Should You Consider the Impact of Moisture Storage in Building Materials?

ASHRAE Seminar 54 - Energy Efficient Design of Dedicated Outdoor Air Systems
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What is Moisture Storage?

or Moisture Capacitance

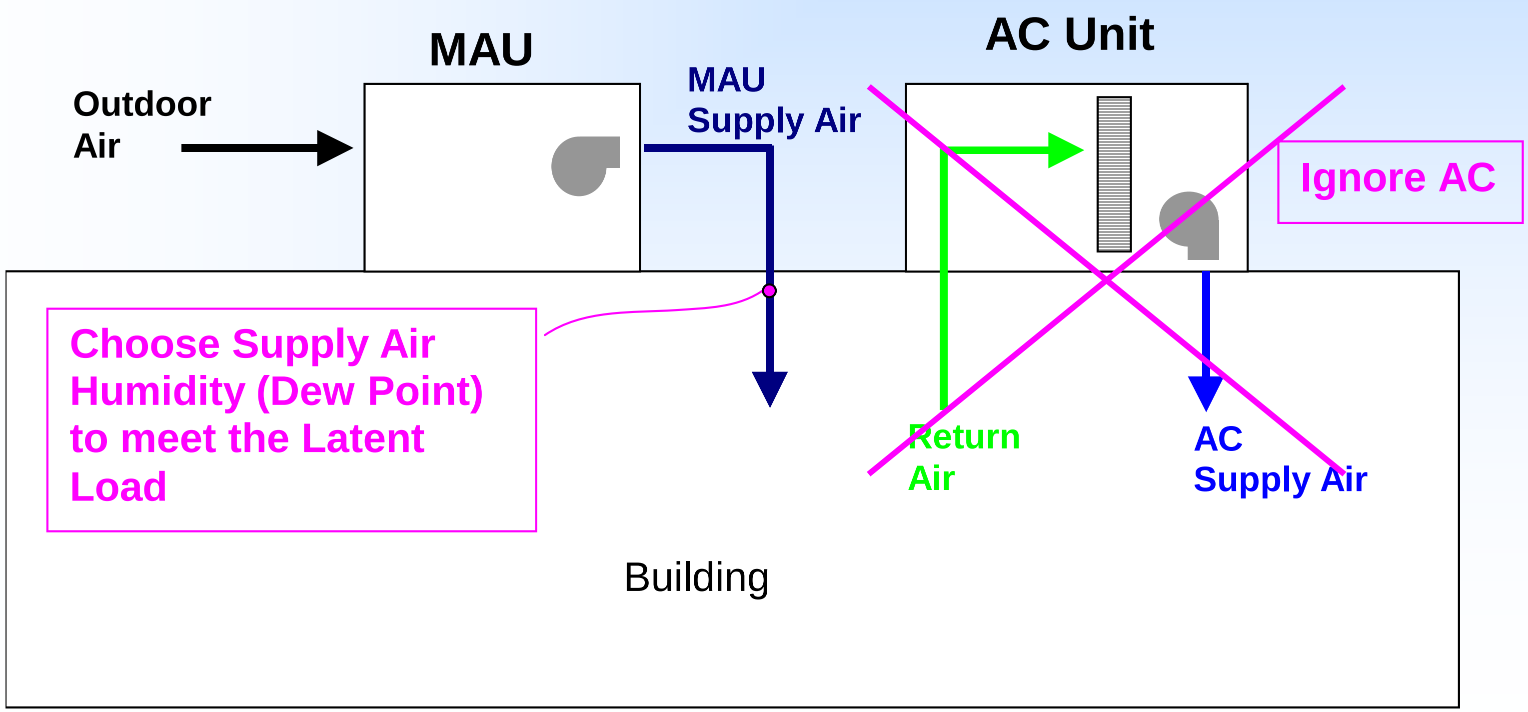
- Zone Air, Walls and Furnishings can hold moisture
  - Building materials adsorb moisture from the zone air
  - Moisture capacitance slows down changes in zone humidity
  - Analagous to thermal capacitance for cooling
- How does this Affect MAU Design?
  - Steady-state moisture load calculations tend to overpredict MAU size requirements
  - High Dew Pt conditions only last a few hours

MAU Design

(or Dedicated Outside Air System)

<u>Design Approach</u>:

- Precondition ventilation air separately
- Select supply air dew pt to maintain desired space humidity at “worst” conditions



Traditional Moisture Load Calculations

Moisture gains = Dehumidification Capacity

- Moisture gains: People & Infiltration
- DH Capacity: Dry supply air &
  AC capacity

Load Calculation Procedure

1. Specify the internal loads, ventilation rate and space humidity set point
2. Calculate required supply air humidity

Traditional Mass Balance

$$\overbrace{Q_{people} + \dot{m}_{\inf}(w_{outdoor} - w)}^{\text{Moisture Gains}} = \overbrace{Q_{AC} + \dot{m}_{vent}(w - w_{\sup ply})}^{\text{Dehumidification Capacity}}$$

With Moisture Capacitance

$$C_a \frac{dw}{dt} = \overbrace{\left[Q_{people} + \dot{m}_{\inf}(w_{outdoor} - w)\right]}^{\text{Moisture Gains}} - \overbrace{\left[Q_{AC} + \dot{m}_{vent}(w - w_{\sup ply})\right]}^{\text{Dehumidification Capacity}}$$

w = humidity ratio (lb/lb)	Q_{people} = generation rate (lb/h)
m = air flow rate (lb/h)	Q_{AC} = dehumidification rate (lb/h)

