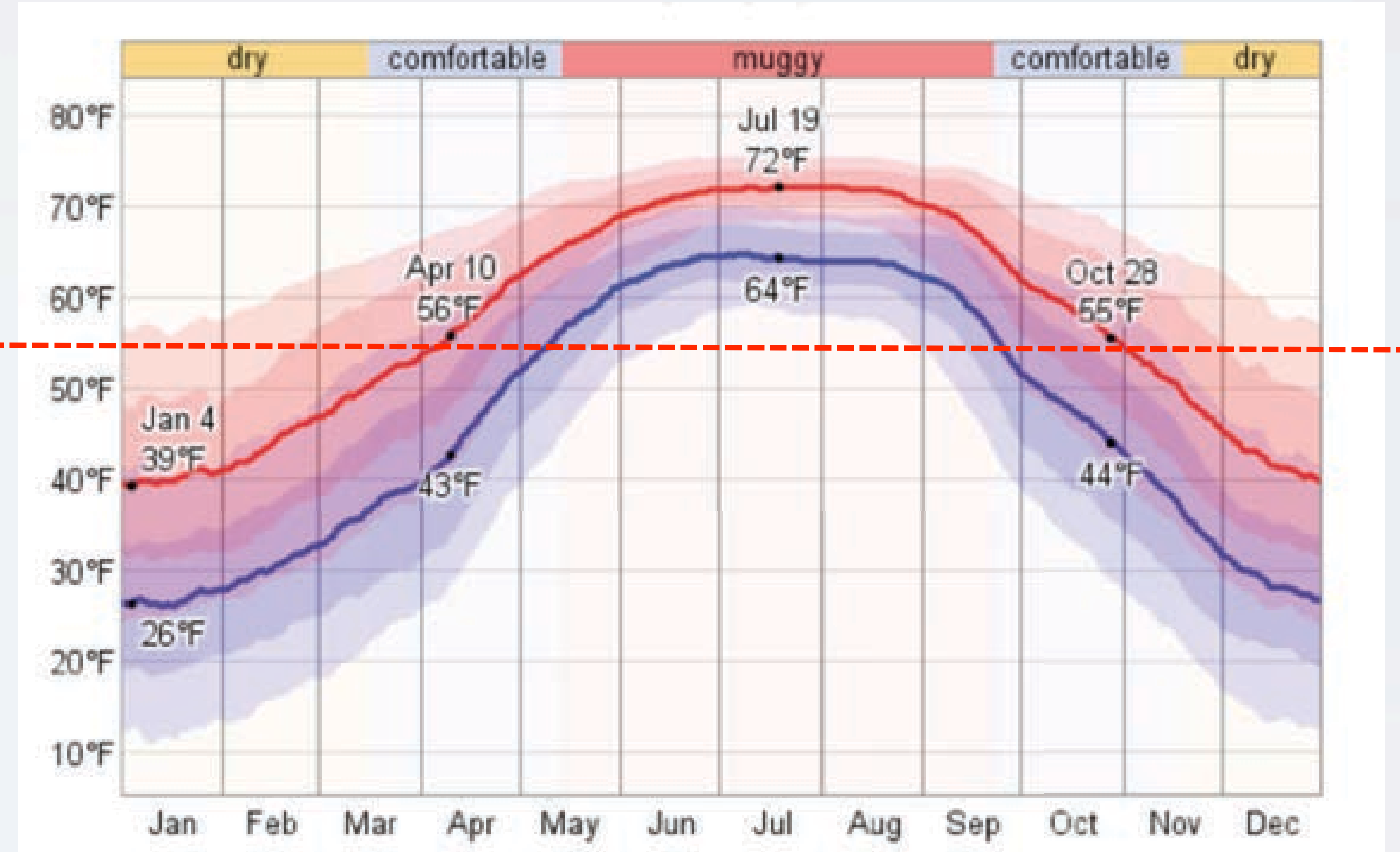


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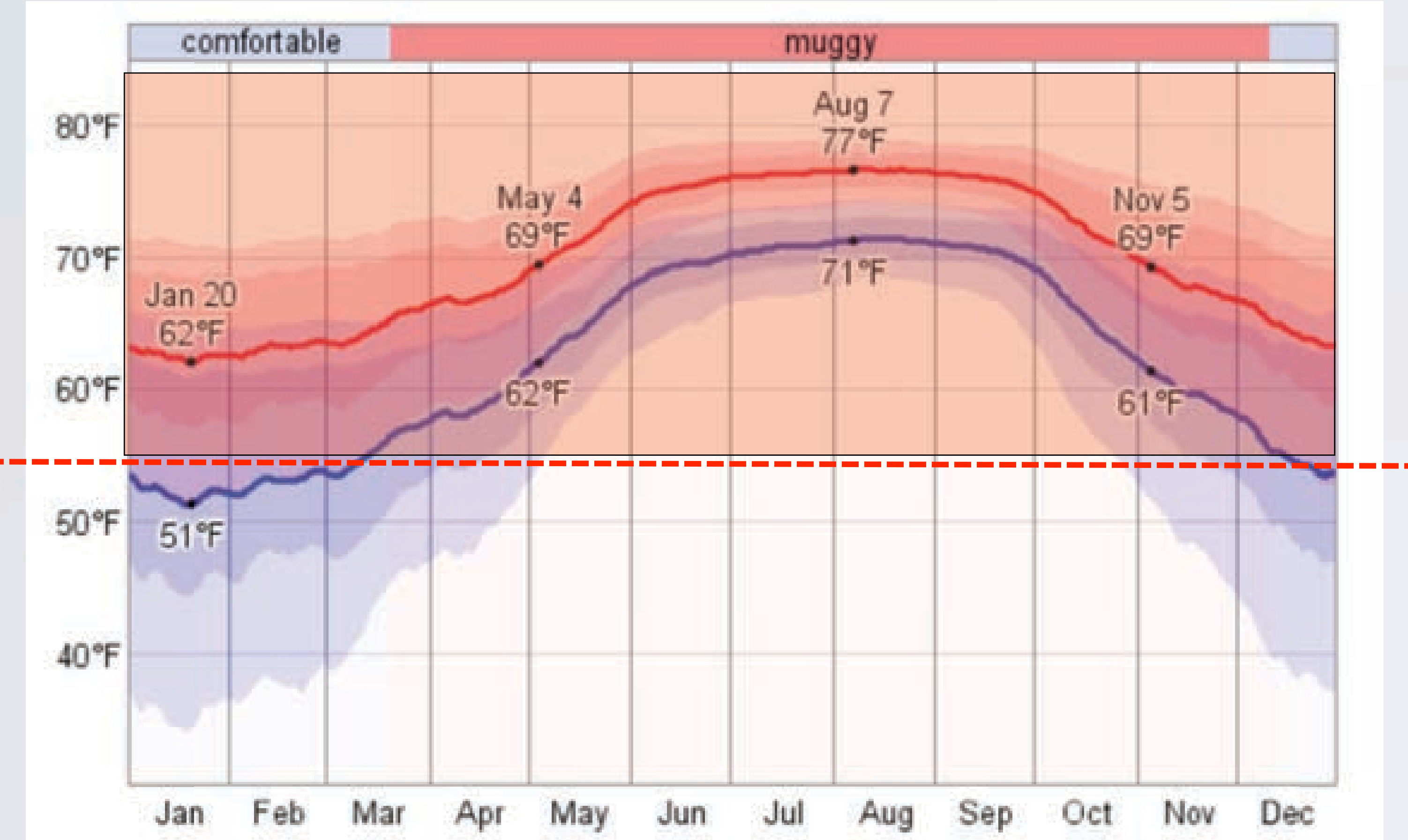


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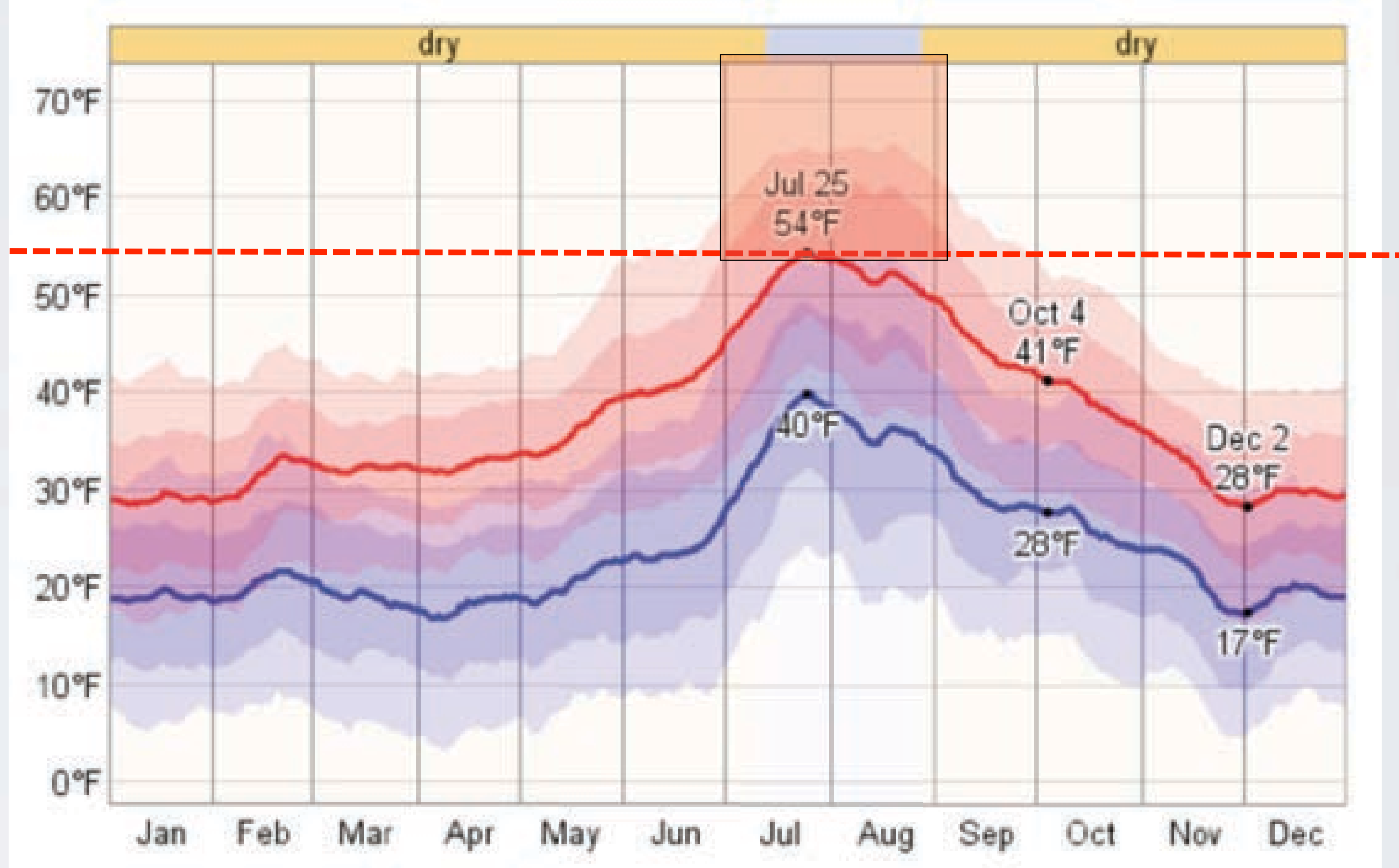
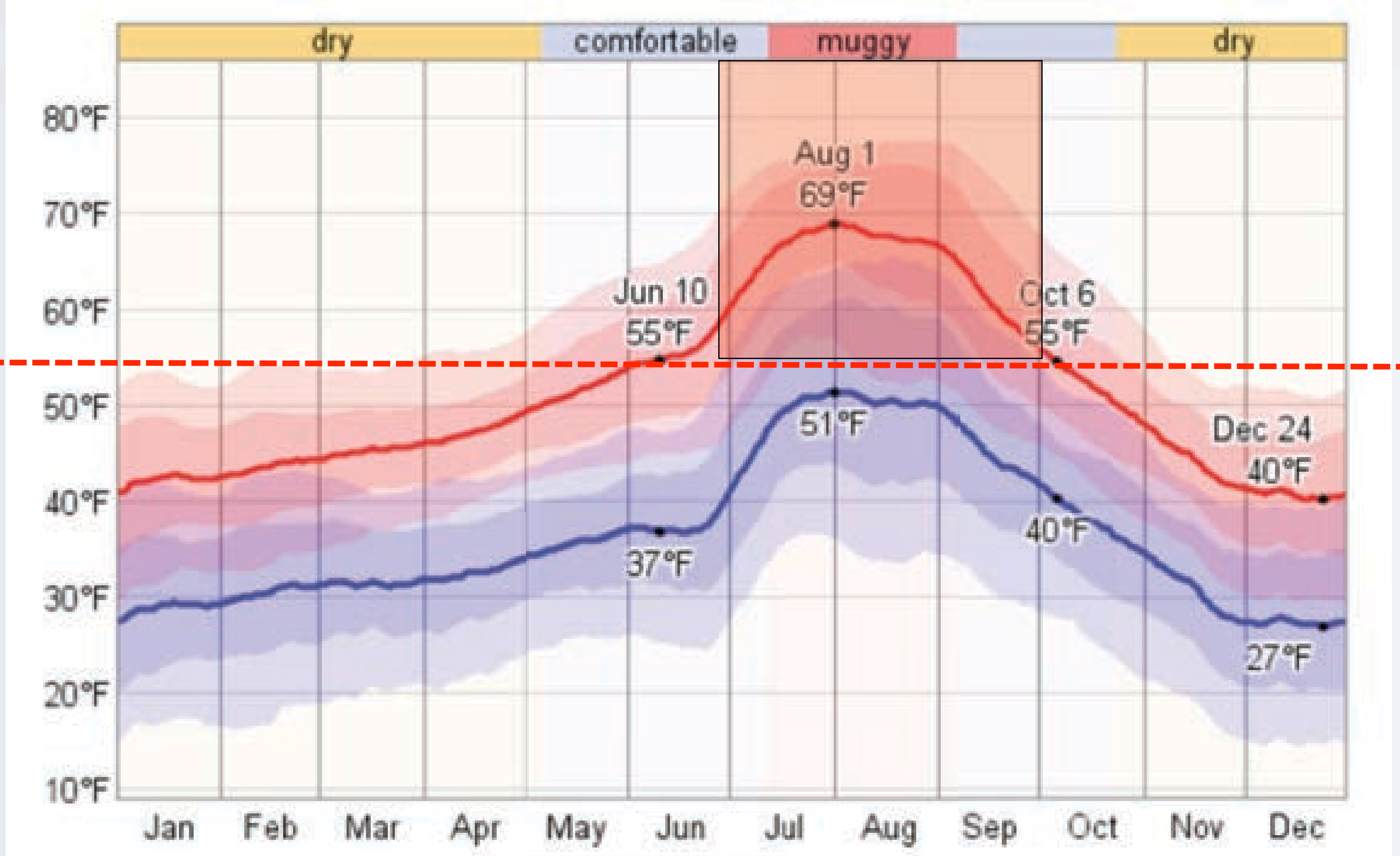



