

Today's Challenges Impact System Design Choices:

A Look at a Leading DOAS Solution to Meet Building Requirements

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Trend Toward Lower Building Energy Use

As buildings are designed for lower energy use, there is typically a reduction in sensible cooling loads, giving designers options to use zone-level sensible cooling systems.

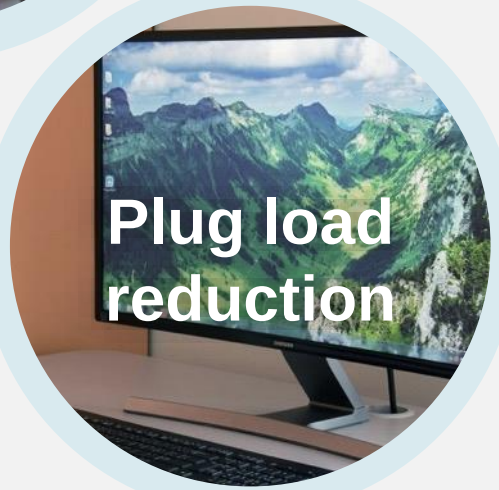




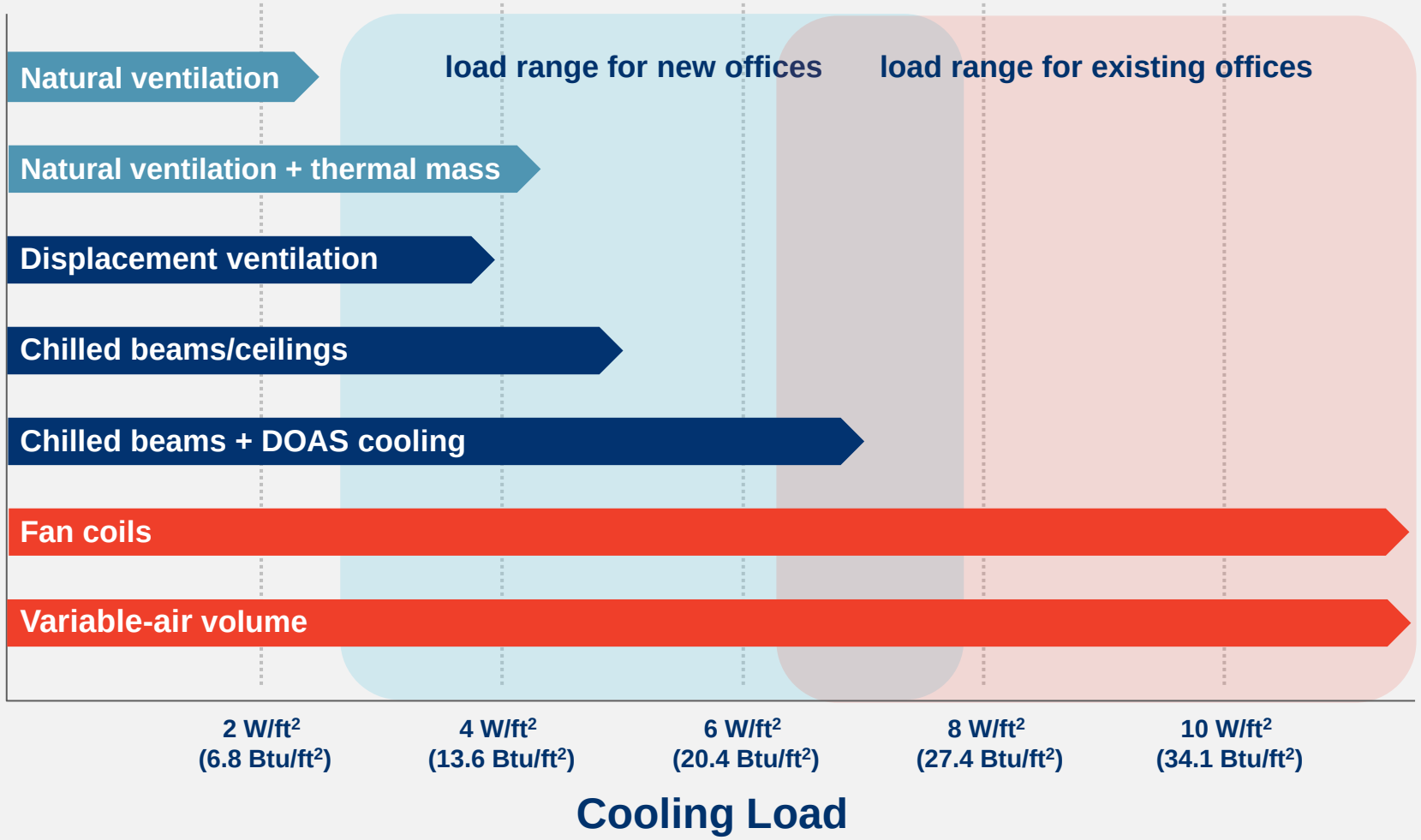








Trend Toward Lower Building Energy Use



The reduction in sensible cooling loads often means that systems that use zone-level, sensible-only cooling equipment are more economically feasible and practical.

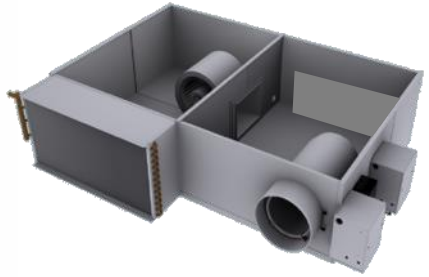
Source: Eley, C. *Design Professionals Guide to Zero Net Energy Buildings*. Island Press. 2016.

Leveraging Learnings to Advance System Design



1960s

Initial cold air induction systems used very cold chilled water to induce airflow into the device.



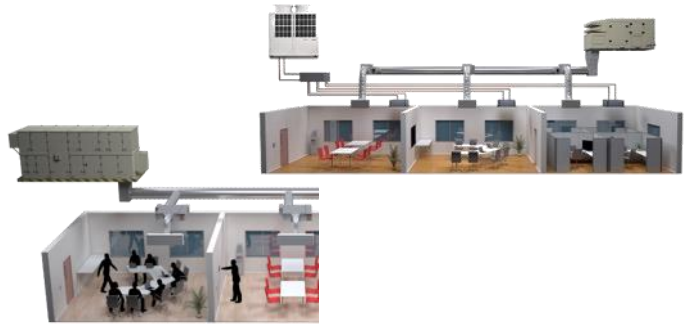
1980s

VAV gains critical mass, introduction of fan-powered VAV – a derivative of VAV to improve heating and comfort.



2000s

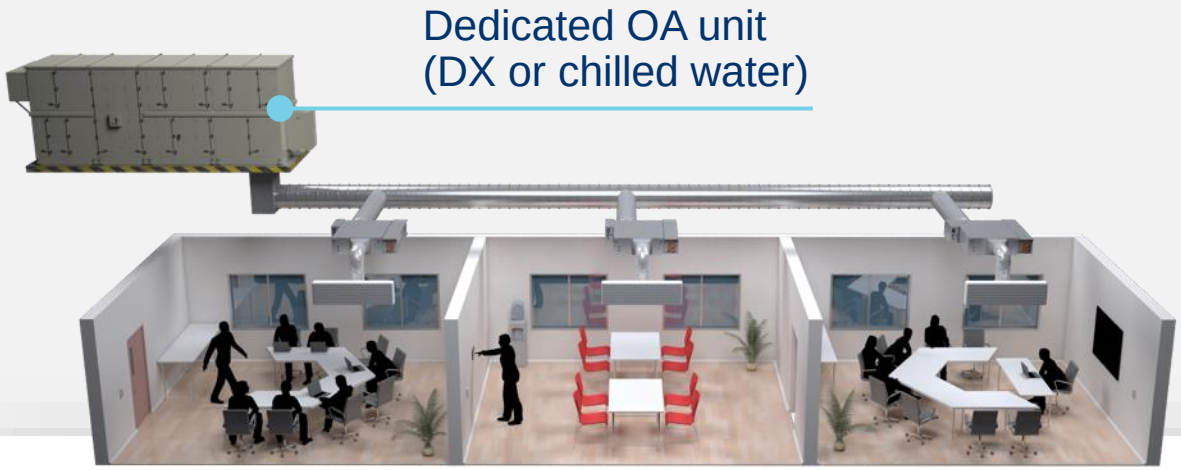
Second-generation induction (chilled beam) systems emerge, modified for NA market with higher cooling and heating loads vs. Europe.



Today

Accelerated building technologies are driving loads down—creating a need for new system types, better integration top to bottom with a focus on outside air management. Sensible cooling systems are expanding in scope with advancements to incorporate electrification concepts.

Dedicated Outdoor Air System (DOAS)



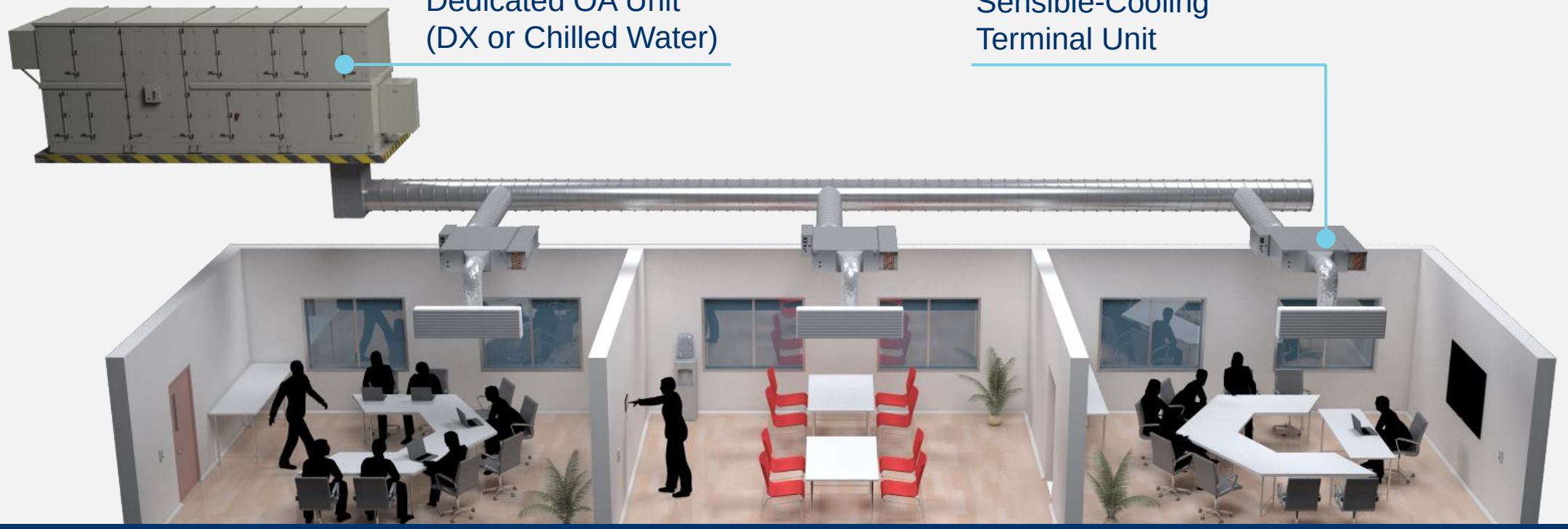


Today's Systems

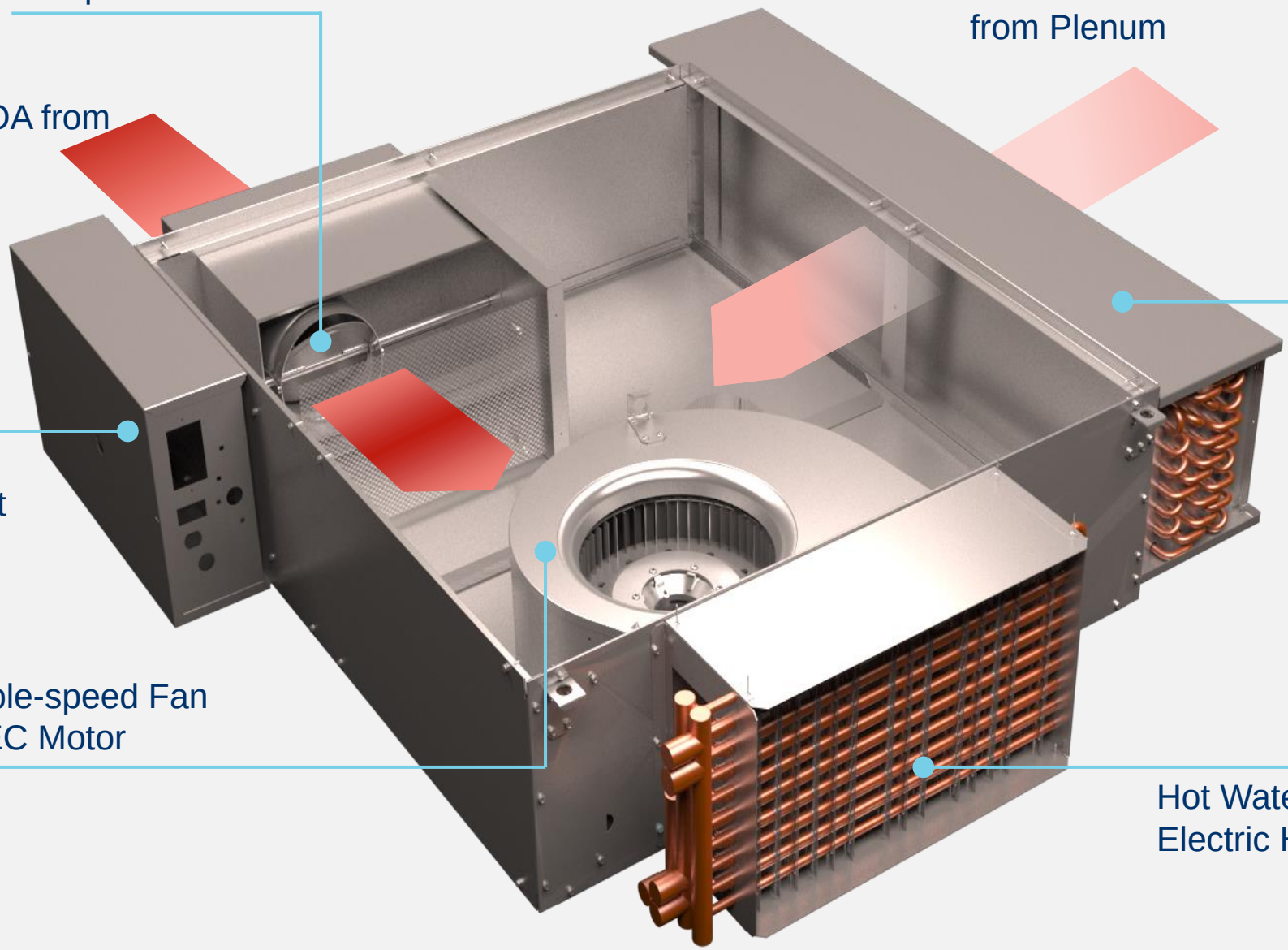
More efficient building designs are driving cooling loads down, creating a need for better integration of cooling, heating and ventilation systems.

DOAS provides all dehumidification to control indoor dew point to ≤ 55ºF, zone-level terminals provide only sensible cooling.

Why is This the New System Trane is Focusing On?

