Temperature and Humidity Control for Surgery Rooms

John Murphy, ASHRAE Fellow, LEED® AP BD+C
Applications Engineer
Trane
La Crosse, Wisconsin

Copyrighted Materials / Disclaimer

- This presentation is protected by U.S. and international copyright laws. Reproduction, distribution, display, and use of the presentation without written permission of Trane is prohibited.

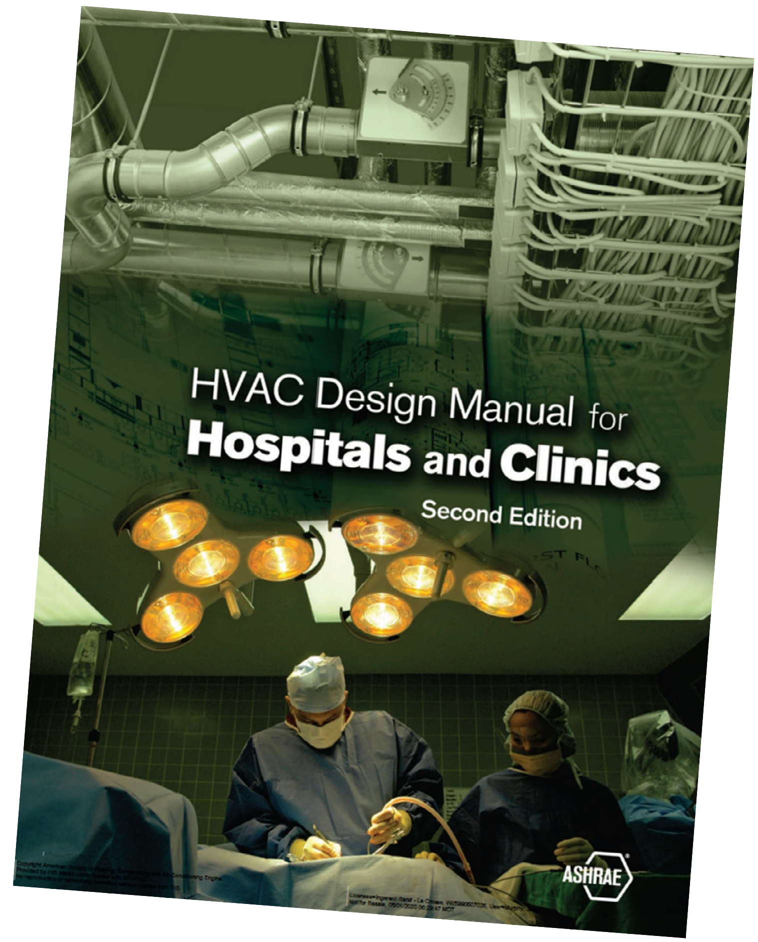
- Trane believes the facts and suggestions presented here to be accurate. However, final design and application decisions are your responsibility. Trane disclaims any responsibility for actions taken on the material presented.

Topics We Will Cover

- Impact of temperature and humidity on HVAC system design
- HVAC system solution alternatives for surgery (operating) rooms

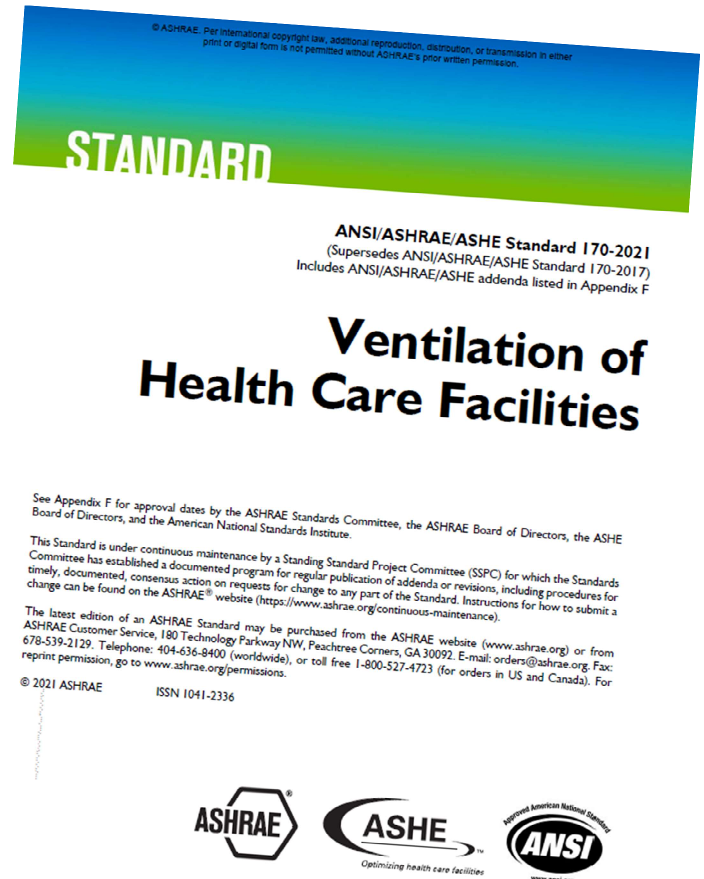
Why Are Both Temperature and Humidity Control Important?