Las Vegas

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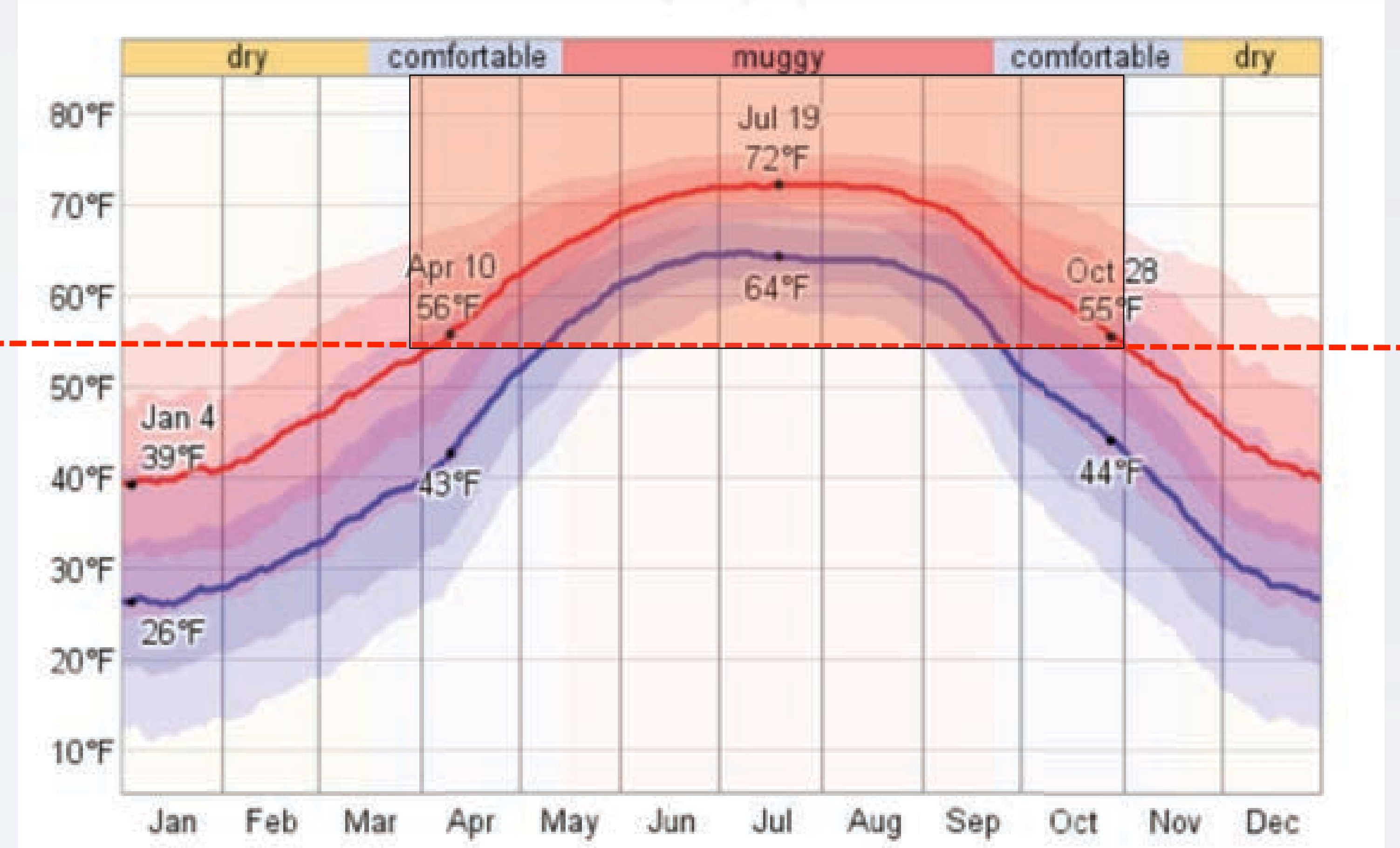


Dallas, TX

# Finally... the importance of keeping UN-OCCUPIED buildings DRY

**Henryville - Southern Indiana**
**Indoor Condensation**

# Finally... the importance of keeping UN-OCCUPIED buildings DRY

School in Houston (After Summer Vacation)


Henryville - Southern Indiana
Indoor Condensation

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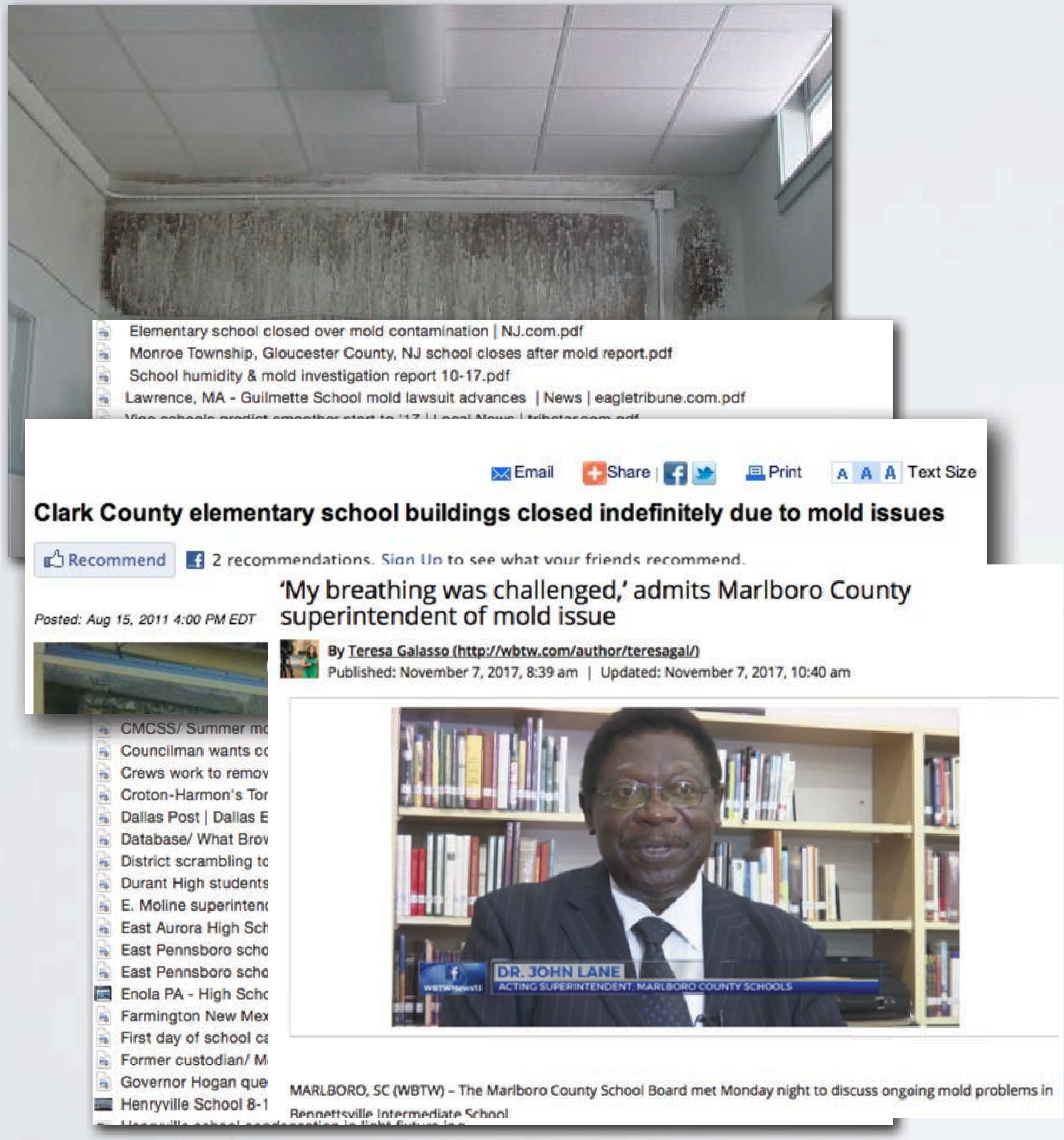



Henryville - Southern Indiana
Indoor Condensation

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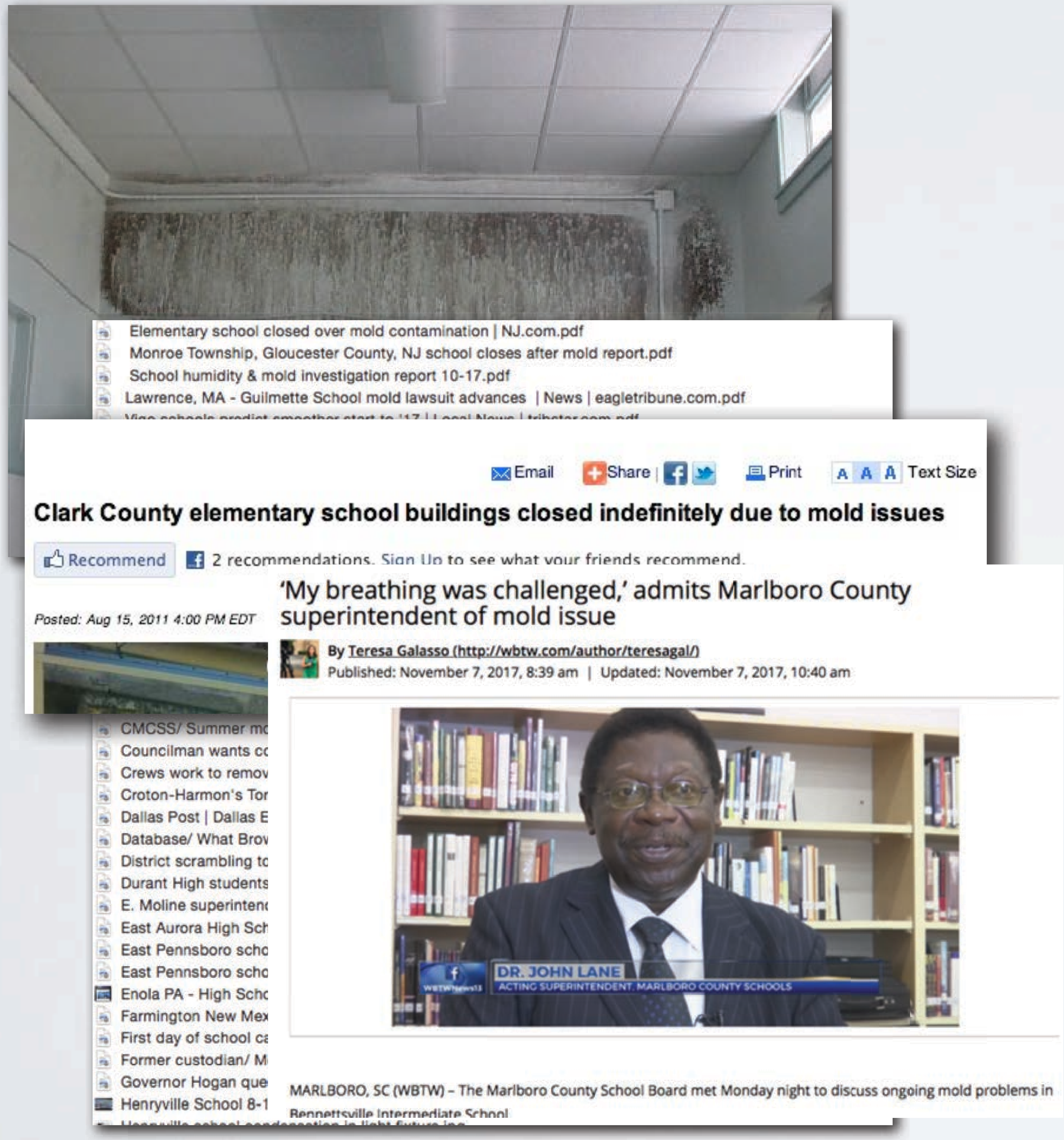



