

The DOAS Paradigm Shift

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The logo for Addison HVAC features the word "ADDISON" in a bold, dark green, sans-serif font. A white, curved swoosh underline is positioned beneath the text, starting under the 'A' and ending under the 'N'. A small registered trademark symbol (®) is located at the bottom right of the word.

ADDISON®

Background: The Evolution of Dedicated Outdoor Air Systems

A building's air conditioning load comes from a variety of sources

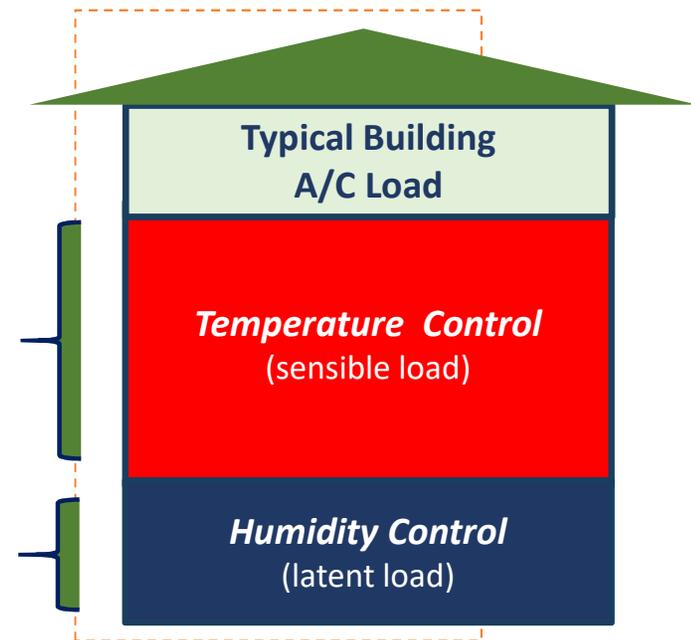
	SENSIBLE	LATENT
EXTERNAL	<ul style="list-style-type: none">• Ventilation (OA temperature differential)• Infiltration (OA temperature differential)• Heat conduction through envelope• Fenestration	<ul style="list-style-type: none">• Ventilation (OA humidity differential)• Infiltration (OA humidity differential)• Permeation
INTERNAL	<ul style="list-style-type: none">• Occupants (sensible heat gain)• Lights• Fans and other motors• Plug loads (electronics, appliances, etc.)	<ul style="list-style-type: none">• Occupants (respiration and perspiration)• Plants• Cooking• Washrooms, showers, etc.

Air conditioning must handle sensible and latent loads, including the contribution from ventilation air on both loads

Primary Sources

- Outside air ventilation
 - Occupants
 - Lighting & plug loads
- Solar gains & thermal conduction

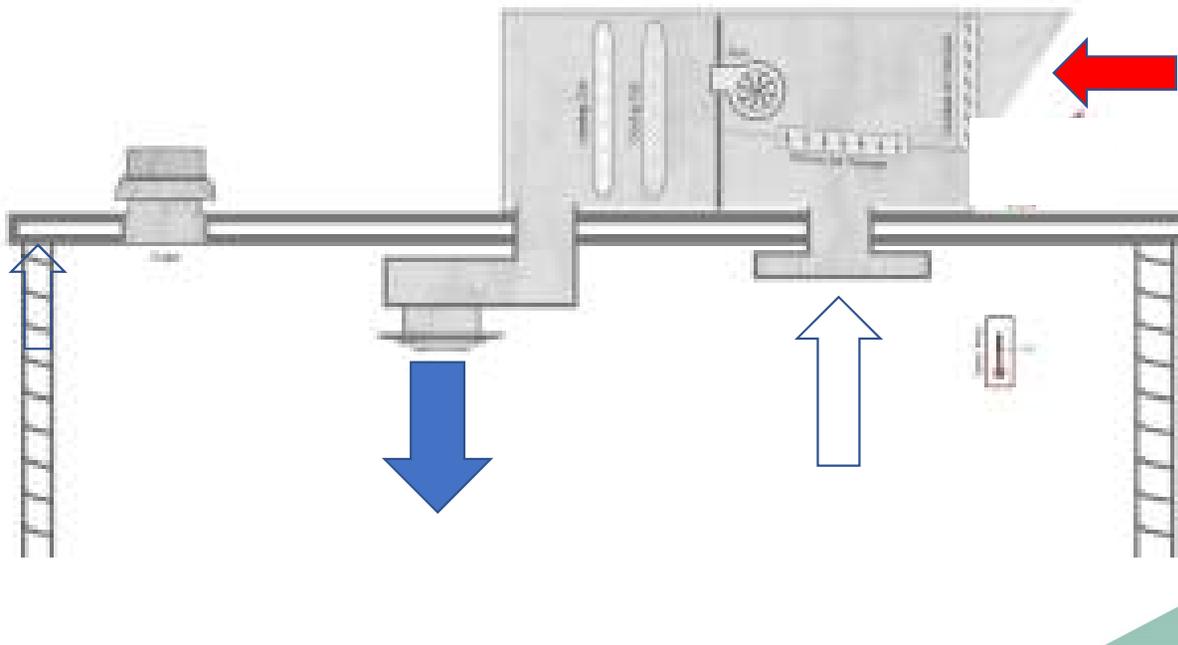
- Outside air ventilation
 - Occupants



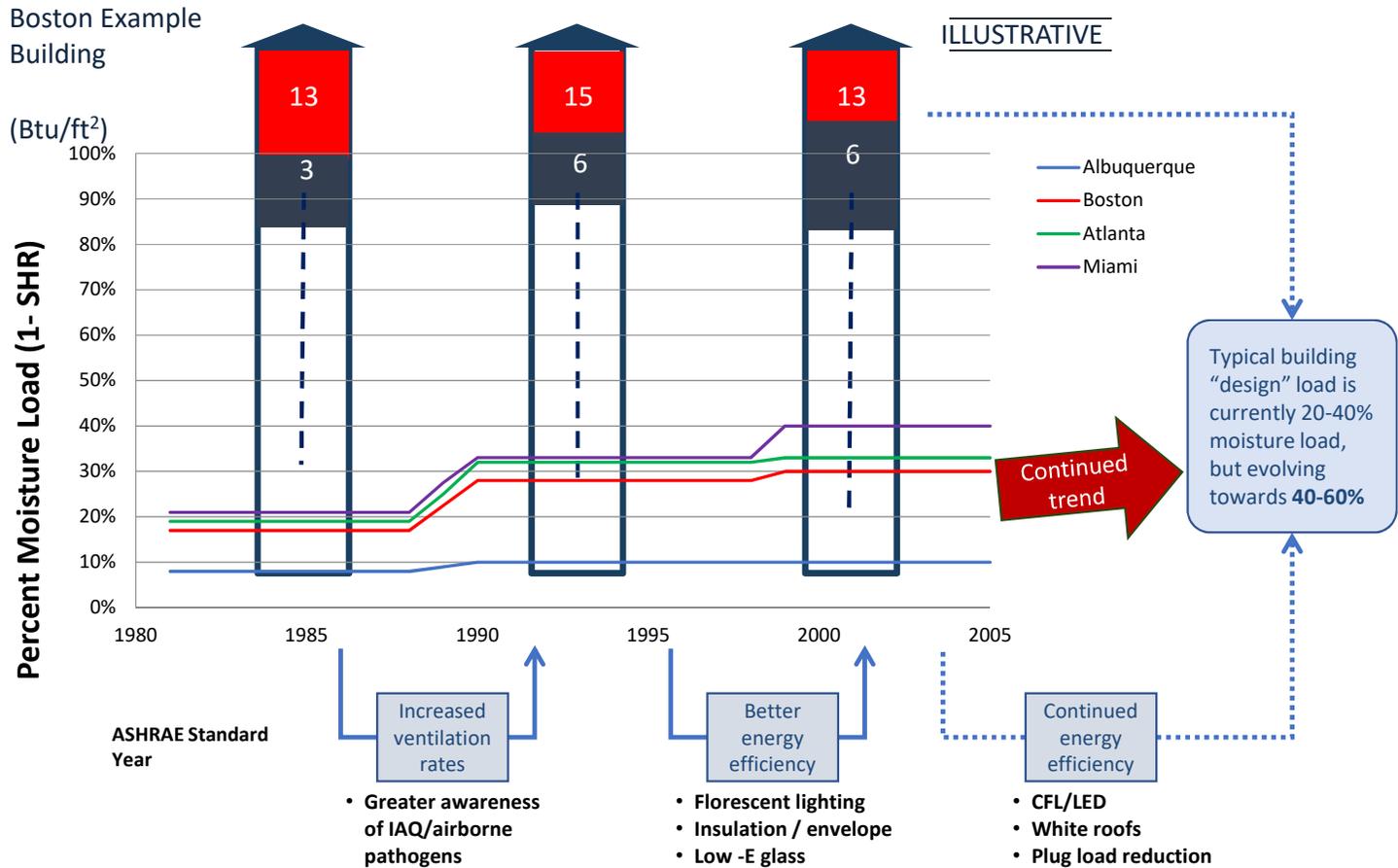
It's very difficult to control temperature and humidity with a single system and one set point (thermostat)

The old way to introduce outdoor air created humidity problems and wasted energy

- Requires constant supply fan operation during occupied hours to meet ventilation code
- Pumps humid air into the building whenever compressors cycle off
- Cannot control to both variable loads (internal and external)
- Terminal reheat is often added to avoid over-cooling the space
- The most common “fix” is closing the OA damper

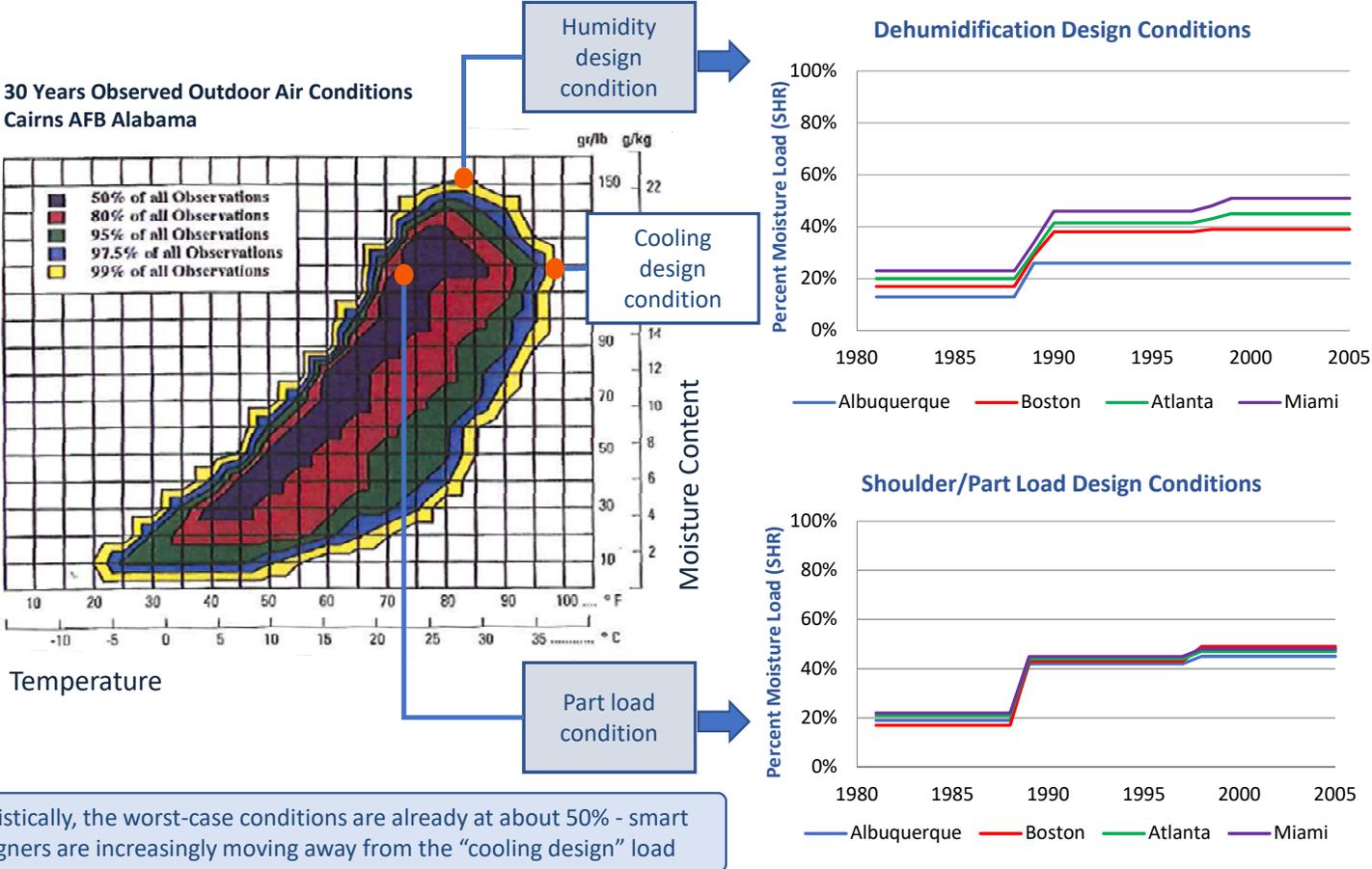


The fraction of moisture load in HVAC is substantially increasing in building design standards