- Occupant comfort
- Infection control
- Prevent drying of mucous coating in respiratory tracts
- Surgeons want it



Requirements for Operating Rooms

operating room	
Dry-bulb temperature	68°F to 75°F
Relative humidity	20% to 60%
Minimum total airflow	20 ACH
Minimum outdoor airflow	4 ACH


© ASHRAE. Per international copyright law, additional reproduction, distribution, or transmission in either print or digital form is not permitted without ASHRAE's prior written permission.

STANDARD

ANSI/ASHRAE/ASHE Standard 170-2021
(Supersedes ANSI/ASHRAE/ASHE Standard 170-2017)
Includes ANSI/ASHRAE/ASHE addenda listed in Appendix F

Ventilation of Health Care Facilities

See Appendix F for approval dates by the ASHRAE Standards Committee, the ASHRAE Board of Directors, the ASHE Board of Directors, and the American National Standards Institute.

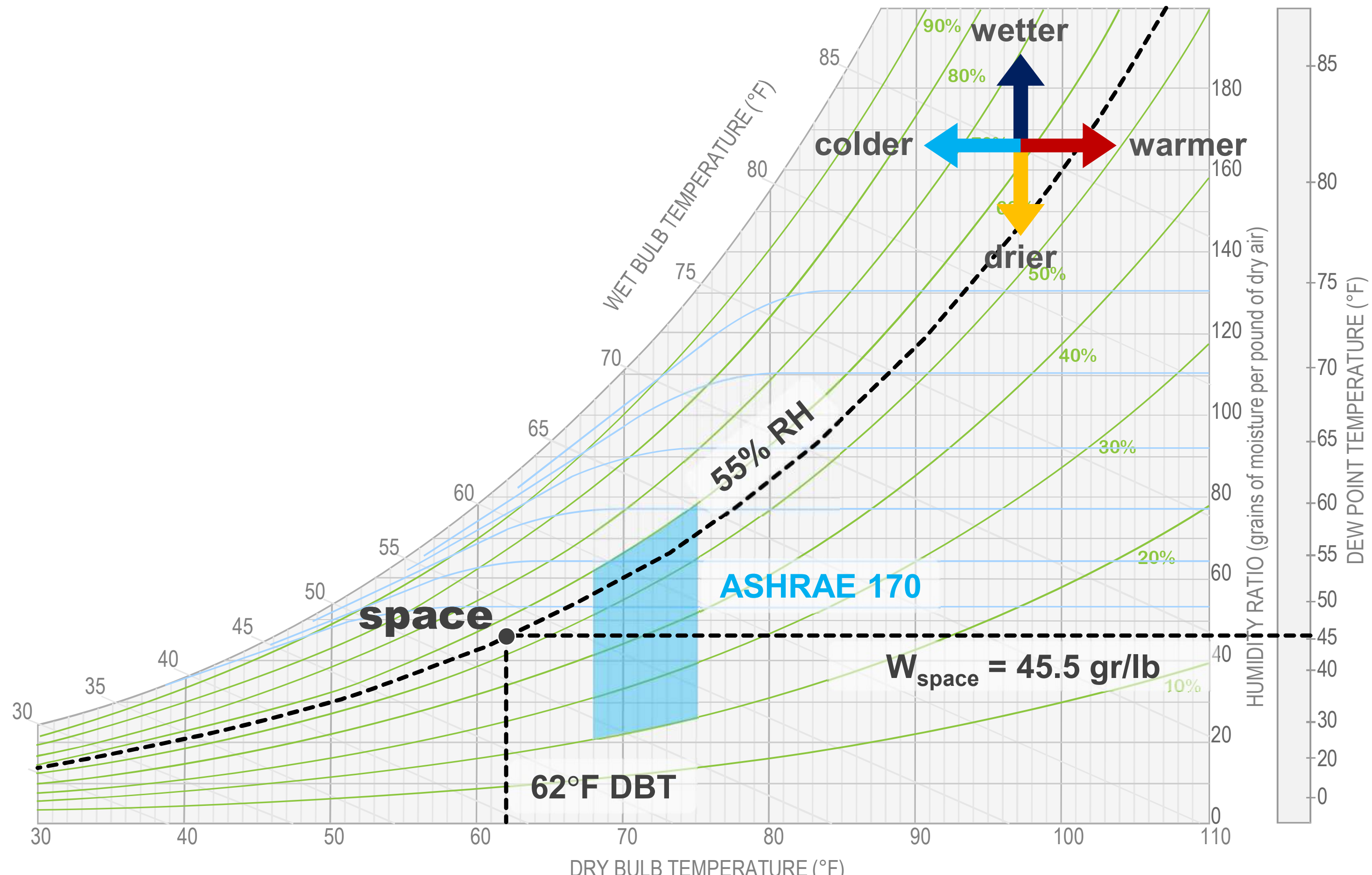
This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (https://www.ashrae.org/continuous-maintenance).