Henryville - Southern Indiana
Indoor Condensation

# The importance of keeping UNOCCUPIED buildings dry
# More examples....

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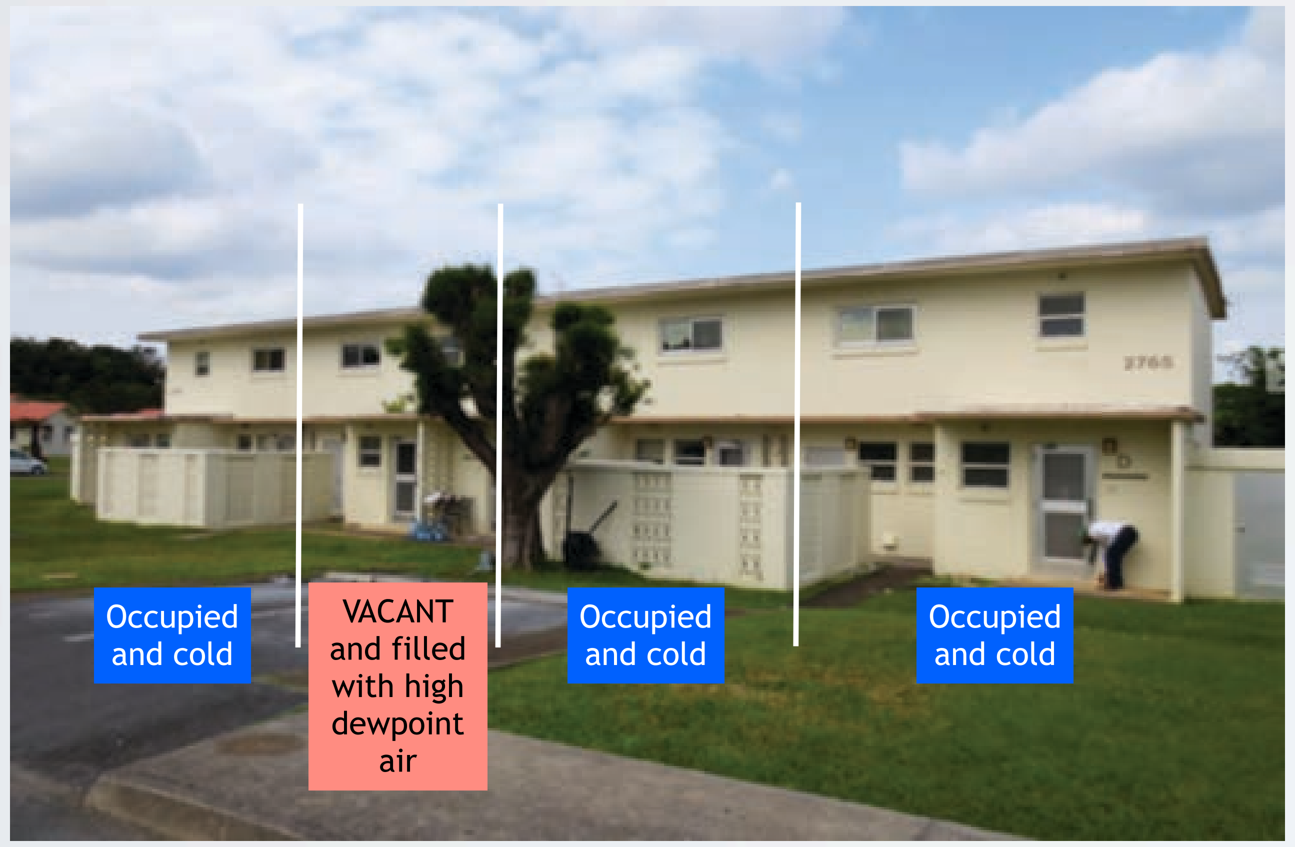

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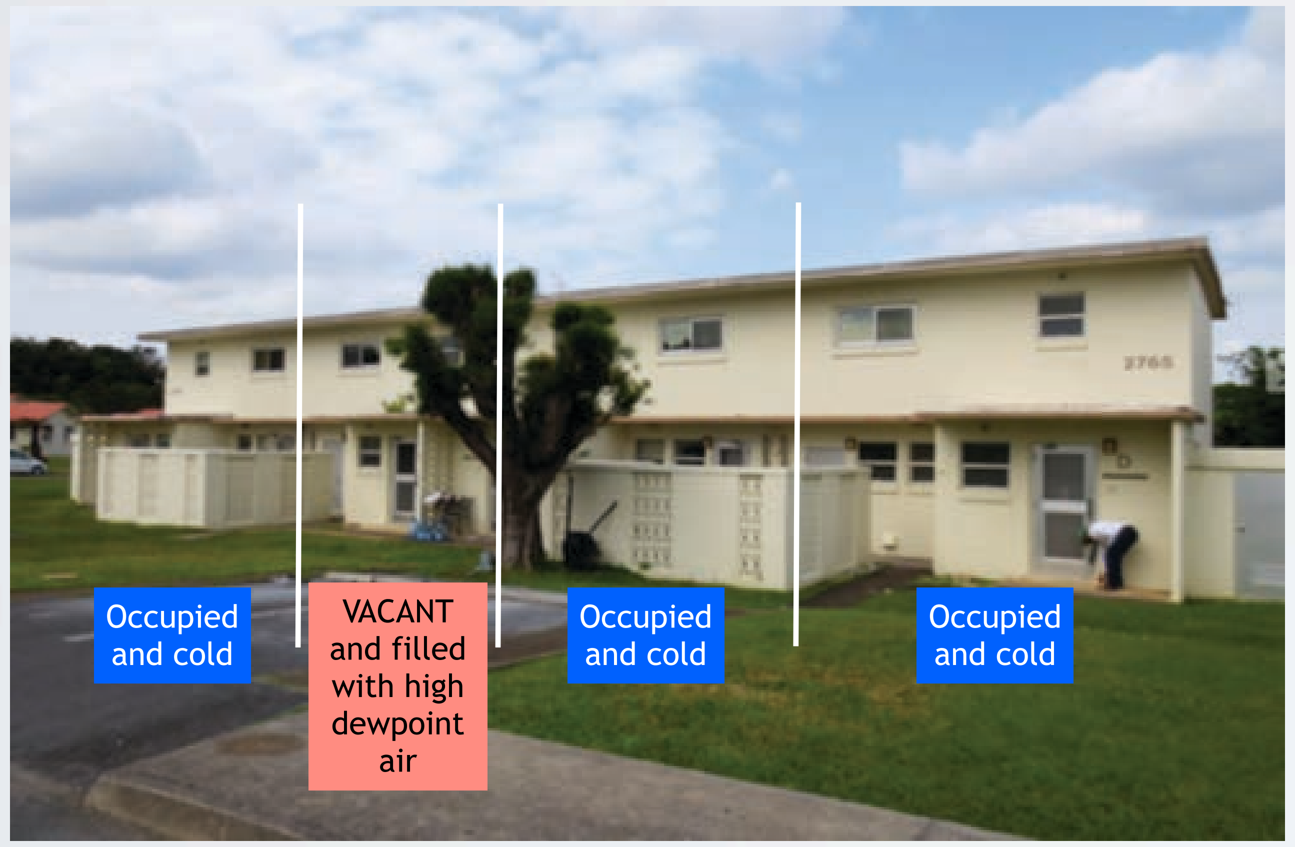

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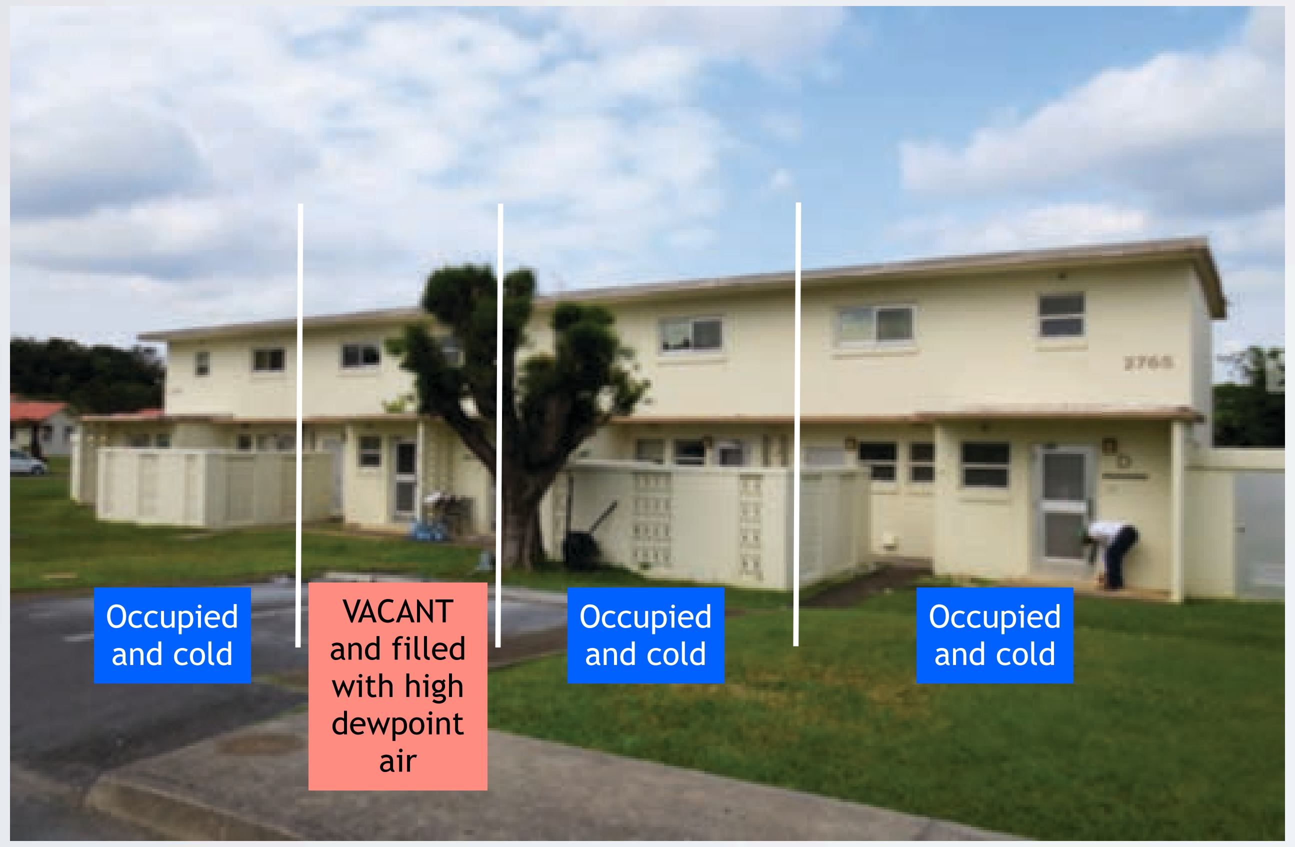