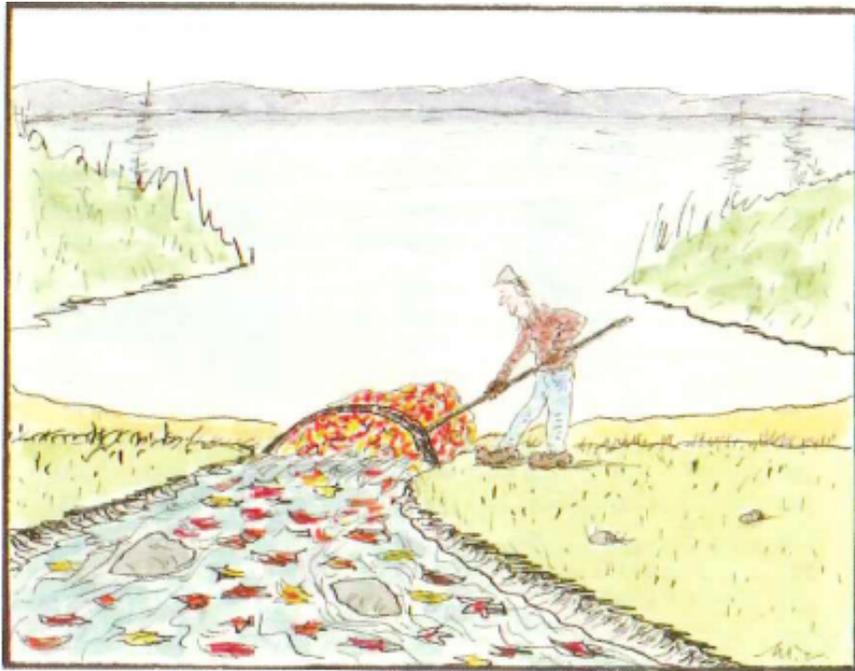
Source: TIAx

Traditional “design” conditions do not reflect the true challenge of moisture control in modern buildings

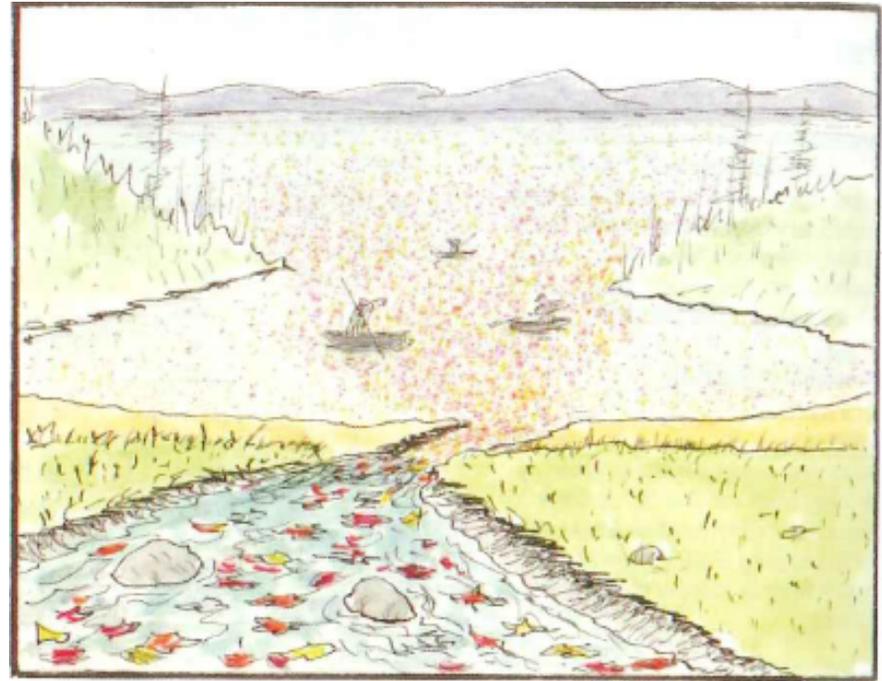


Source: TIAx

Best Practice - dry the air before it enters the building



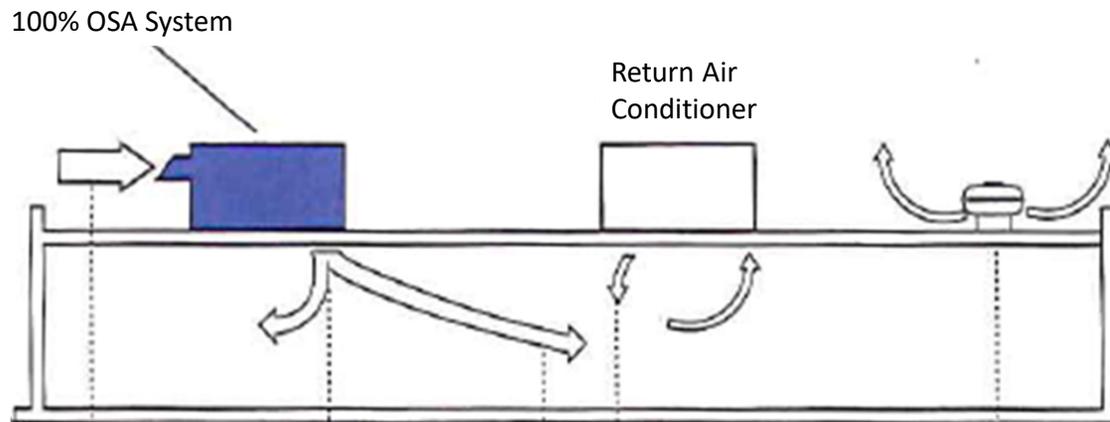
Collecting leaves at the source, before they mix into the lake.



It takes more people and more work to chase them all down and fish them out.

ASHRAE best practice design standards call for separate equipment to treat ventilation and/or latent loads

ASHRAE Handbook Ch. 6.7: Although most centralized and decentralized systems are very effective at handling the space sensible cooling and heating loads, they are less effective (or ineffective) at handling ventilation air or latent loads. As a result, outside air should be treated **separately**.



Dried outdoor air can provide all the dehumidification capacity the building requires.

Outdoor Air
Hot and humid, it must be cooled and dehumidified.

Dehumidified
Dries the incoming air to a condition below the desired space humidity set point

Dry Ventilation Air
Will remove the moisture loads generated inside the building.

Air Inside the Space
Is it at or below the desired humidity set point.

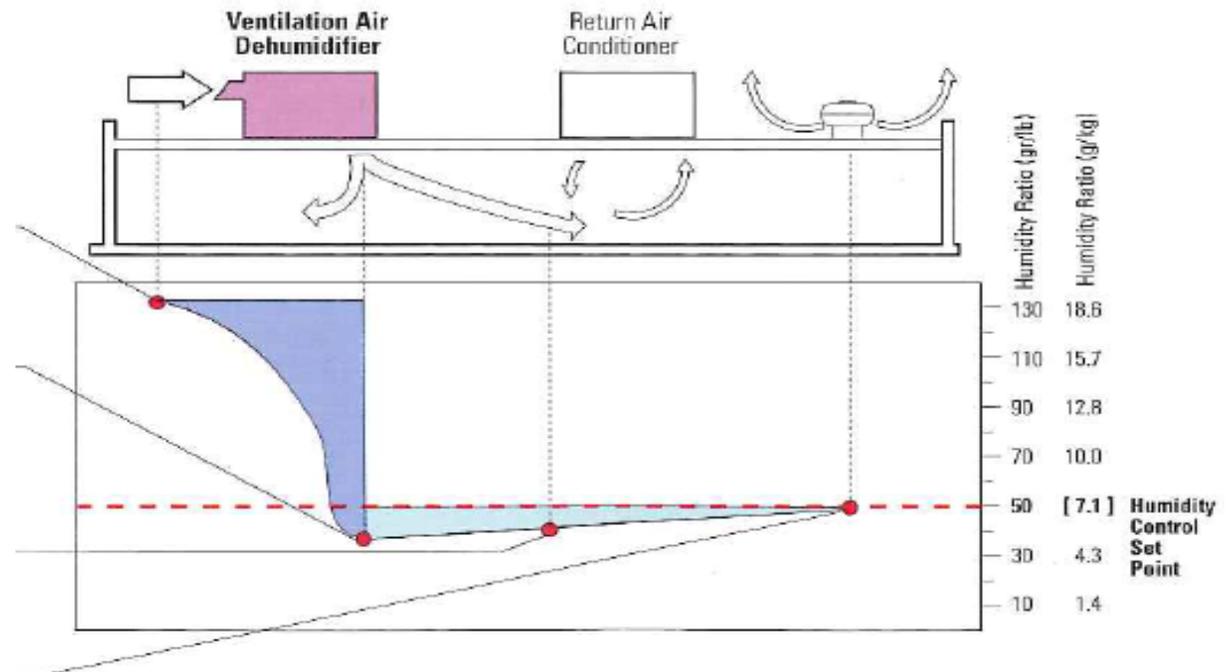


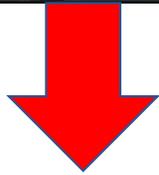
Fig. 13.2 Dry Ventilation Air

When outdoor air is dried, it can usually provide all the dehumidification capacity the building needs.