The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 180 Technology Parkway NW, Peachtree Corners, GA 30092. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

© 2021 ASHRAE ISSN 1041-2336

psychrometry: the science of air conditioning

Example Operating Room: Desired Space Conditions



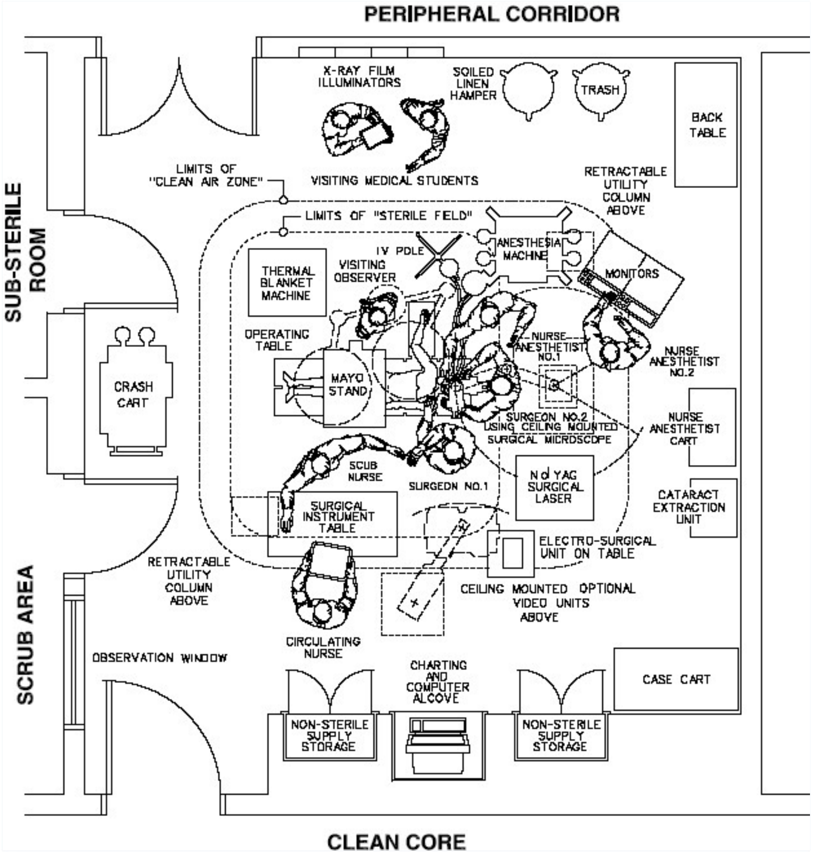
Source: Trane

Example Operating Room: Airflows

450 ft^2 operating room with a 10-ft ceiling (room volume = 4500 ft^3)

$$\mathbf{CFM_{SA} = 20\ ACH \times 4500\ ft^3 / 60\ min/hr}$$
$$\mathbf{= 1500\ cfm}$$

$$\mathbf{CFM_{OA} = 4\ ACH \times 4500\ ft^3 / 60\ min/hr}$$
$$\mathbf{= 300\ cfm}$$