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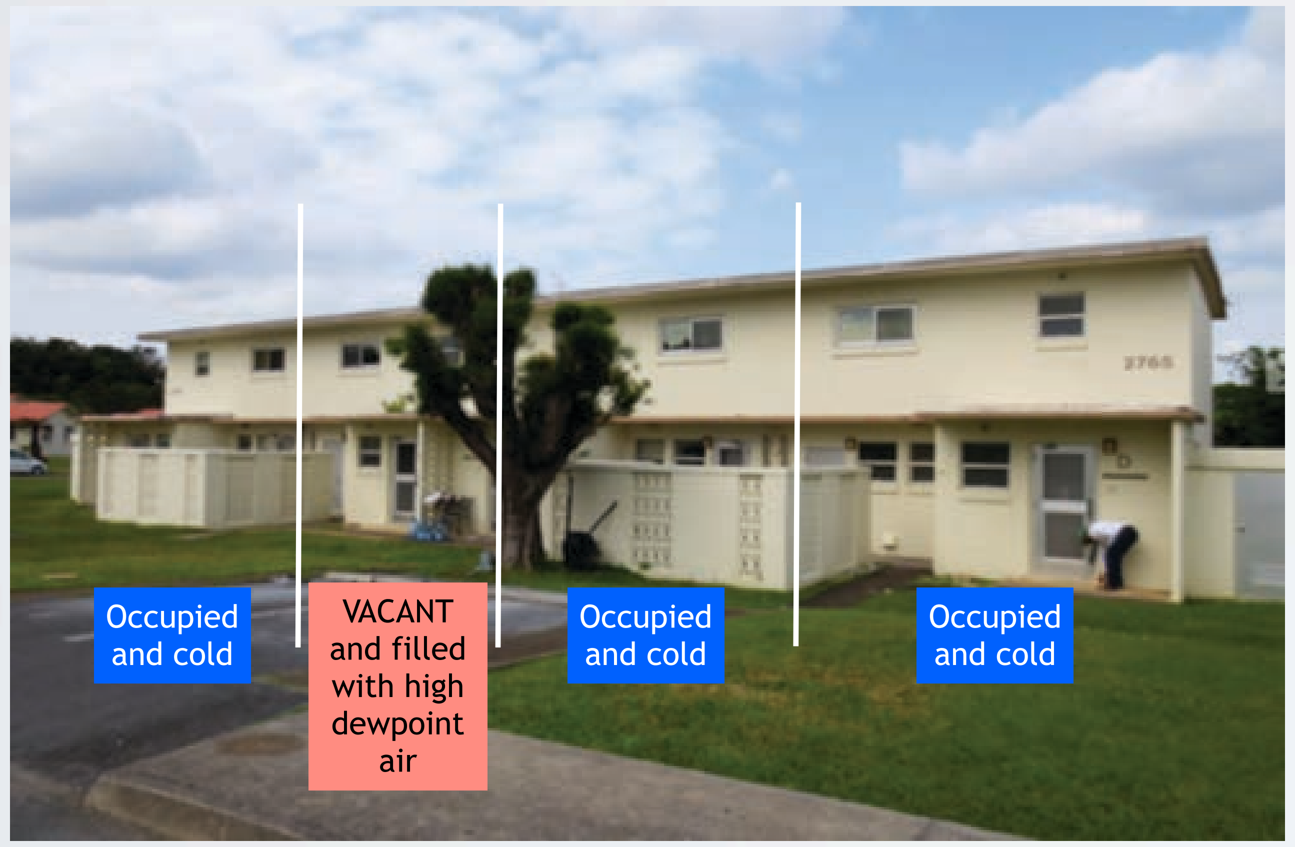


# RH (of the air) is not a reliable indicator of risk

## **Control the dew point**

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# **Control the dew point**


**Growing mold because the air DEW POINT temperature is so close to the SURFACE TEMPERATURE**

(18°C dew point v. 19°C Surface)

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**Air**
**54% RH**

**Growing mold because the air DEW POINT temperature is so close to the SURFACE TEMPERATURE**

(18°C dew point v. 19°C Surface)

# RH (of the air) is not a reliable indicator of risk
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## **Control the dew point**

Sensor 1.

RH in the air

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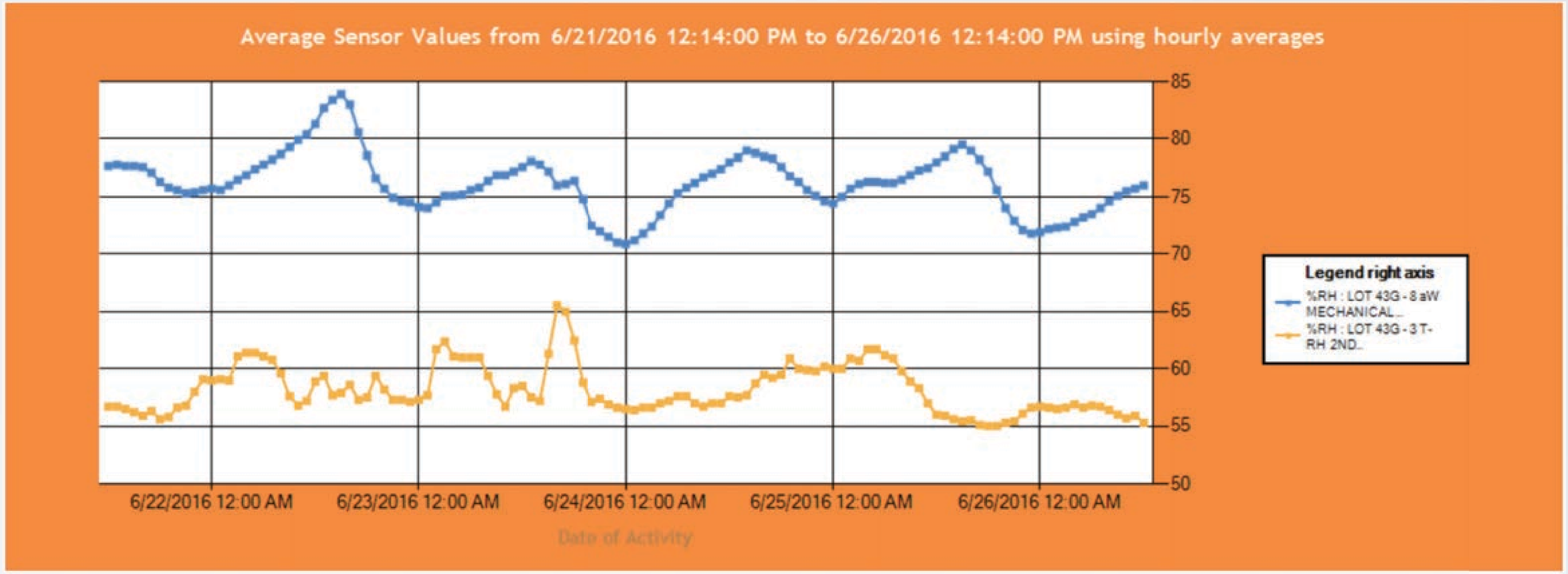


| | %RH : LOT 43G - 8 aW MECHANICAL CLOSET - ATTIC - STOP 9/13 | %RH : LOT 43G - 3 T-RH 2ND FLOOR HALLWAY - STOP 9/13 |
|---|---|---|
| min | 70.90 | 55.00 |
| max | 83.90 | 65.50 |
| diff | 13.00 | 10.50 |

# RH at the surface is not the same as RH in the air

# Control the dew point

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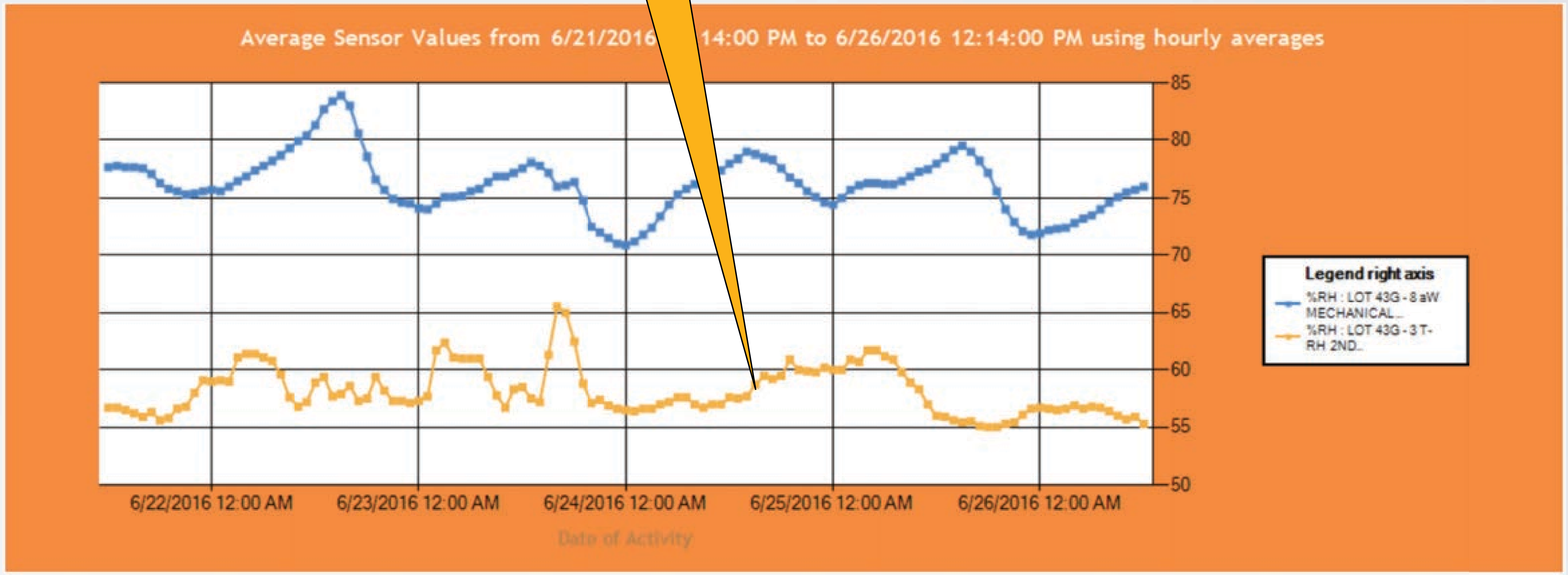
RH in the air

Sensor 2.
RH at the surface

**Air**
**58% RH**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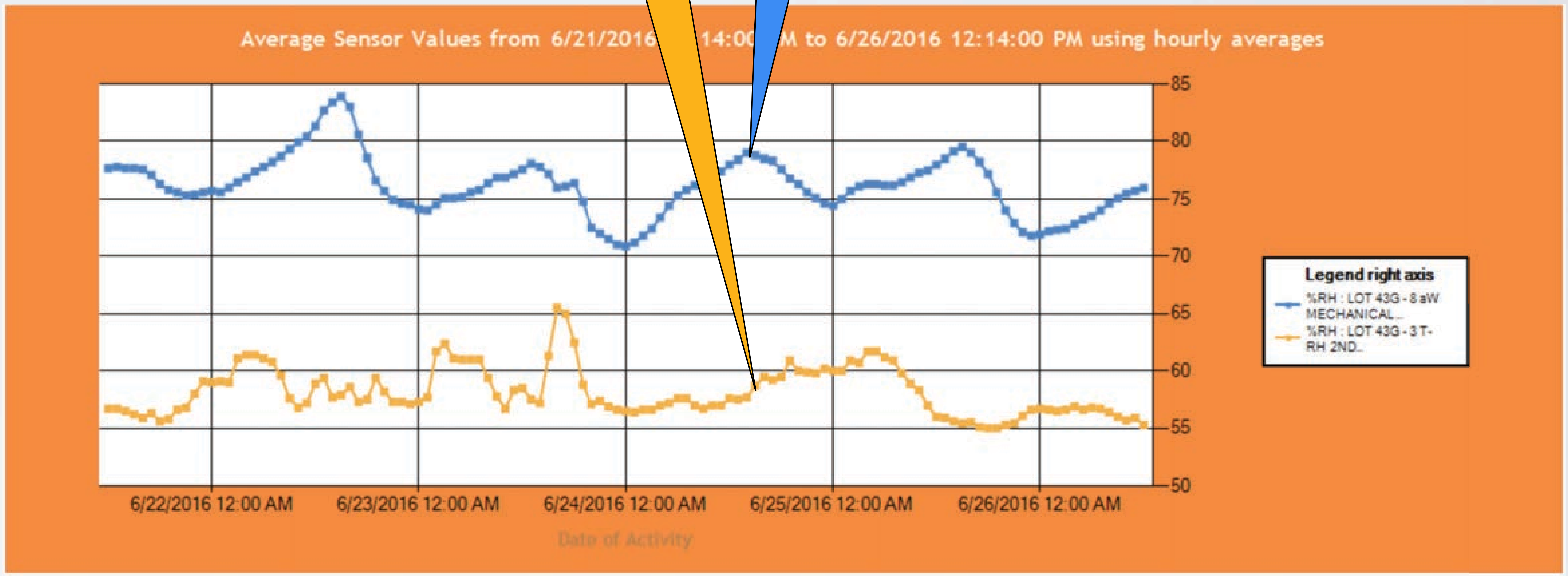
RH at the surface