What Should Capacitance Factor Be?

$$C_a = [\rho \cdot V] \text{ x } N$$

- N is a multiplier times zone air mass
- Shirey at FSEC has used detailed building simulations to estimate the multiplier N
- Moisture storage is actually decoupled from air mass or node (phase lag)
- Typically **N=10-20** for most building applications

Steady-State Calculations

$$w = \frac{(Q_{people} + \dot{m}_{\inf} w_{outdoor} - Q_{AC} + \dot{m}_{vent} w_{\sup ply})}{(\dot{m}_{\inf} + \dot{m}_{vent})}$$

Transient Calculations

$$w^{j+1} = w^{j} + \frac{\Delta t}{C_a}\left[Q_{people} + \dot{m}_{\inf}(w^{j}_{outdoor} - w^{j}) - \dot{m}_{vent}(w^{j} - w_{\sup ply})\right]$$

w = humidity ratio (lb/lb)	Q_{people} = generation rate (lb/h)
m = air flow rate (lb/h)	Q_{AC} = dehumidification rate (lb/h)

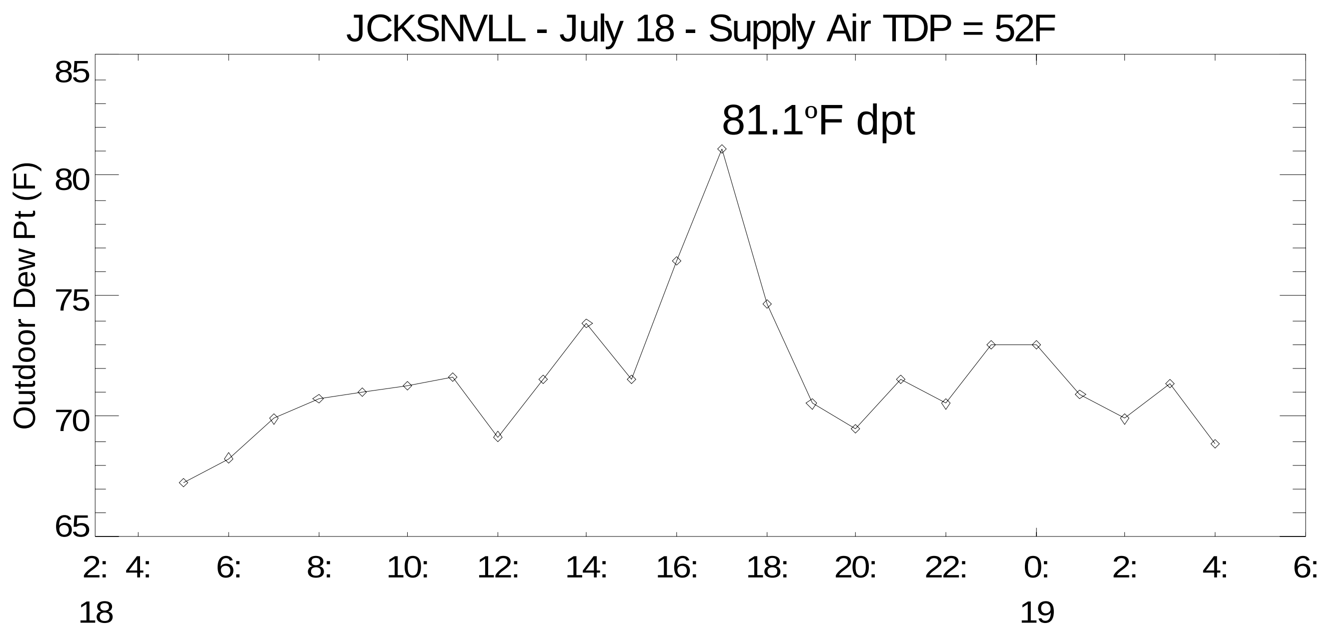
Jacksonville

<u>Classroom:</u>

1,500 sq ft, 0.1 ACH

30 people 15 cfm/p

MAU: 450 cfm
52ºF dpt

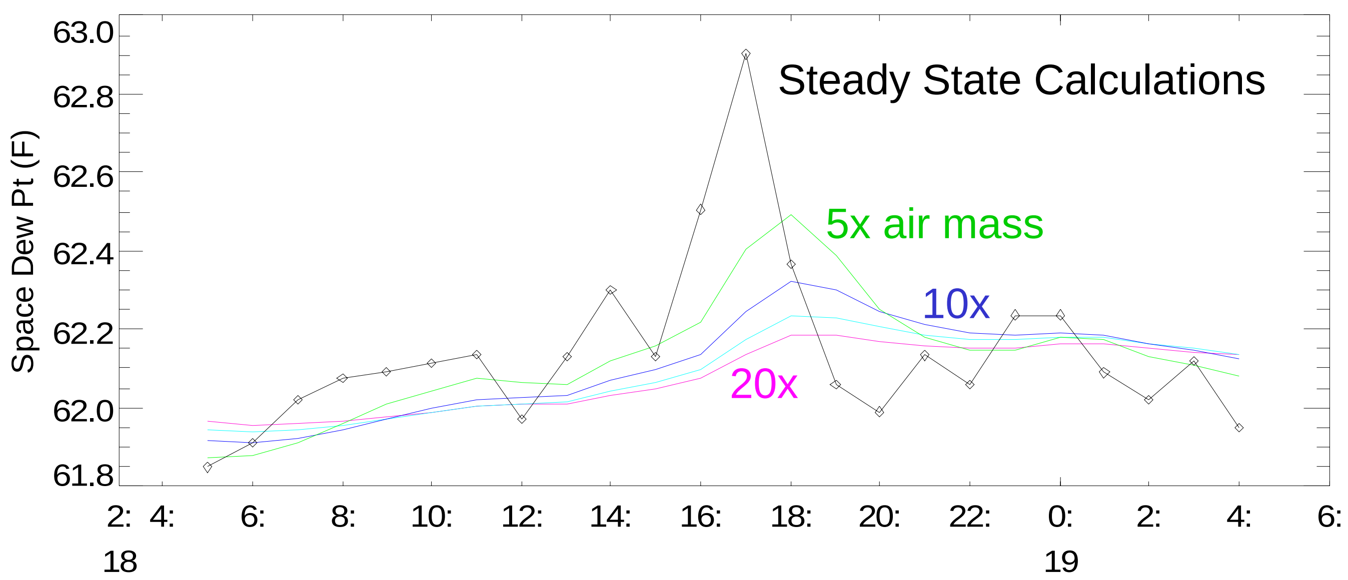


<u>Space Dew Pt:</u>

62.9ºF – SS calcs

<u>62.2ºF</u> – 20x air mass

0.7ºF – “error”



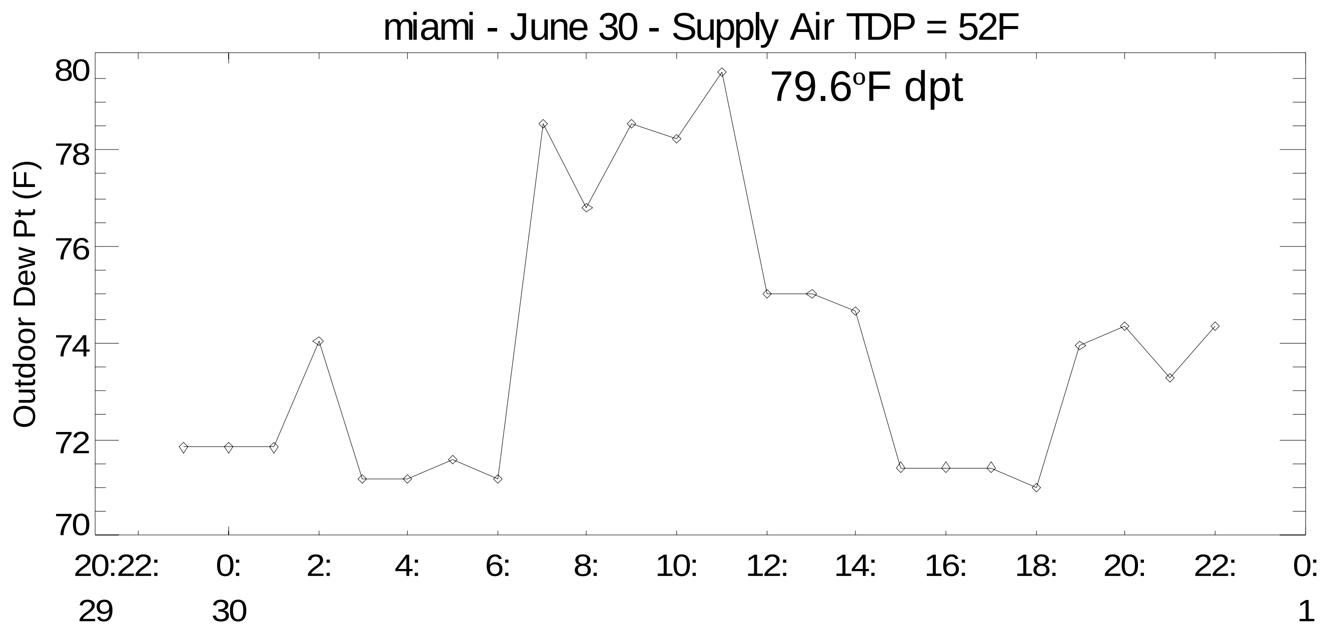
Miami

Classroom:

1,500 sq ft, 0.1 ACH

30 people 15 cfm/p

MAU: 450 cfm
52ºF dpt

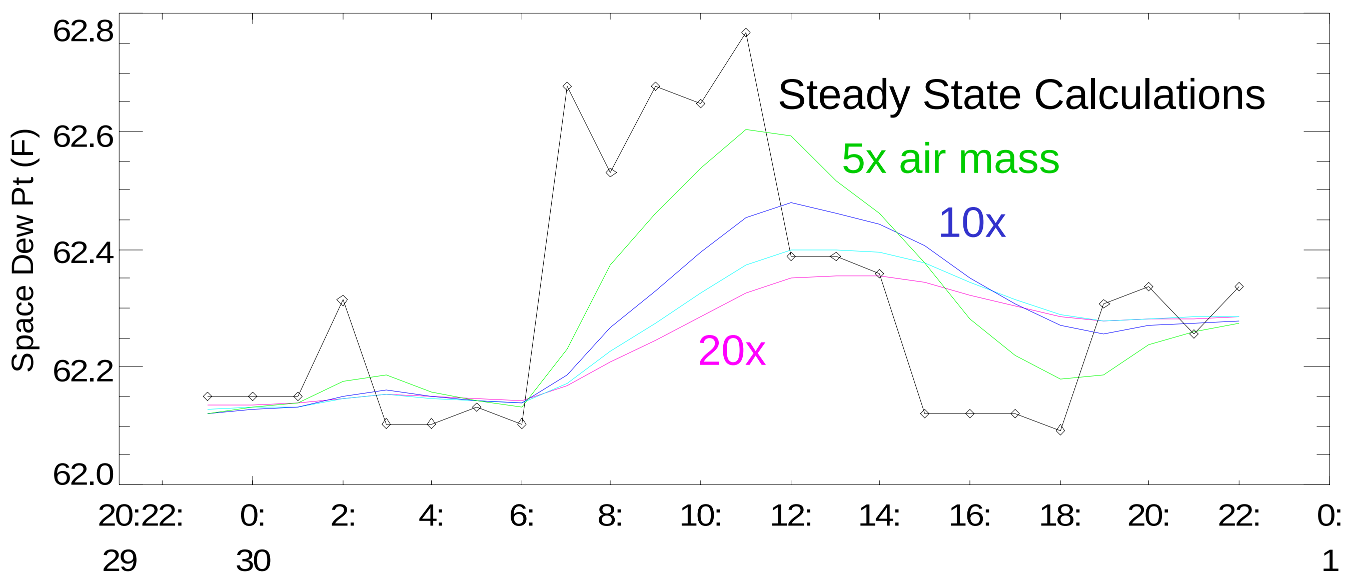


Space Dew Pt:

62.8ºF – SS calcs

62.4ºF – 20x air mass

0.4ºF – "error"



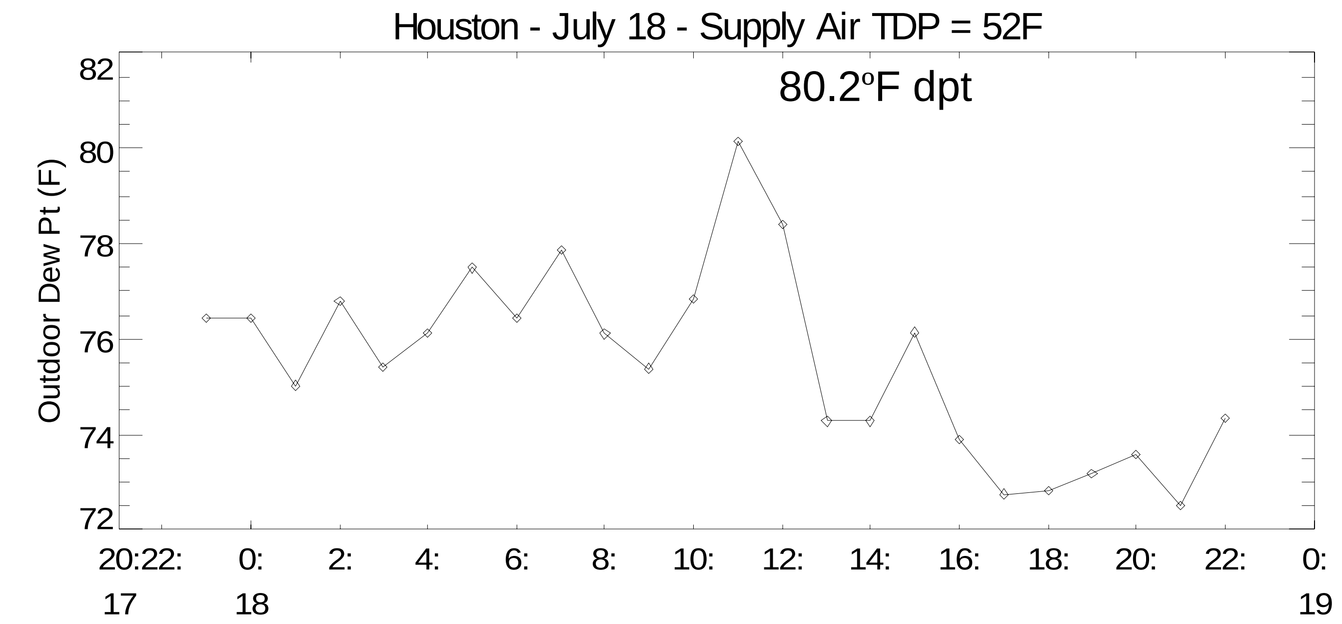
Houston

Classroom:

1,500 sq ft, 0.1 ACH

30 people 15 cfm/p

MAU: 450 cfm
52ºF dpt

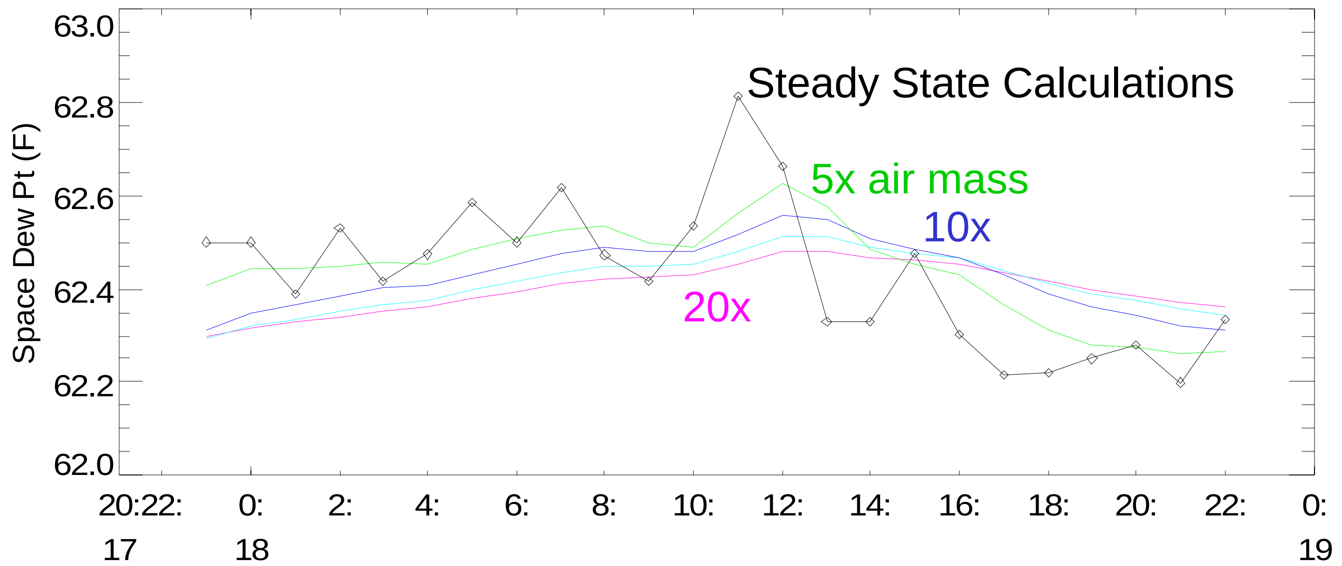


Space Dew Pt:

62.8ºF – SS calcs

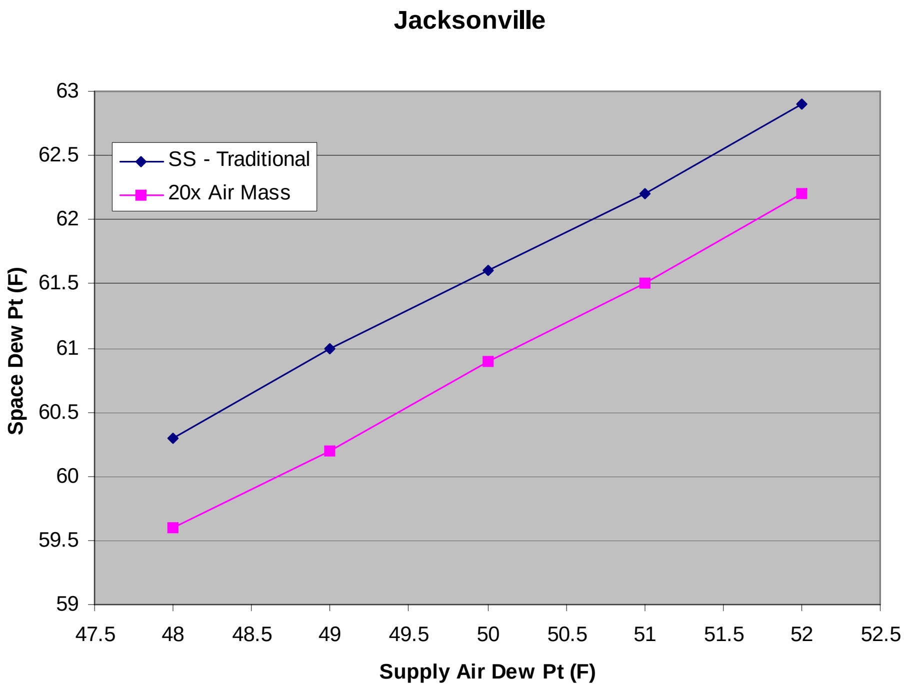
62.5ºF – 20x air mass

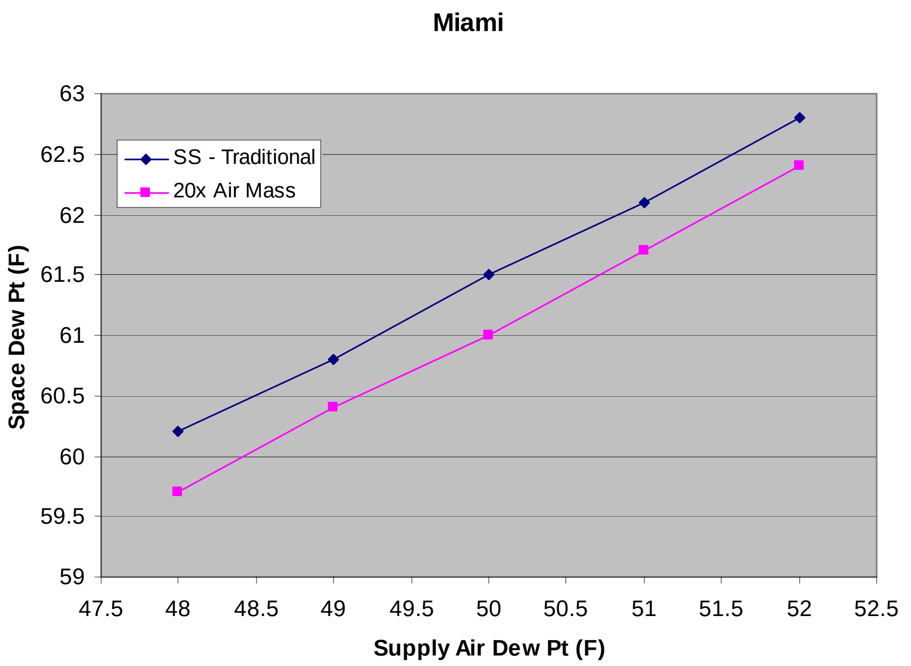
0.3ºF – “error”



Impact of Moisture Capacitance

- Predicts lower space dew point by 0.3-0.7ºF
- About the same impact as increasing supply air dew point by 1ºF
- But even more impact in other building applications!