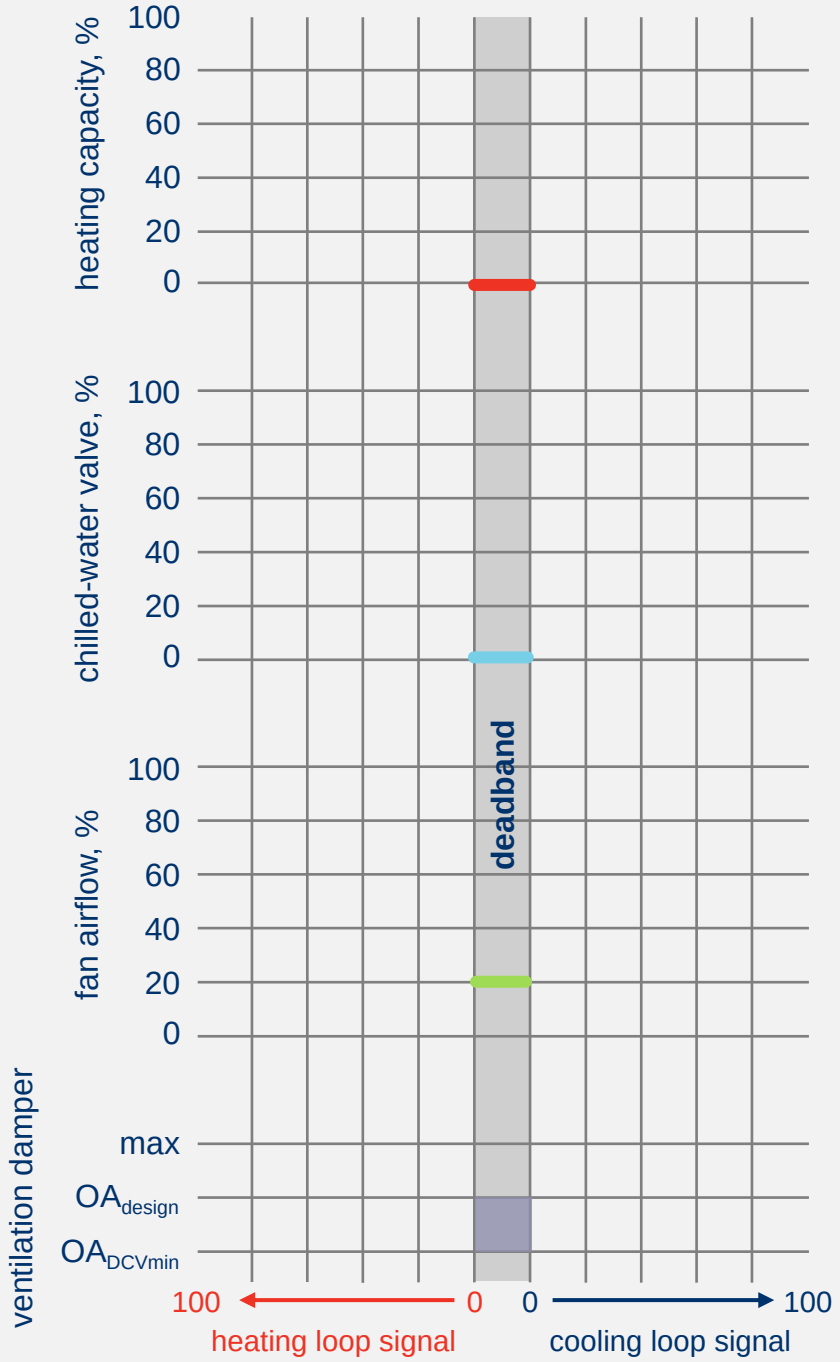


DOAS provides all dehumidification to control indoor dew point to ≤ 55ºF, zone-level terminals provide only sensible cooling using 56ºF to 60ºF water.


Airflow-measuring Damper
Recirculated Air from Plenum
Conditioned OA from DOAS
Sensible-Only Cooling Coil
Factory-mounted, Pre-engineered Unit Controller
Variable-speed Fan with EC Motor
Hot Water or Electric Heat

Occupied Mode:

Deadband



Hot-water valve closed
(electric heater off)

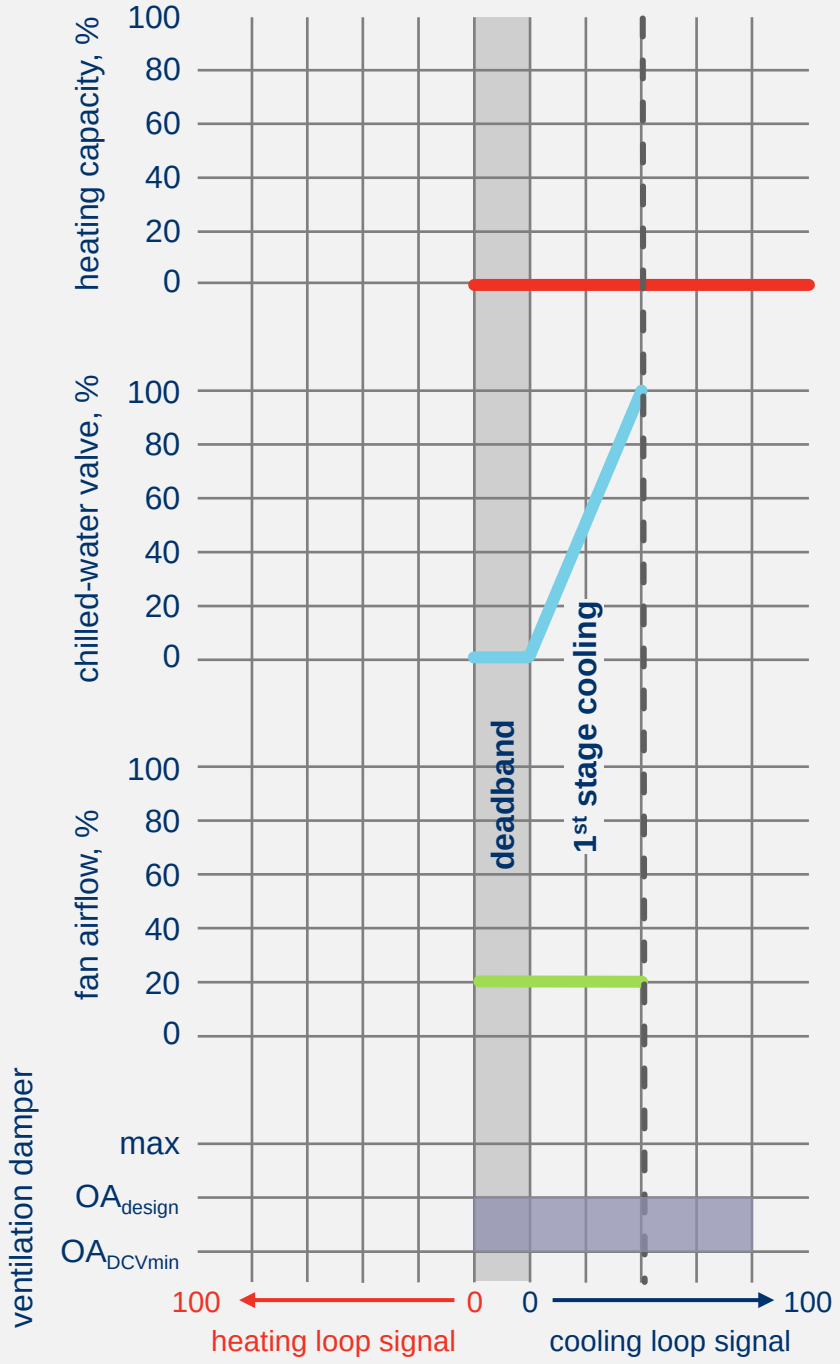
Chilled-water valve closed

Fan operates at
minimum airflow setpoint

Ventilation air damper at
current minimum OA setpoint

Occupied Mode:

Cooling (1st stage)



Hot-water valve closed (electric heater off)

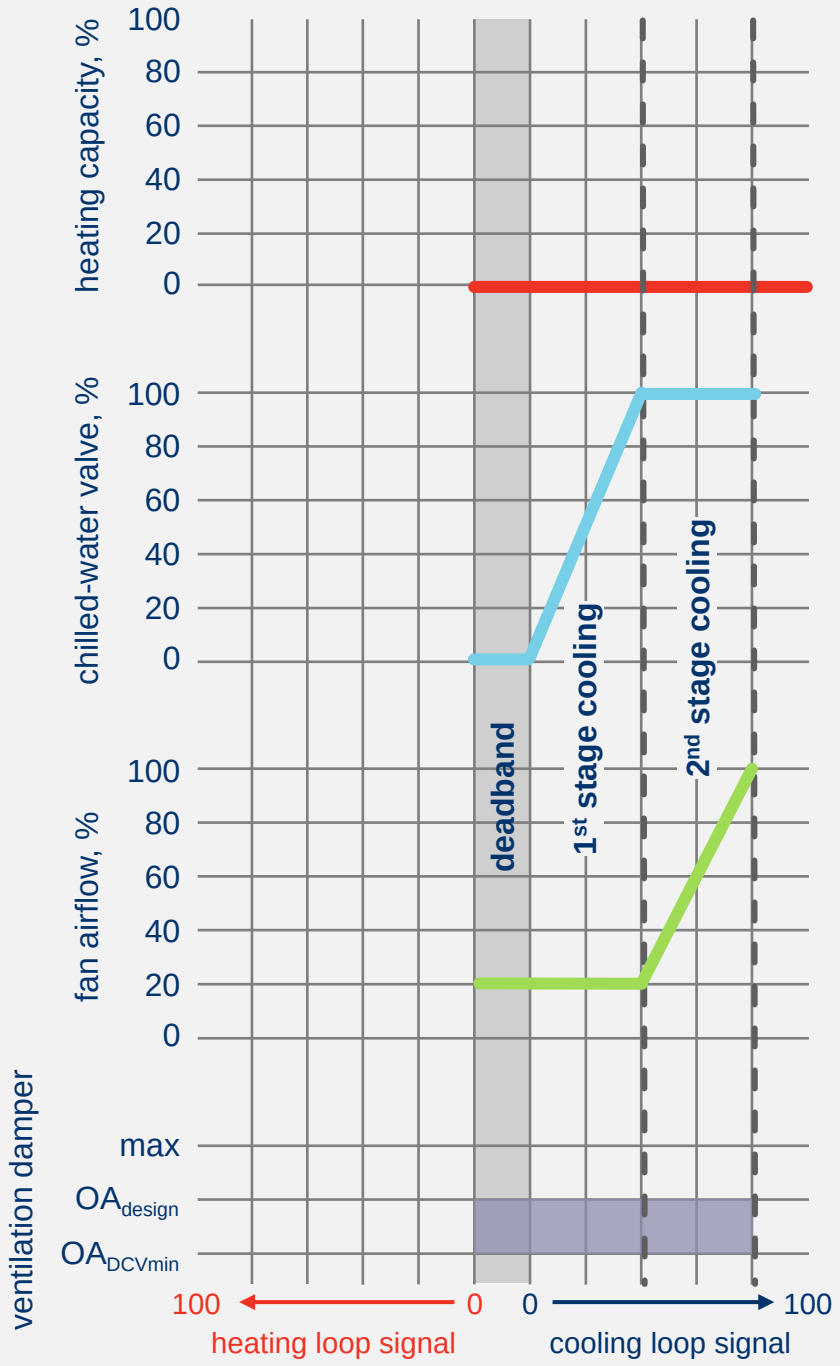
Chilled-water valve modulates between 0% and 100% open

Fan operates at minimum airflow setpoint

Ventilation air damper at current minimum OA setpoint

Occupied Mode:

Cooling (2nd stage)



Hot-water valve closed (electric heater off)

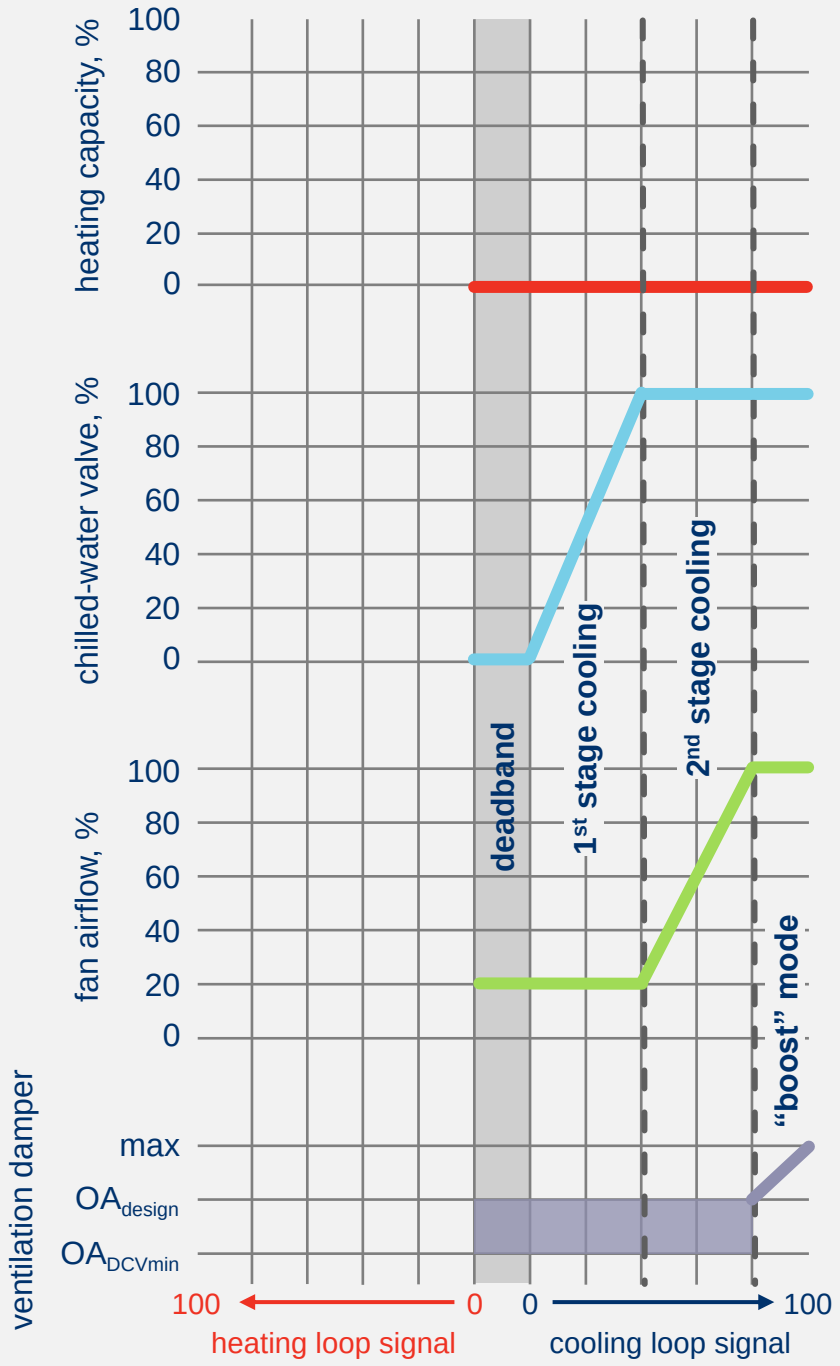
Chilled-water valve 100% open

Fan modulates between minimum and maximum airflow setpoints

Ventilation air damper at current minimum OA setpoint

Occupied Mode:

Cooling (“boost”)



Hot-water valve closed
(electric heater off)

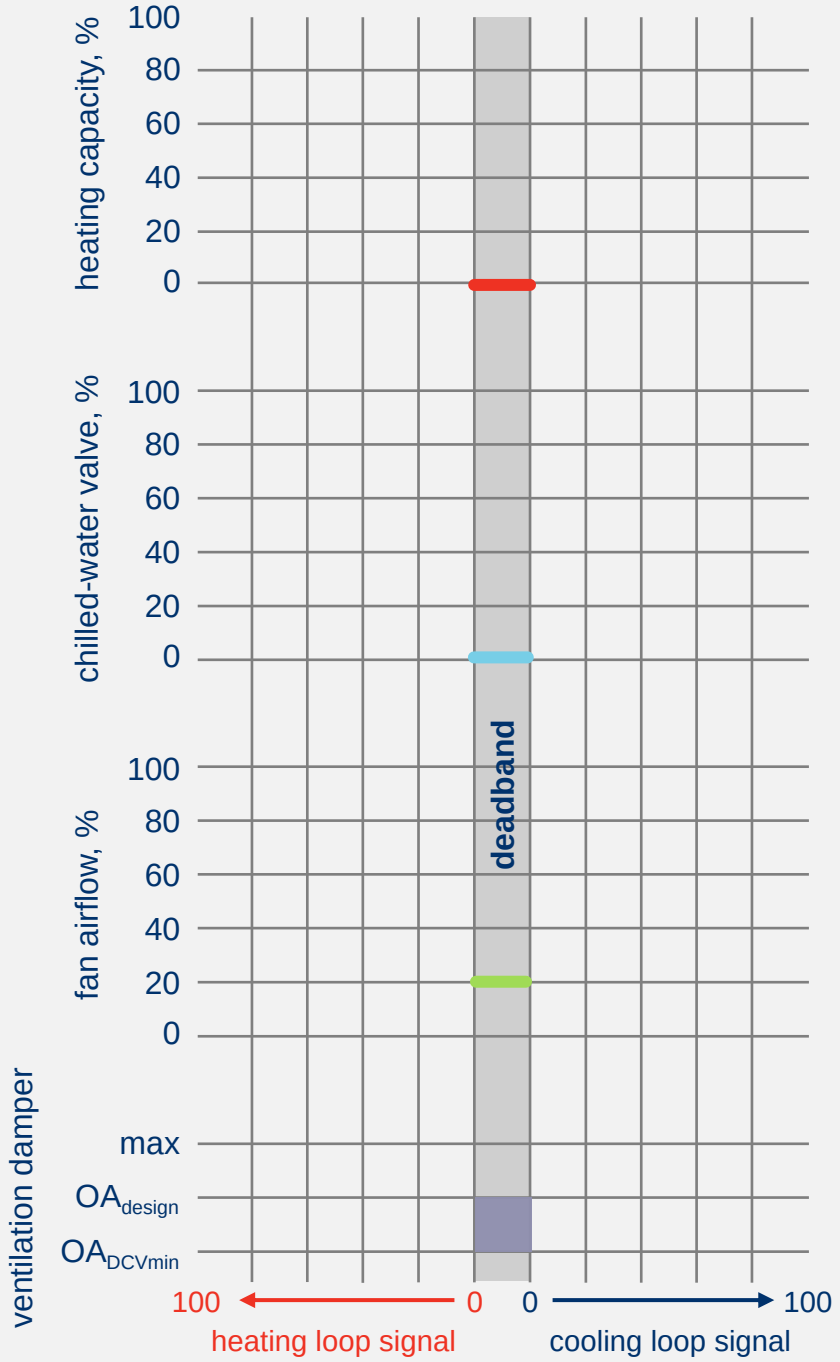
Chilled-water valve
100% open

Fan operates at
maximum airflow setpoint

Ventilation air damper modulates between minimum OA and maximum airflow setpoints