**Air**
**58% RH**

**Surface**
**79% RH**

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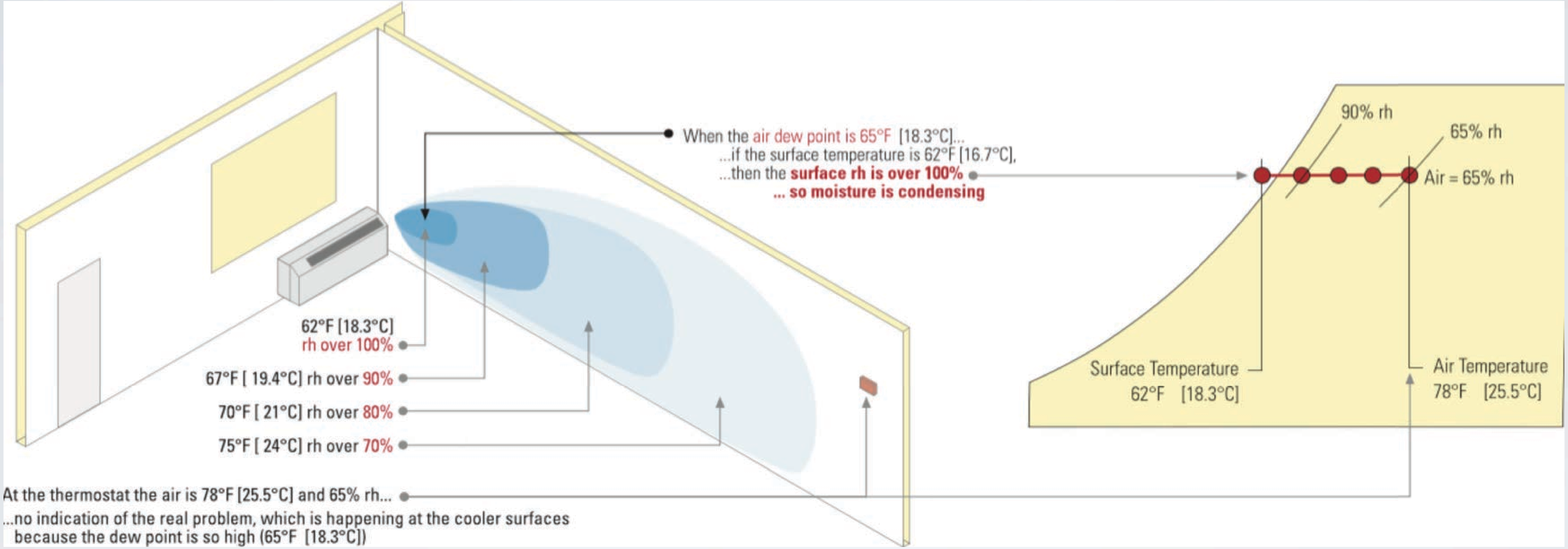

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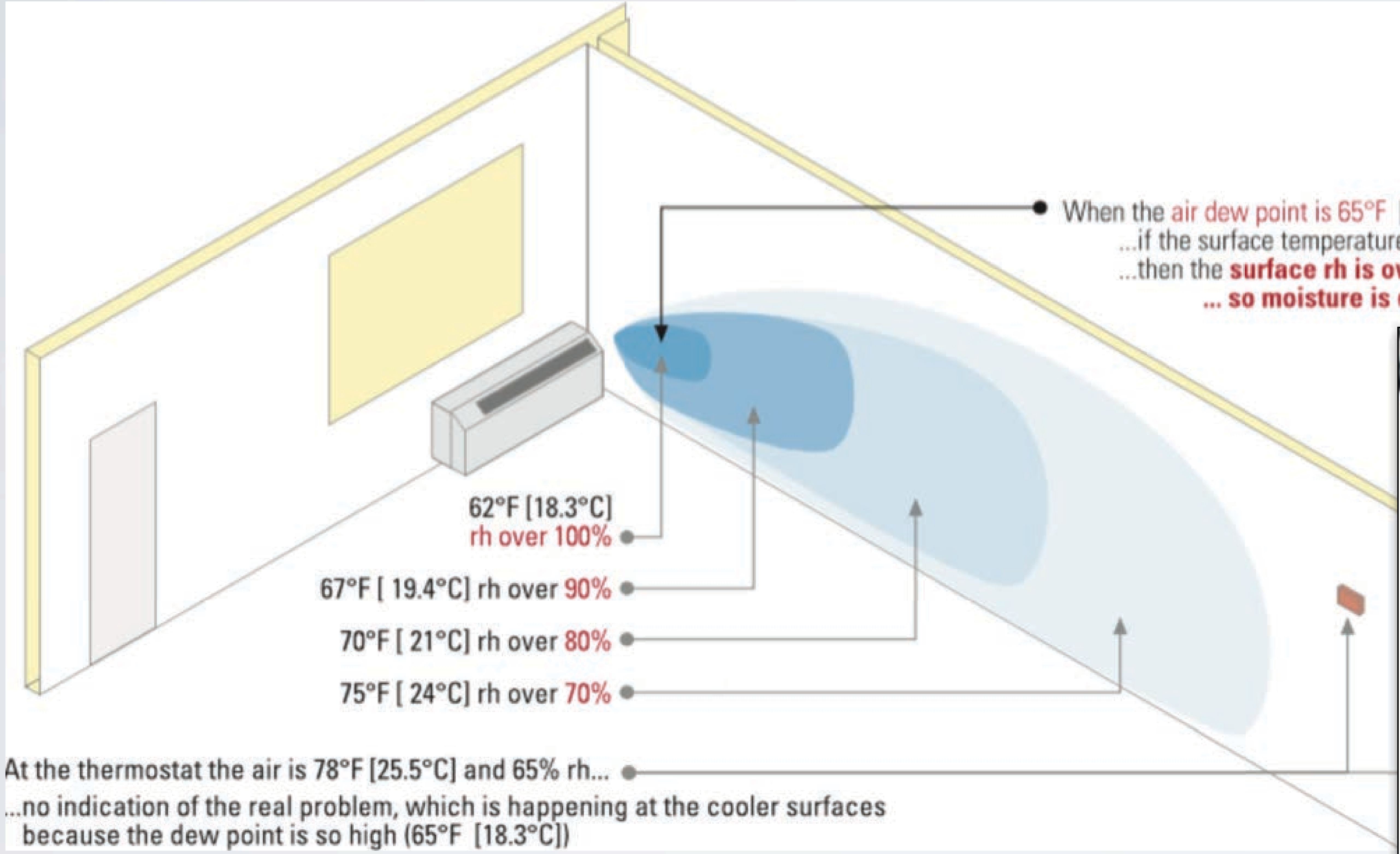


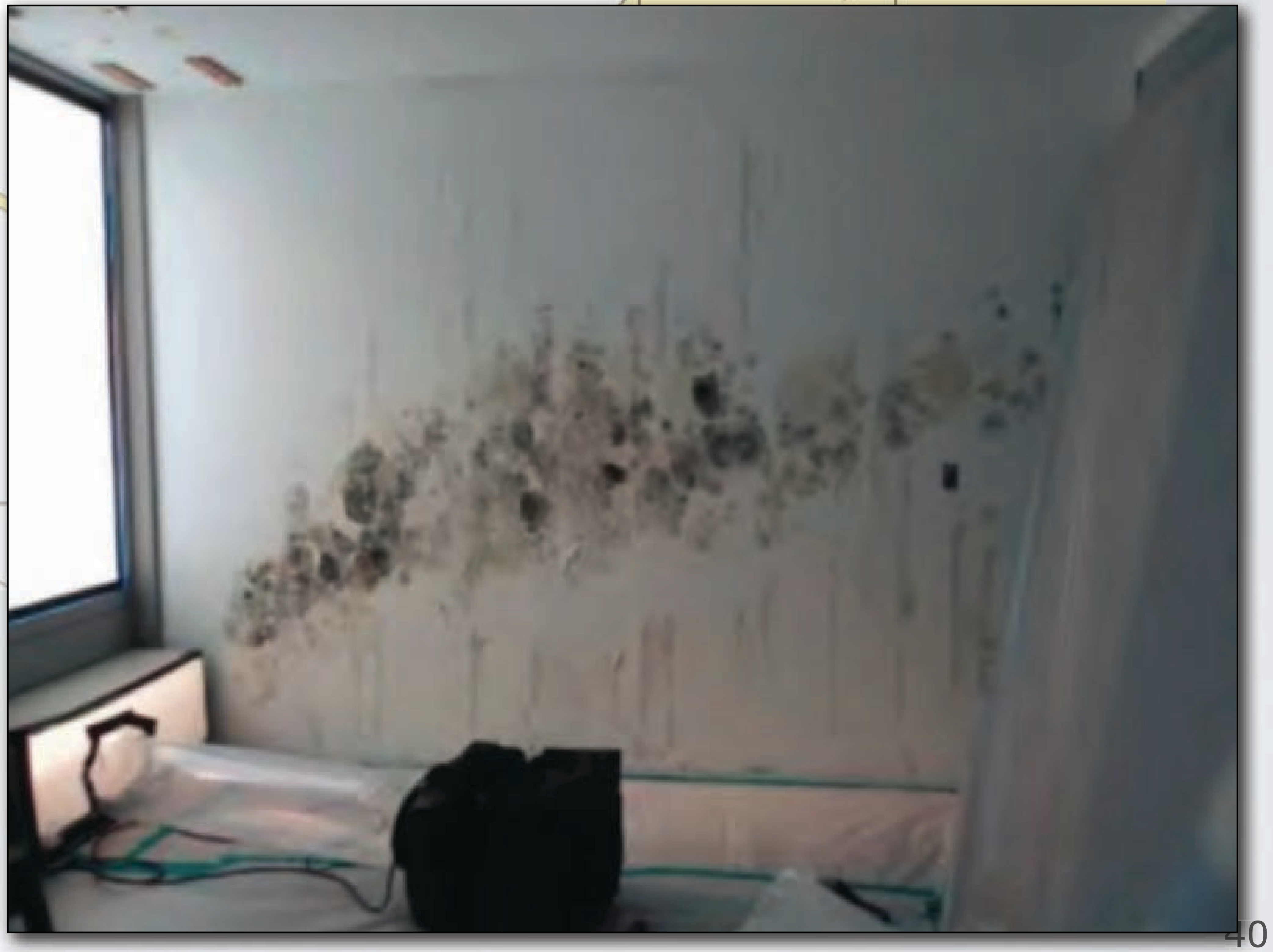

Institutional/Commercial Buildings

# DOAS can keep them DRY during **UN**-occupied hours

Institutional/Commercial Buildings

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## Schools prevent mold over summer break

By Sari Soffer
Published: May 30, 2017, 5:21 pm

Schools prevent mold over summer break

00:00 / 00:15

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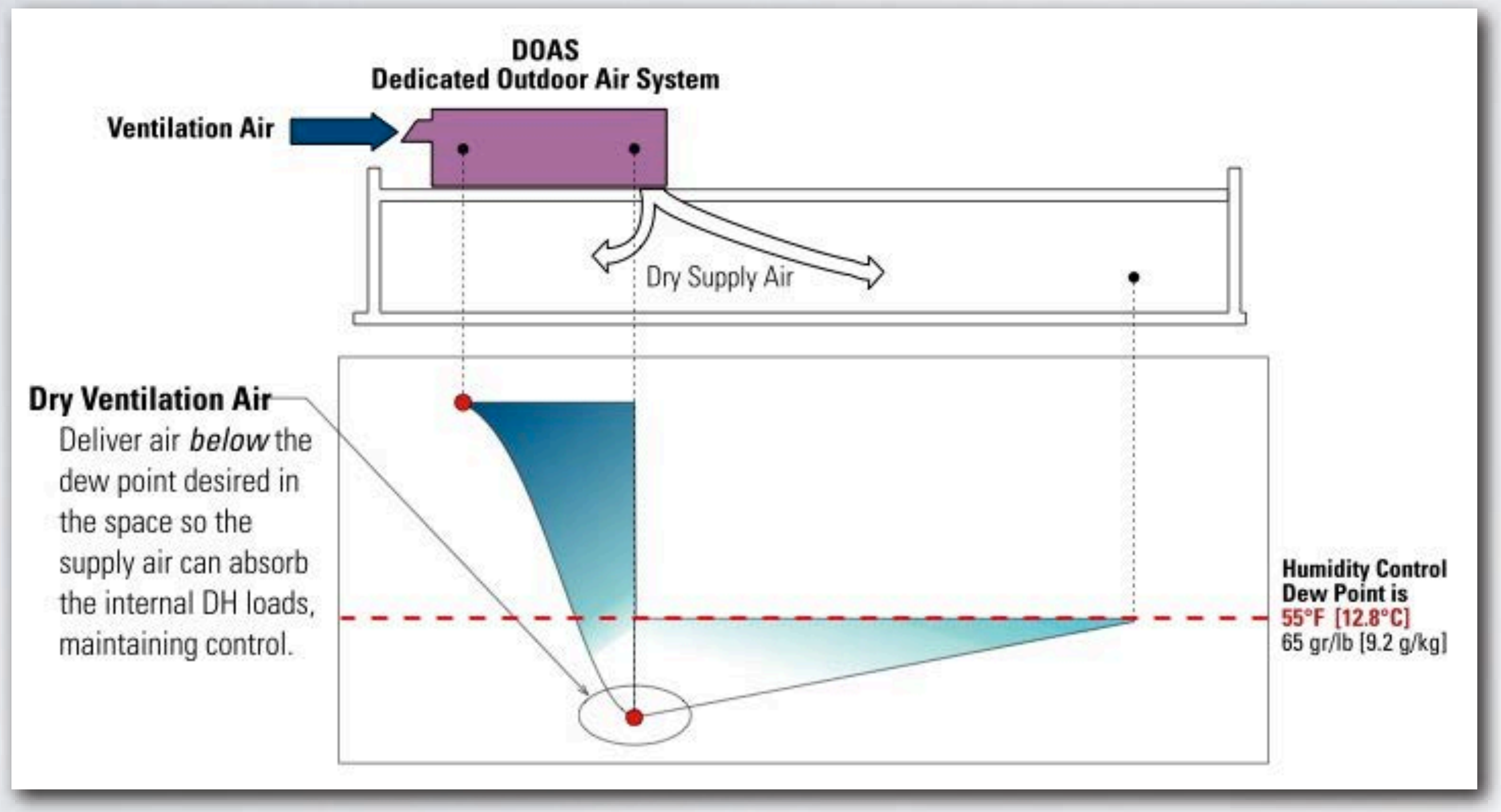