THE CONTEMPORARY PARADIGM



Conventional DOAS
with hot gas reheat



Ventilate for
peak occupancy
and
reheat to neutral
temperature to
avoid over-cooling



Zone air conditioning
handles all
sensible cooling loads

THE CONTEMPORARY PARADIGM

Divide & Conquer:

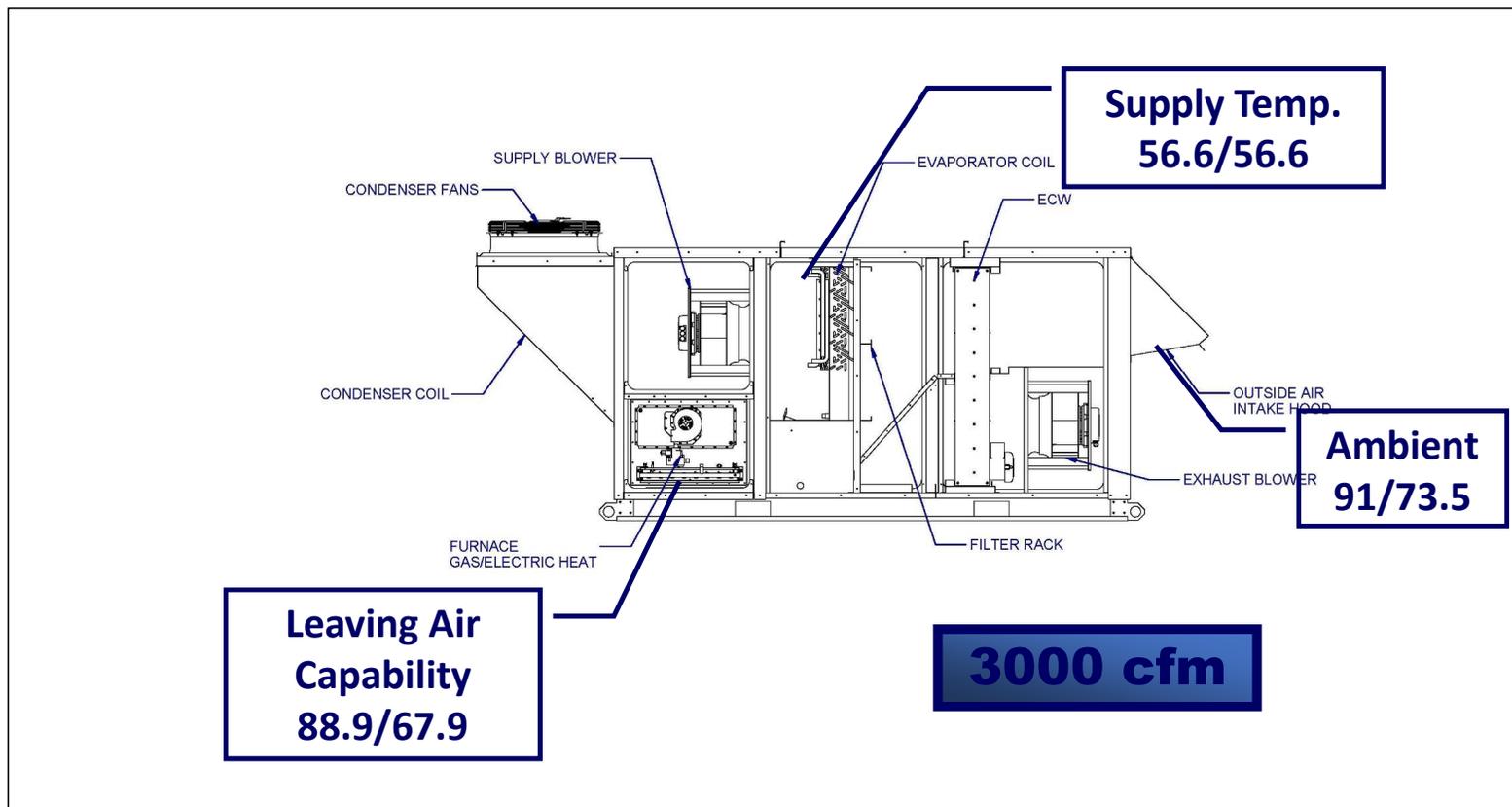
DOAS over-ventilates with dried air to overcome all latent loads
(Who cares it dehumidifies too much- occupants never complain it's "too dry")

	SENSIBLE	LATENT
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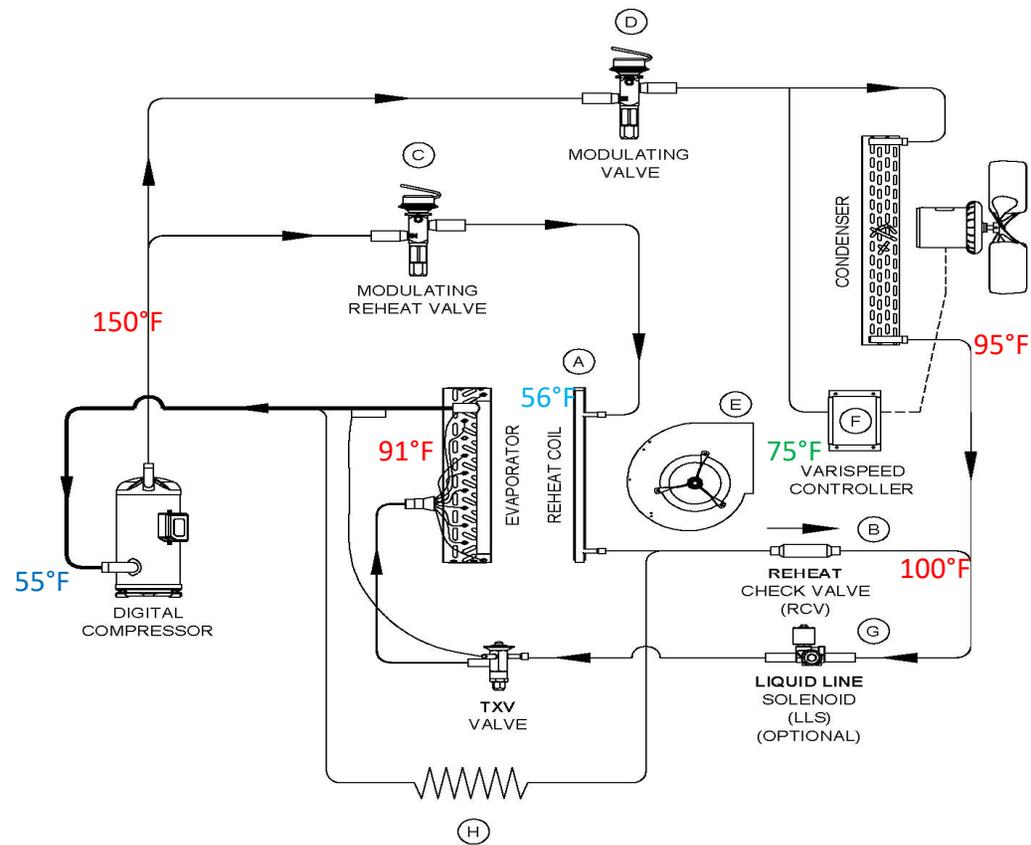
Zone AC Units Handle All Remaining Sensible Loads

100% Outside Air Examples

100% Outside Air Summer Design w/Reheat



Hot Gas Reheat Using Digital Scroll



ALTITUDE: SEA LEVEL
 BAROMETRIC PRESSURE: 29.921 in. HG
 ATMOSPHERIC PRESSURE: 14.696 psia

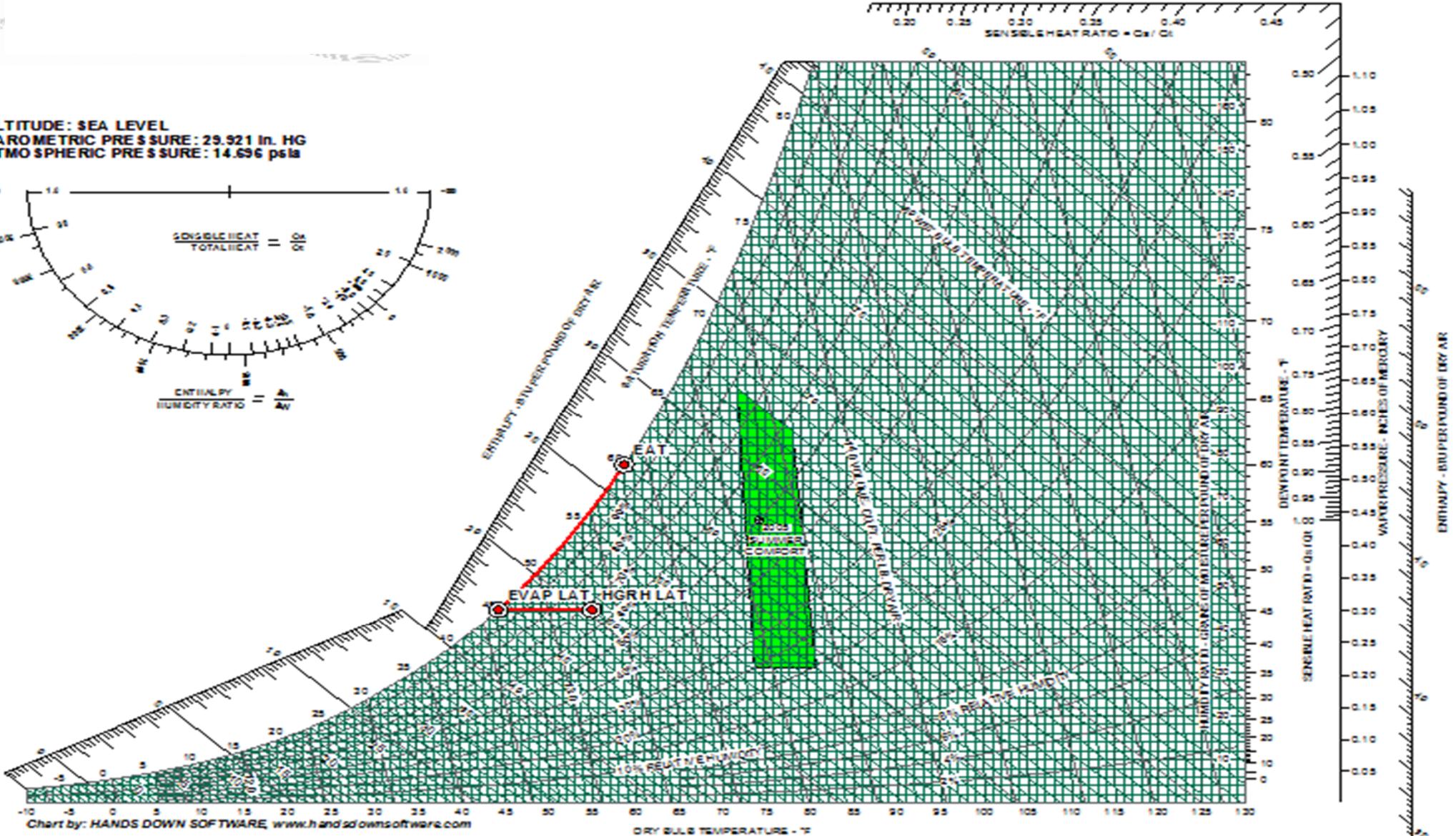
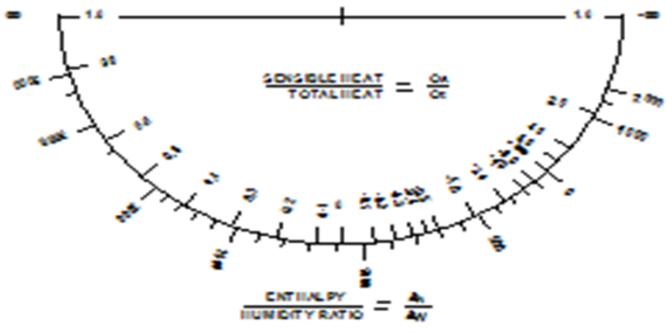
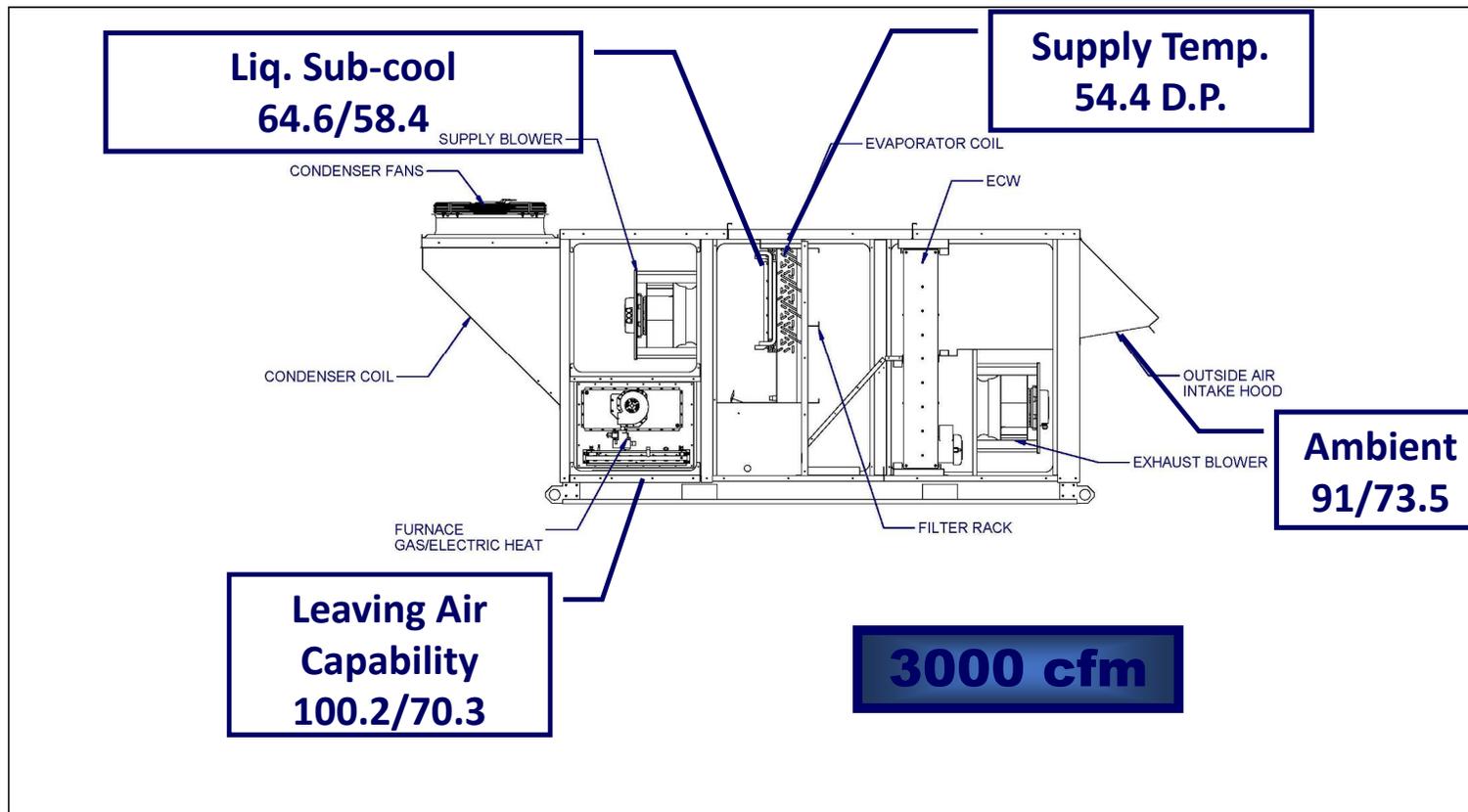


Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

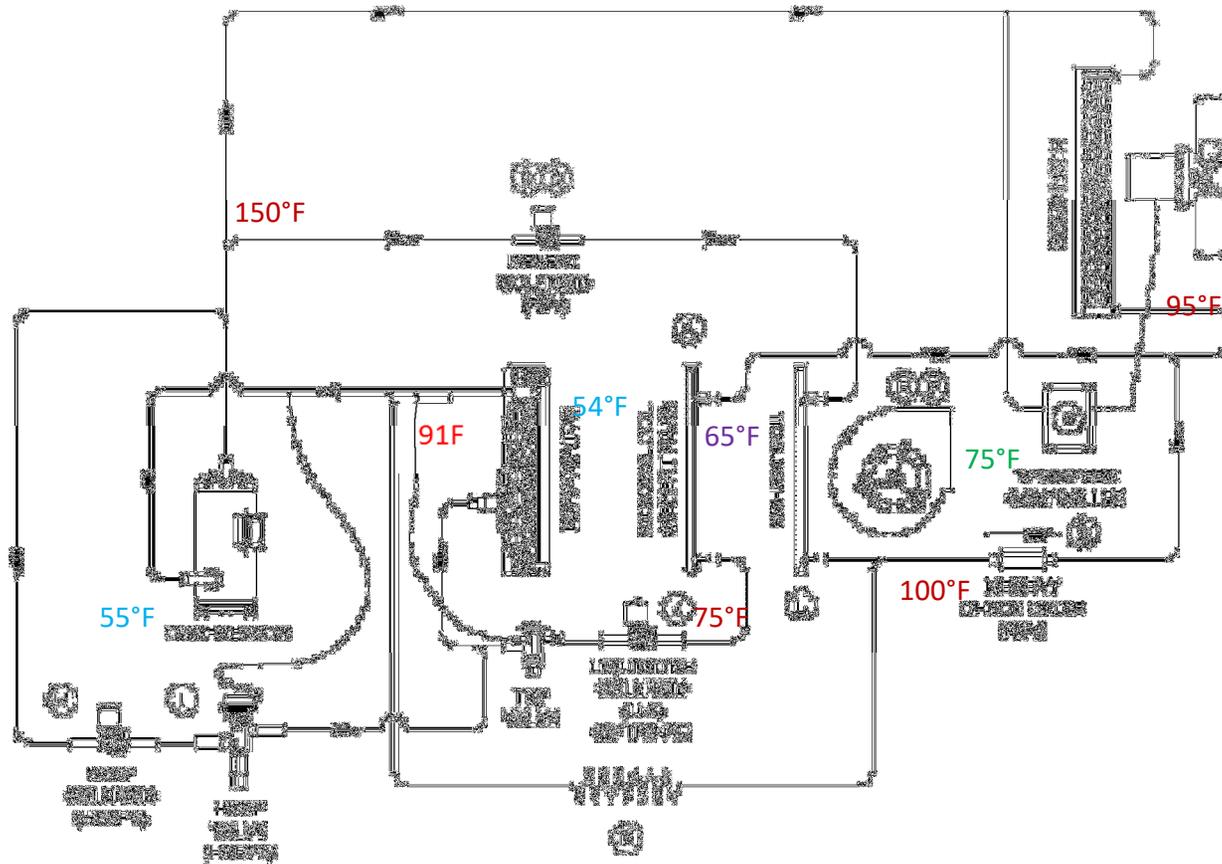
DRY BULB TEMPERATURE - °F

ENTHALPY - BRUPERFOUND OF DRY AIR

100% Outside Air Summer Design Load w/Reheat Plus Sub-cooling



Hot Gas Dual Circuit Reheat Plus Sub-Cooling



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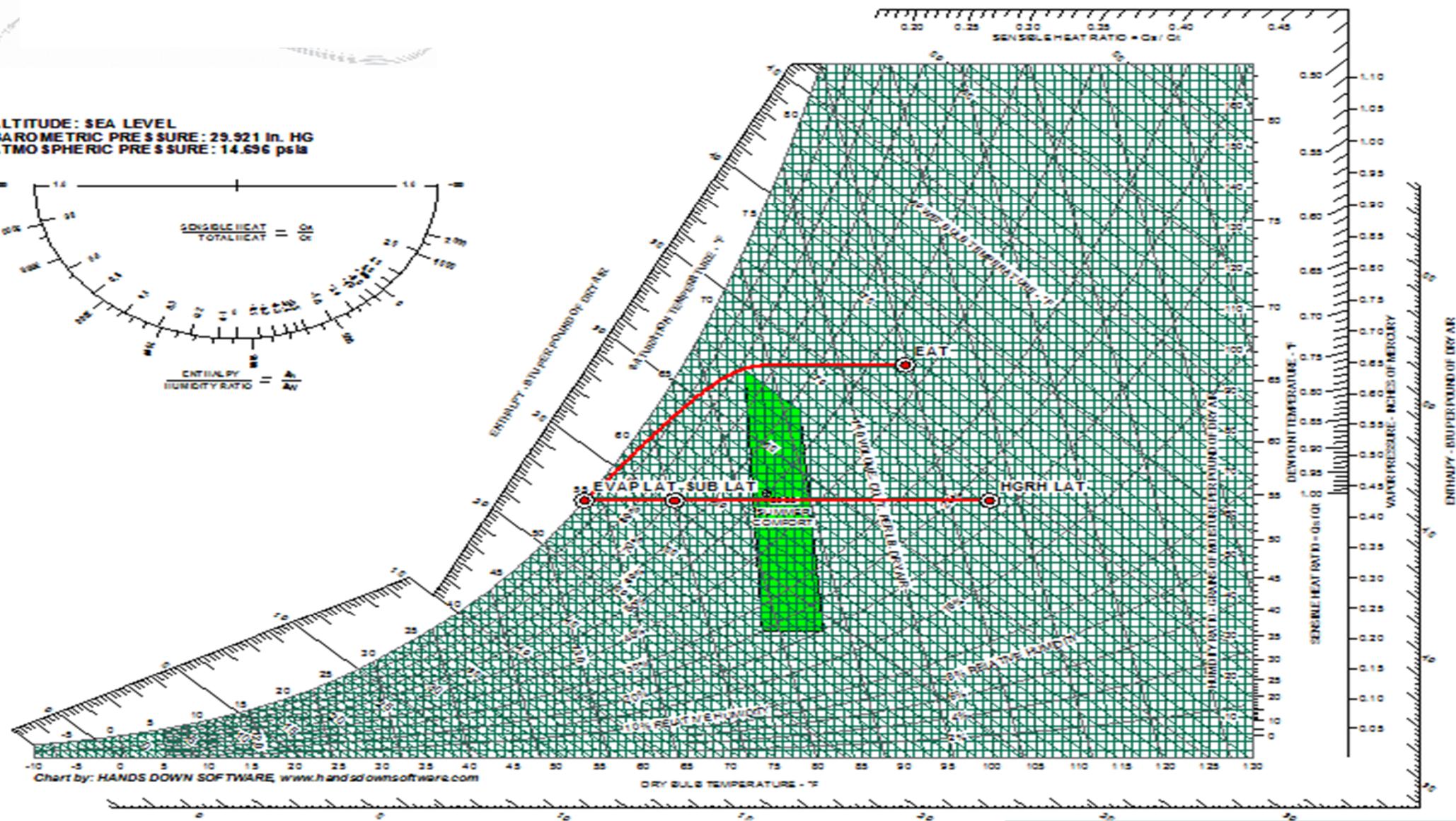
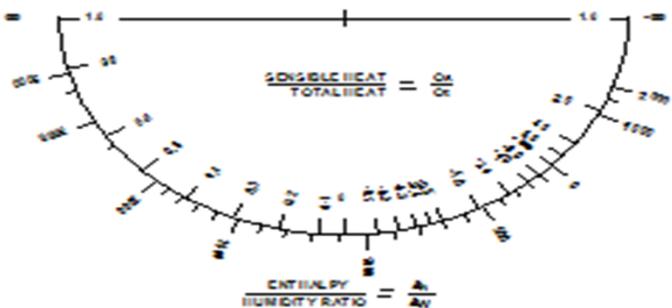
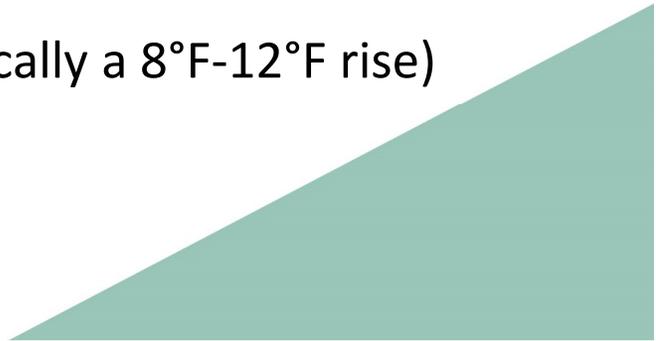


Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

Liquid Sub-Cooling Reheat

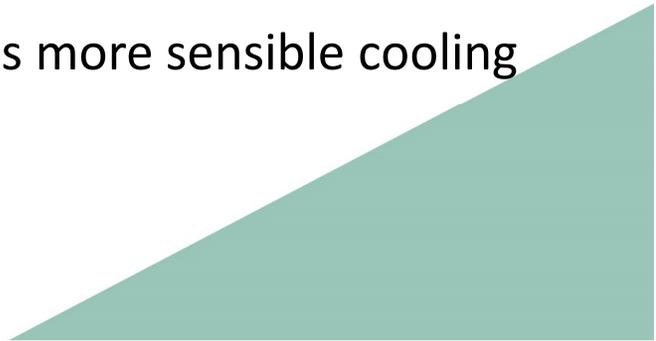
- ▶ Proven technology, patented in 1995 under the trademark *Reheat Plus*
 - ▶ Liquid refrigerant leaving the condenser passes through a 1-row coil downstream of the cooling coil
 - ▶ Refrigerant is sub-cooled before entering the expansion valve, enhancing the total cooling capacity of the evaporator by up to 20%
 - ▶ Air passing through the sub-cooling coil is reheated (typically a 8°F-12°F rise)
- 

What if part load conditions require some reheat during periods of low occupancy?

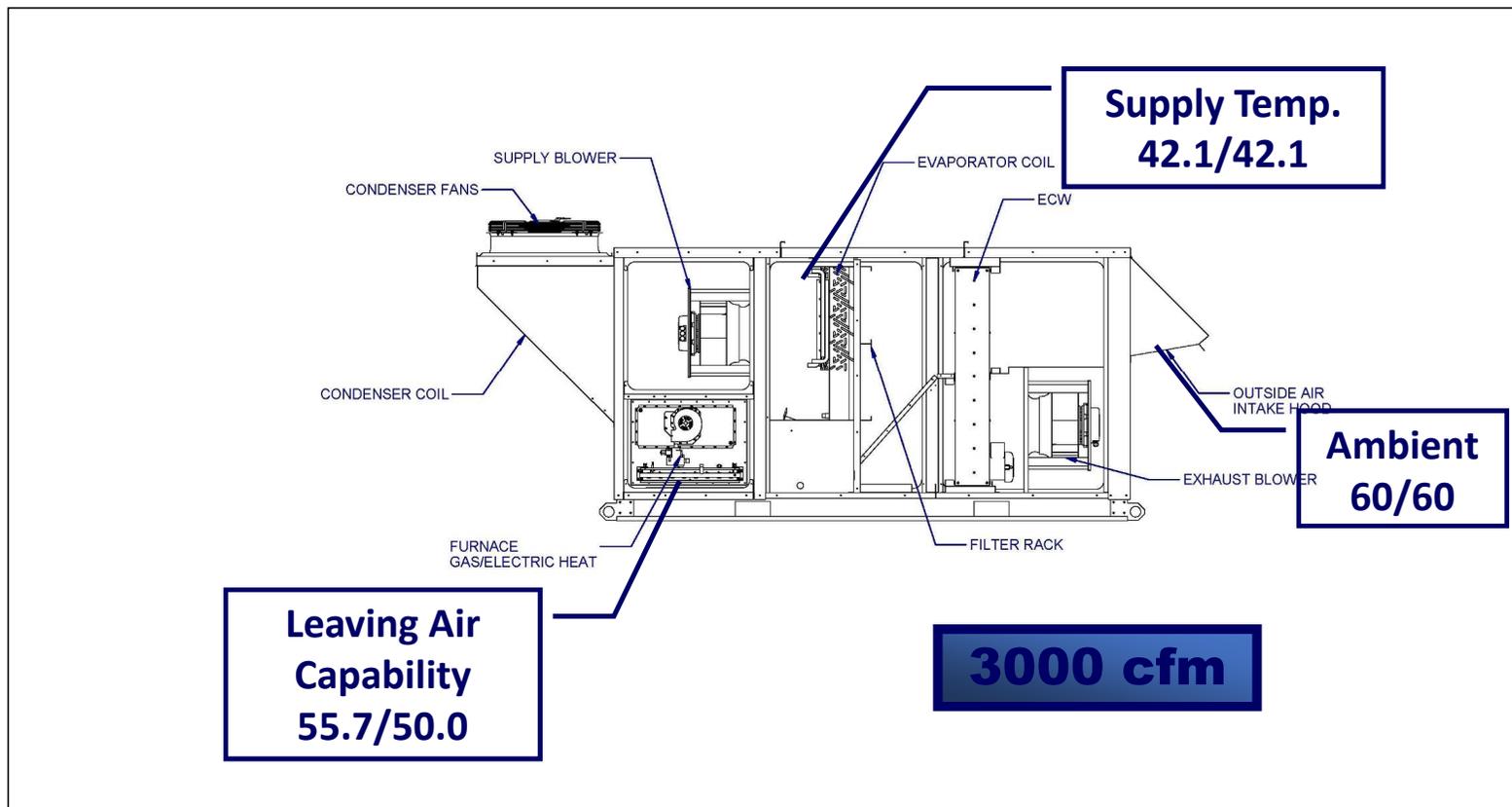
Utilize heat recovery in series with the cooling coil to maximize efficiency:

- Wrap-around heat pipes work well in CW/HW AHUs
 - Plate heat exchangers can also be used in wrap-around configuration to pre-cool air upstream of the cooling coil and reheat downstream
 - Liquid sub-cooling is the best technology for DX DOAS
 - Lower air-side pressure drop than heat pipe or plate HX
 - Switchable (unlike heat pipe or plate HX)
 - Works regardless of OA entering conditions
(heat pipe and plate HX are ineffective during part load conditions)
- 

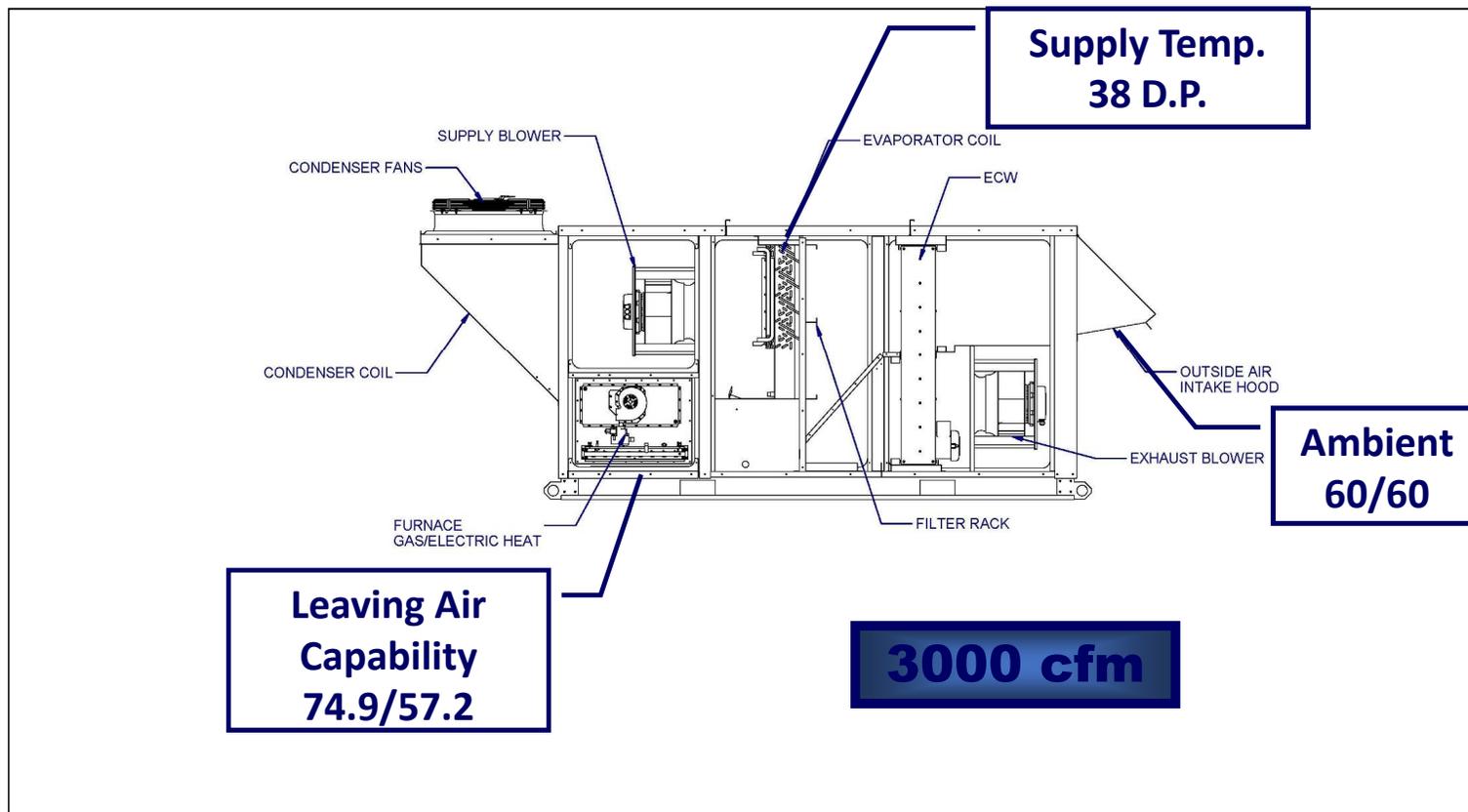
Liquid Sub-Cooling Reheat

- ▶ Refrigerant-based energy recovery in series with the cooling coil (more efficient than wrap-around heat pipe)
 - ▶ Meets the criteria in ASHRAE 90.1 Section 6.5.6.1 granting an exception for mandatory exhaust air energy recovery, “systems requiring dehumidification that employ heat recovery in series with the cooling coil”
 - ▶ Combined with VRF technology, the inverter compressor is able to slow down to conserve energy without compromising latent performance
 - ▶ Switchable to match the SHR of the building load (provides more sensible cooling when needed)
- 