Occupied Mode:

Deadband



Hot-water valve closed
(electric heater off)

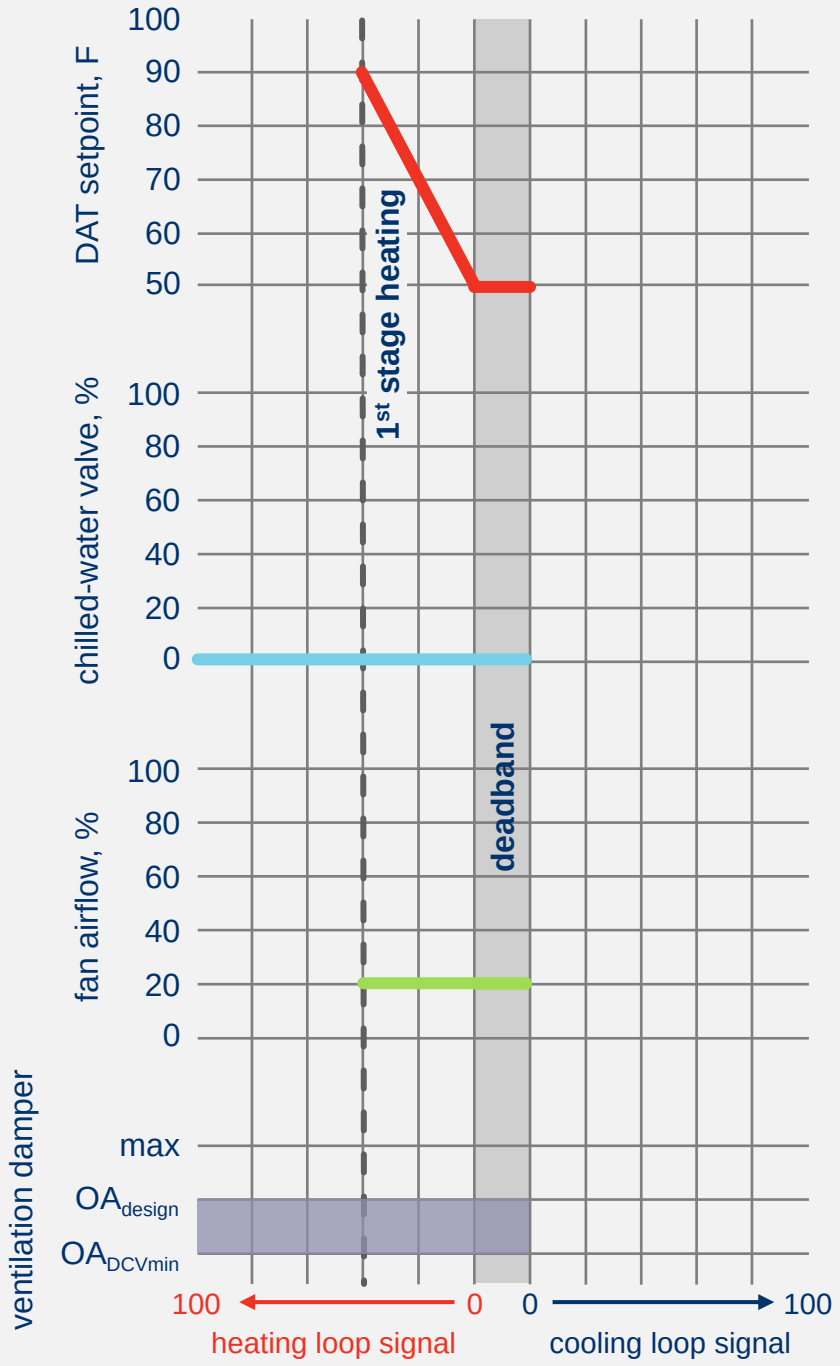
Chilled-water valve closed

Fan operates at
minimum airflow setpoint

Ventilation air damper at
current minimum OA setpoint

Occupied Mode:

Heating (1st stage)
with modulating heat



Hot-water valve (or SCR electric heater) modulates to maintain zone temperature

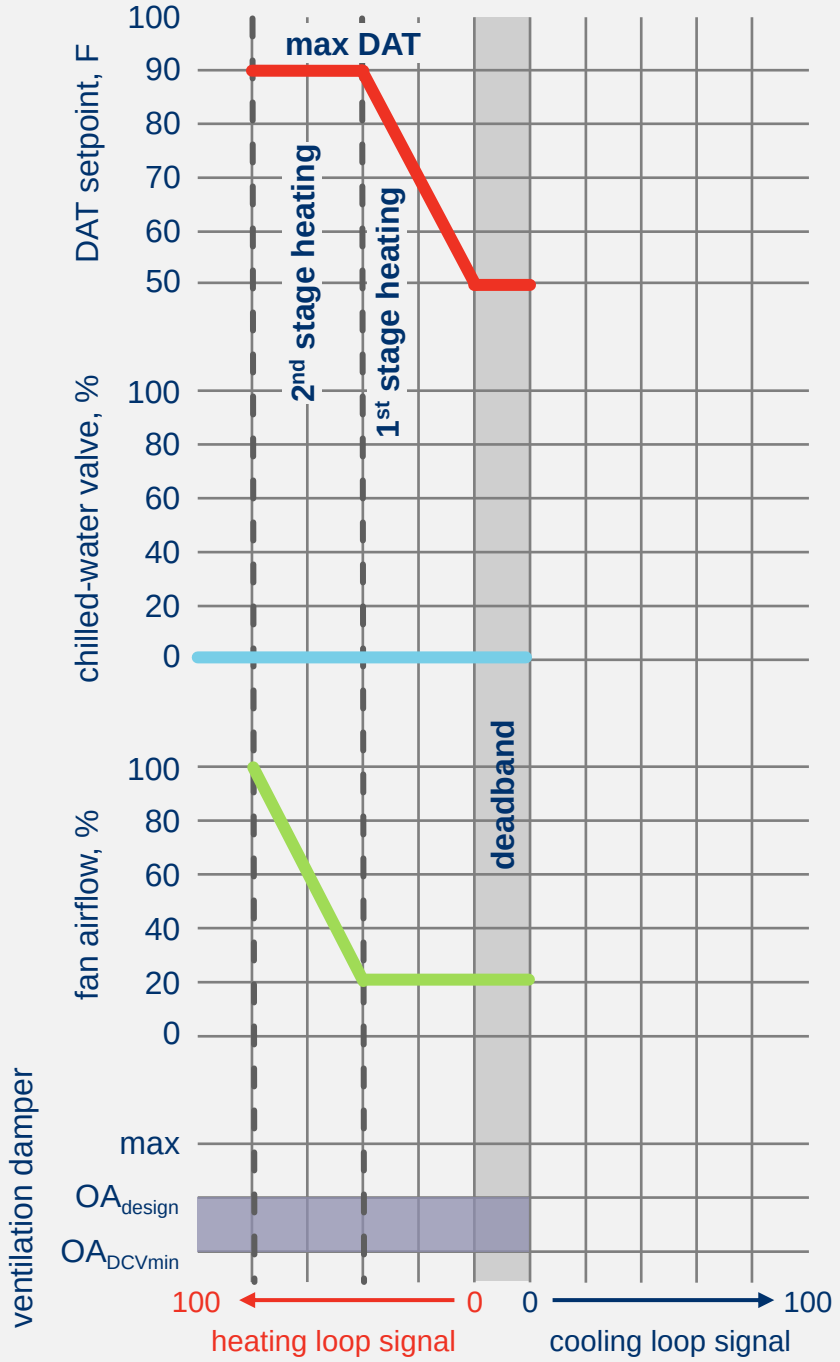
Chilled-water valve closed

Fan operates at minimum airflow setpoint

Ventilation air damper at current minimum OA setpoint

Occupied Mode:

Heating (2nd stage)
with modulating heat



Hot-water valve (or SCR electric heater) modulates to maintain discharge air temperature at maximum limit

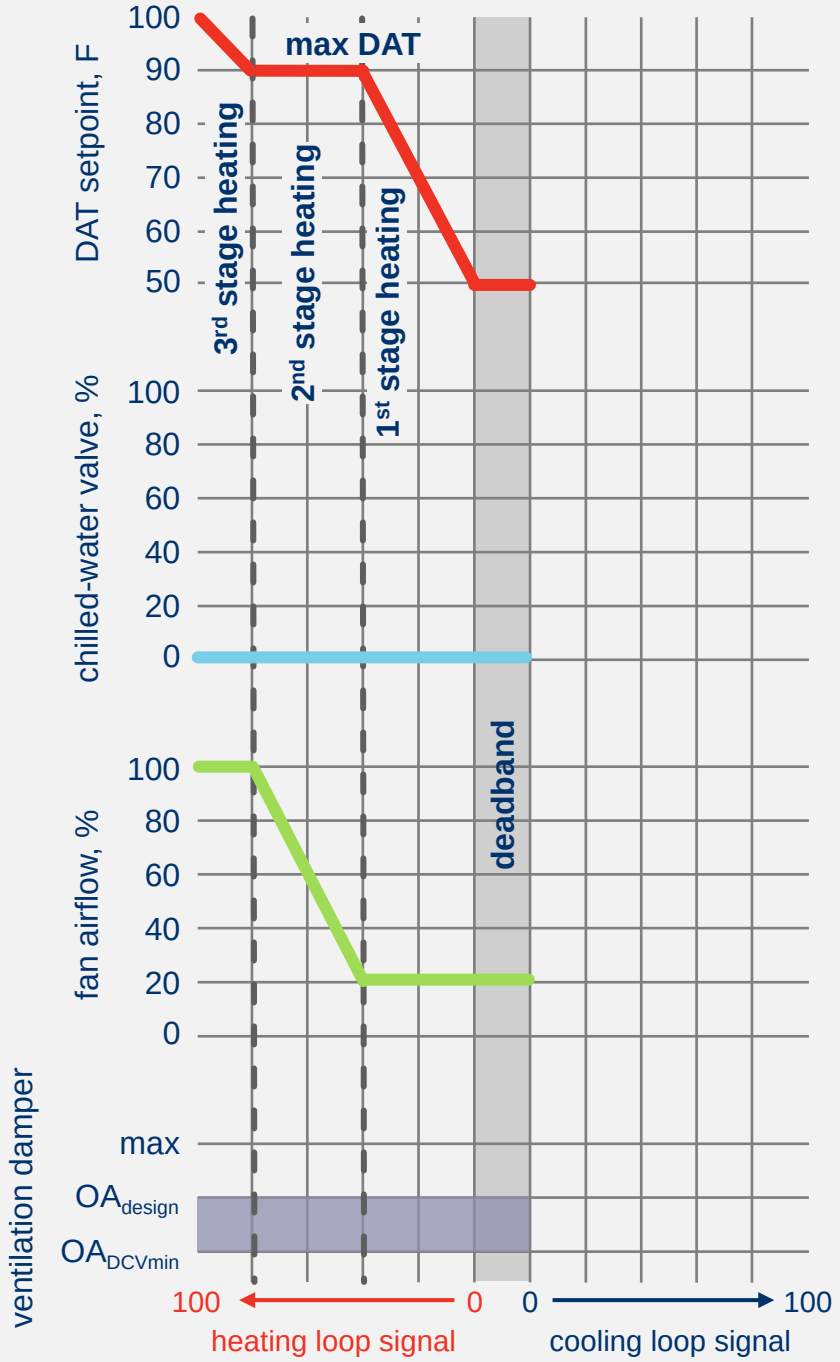
Chilled-water valve closed

Fan modulates between minimum and maximum airflow setpoints

Ventilation air damper at current minimum OA setpoint

Occupied Mode:

Heating (3rd stage)
with modulating heat



Hot-water valve (or SCR electric heater) modulates to maintain zone temperature

Chilled-water valve closed

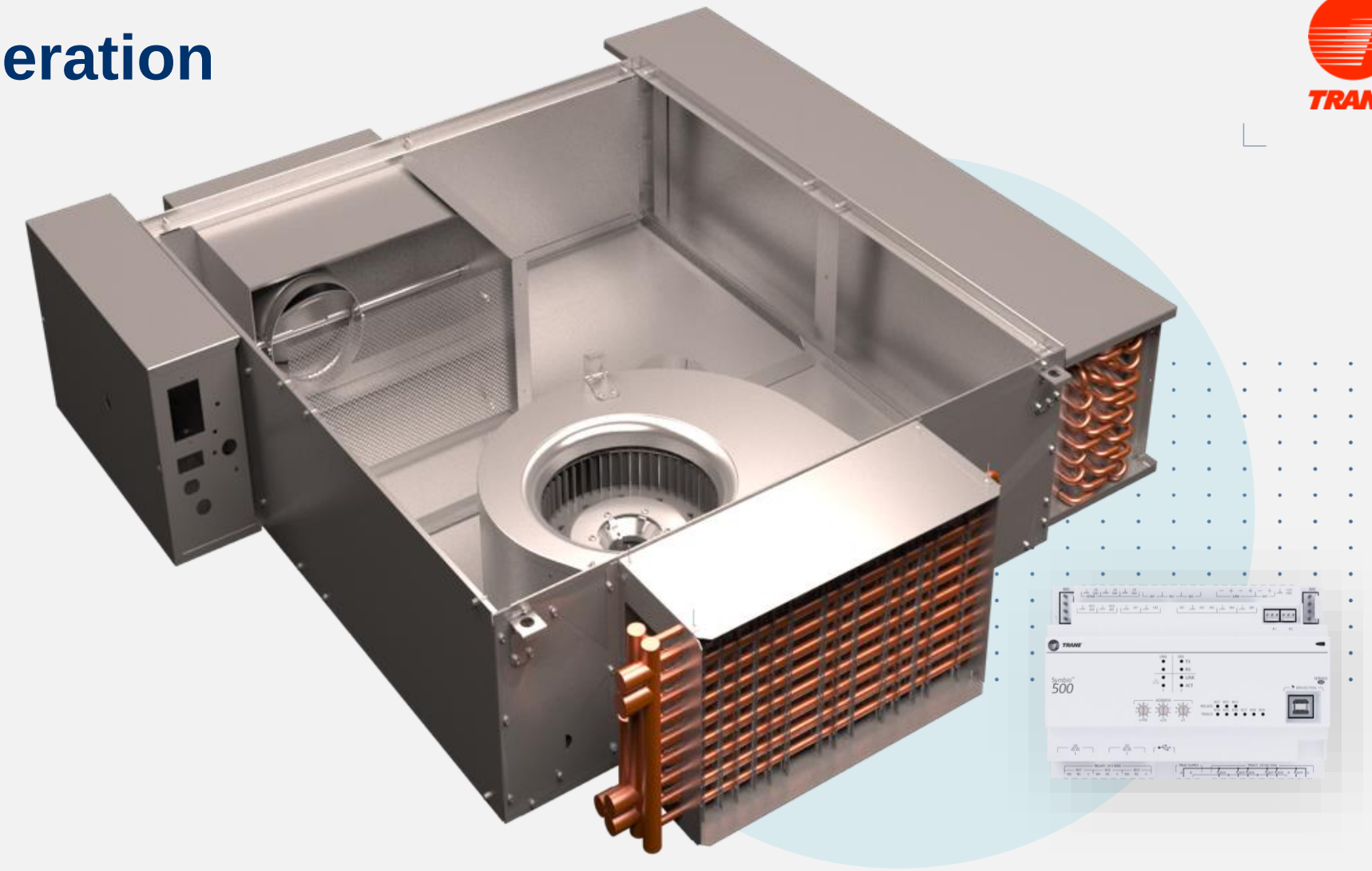
Fan operates at maximum airflow setpoint