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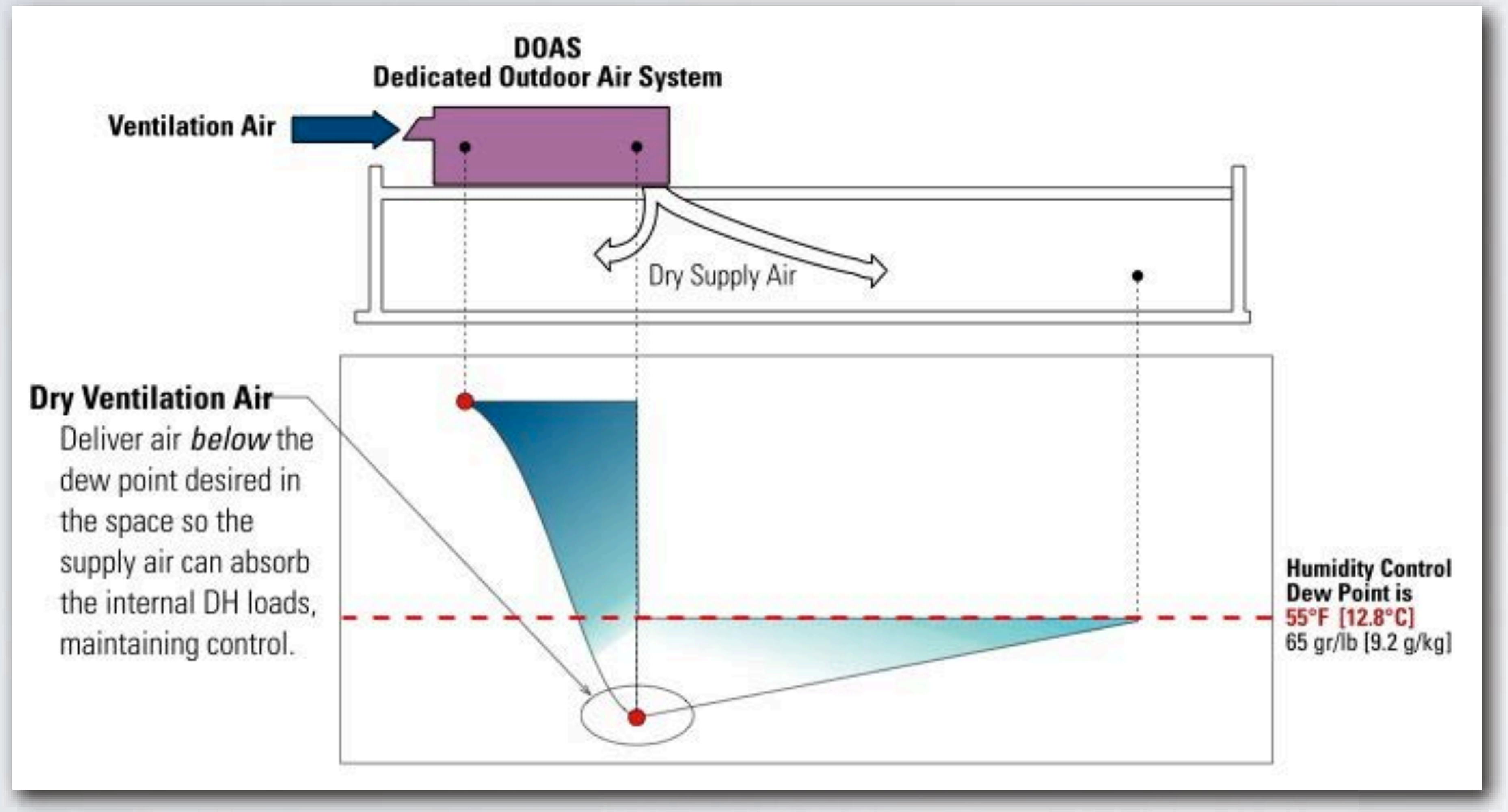

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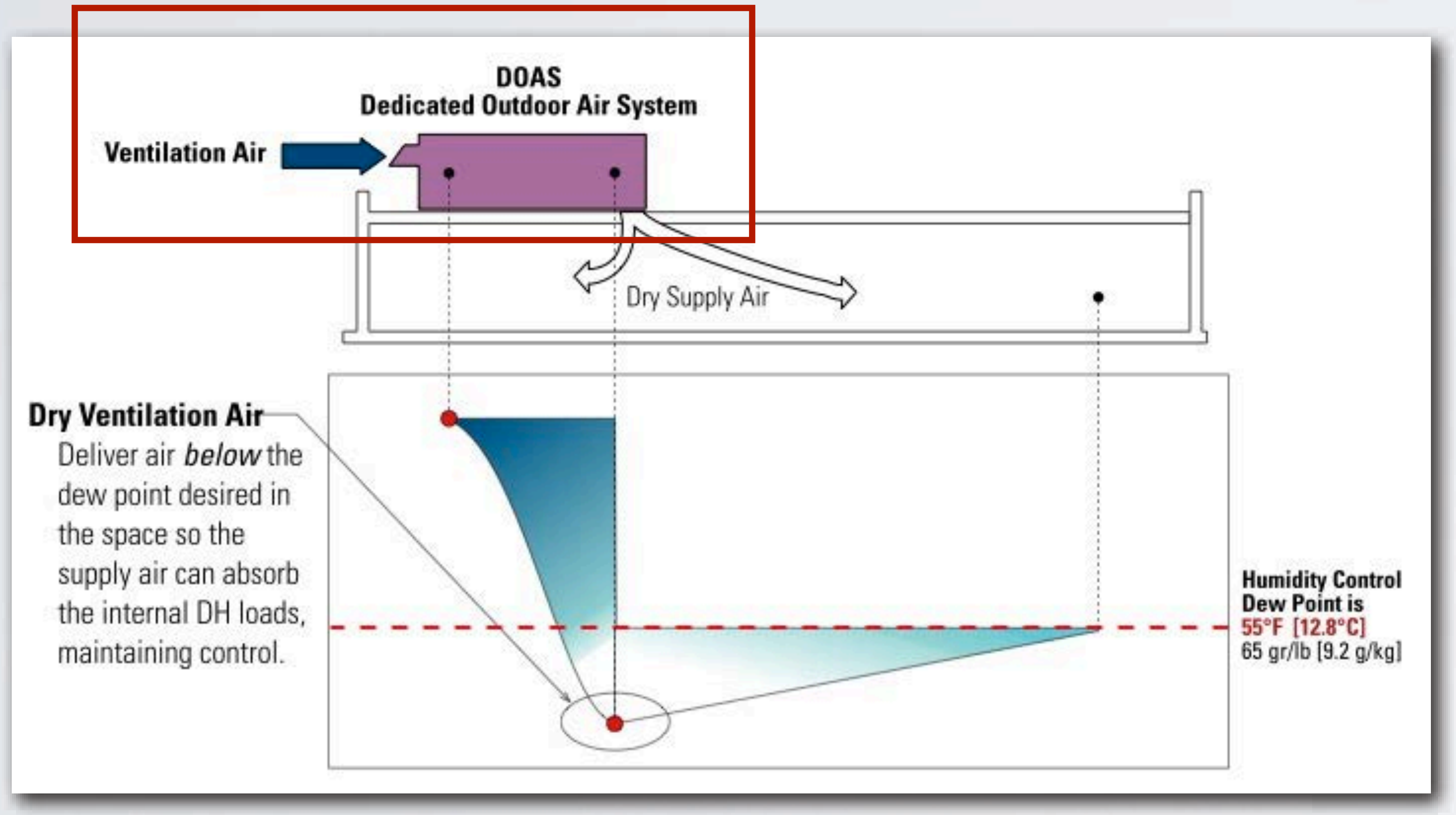

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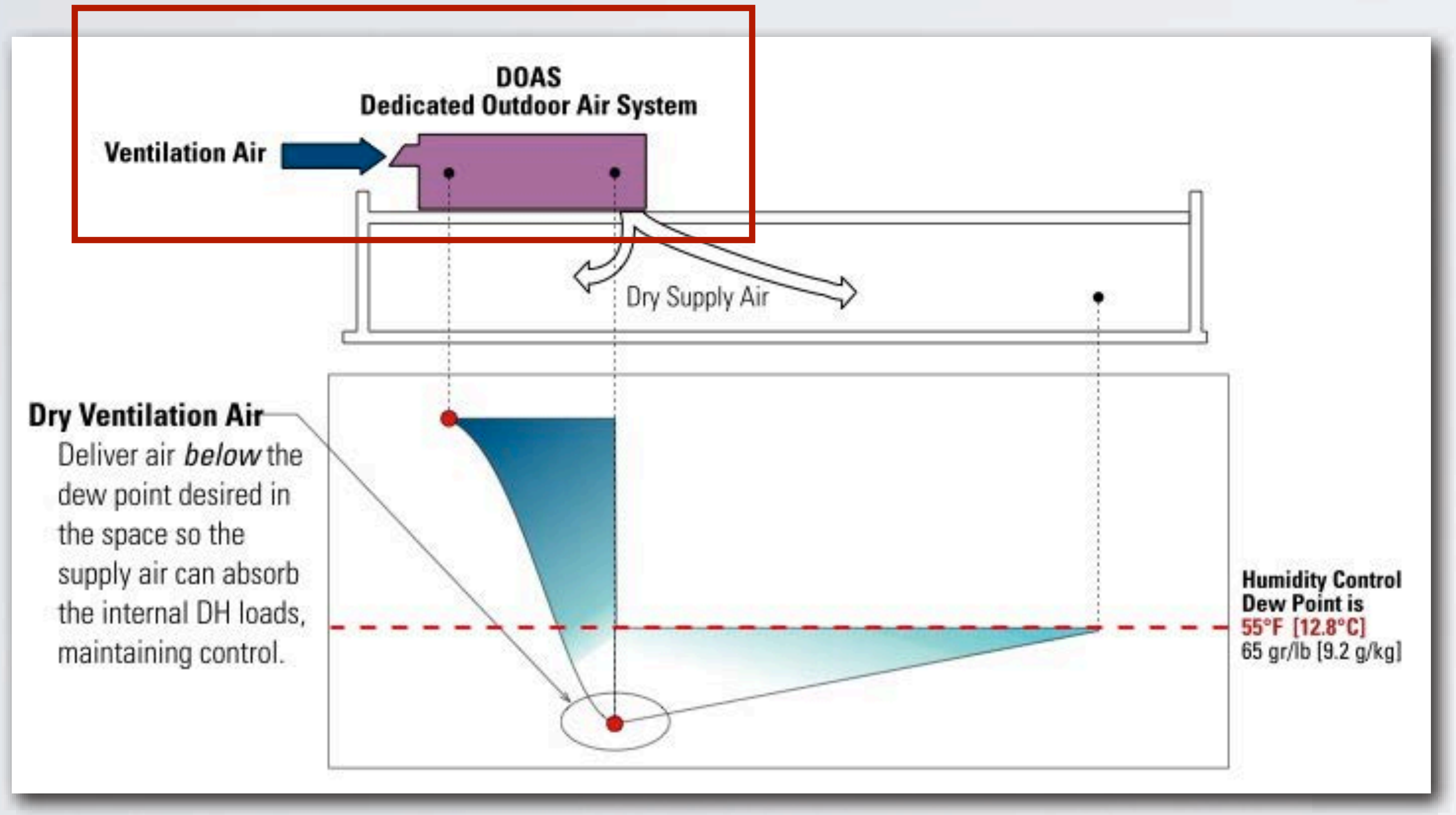