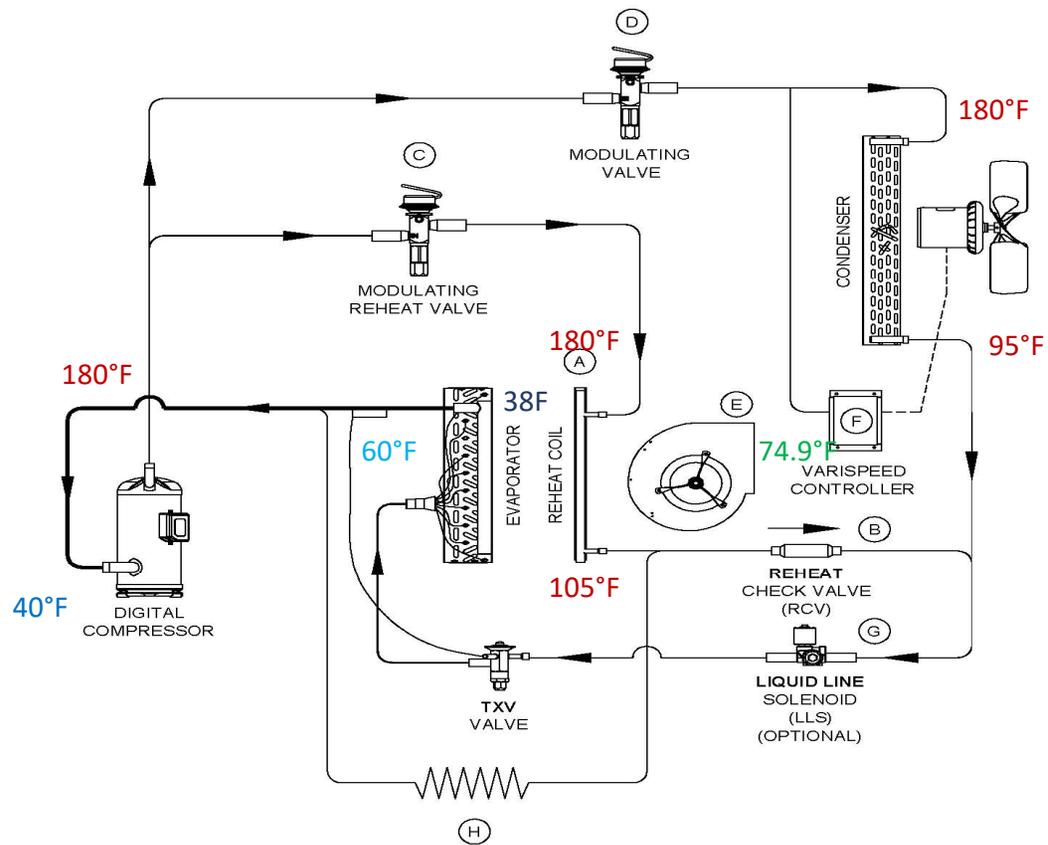
100% Outside Air Part Load Design w/Single Circuit Reheat



100% Outside Air Low Ambient Part Load Dual Circuit Reheat



Hot Gas Reheat Using Dual Circuit Reheat Part Load





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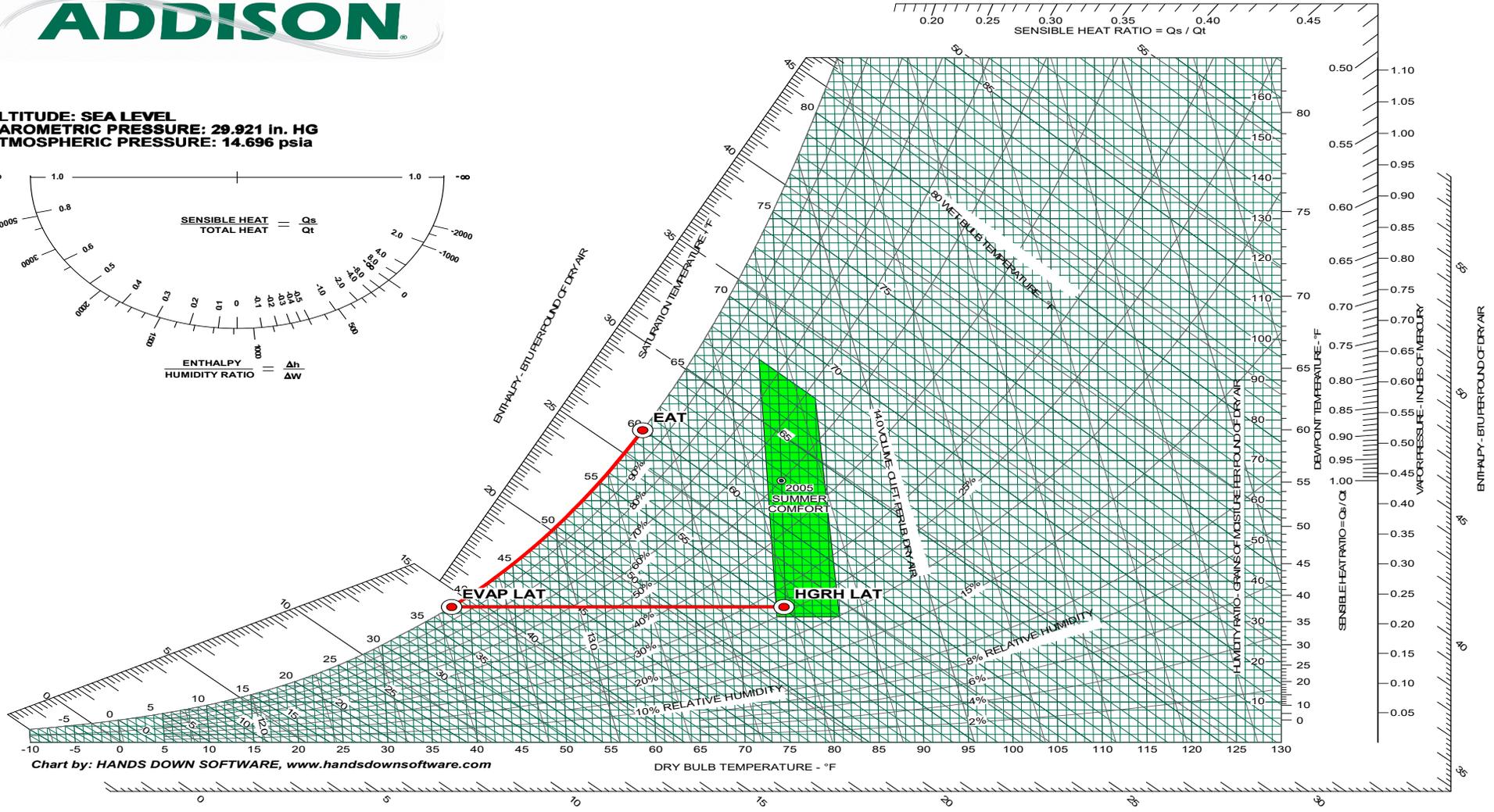
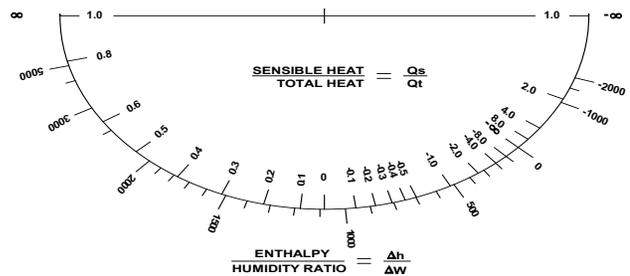
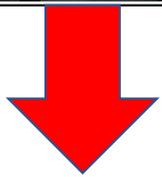


Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

WHAT'S WRONG WITH THE CONTEMPORARY PARADIGM?



Conventional DOAS
with hot gas reheat



Neutral air has no
impact on space
sensible loads

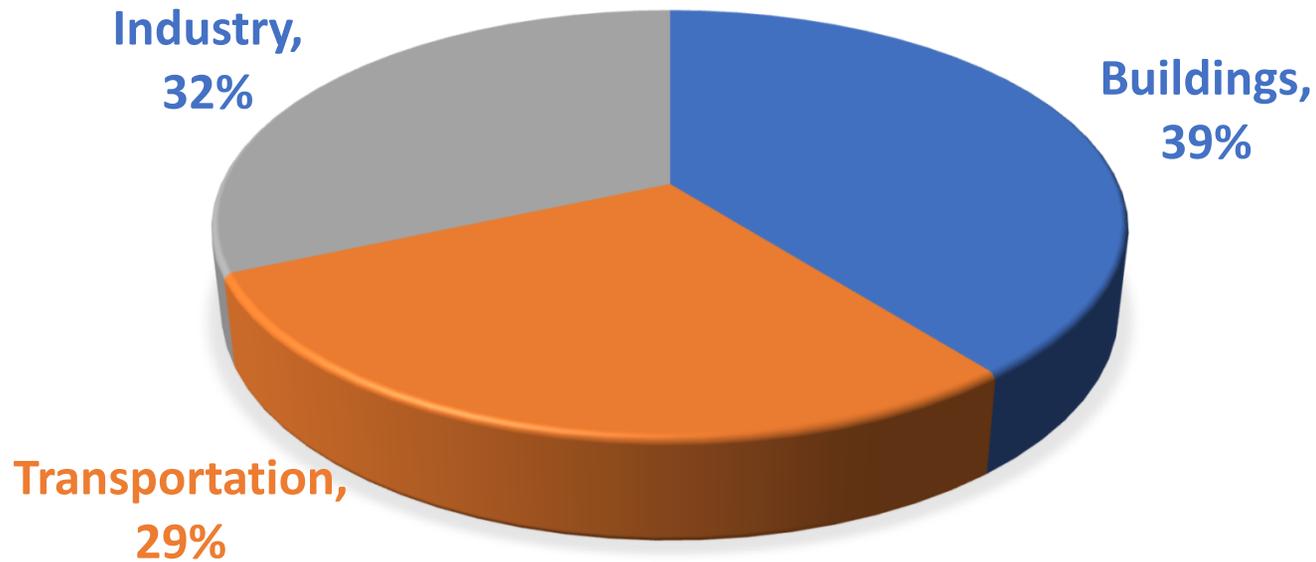


Zone AC units
handling all
sensible loads

- Over-ventilating is expensive and unnecessary
- The latent loads can be met without over-ventilating
- If reheat is needed to avoid over-cooling the space then the DOAS is over-ventilating
- If reheat is needed to avoid over-cooling the space, then the DOAS has more than enough sensible capacity to handle the sensible loads (and it's being wasted)

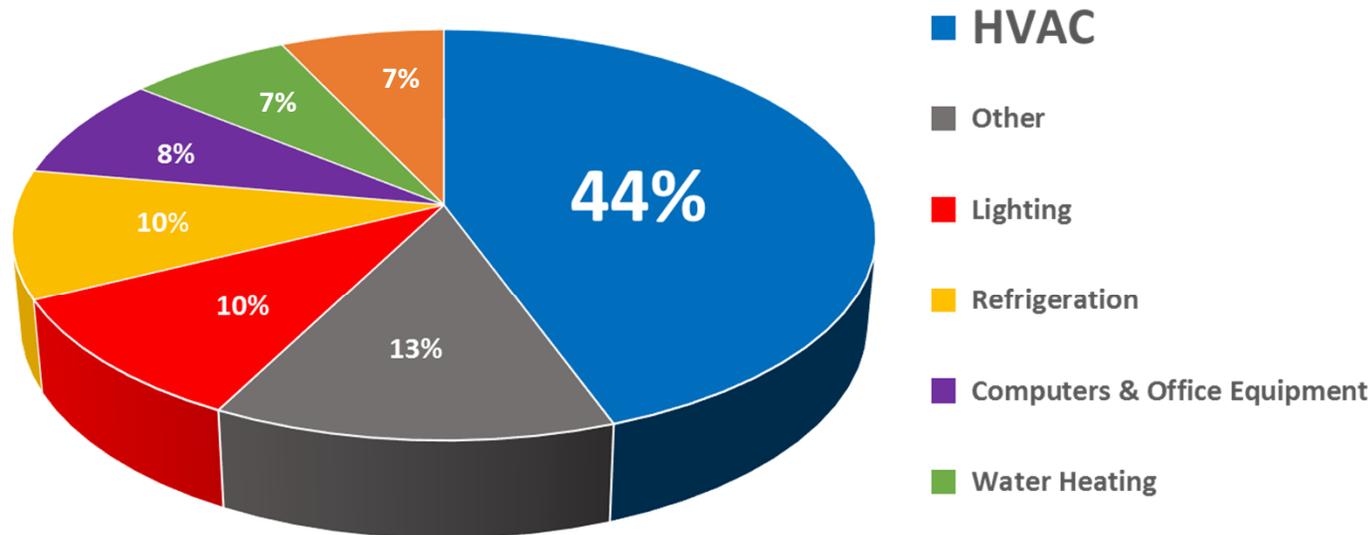
Demand for Increased Efficiency Driving DOAS Innovation