Ventilation air damper at current minimum OA setpoint

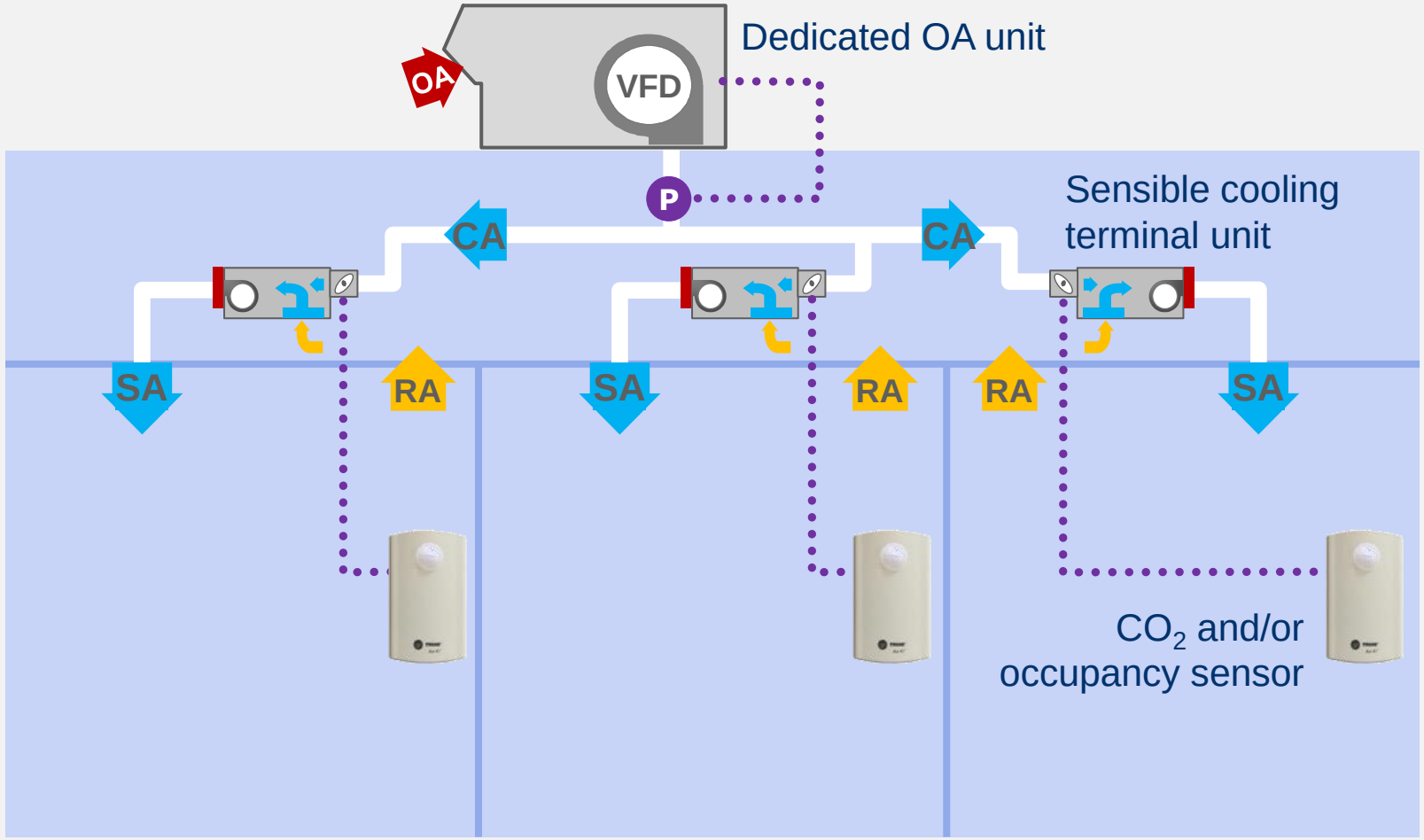
Summary

Sequence of Operation

- Minimizes energy
- Ensures comfort
- Optimizes ventilation

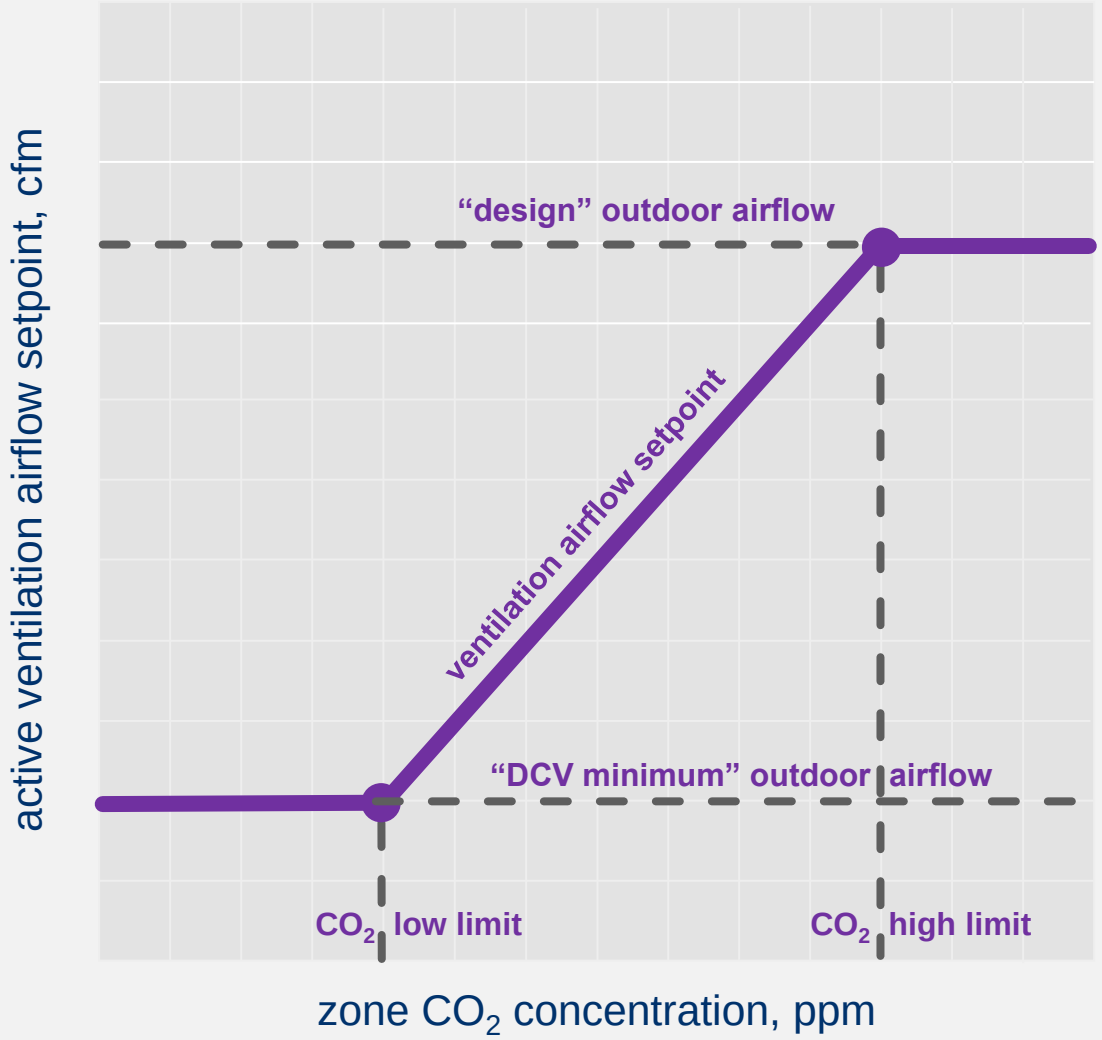


Demand-Controlled Ventilation (DCV)



Occupied Mode:

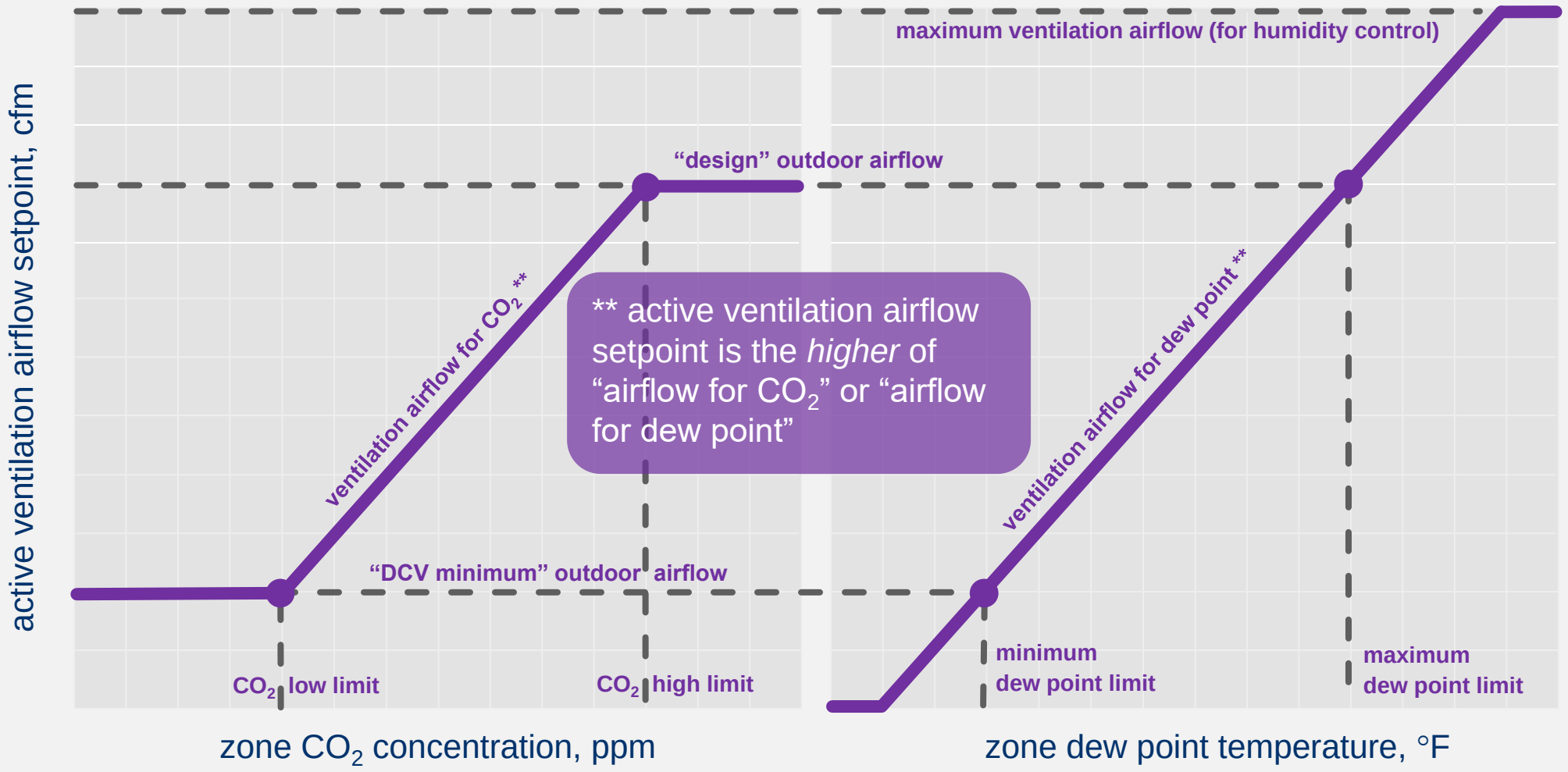
Demand-Controlled Ventilation (DCV)



Ventilation airflow setpoint adjusted based on zone CO_2 concentration (or occupancy sensor)

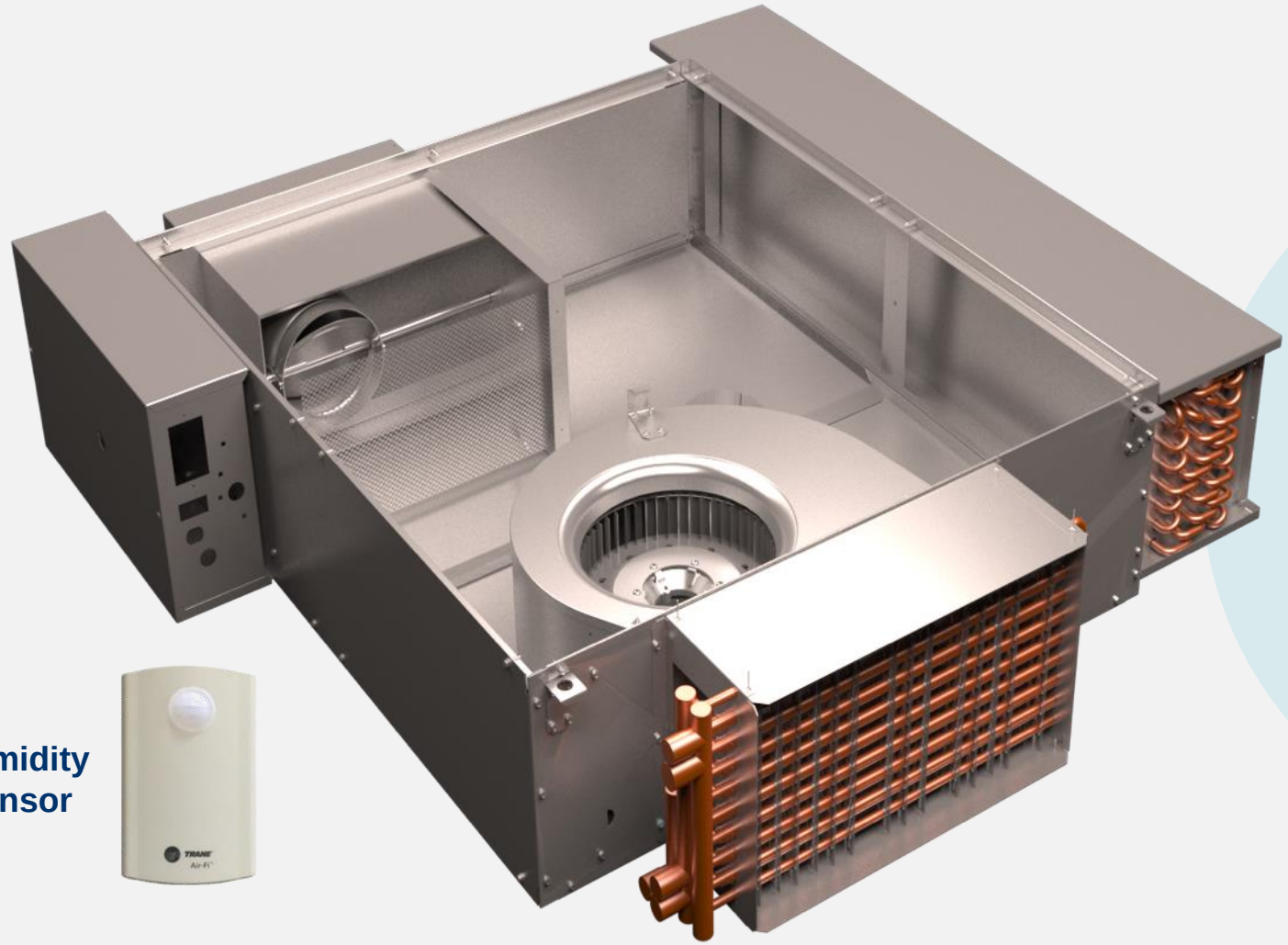
Occupied Mode:

Active Humidity Control



Occupied Mode:

Condensate Avoidance



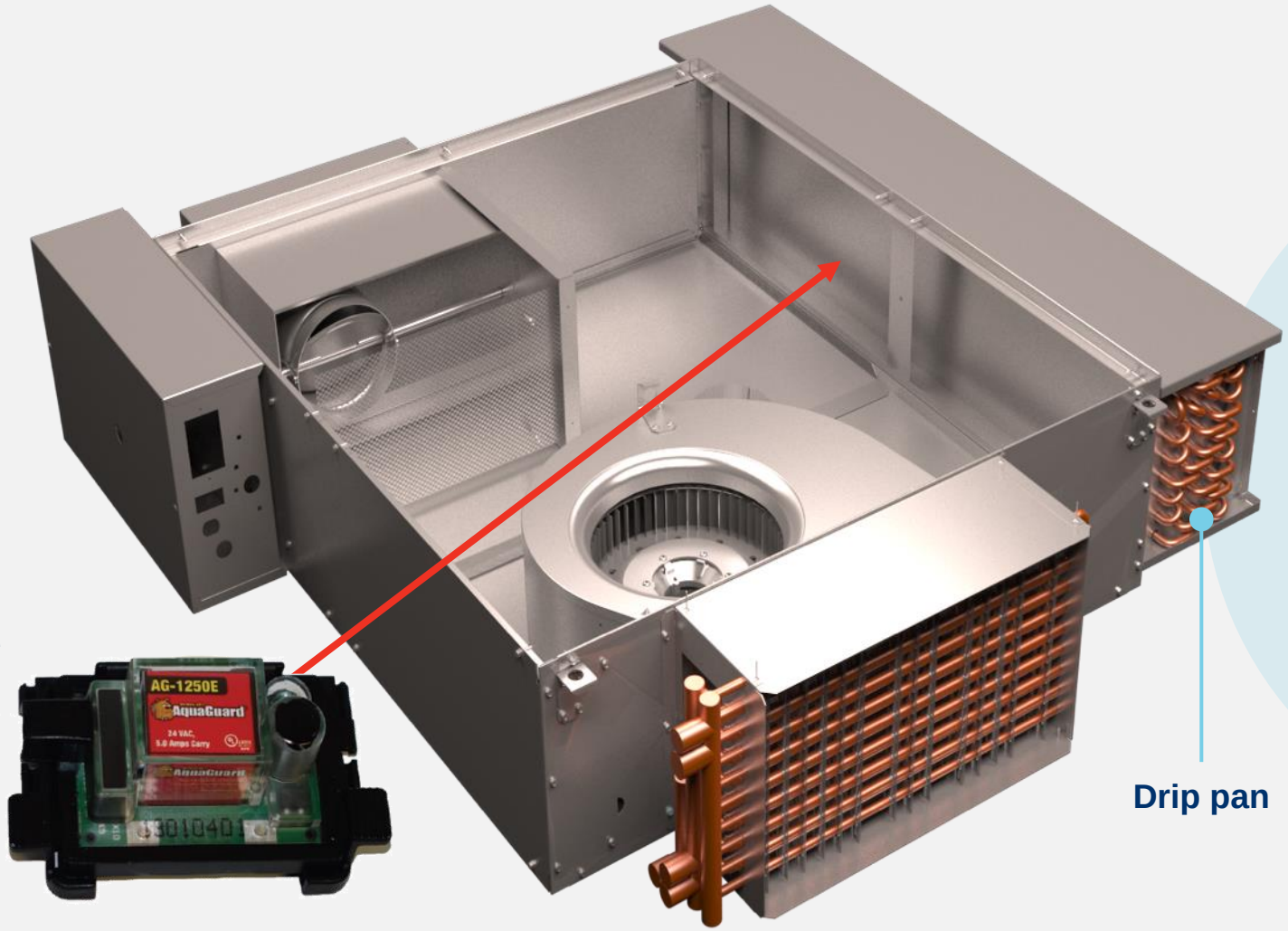
Humidity sensor

If zone dew point rises above entering chilled-water temperature, chilled-water valve is closed while the fan and ventilation damper continue to operate.