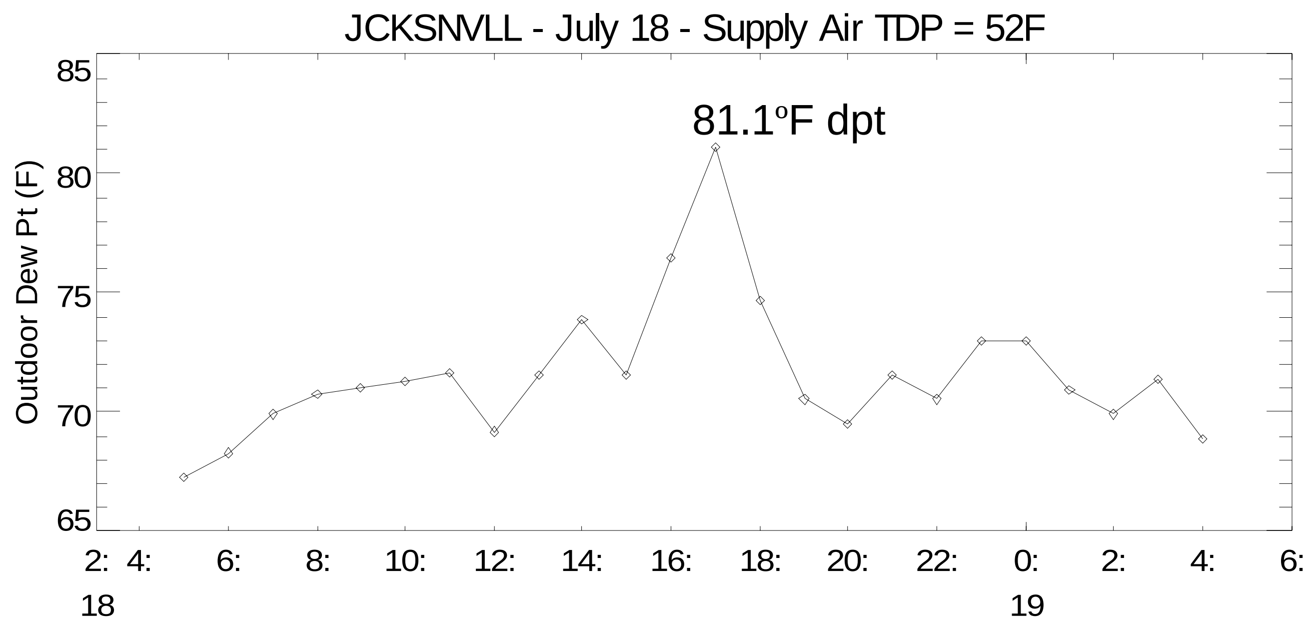
Jacksonville

Office:

1,500 sq ft, 0.1 ACH

10 people 15 cfm/p

MAU: **150 cfm**
52ºF dpt

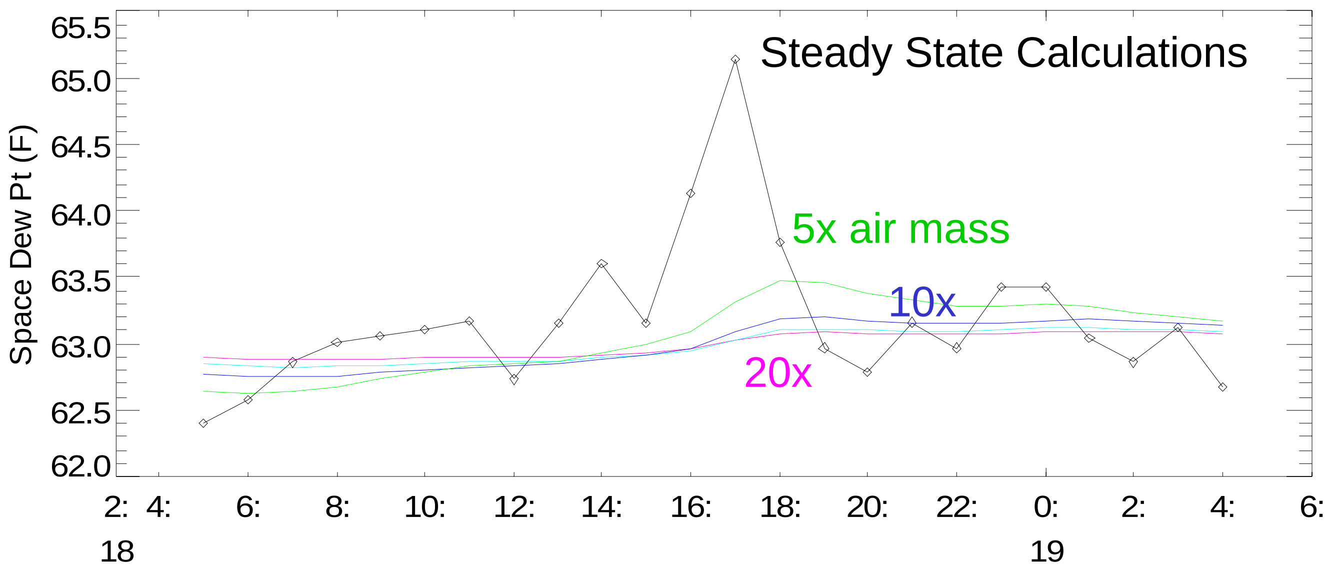


Space Dew Pt:

65.1ºF – SS calcs

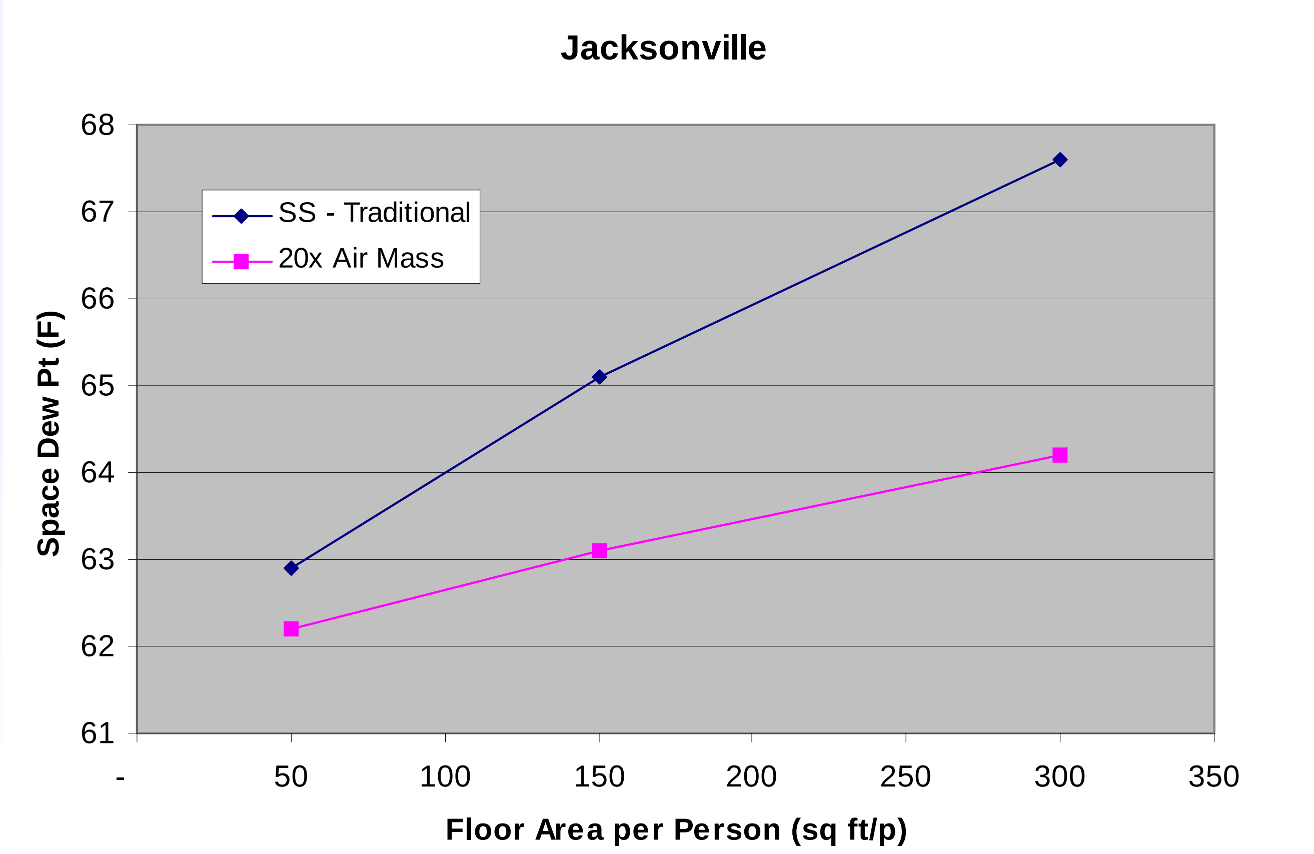
63.1ºF – 20x air mass

3.0ºF – “error”