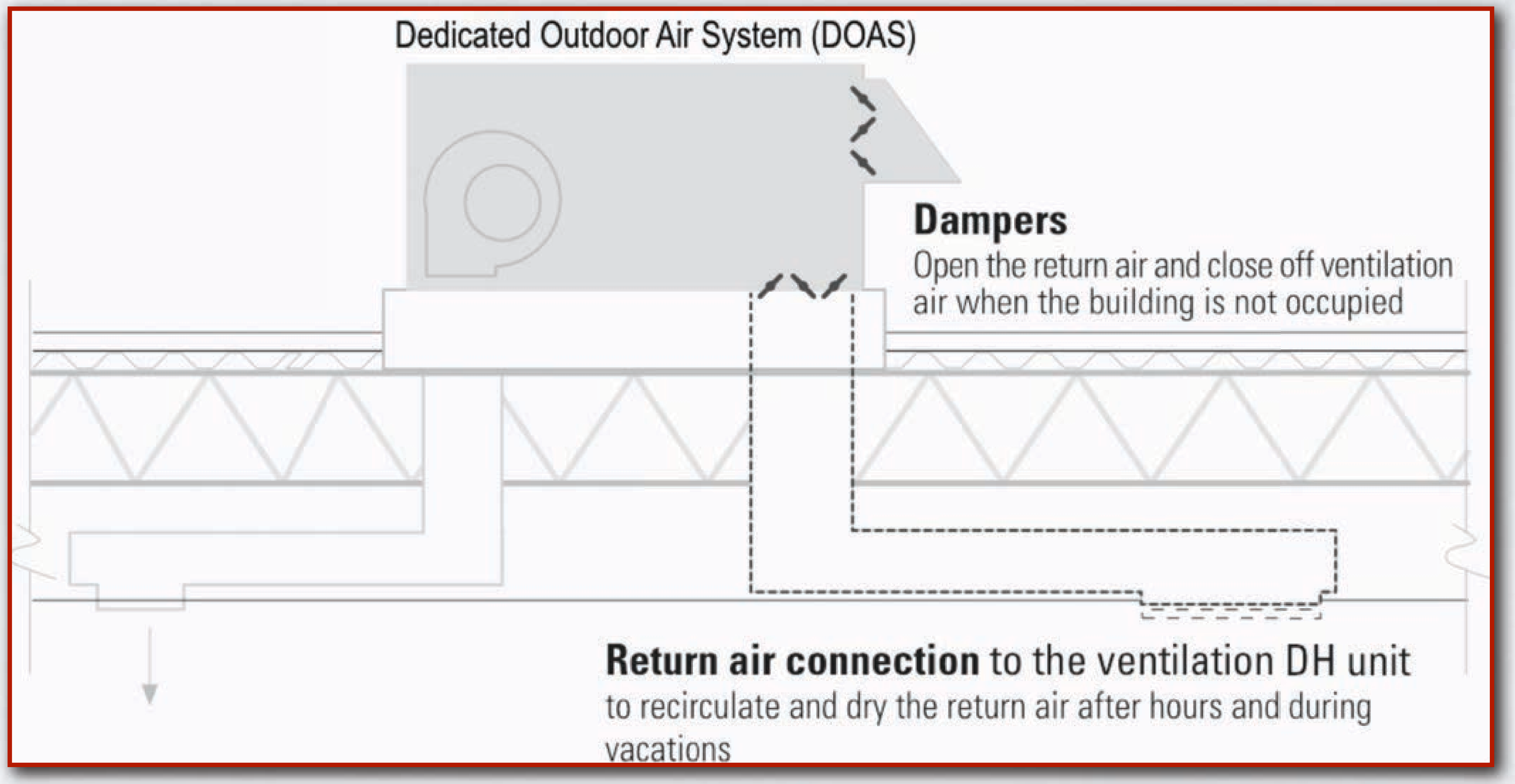

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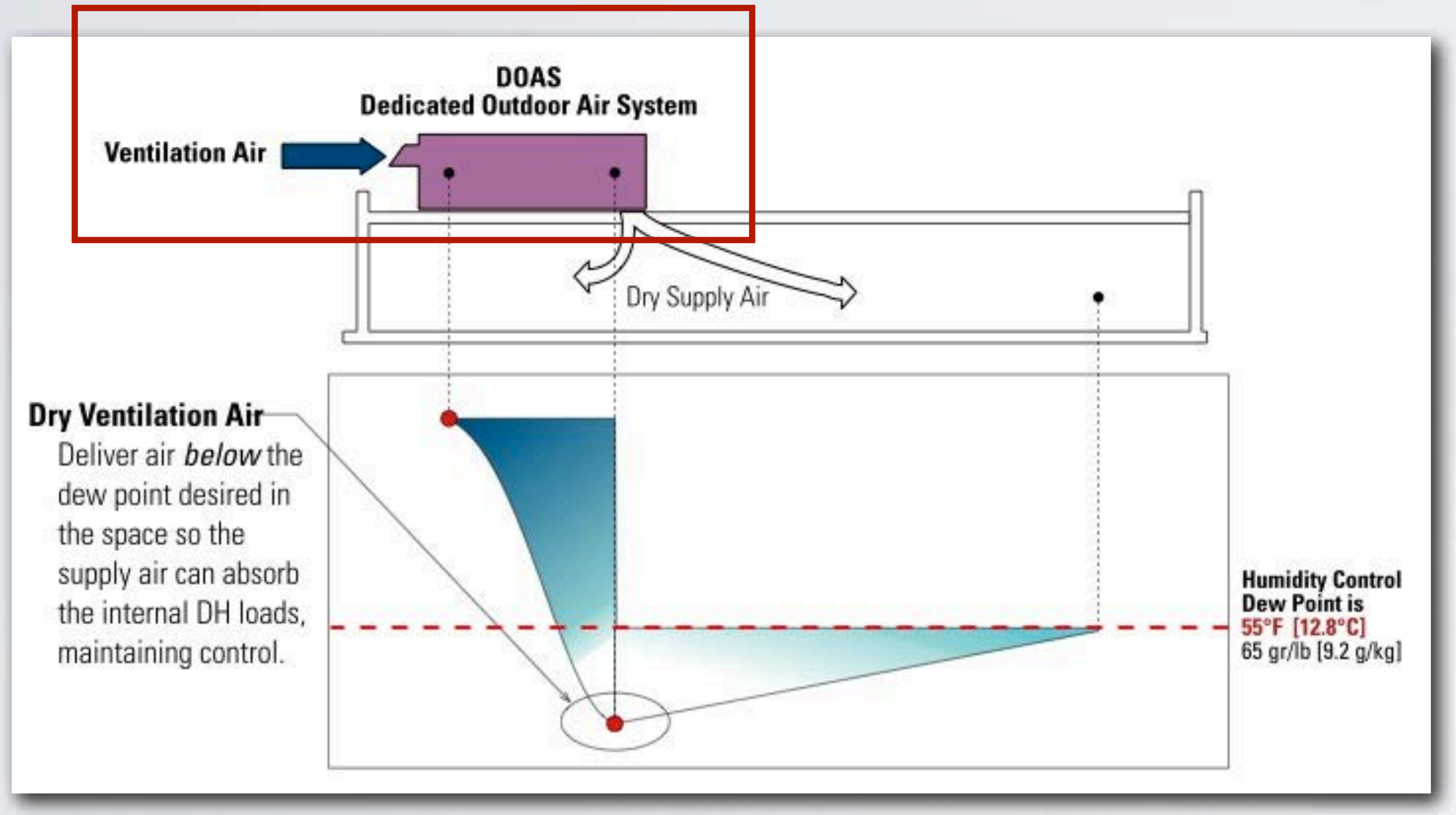


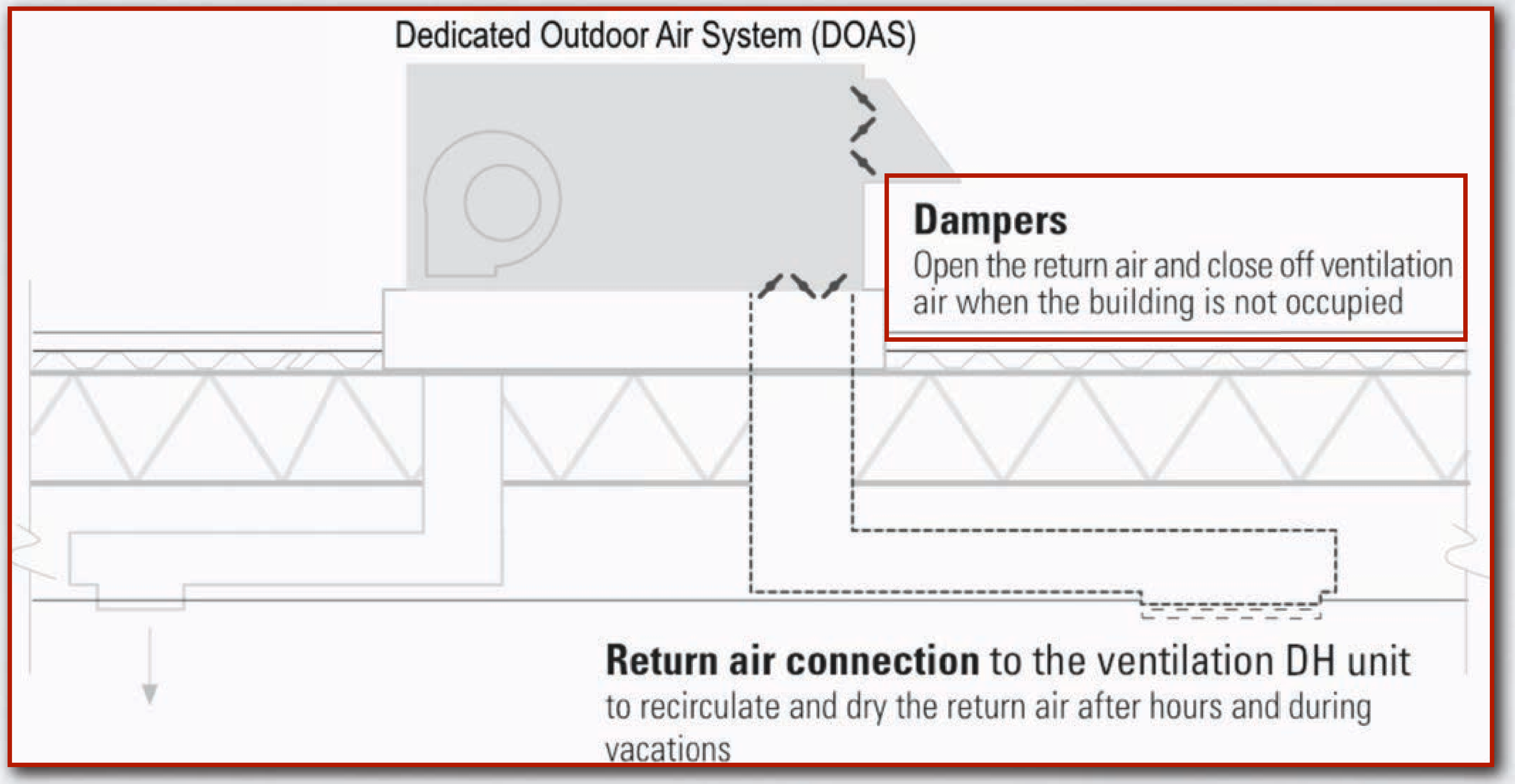

# Residential ventilation and dehumidification **(Andy Åsk)**

**Separate** equipment and controls for Cooling, Ventilation and Dehumidification

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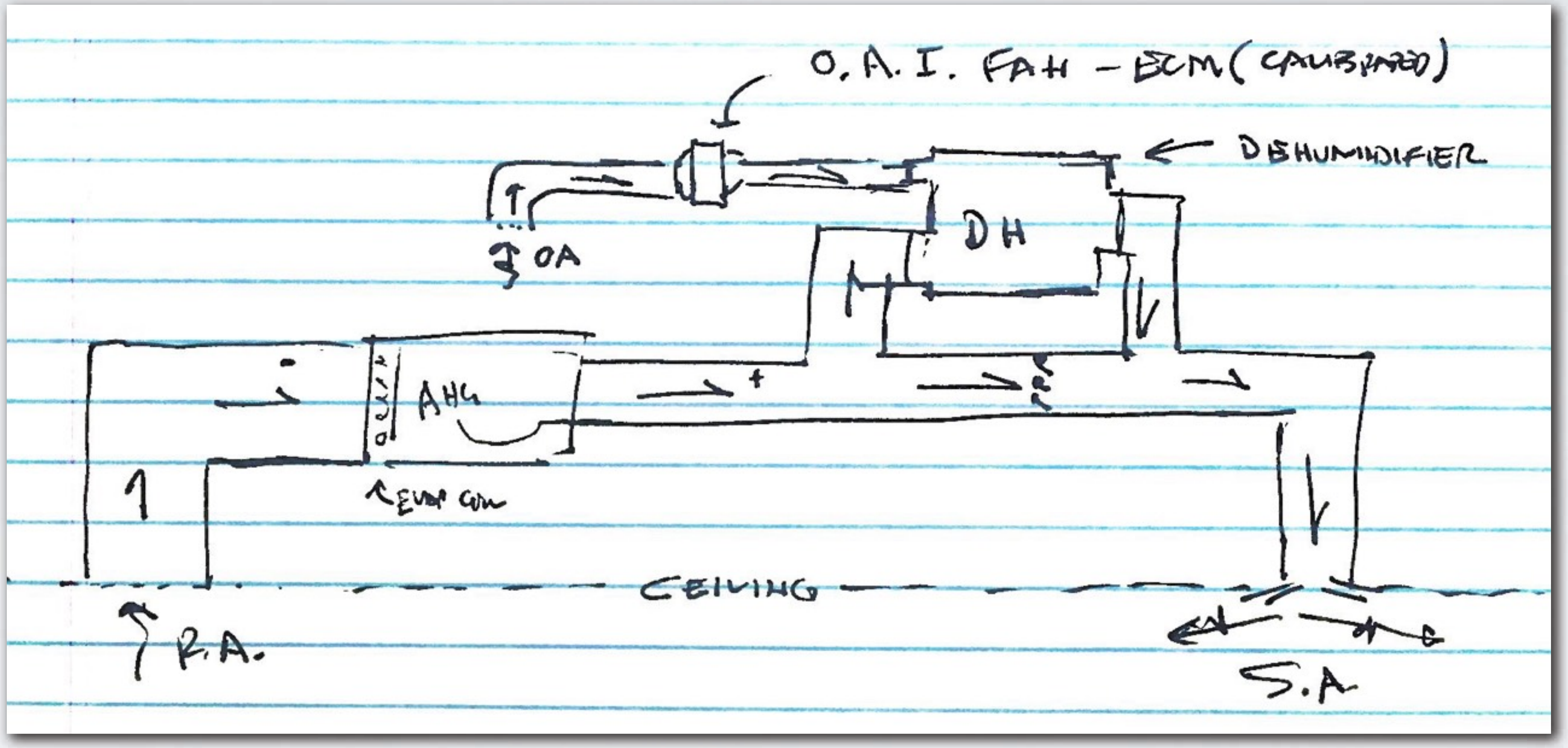