Returns to normal operation when zone dew point drops back below threshold.

Occupied Mode:

Condensate Detection



Moisture sensor

Drip pan

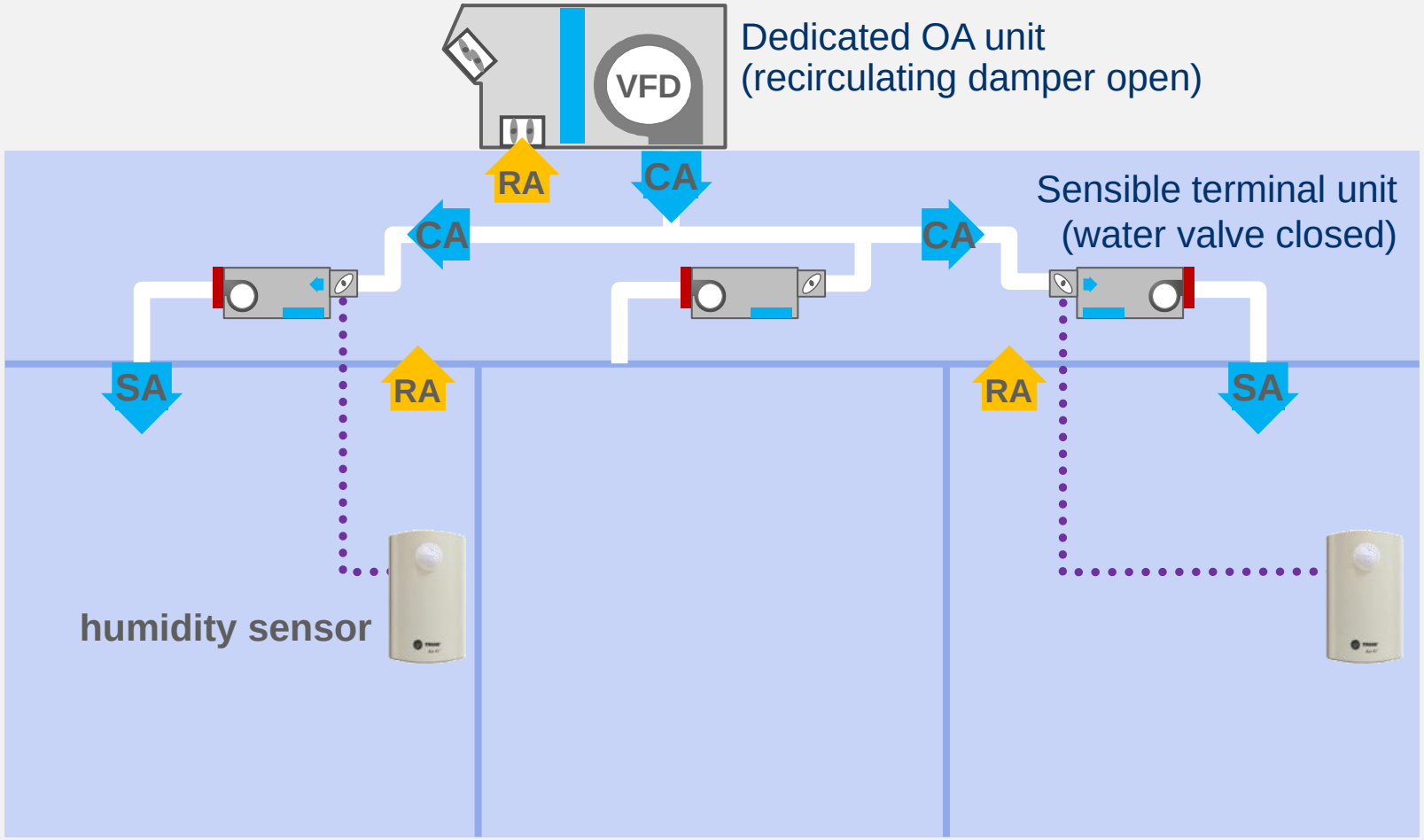
When condensate is detected, chilled-water valve is closed while the fan and ventilation damper continue to operate.

Returns to normal operation when condensate is no longer detected.

Three Levels of Condensation Prevention

1. **Active humidity control** (requires zone humidity sensor)
   - Ventilation airflow setpoint is reset based on zone dew point
2. **Condensate avoidance** (requires zone humidity sensor)
   - Chilled-water valve closed if zone dew point > entering chilled water temperature
3. **Condensate detection** (moisture sensor is standard)
   - Chilled-water valve closed if condensate detected in drip pan

Morning Dryout (Humidity Pull-down Mode)

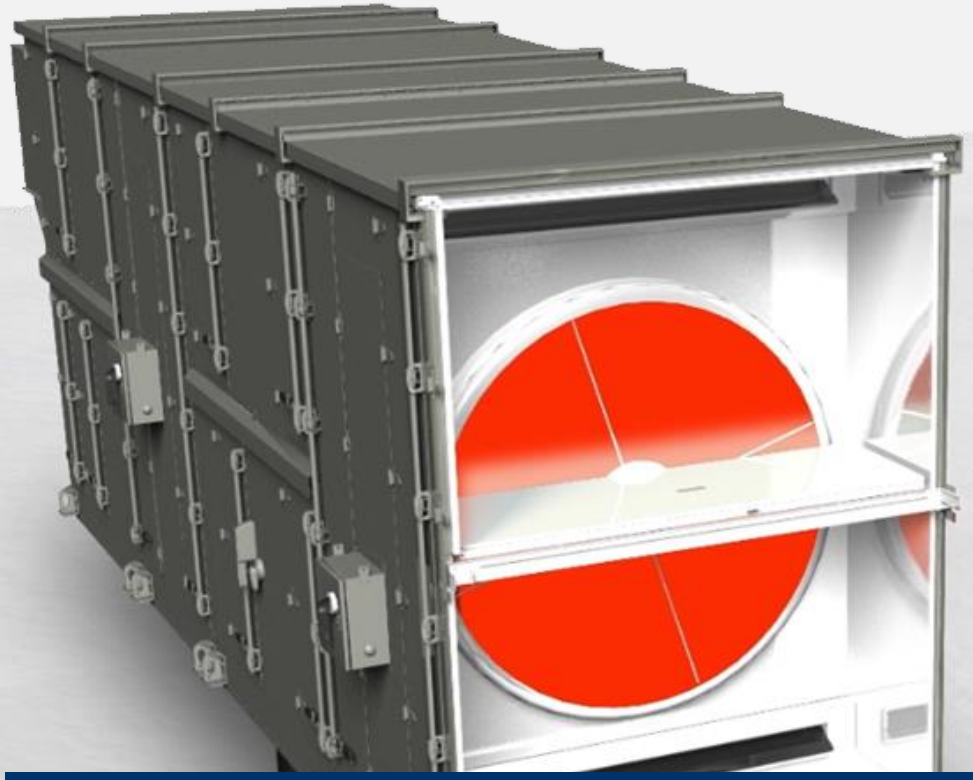


Dedicated OA unit
- OA damper closed
- Recirculating damper open
- Dehumidifying coil on

Terminal unit
- Fan on
- Chilled-water valve closed
- Ventilation damper open

Increased Flexibility to Trim Energy and Actively Control Humidity

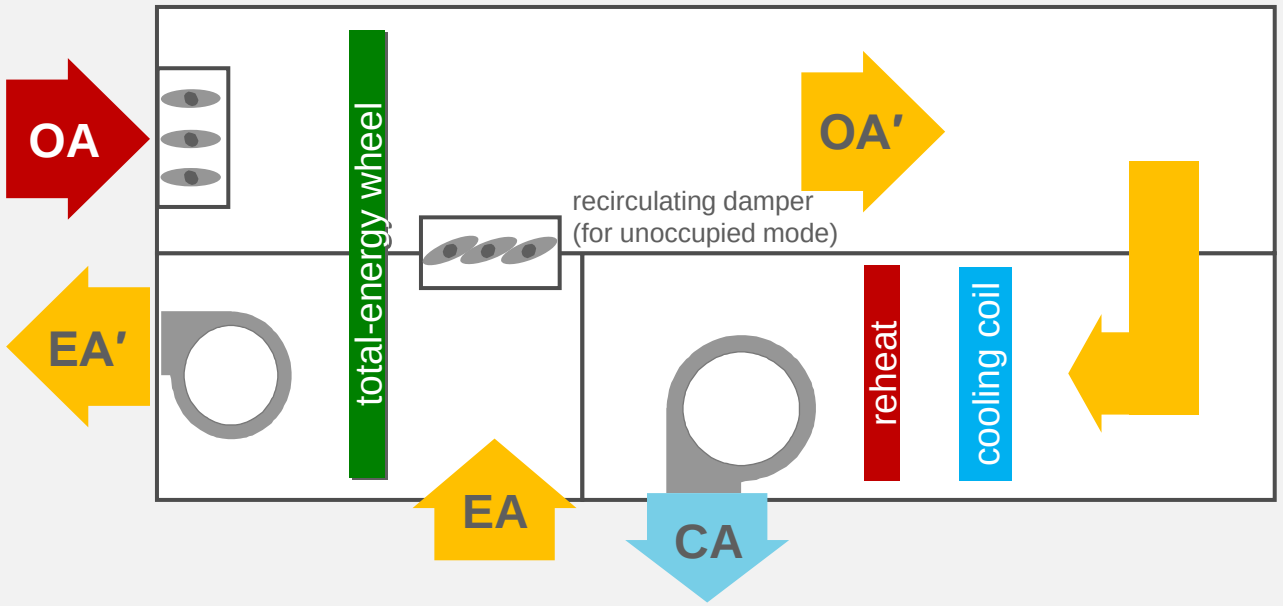
Dedicated Outdoor Air System (DOAS)