Example Operating Room: Space Loads

Lighting

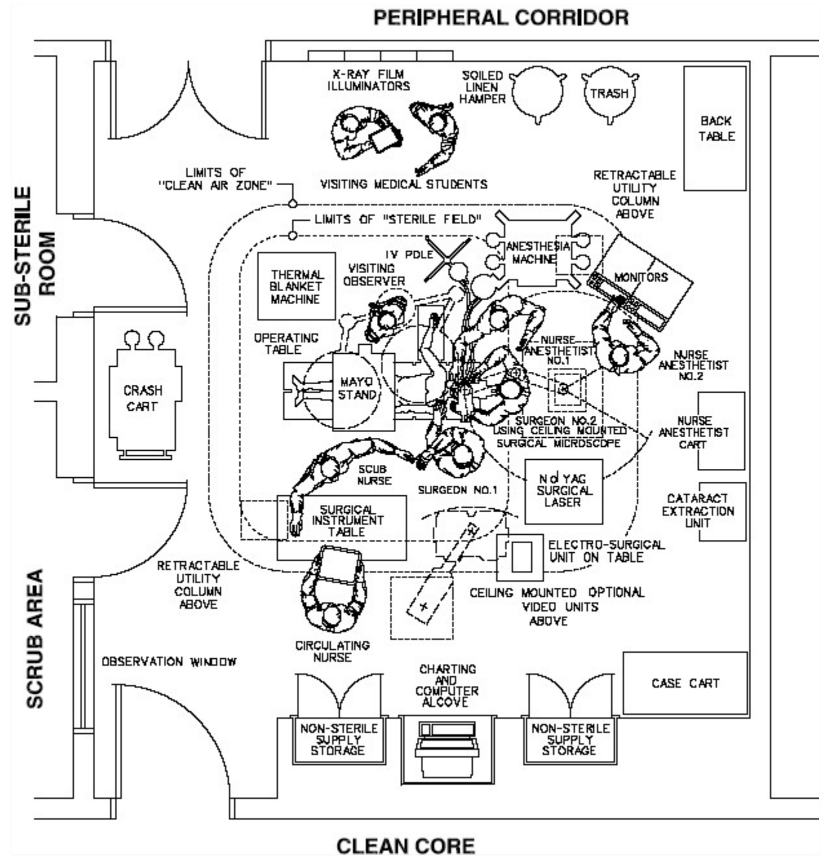
- 3 Watts/ft^2

People (qty = 8)

- 250 Btu/hr/person sensible
- 200 Btu/hr/person latent

Equipment

- ECG/RESP: 50 Watts
- Blanket warmer: 221 Watts
- Anesthesia machine: 166 Watts
- Blood pressure meter: 29 Watts



Example Operating Room: Space Loads

	Sensible Load (Btu/hr)	Latent Load (Btu/hr)
Lighting	4600	
People	2000	1600
Equipment	1590	
Totals	**8190**	**1600**

$$\text{space SHR} = \frac{8190}{8190 + 1600} = 0.84$$

(sensible heat ratio)

Psychrometry: The Science of Air Conditioning

- **Design specifications**
  - Desired space dry-bulb temperature
  - Desired space humidity level
  - Supply airflow
  - Space sensible and latent loads

- **Calculated conditions**
  - Space SHR (sensible heat ratio)
  - Required supply-air conditions (DBT and DPT)

example operating room

Temperature-Based Design

$$Q_{space,sensible} = 1.085 \times CFM_{SA} \times (DBT_{space} - DBT_{SA})$$

$Q_{space,sensible}$ = design space sensible load (Btu/hr)

CFM_{SA} = supply airflow (cfm)

DBT_{space} = desired dry-bulb temperature in the space (°F)

DBT_{SA} = required dry-bulb temperature of the supply air (°F)