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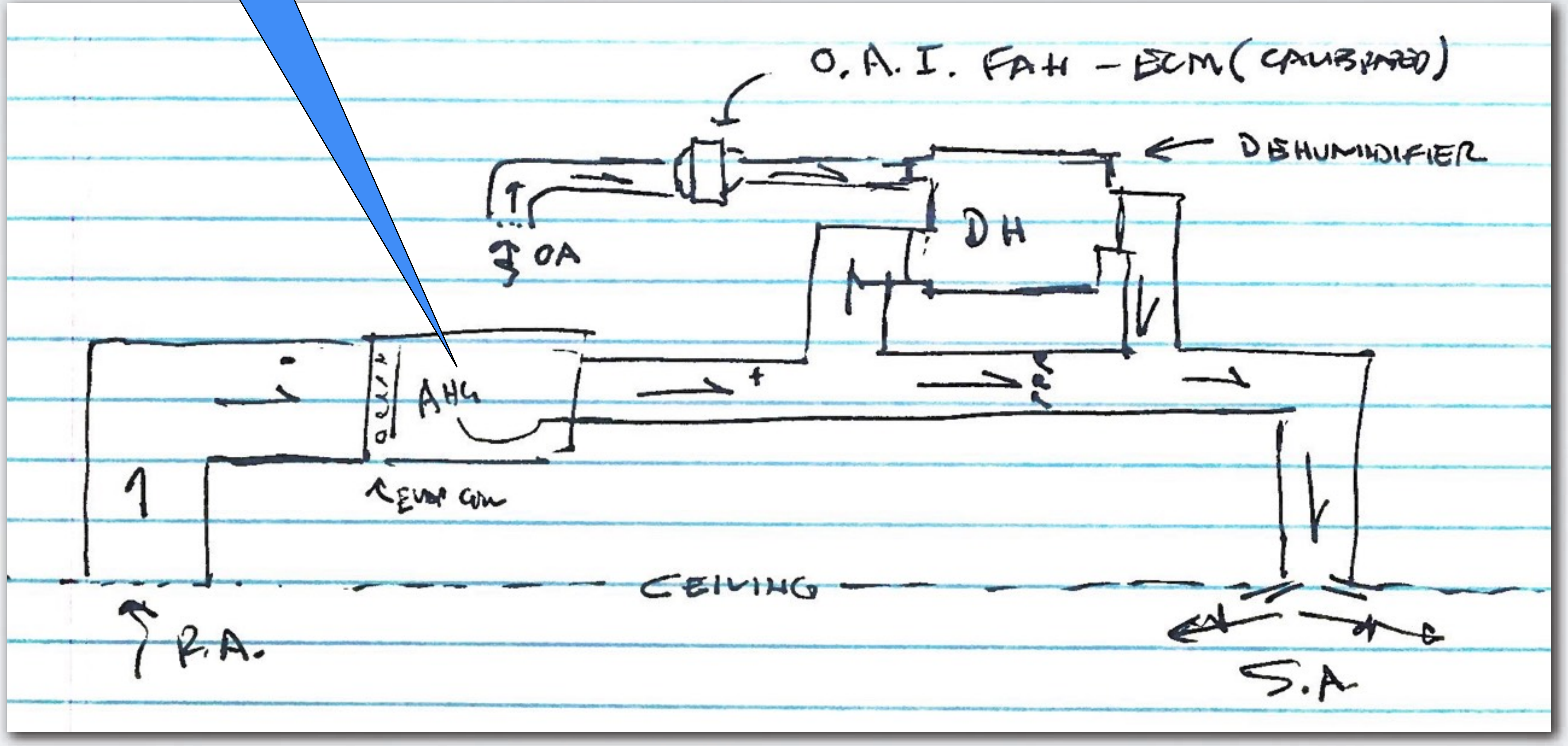
**AC for cooling (Thermostat)**



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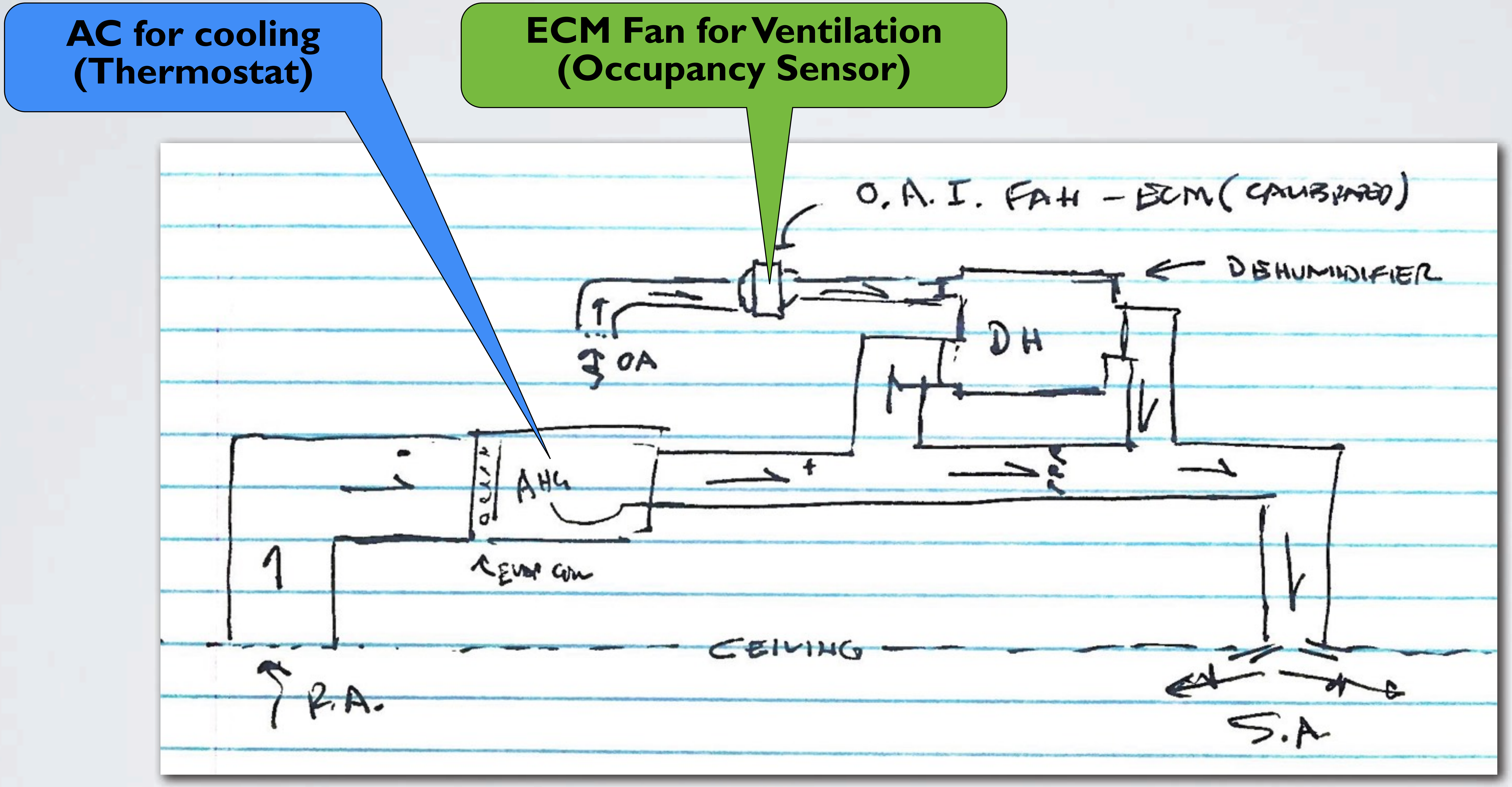

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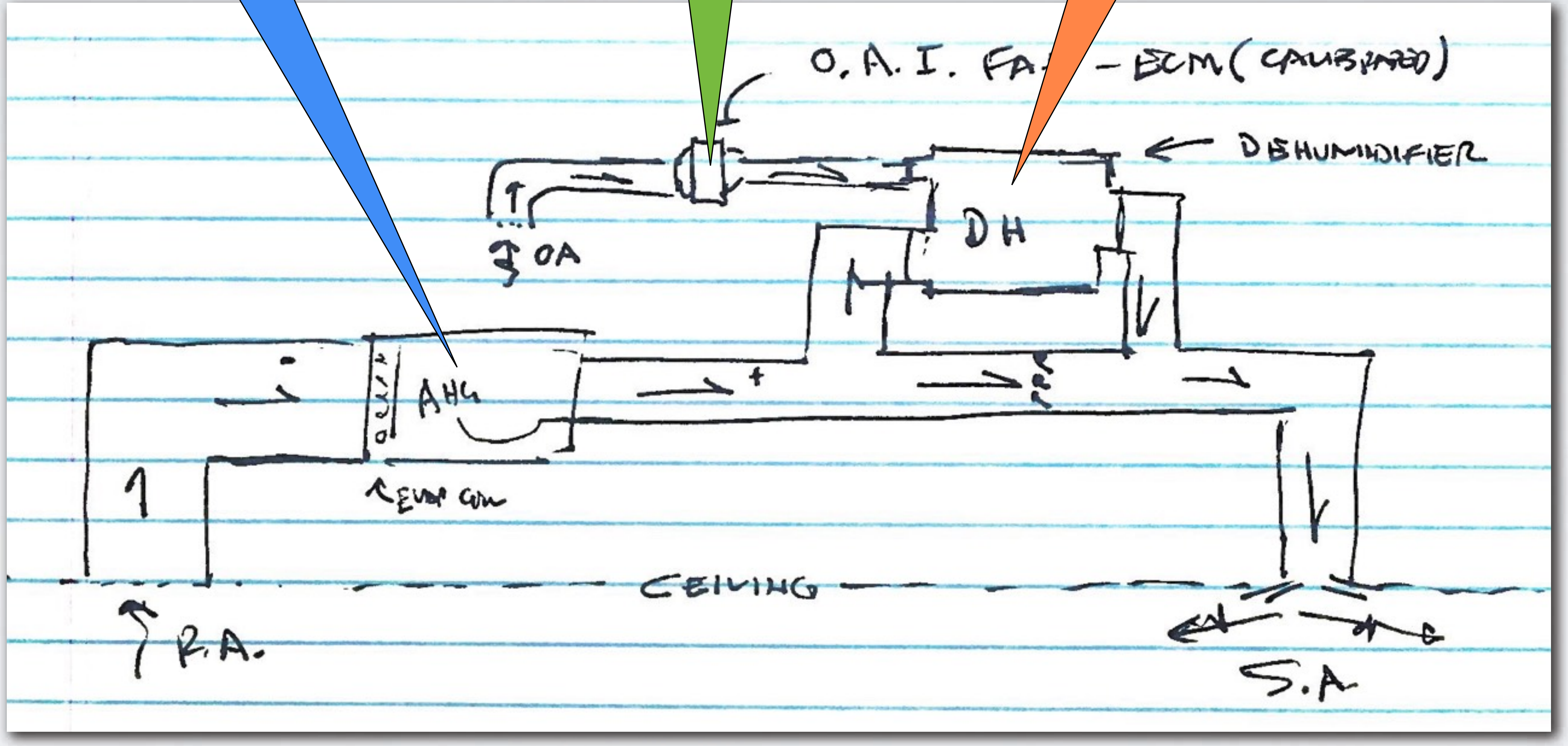
**Separate** equipment and controls for Cooling, Ventilation and Dehumidification

**AC for cooling (Thermostat)**

**ECM Fan for Ventilation (Occupancy Sensor)**

**Dehumidifier for Drying (Dehumidistat)**



SUMMARY…

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2. **Dry the ventilation air**, using ASHRAE peak dew point design data to size the ventilation dehumidifier.
3. **STOP ventilation + exhausts** when nobody's in the building.
4. **Keep unoccupied buildings DRY (not cool)** by recirculating and operating the ventilation dehumidifier.