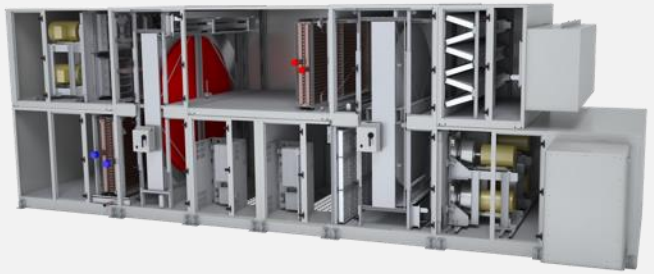


DOAS provides dehumidification to control indoor dew point to ≤ 55ºF

Total-Energy Wheel + Cooling Coil + Reheat











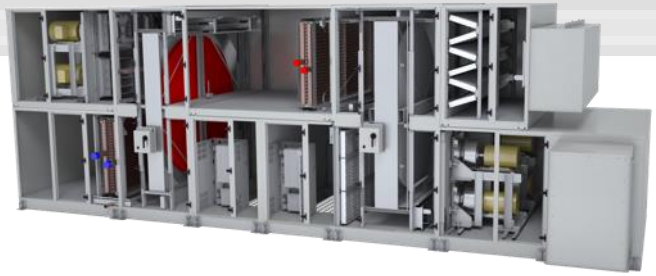


DOAS Configurations for Sensible Cooling Systems



#1 – Total-Energy Wheel + Cooling Coil + Reheat

'cold' supply air delivered from DOAS



#2 – Total-Energy Wheel + Cooling Coil + CDQ Wheel

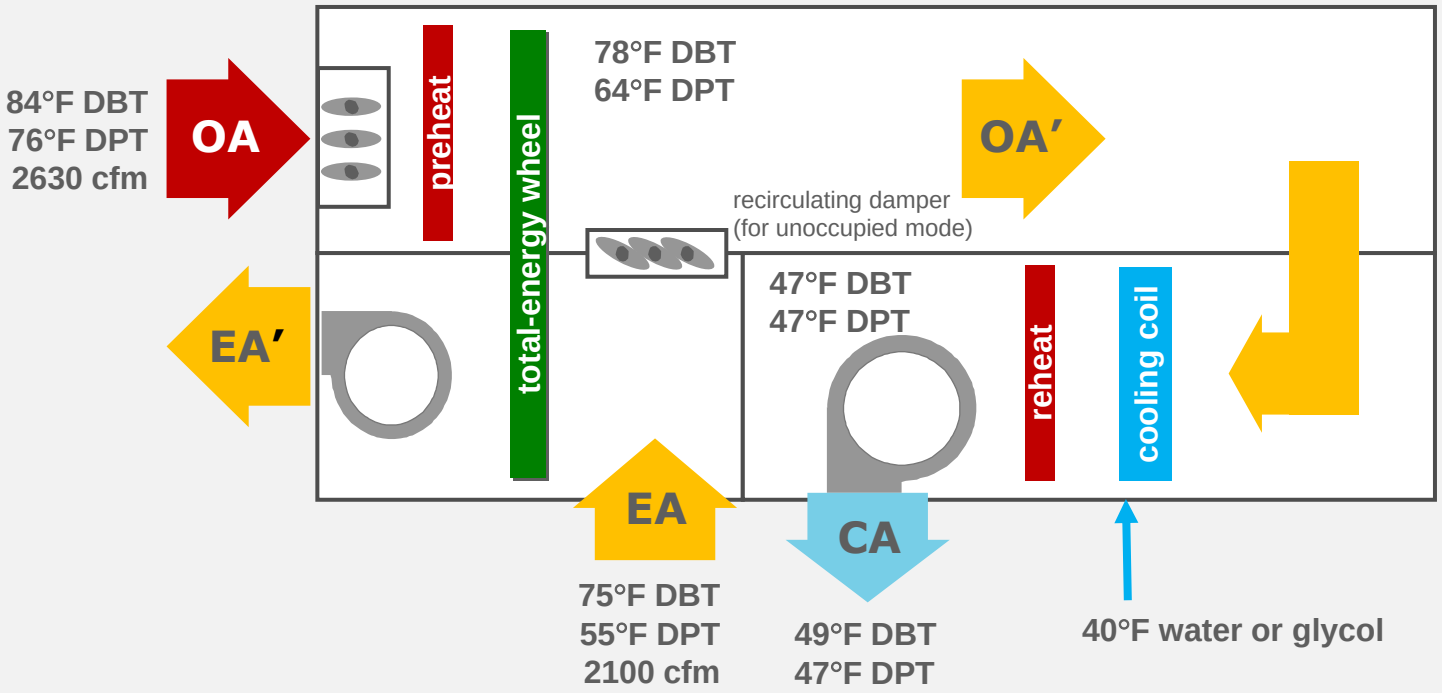
'cool' supply air delivered from DOAS



#3 – Total-Energy Wheel + Cooling Coil + Fixed-Plate HX

'neutral' supply air delivered from DOAS

Total-Energy Wheel + Cooling Coil + Reheat

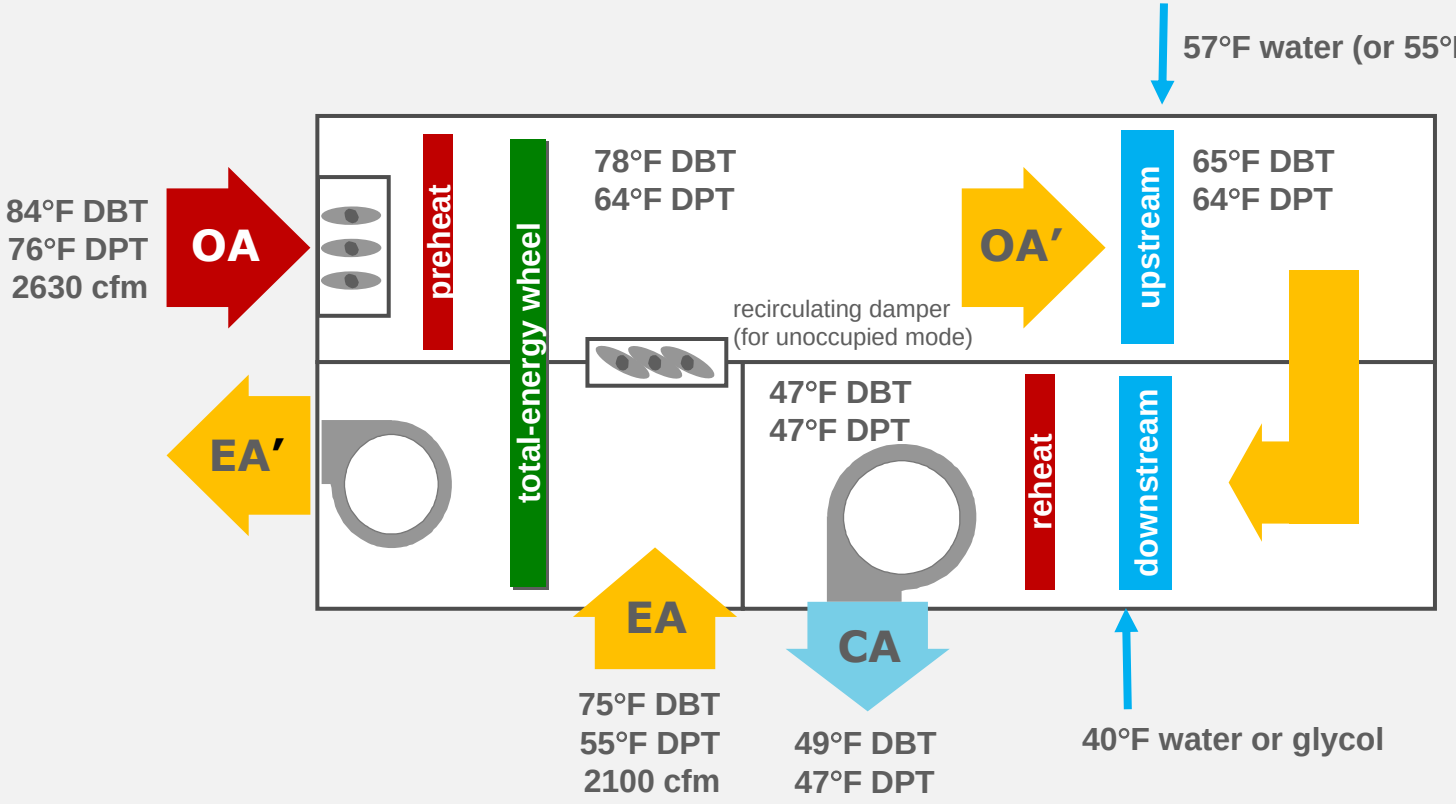


- Simplest and smallest footprint of these three AHU configurations
- Delivers the coldest air, allowing for zone-level terminals to be downsized the most
- Requires careful attention to downstream duct insulation to prevent condensation

Q_{CC} = 14.3 tons (40°F water or glycol)

Sensible cooling provided by 49°F conditioned air (CA) = 6.2 tons

Total-Energy Wheel + Two Cooling Coils + Reheat



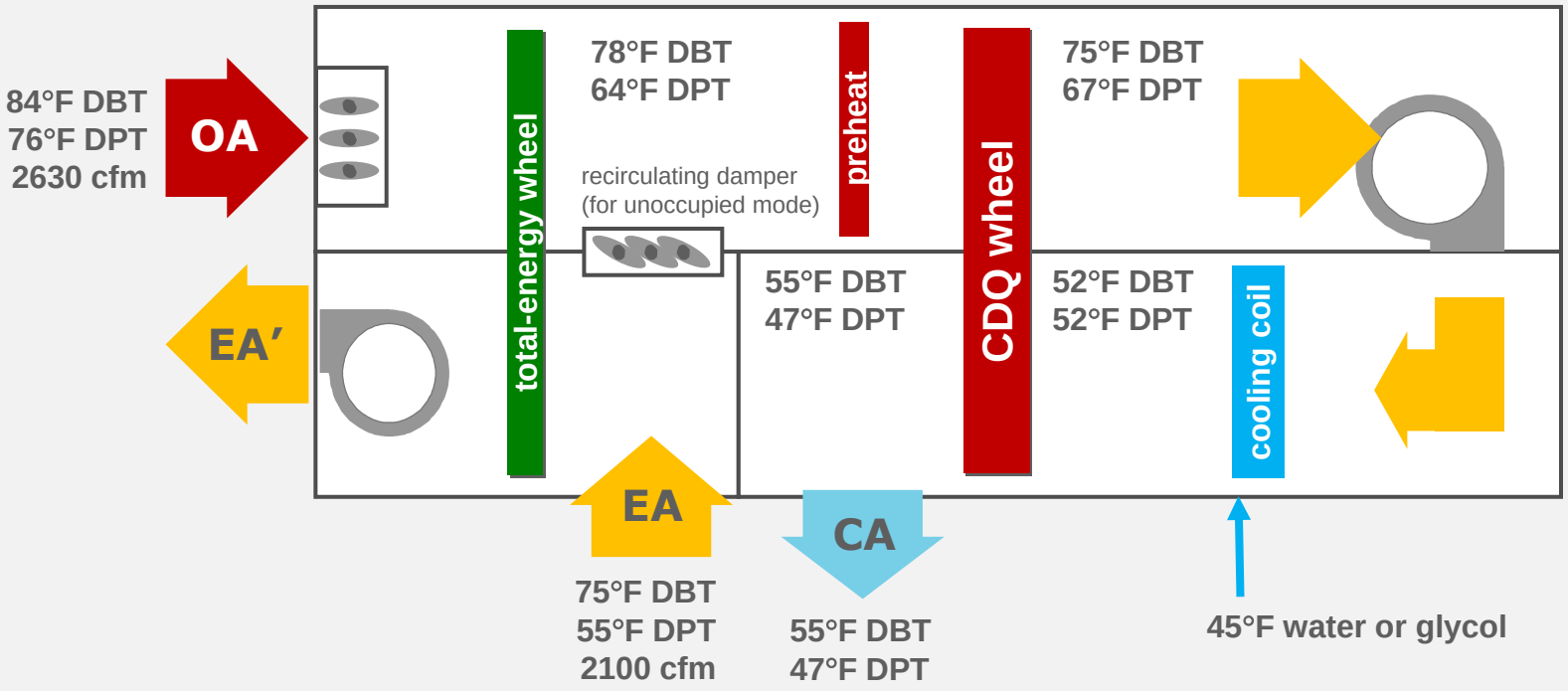
- Allows the “cold water” chiller to supply warmer water than in the other two configurations
- Leaving air dry-bulb temperature is warmer than in Configuration #1, reducing risk of condensation on downstream ductwork
- Still delivers cold air, allowing for zone-level terminals to be downsized (but not as much as with Configuration #1)
- Added pressure loss in the airstream (due to the CDQ wheel) results in increased DOAS fan energy

$Q_{CC,upstream}$ = 3.1 tons (57°F water or 55°F glycol)

$Q_{CC,downstream}$ = 11.2 tons (40°F water or glycol)

Sensible cooling provided by 49°F conditioned air (CA) = 6.2 tons

Total-Energy Wheel + Cooling Coil + CDQ Wheel

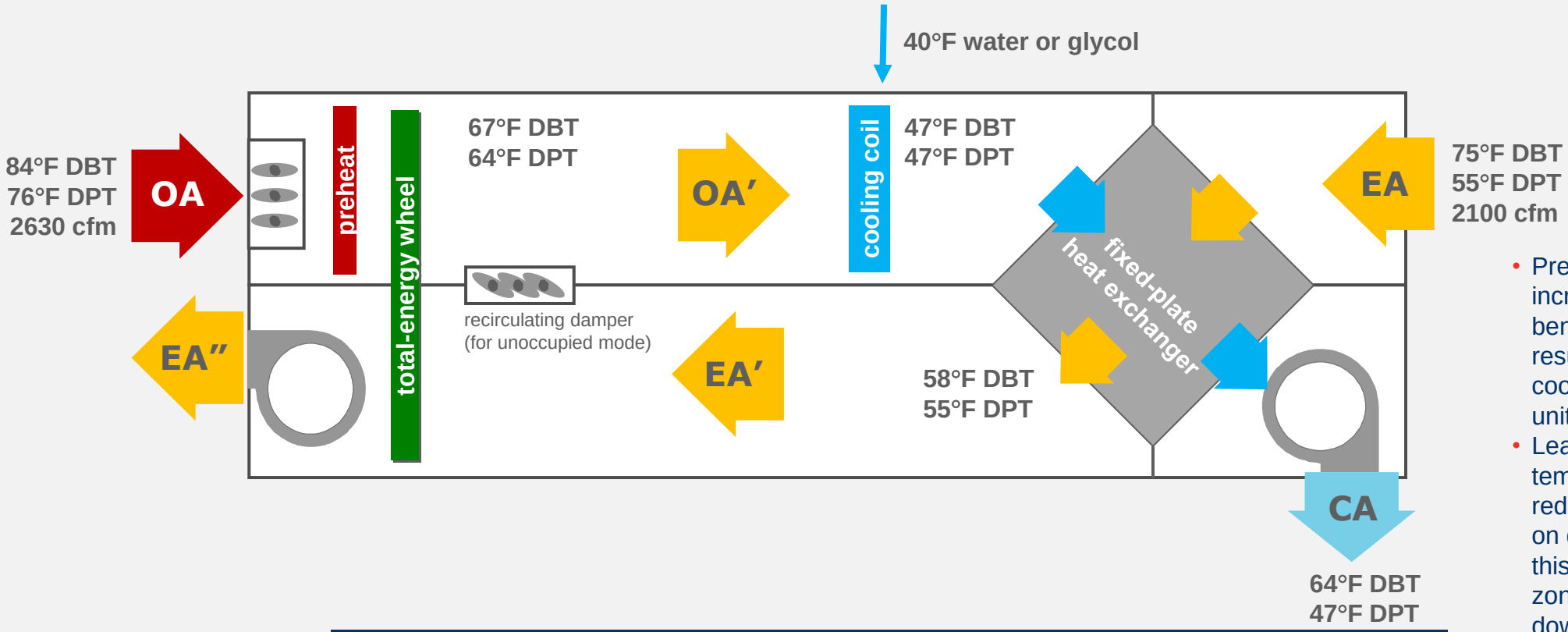


Q_{CC} = 13.0 tons (45°F water or glycol)

Sensible cooling provided by 55°F conditioned air (CA) = 4.9 tons

Dedicated OA Unit Configuration #3 (neutral supply air)

Total-Energy Wheel + Cooling Coil + Fixed-Plate HX

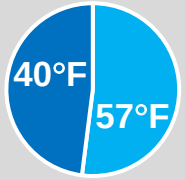
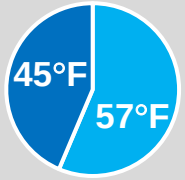
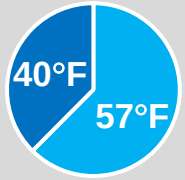
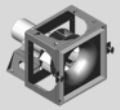
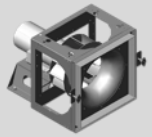
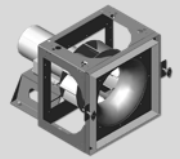


Q_{CC} = 11.3 tons (40°F water or glycol)

Sensible cooling provided by 64°F conditioned air (CA) = 2.6 tons

- Pre-cooling of exhaust air increases energy-saving benefits of total-energy wheel, resulting in smallest design cooling load on dedicated OA unit
- Leaving air dry-bulb temperature is warmer, reducing risk of condensation on downstream ductwork, but this warmer air does not allow zone-level terminals to be downsized as much
- Added pressure losses in the airstreams (due to the fixed-plate HX) results in increased DOAS fan energy

DOAS Configurations

	Configuration #1 cold supply air	Configuration #2 cool supply air	Configuration #3 neutral supply air
DOAS supply air conditions	**49°F DBT** 47°F DPT	**55°F DBT** 47°F DPT	**64°F DBT** 47°F DPT
DOAS chilled water temperature	**40°F**	**45°F**	**40°F**
Cold water / warm water capacities			
DOAS fan power			
DOAS air handler footprint and weight			

DOAS with Sensible Cooling Terminals System

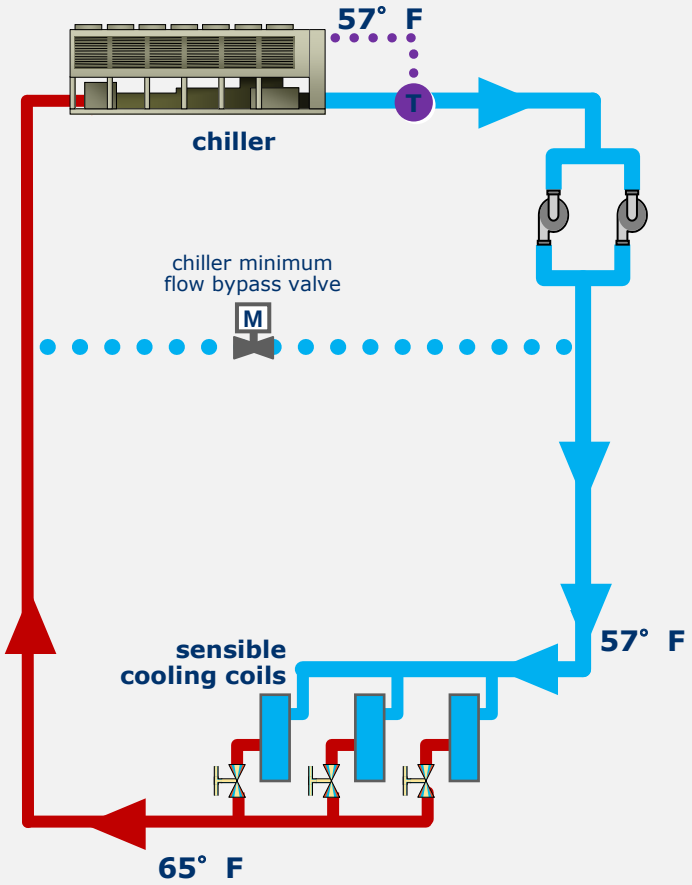
Chilled water delivered to the sensible-cooling terminal units must be warm enough to avoid condensation (e.g., 56ºF to 60ºF)

Chilled water delivered to the dedicated OA unit must be cold enough to sufficiently dehumidify the building (e.g., 38ºF to 45ºF)