Moisture Capacitance Matters More in "Low Occupant Density" Applications

- The "Over-prediction" with Steady State Calculations can exceed 3ºF



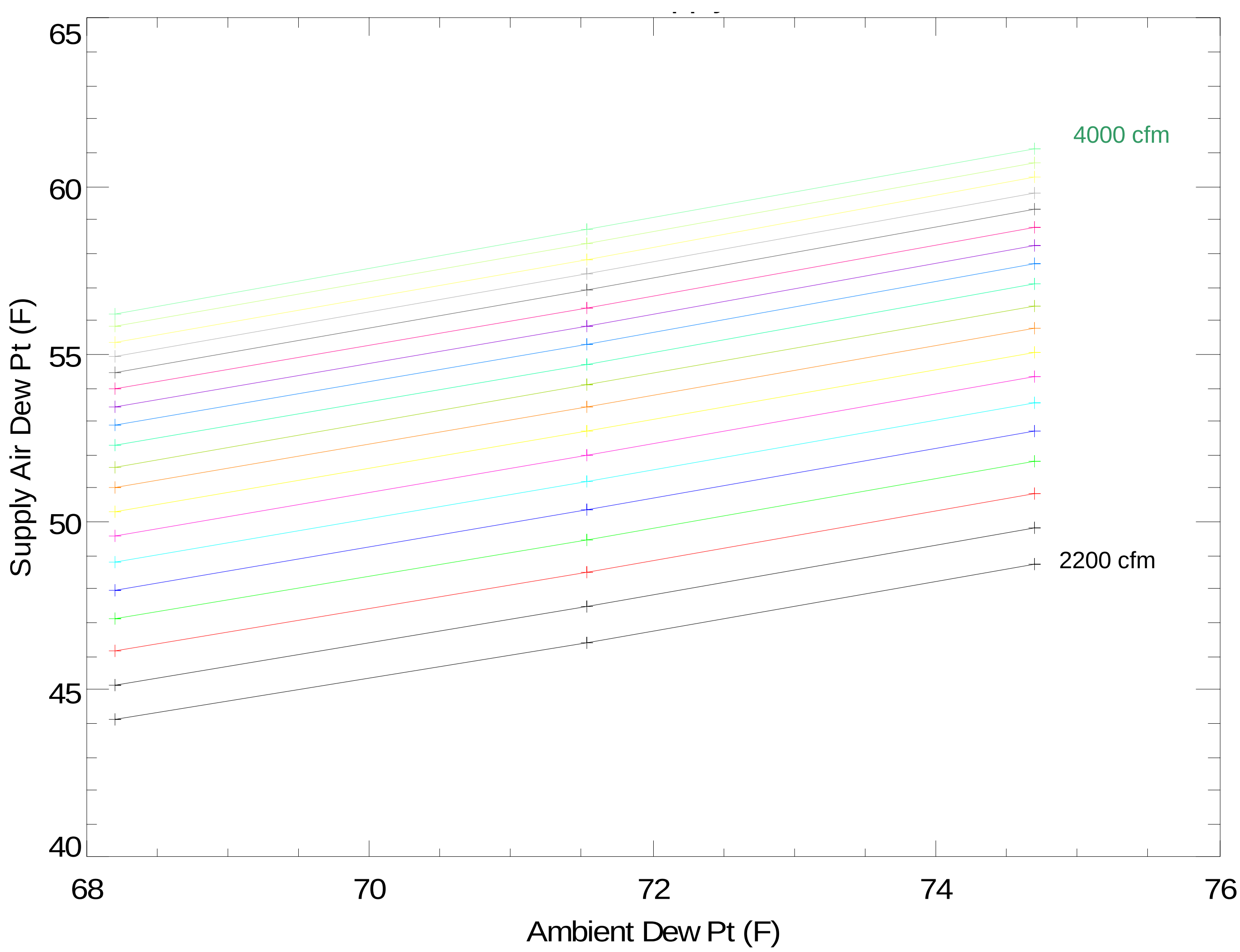
Why Does This Matter?

- Steady-State moisture load calculations over-predict the necessary supply air dew pt
- It takes a “larger” MAU to provide lower supply air dew pt for a given airflow

- Everyone knows that you <u>can’t do simple steady state calculations for sensible cooling loads</u> …
- So why do we do it for moisture?

MAU Catalog Data

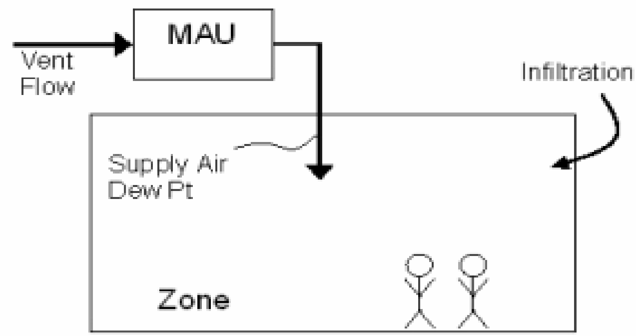
- Nominal 4000 cfm MAU (at 61F dpt)
- Only provides 2200 cfm at 49F dpt



Web Tool Available

Make-Up Air Unit Moisture Loads Tool

This tool demonstrates the effects of moisture capacitance on the latent sizing calculations for a makeup air unit (MAU). For peak humidity periods, the latent load in the space can be much larger than the dehumidification capacity but reasonable space conditions can still be maintained. The reason is moisture capacitance. The moisture capacitance is estimated by taking the space volume and multiplying by the moisture capacitance factor (typical values range from 1 to 20). By selecting different inputs below, the effects of moisture capacitance on space humidity levels can be demonstrated.



Select Parameters

Background Infiltration Rate (Air Changes per Hour) [ ]

Occupant Activity Level: [Seated at Rest (140 Btu/h Latent)]

Number of Occupants [ ]

Volume of Space (cubic feet) [ ]

MAU Supply Air Dewpoint (deg F) [ ]

MAU Supply Air Flow Rate (cfm) [ ]

Select TMY2 Weather Data: [Albany, New York]

Moisture Capacitance Factor [ ] (Enter 0 for steady state calcs)

Select Occupancy Schedule (Check boxes for hours of operation)

Pre-defined Schedules: [12:00am - 12:00am] [6:00am - 6:00pm] [8:00am - 5:00pm] [Match Ventilation]

☐ 12:00 am - 1:00 am	☐ 1:00 am - 2:00 am	☐ 2:00 am - 3:00 am	☐ 3:00 am - 4:00 am
☐ 4:00 am - 5:00 am	☐ 5:00 am - 6:00 am	☐ 6:00 am - 7:00 am	☐ 7:00 am - 8:00 am
☐ 8:00 am - 9:00 am	☐ 9:00 am - 10:00 am	☐ 10:00 am - 11:00 am	☐ 11:00 am - 12:00 pm

Summary

- Traditional steady state moisture load calculations “over-predict” the required supply air dew point
  - predicted supply air dew point can be too low by 1-3ºF
  - error is larger in low occupancy buildings
- Providing 1-3ºF warmer supply air dew pt reduces MAU size and cost
- Web tool is available to illustrate the concept