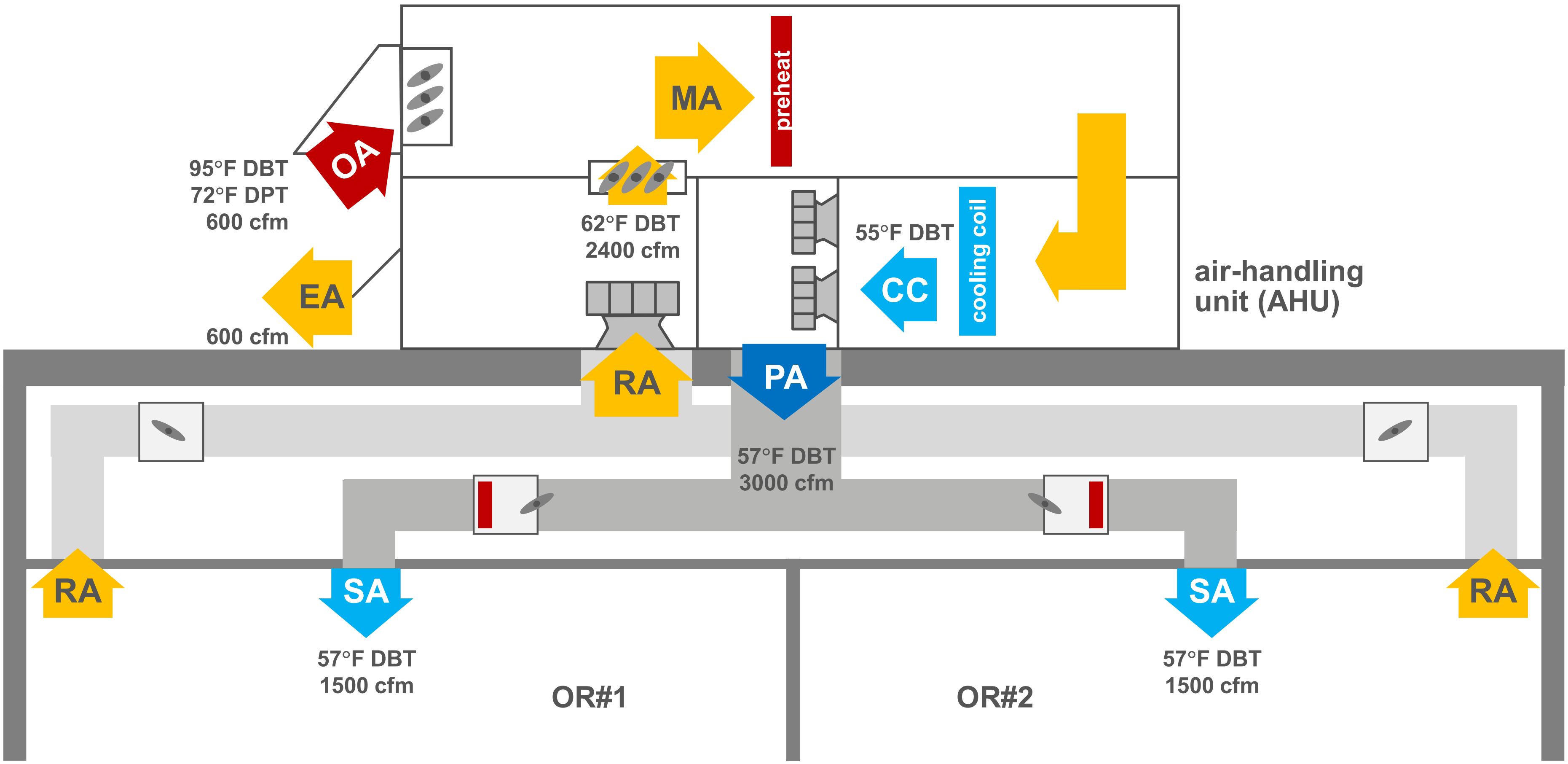
$$8190 \text{ Btu/hr} = 1.085 \times 1500 \text{ cfm} \times (62°F - DBT_{SA})$$

$$DBT_{SA} = 57.0°F$$

Note: The 1.085 in this equation is not a constant; it is a function of the density and specific heat of the air. At "standard air" conditions and at sea level, these properties result in the value 1.085. Air at other conditions and other elevations will cause this factor to change.