Single Temp Chiller Plants

- Single Chiller
  - Optional: waterside economizer
- Air Cooled DX DOAS Unit

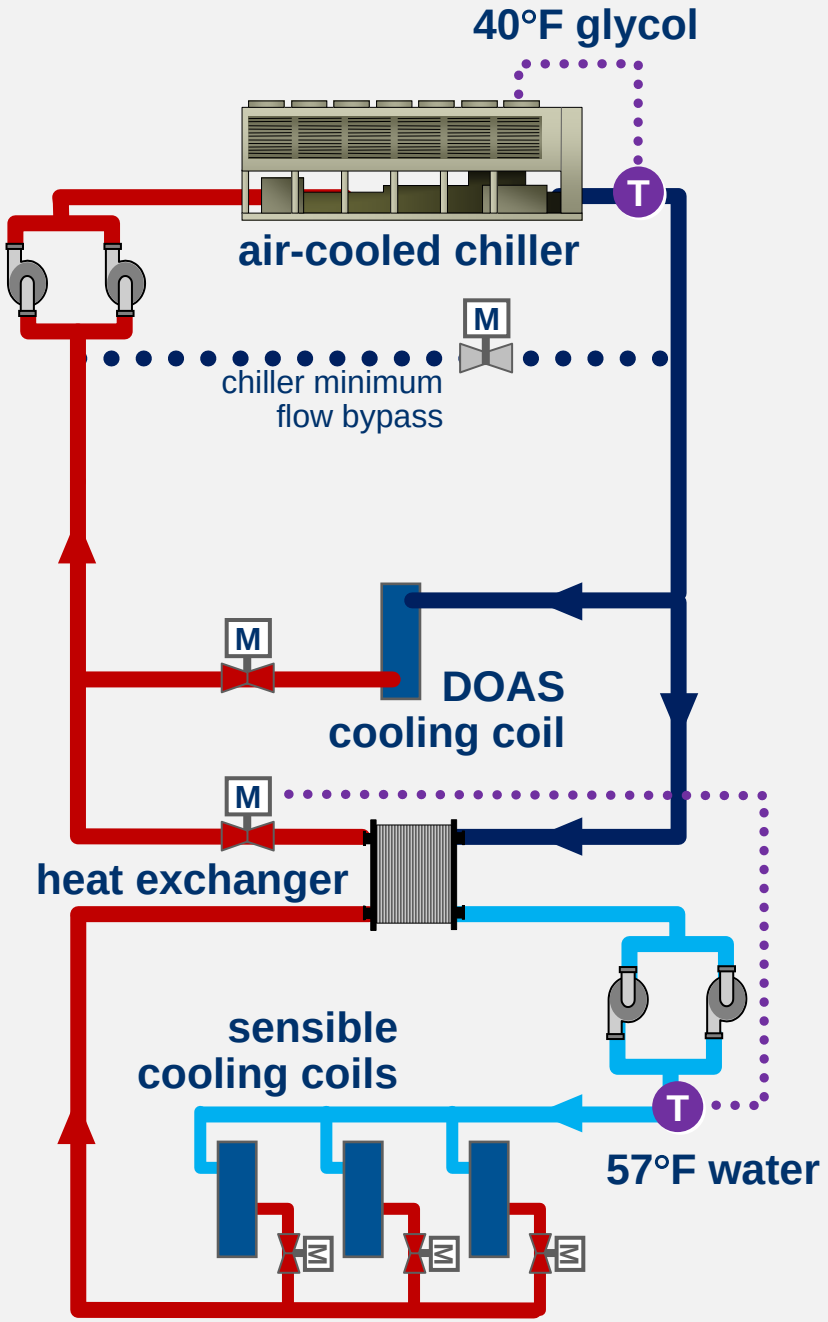


Air-Cooled
DX DOAU Unit



Dual-Temp Chiller Plants

- Single Chiller with Intermediate HX

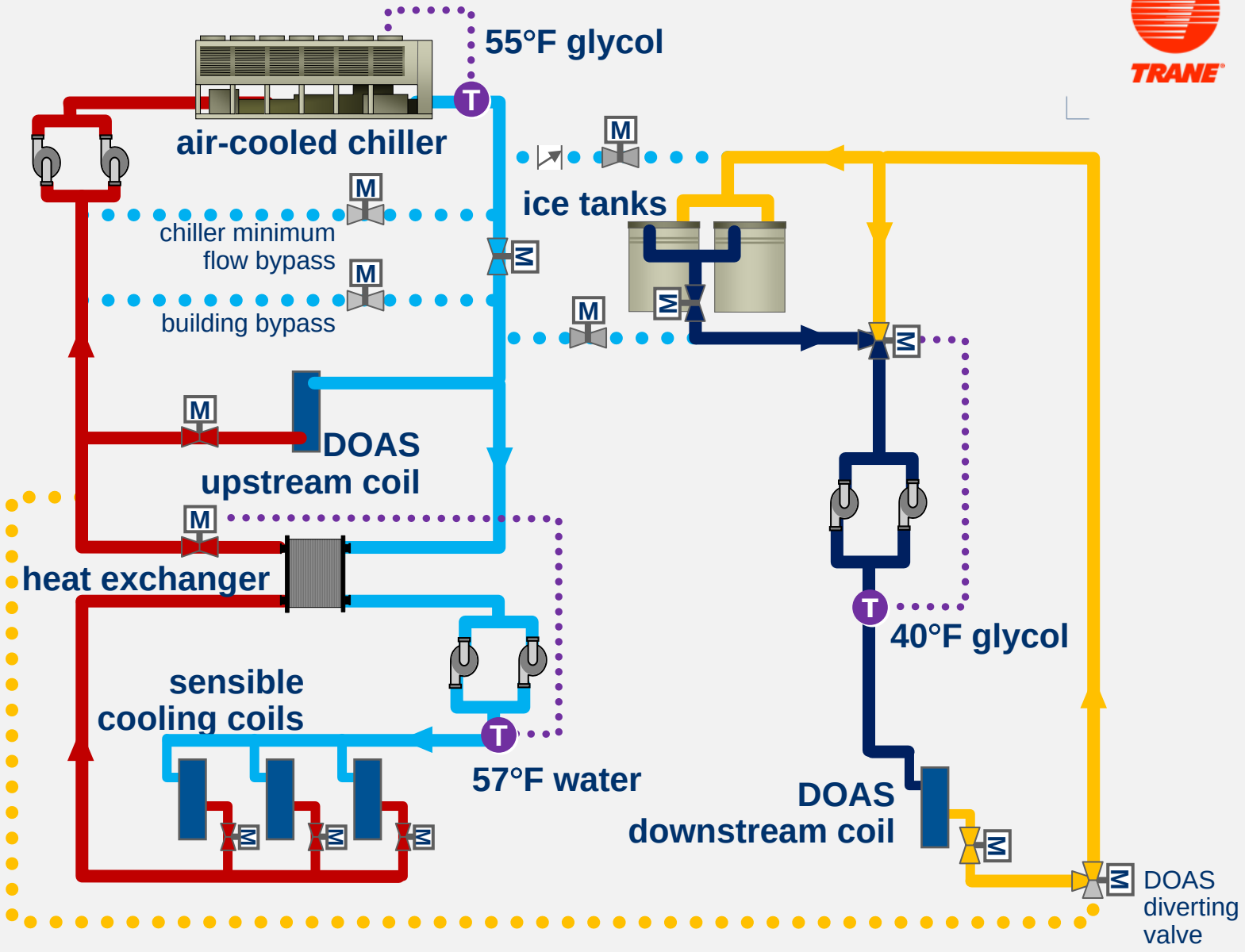


Single-Chiller, Dual-Temp Plant

with ice storage

Adding a diverting valve with connecting pipe, and using two cooling coils in series in the dedicated OA unit, allows:

- Operation of chiller only during daytime, if ice is not available
- Use of melting ice to satisfy terminal unit cooling loads. Also, on days when not all the ice is needed for DOAS dehumidification
- Zone-sensible cooling and/or dehumidification at night, while concurrently making ice

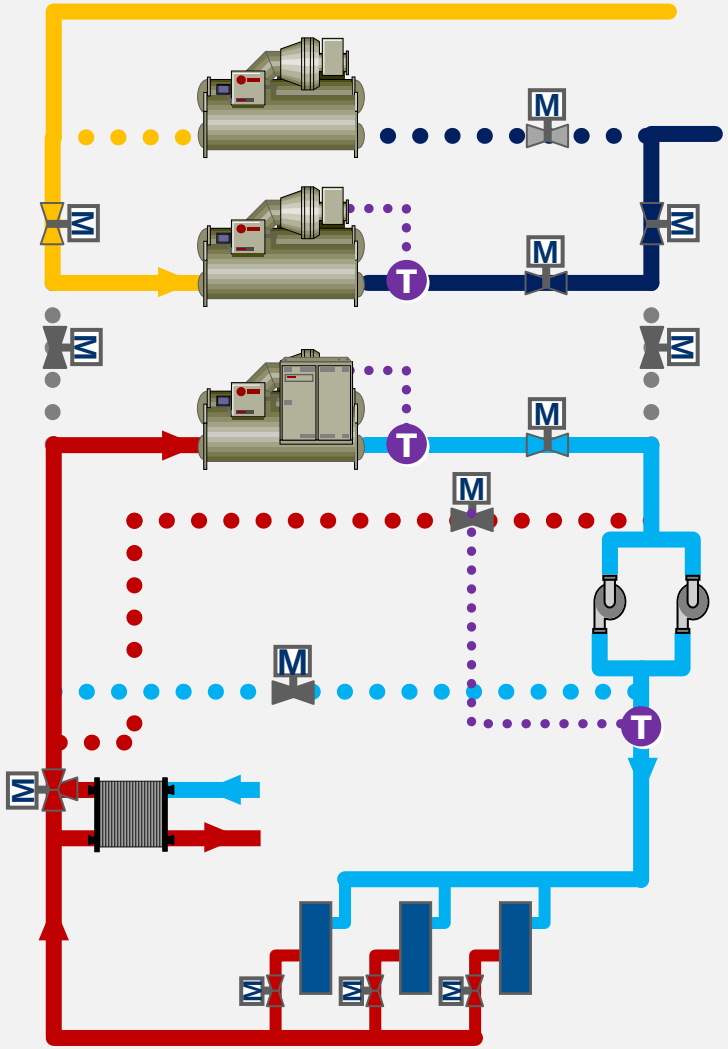


DOAS with Sensible Cooling Terminals System

Dual-Temp Chiller Plant Configurations

- Single Chiller with Intermediate HX
- Single Chiller with Blending Valve
- Single Chiller with Thermal Energy Storage
- Two Chillers with Dedicated Loops
- Three-plus Chillers on Dedicated Loops

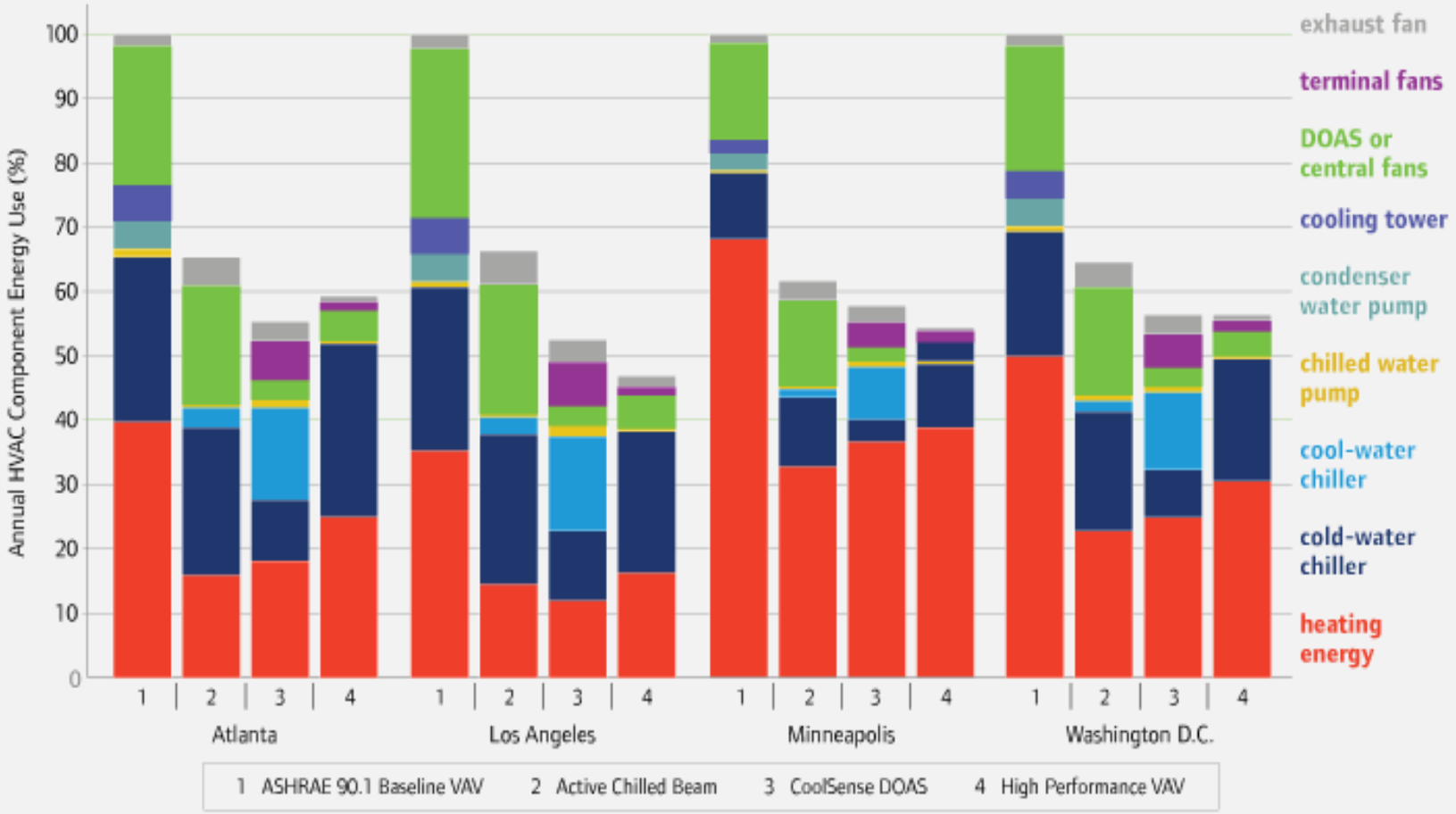
Integration of heat pump chillers!



Energy Performance Comparison

- **Active chilled beam system**
  - Four-pipe active chilled beams
  - Separate CV primary AHUs for perimeter vs. interior, with total-energy wheels
  - Separate chiller plants (57ºF to chilled beams, 45ºF to primary AHUs)
- **Sensible Cooling paired with DOAS system**
  - Terminal units with variable-speed fans, hot-water heating coils and DCV
  - Dedicated OA AHU with total energy wheel
  - Separate chiller plants (57ºF to terminal units, 40ºF to DOAS)
- **High-performance VAV system**
  - Central AHU with total energy wheel
  - Optimized control strategies (demand-controlled ventilation, fan-pressure optimization and supply-air temperature reset)
  - Single chiller plant (40ºF to central AHU)

Energy Performance Comparison



Office building: 268,000 ft²

Chilled beam system

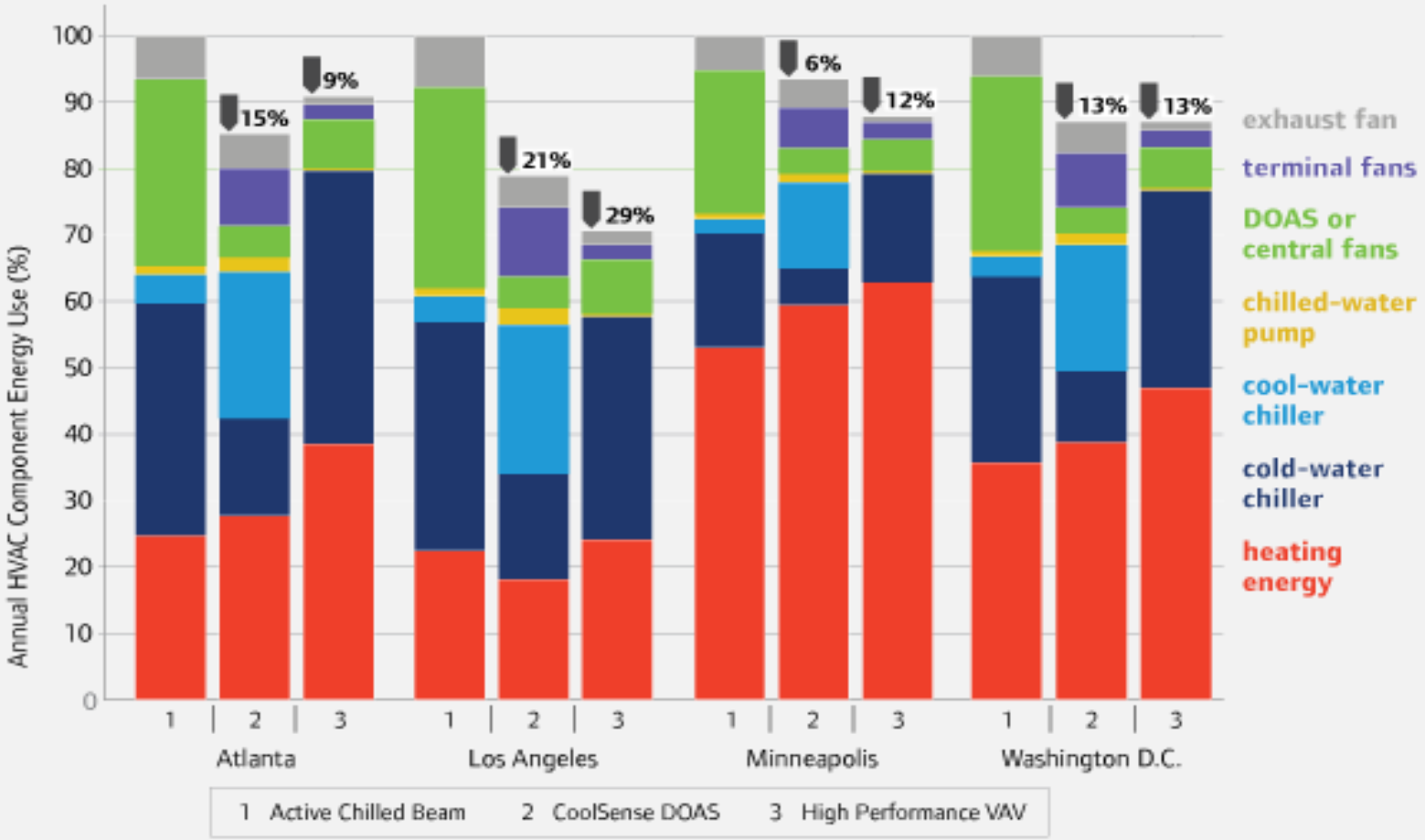
- Four-pipe active chilled beams
- Separate CV AHUs for perimeter vs. interior with energy wheels in each
- Separate chiller plants (57ºF to ACBs, 45ºF to AHUs)

CoolSense system

- Terminal units with variable-speed fans and hot water heating coils
- Dedicated OA AHU with total energy wheel
- Separate chiller plants (57ºF to terminals, 40ºF to AHU)

Source: Trace 700 output October 2017.