In North America, buildings consume more energy than transportation or industry



Source: U.S. Energy Information Administration, 2016

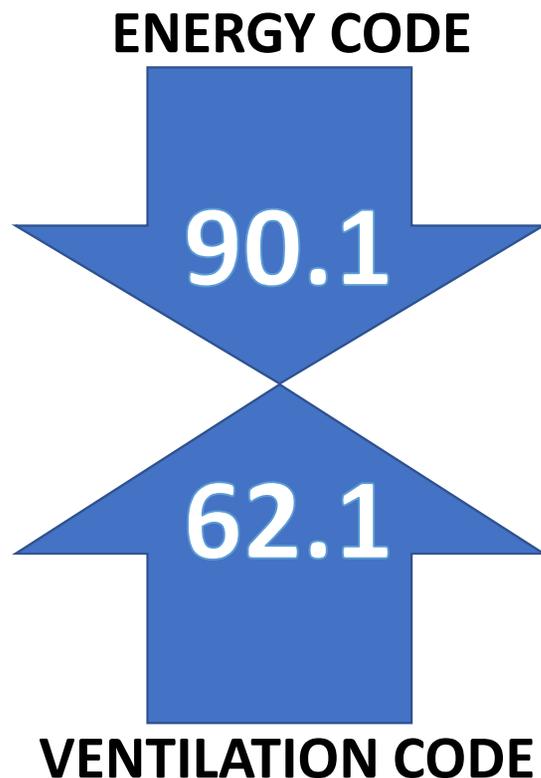
HVAC represents the largest portion of energy consumption in typical commercial buildings



Source: U.S. Energy Information Administration, 2012 Commercial Buildings Energy Consumption Survey: Energy Usage Summary, Table 5 (March 2016)

Much of that energy goes into conditioning ventilation air

Energy Consumed by DOAS is Increasingly Becoming a Higher Portion of the Total HVAC Load



- Better Insulation
- Low-E Glass
- Cool Lighting
- Higher Efficiency Zone Cooling
- **Sensible Loads are Dropping**
- **Sensible Cooling Equipment Getting More Efficient**

- Minimum OA Requirements for IAQ
- Ventilation Rates Determined by Maximum Occupancy
- DOAS Selected for Peak Conditions
- **Building SHR is Dropping**
- **Latent Cooling Remains Inefficient**

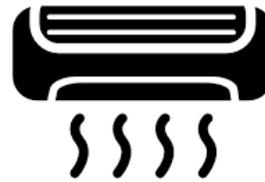
Lagging Efficiency Requirements for DOAS Units

- ▶ No rating system existed for DX DOAS units until 2013 when Standard 920 was approved by ANSI and published by AHRI. The 2016 version of Standard 90.1 is the first to include minimum efficiency requirements for DX DOAS, but is not yet widely adopted.
 - ▶ Some DOAS manufacturers still publish EER/IEER ratings based on AHRI Standard 340/360 operating requirements (totally meaningless for DOAS applications)
 - ▶ AHRI Standard 920 for DX-DOAS cites, “**Further energy savings may be realized by providing only the amount of ventilation air necessary...**” Currently, however, no test standard exists for rating the performance of DOAS units operating at reduced CFM for Demand-Based Ventilation
 - ▶ Standard 90.1-2016 recognizes the inefficiency of reheating to neutral temperature (Section 6.5.2.6 – “**Units that provide ventilation air to multiple zones and operate in conjunction with zone heating and cooling systems shall not use heating or heat recovery to warm supply air above 60°F when representative building loads or outdoor air temperature indicate the majority of the zones require cooling.**”
- 

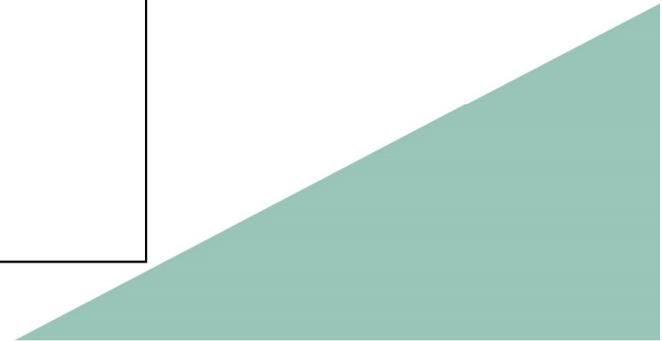
THE NEW PARADIGM



Precise ventilation
to match occupancy
allowing
sensible cooling
to offset heat gain
from occupants



Reduced load on zone air
conditioning
(smaller equipment)



THE NEW PARADIGM

Doing More with Less:

DOAS ventilates to match occupancy demand, with just enough dried air to overcome latent loads, and cool supply air to meet some of the sensible loads

	SENSIBLE	LATENT
EXTERNAL	<ul style="list-style-type: none">• Ventilation (OA temperature differential)• Infiltration (OA temperature differential)• Heat conduction through envelope• Fenestration	<ul style="list-style-type: none">• Ventilation (OA humidity differential)• Infiltration (OA humidity differential)• Permeation
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Zone AC Units Handle Fewer Sensible Loads

Ventilating to Occupancy Eliminates the Need for Reheat

Code Requirement: 10 CFM/person + 0.12 CFM/sq. ft.

Occupant Density: 35 persons/1000 sq. ft.

Average Requirement: 13.4 CFM/person

Sensible Heat Gain per Occupant: 250 btuh (average office worker)

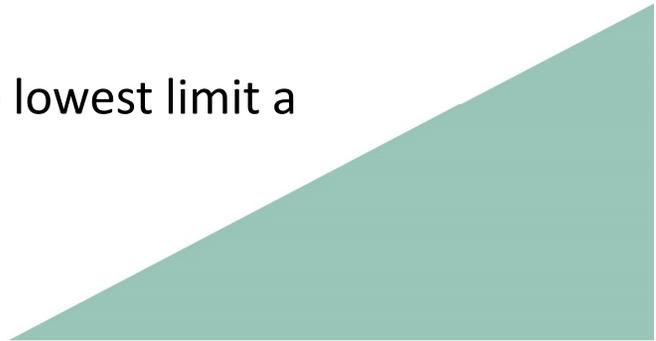
DOAS Sensible Cooling:
(without reheat)

$$\begin{aligned} Q_s &= (1.08)(\text{CFM})(\text{deltaT}) \\ &= (1.08)(13.4)(72^\circ\text{F}-55^\circ\text{F}) \\ &= \underline{246 \text{ btuh/person}} \end{aligned}$$

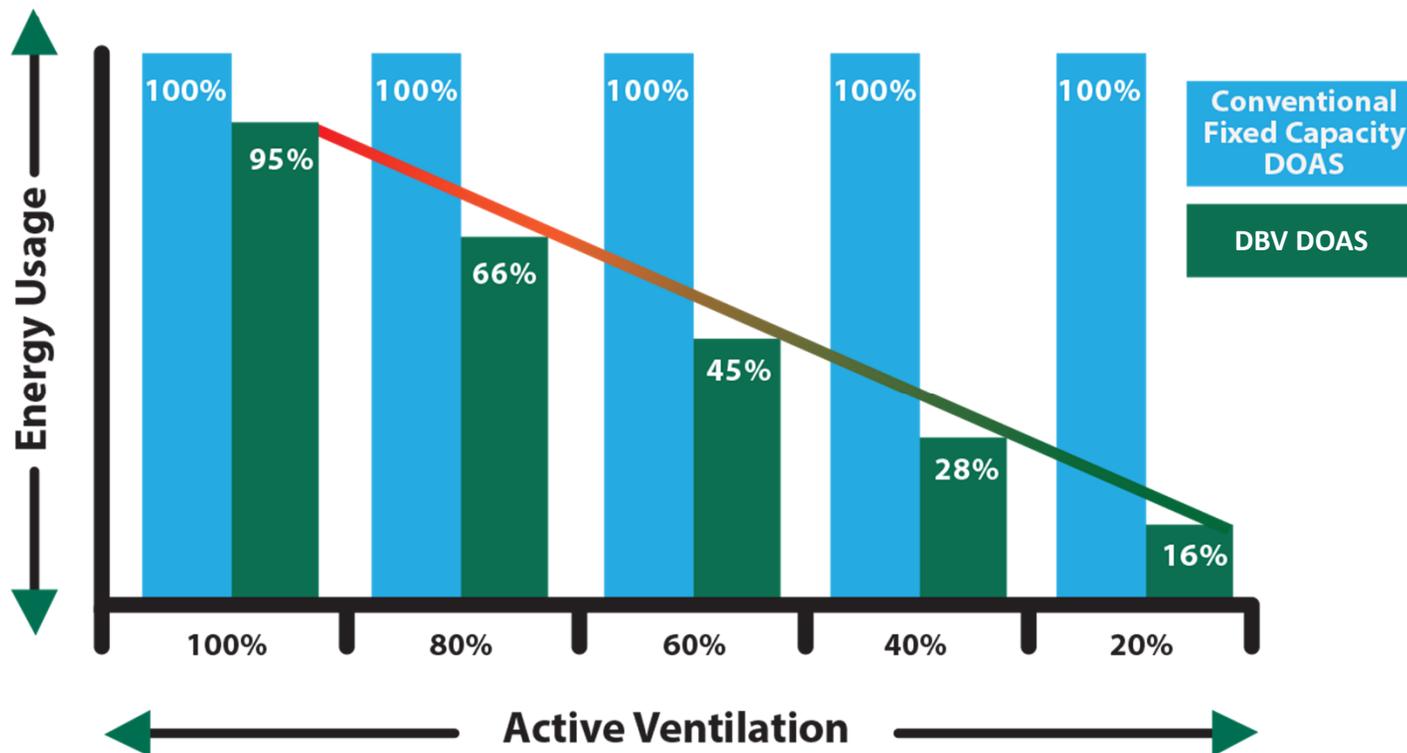
HOT GAS REHEAT ISN'T FREE.....IT WASTES COOLING!



Don't Most Packaged DOAS Units Offer VAV Control?