Energy Performance Comparison



Office building: 268,000 ft²

Chilled beam system

- Four-pipe active chilled beams
- Separate CV AHUs for perimeter vs. interior with energy wheels in each
- Separate chiller plants (57ºF to ACBs, 45ºF to AHUs)

CoolSense system

- Terminal units with variable-speed fans and hot water heating coils
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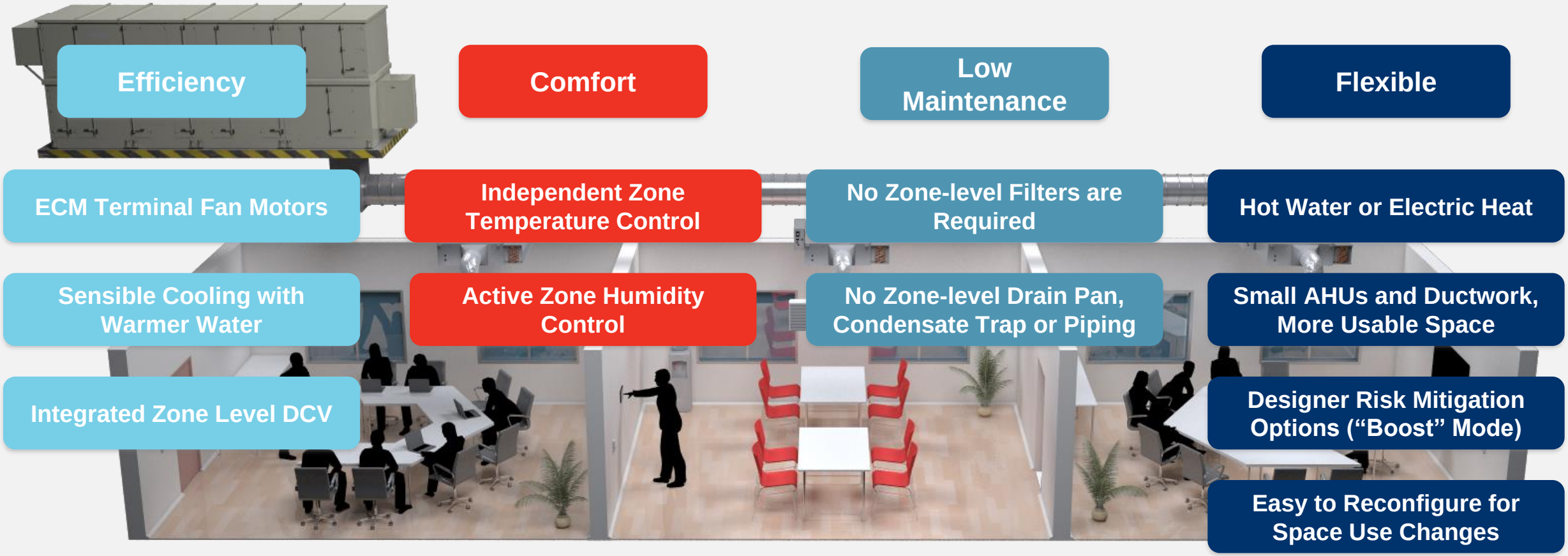
Summary of Benefits



- Efficiency
- Comfort
- Low Maintenance
- Flexible
- ECM Terminal Fan Motors
- Independent Zone Temperature Control
- No Zone-level Filters are Required
- Hot Water or Electric Heat
- Sensible Cooling with Warmer Water
- Active Zone Humidity Control
- No Zone-level Drain Pan, Condensate Trap or Piping
- Small AHUs and Ductwork, More Usable Space
- Integrated Zone Level DCV
- Designer Risk Mitigation Options (“Boost” Mode)
- Easy to Reconfigure for Space Use Changes

Advantages vs. Active Chilled Beams



Typically, smaller ductwork and smaller AHU

Equipped with a drip pan, optional filter

Easier to implement DCV

Fewer terminal units per zone

Factory-mounted, pre-engineered controls

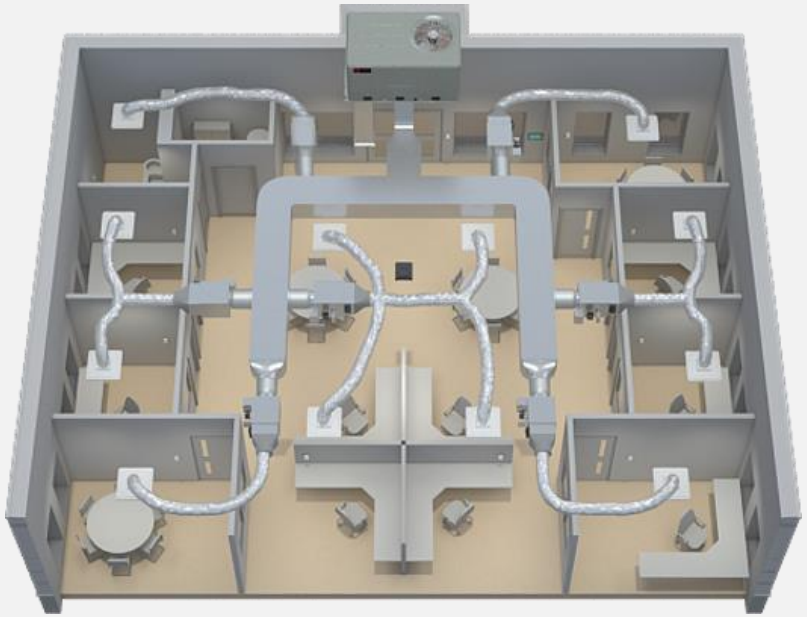
Easier to reconfigure when space usage changes

Allows unoccupied heating or cooling without central fan

Advantages vs. Traditional VAV System

Benefits

- Individual zone temperature control
- Part load energy savings
- Adaptability to building usage changes
- Dehumidification due to constant supply temp
- Smaller ductwork
- Simpler to design ventilation system
- Easier to implement DCV
- Warmer chilled water for sensible cooling
- Typically, less reheat energy
- Allows unoccupied heating or cooling without central fan



Challenges

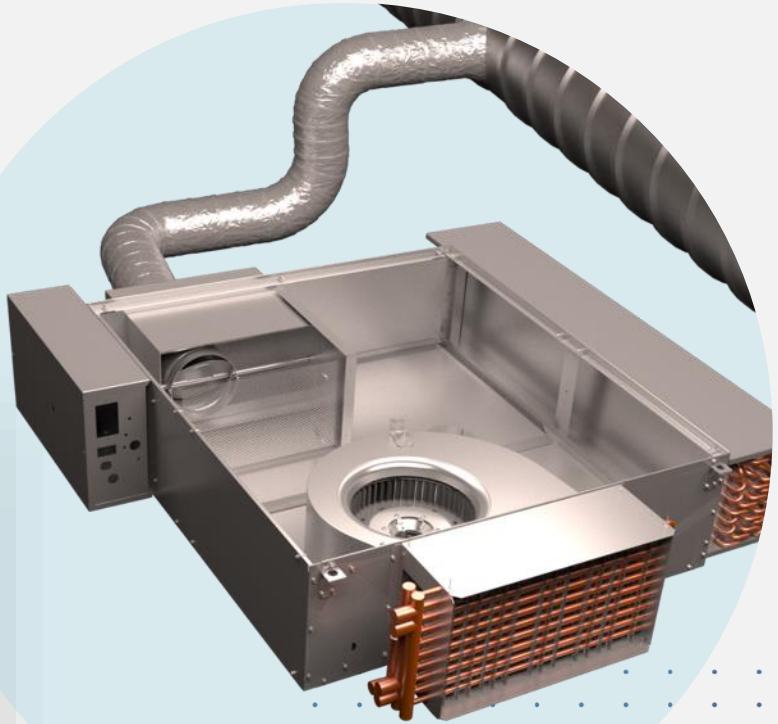
- Supply/return ductwork sized for full airflow
- Ventilation verification
- Local reheat
- More water piping, increased risk for leaks
- Risk of condensation of zone cooling coils
- Little (or no) airside economizing
- Increased pumping energy

CoolSense™ System from Trane

- **Breakout sessions to follow:**
  - Deep dive on electrification opportunities: “Successfully Electrifying Sensible Cooling Systems to Achieve Decarbonization Goals, Tax Incentives and Lower Costs”
  - Exploring how to leverage VRF as a Sensible only Cooling Coil to save energy: “Successful Application of VRF to Electrify Buildings”
  - See how heat pumps can integrate into the system: “Who Said, ‘Use a Heat Pump’?”







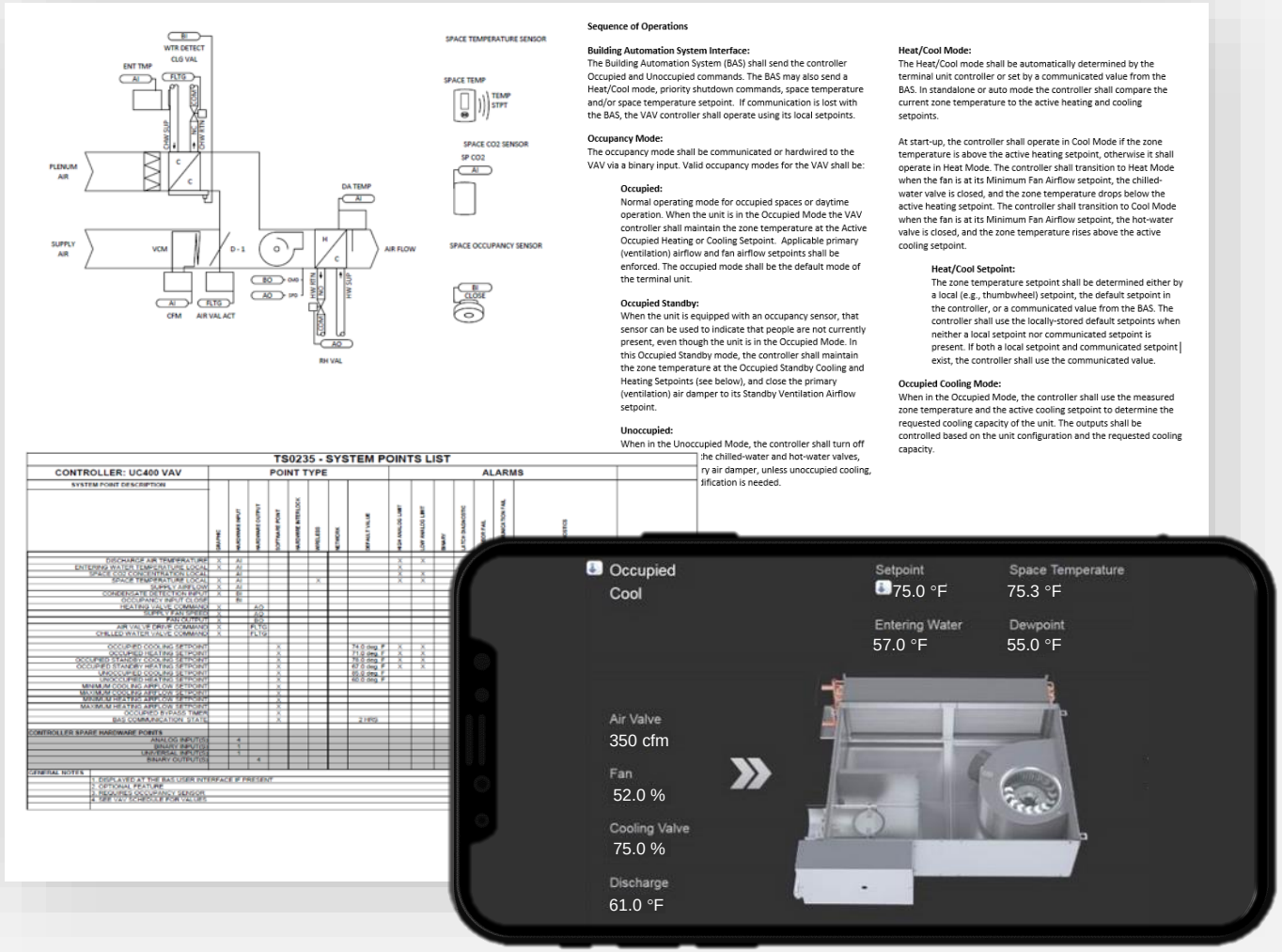
CoolSense™ System

Detailed Controls Documentation

- Controls drawings
- Sequences of operation
- Points lists
- Standard graphics

All available on
TraneEngineer.com





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CoolSense™ Integrated Outdoor Air System

Questions?

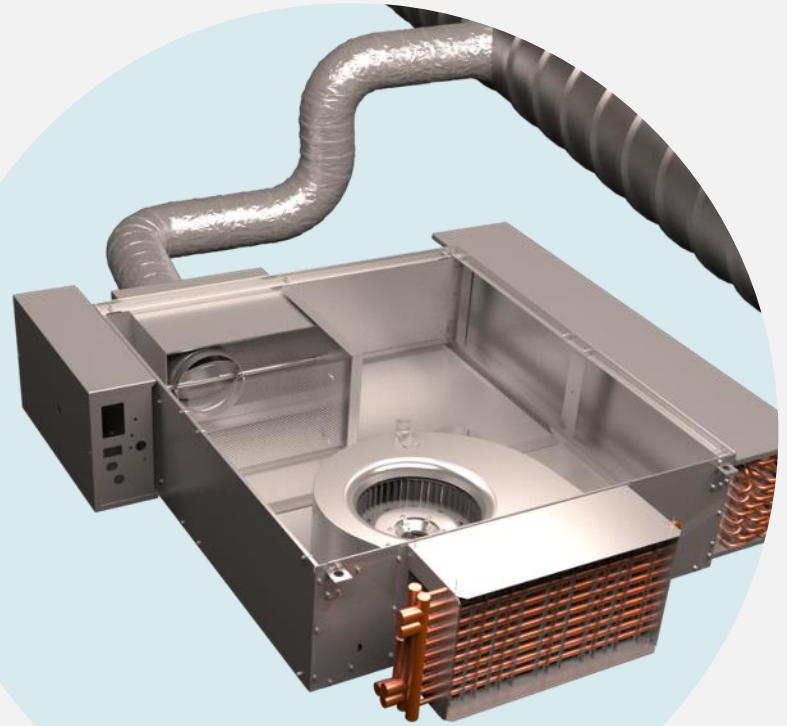
How does _____ work?

I like it but, _____?

Can I use it with _____?

Is this a good application for _____?

Explain how DCV works?



Thank you for your attention.

Additional Resources

- CoolSense™ System Catalog
- CoolSense™ System Design Guide
- CoolSense™ Terminal Unit Product Catalog
- Packaged Outdoor Air Unit Product Catalog
- “Trane CoolSense™ Integrated Outdoor Air System” – YouTube

Back-up Slides for Possible Questions

A Filter is Not Required, but may Still Be Desired

5.8 Particulate Matter Removal. *Particulate matter filters or air cleaners having a minimum efficiency reporting value (MERV) of not less than 8 when rated in accordance with ASHRAE Standard 52.2 shall be provided upstream of all cooling coils or other devices with wetted surfaces through which air is supplied to an occupiable space.*

Exception: *Cooling coils that are designed, controlled and operated to provide sensible cooling only.*

Simultaneous Heating and Cooling

6.5.2.1 Zone Controls. *Zone thermostatic controls shall prevent:*

a. reheating;

b. re-cooling;

c. mixing or simultaneously supplying air that has been previously mechanically heated and air that has been previously cooled, either by mechanical cooling or by economizer systems; and

d. other simultaneous operation of heating and cooling systems to the same zone.

Exceptions:

2b. The airflow rate that is reheated, re-cooled or mixed shall be less than 50% of the zone design peak supply rate.

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