- ▶ OA design conditions require low face velocities across a deep multi-row evaporator coil
 - ▶ Digital scrolls or inverter compressors can effectively modulate cooling capacity during part load, but that does not enable VAV turndown
 - ▶ For units designed for 200-250 fpm at peak design, coil geometry prohibits airflow turndown. Low face velocities (< 175 fpm) across the evaporator coil result in poor and non-uniform heat transfer across the coil
 - ▶ Risks include loss of supply air dew-point control, problems with refrigerant pressure/temperature management, and freezing in the corners of the coil where laminar flow restricts heat transfer
 - ▶ Most manufacturers designate 70%-60% of full airflow as the lowest limit a packaged DOAS can predictably operate
- 

True Demand-Based Ventilation Delivers >50% Energy Savings* Versus Conventional Fixed Capacity DOAS

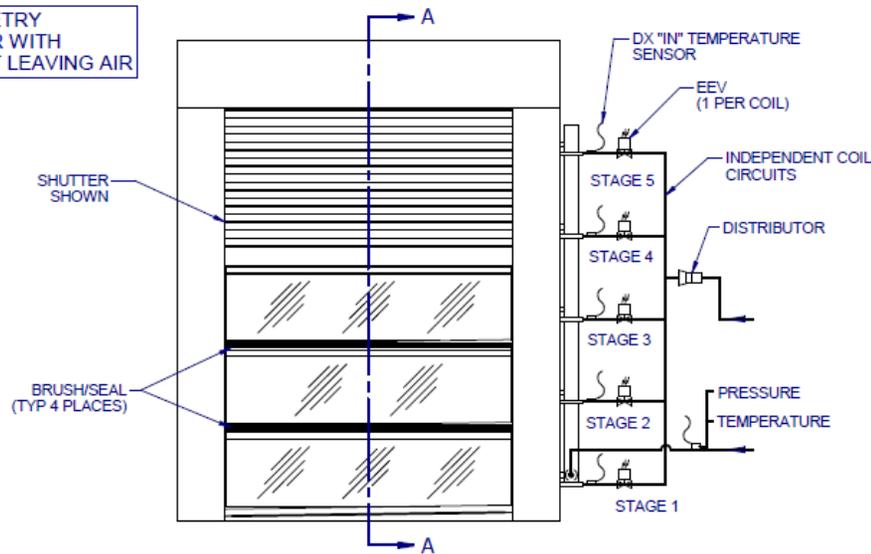


*Source: Florida Solar Energy Center®

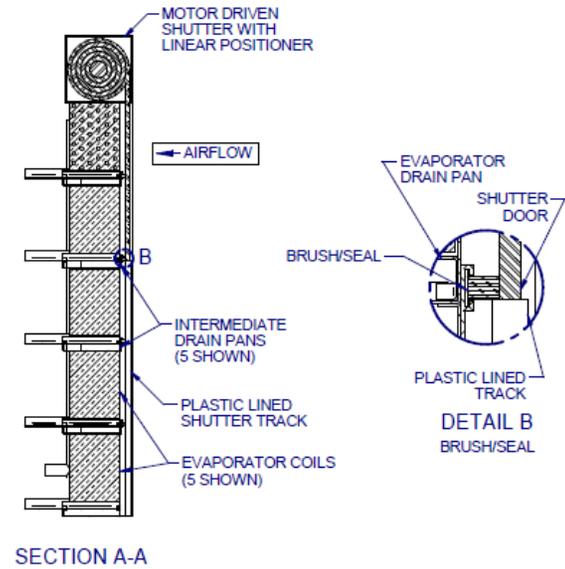
Variable Evaporator Geometry - How It Works

VARIABLE AIR FLOW VARIABLE REFRIGERANT FLOW

VARIABLE COIL GEOMETRY FOR 100% OUTSIDE AIR WITH CONSTANT DEW POINT LEAVING AIR



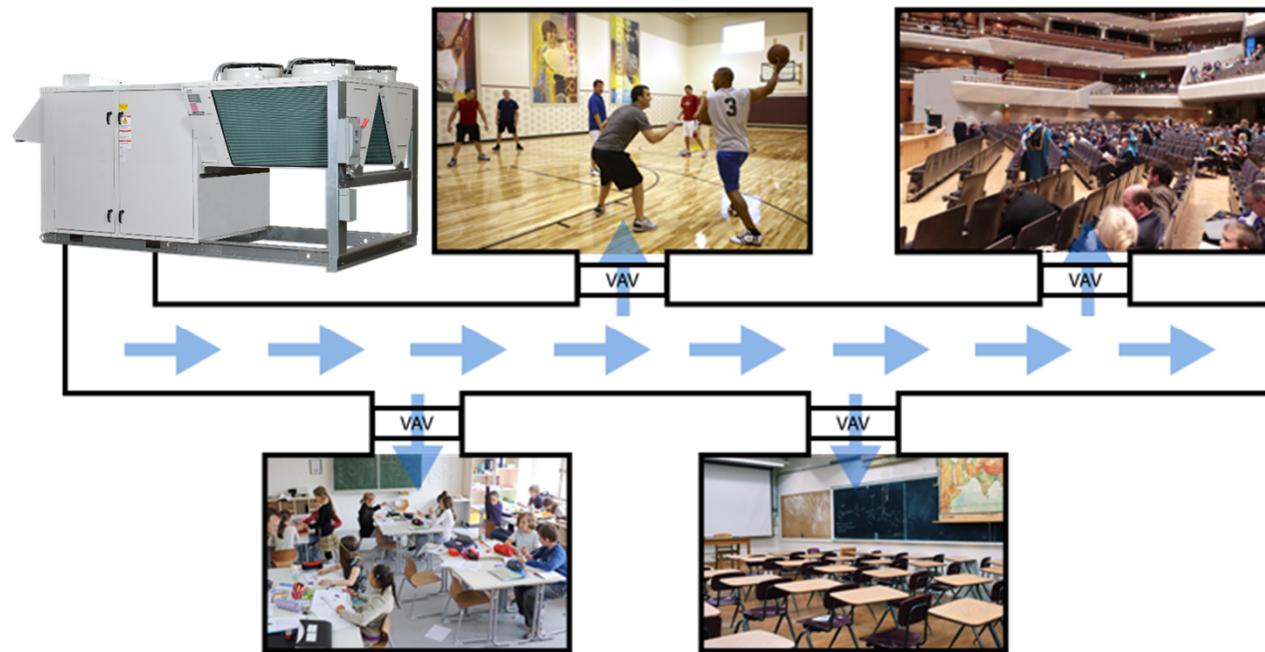
NOTE: 5 EVAPORATOR COILS SHOWN AS AN EXAMPLE



Constant face velocity maintains leaving air dew-point regardless of supply CFM



Occupancy is highly variable and often unpredictable



Only true Demand-Based Ventilation can adjust for the diversity of use between multiple zones

Conventional Fixed Capacity, Variable Compressor Capacity, and True Demand-Based DOAS Comparison

Conventional Fixed Capacity DX DOAS

- ▶ Ventilation per fixed design CFM
- ▶ Not optimized for part load conditions
- ▶ 100% ventilation rate energy consumption whenever the unit is running

Variable Compressor Capacity DX DOAS

- ▶ Effective ventilation turndown to 80%
- ▶ Not optimized for part load conditions
- ▶ Fixed evaporator surface with variable speed compressor
- ▶ Loss of dew point control at part load
- ▶ Some energy savings at part load conditions, but over-ventilates during low occupancy periods

True Demand-Based DX DOAS

- ▶ Effective ventilation turndown to 20% (true demand-based ventilation)
- ▶ Optimized for any condition and ventilation load
- ▶ Brushless permanent magnet variable speed scroll compressor with a fully activated variable coil size
- ▶ Optimize balance between coil size and refrigerant flow maintains dew point control and minimizes energy consumption

THE DOAS PARADIGM SHIFT



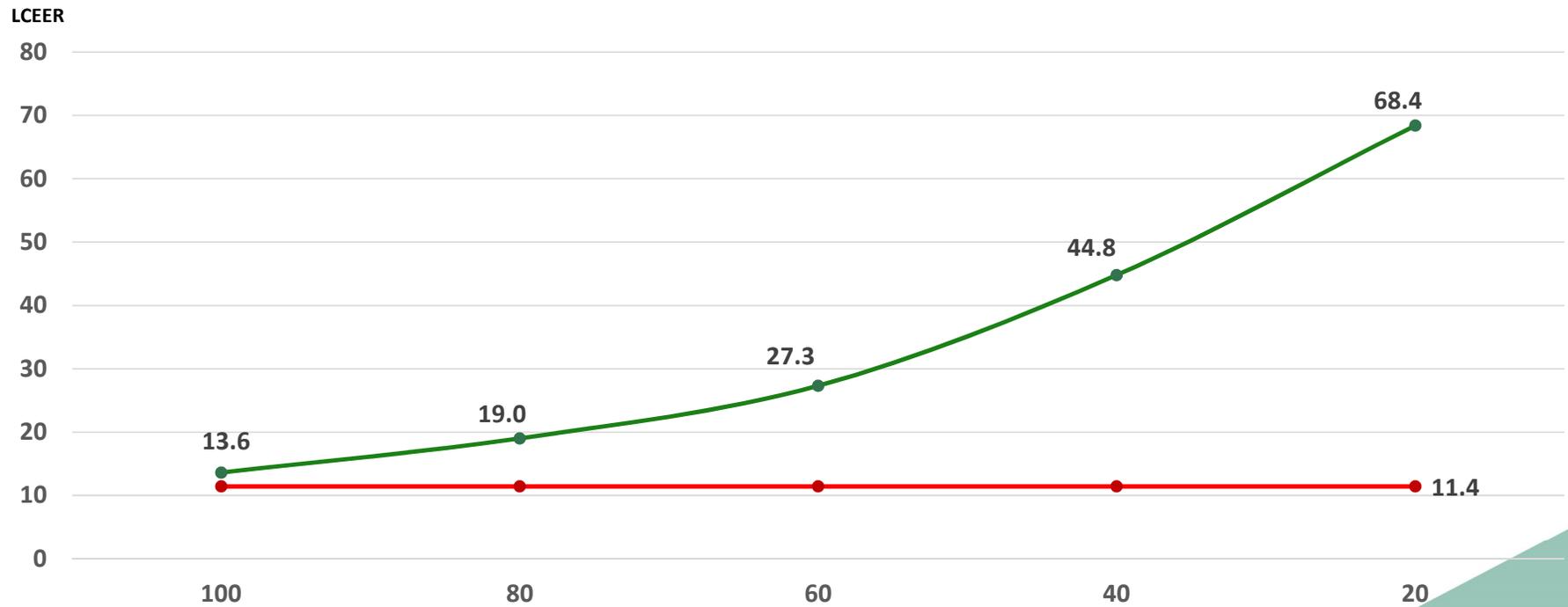
Precise ventilation to match occupancy and provide latent plus sensible space cooling



Smaller zone AC units

- Use Demand-Based Ventilation to avoid unnecessary conditioning of OA
- Specify VRF with variable evaporator geometry to maintain leaving air dew point down to 20% airflow
- Design DOAS supply air dew point to meet all latent load requirements without over-ventilating
- Restrict the use of reheat for air being supplied to spaces where mechanical cooling is required
- Utilize series heat recovery technology in lieu of hot gas reheat
- Downsize zone AC equipment; apply the DOAS sensible cooling capacity

Comparative DOAS EER @ 95°DB/78°WB

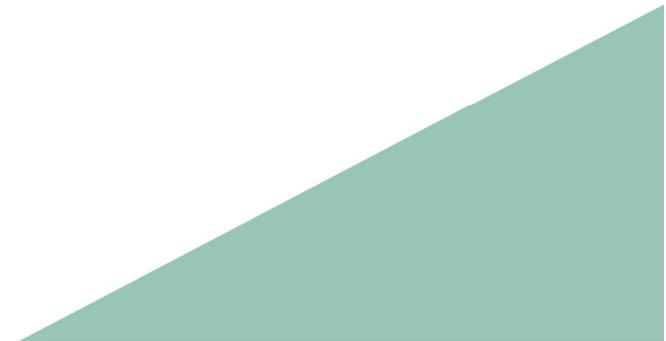


EER @ Demand Ventilation Building Profile

LCOA120 @ 1800 cfm (55°F Leaving DP), with optional liquid subcooling

% Time @ Specified Demand Ventilation	Capacity/CFM	LCEER @ 95/78	LCEER @ 80/73	LCEER @ 68/66	LCEER @ 60/58
10%	100%	13.6	19.7	23.0	22.1
20%	80%	19.0	25.2	33.3	23.9
30%	60%	27.3	37.8	40.8	25.2
30%	40%	44.8	52.0	40.6	27.6
10%	20%	68.4	61.5	44.2	28.2
Weighted LCEER Average @ Demand Ventilation %		33.6	40.1	37.8	25.6

% Time @ Operating Ambient	
95/78	12%
80/73	28%
68/66	36%
60/58	24%
Weighted Average LCEER	35.0



Questions?