example operating room

Temperature-Based Design



example operating room

Temperature-Based Design

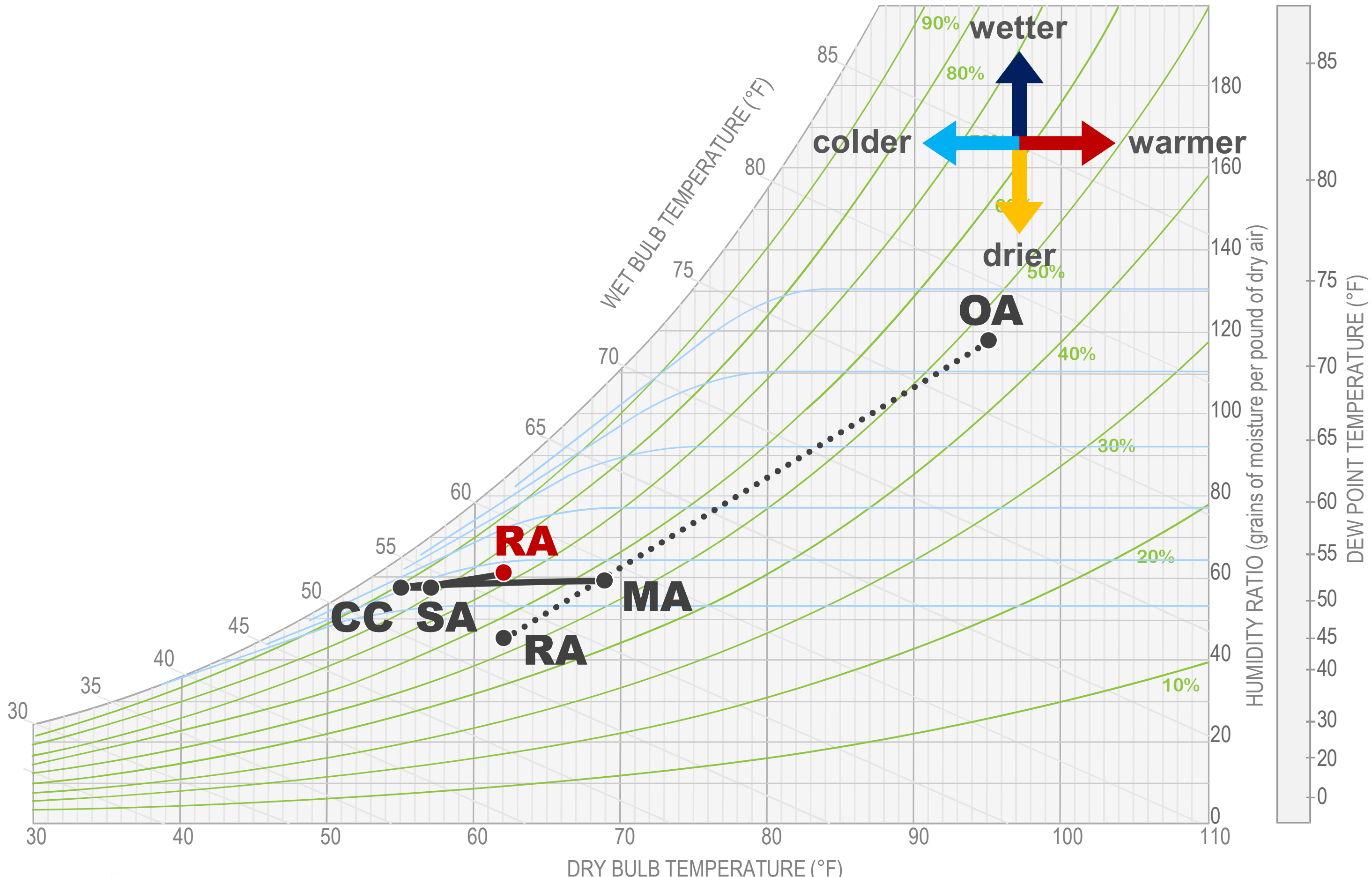
OA 95°F DBT
72°F DPT

RA (space) 62°F DBT
74% RH
(0.84 space SHR)

MA 69°F DBT
53°F DPT

CC 55°F DBT
53°F DPT

SA 57°F DBT
53°F DPT



Source: Trane

example operating room

Temperature-Based Design

OA 95°F DBT
72°F DPT

RA (space) 62°F DBT
74% RH
(0.84 space SHR)

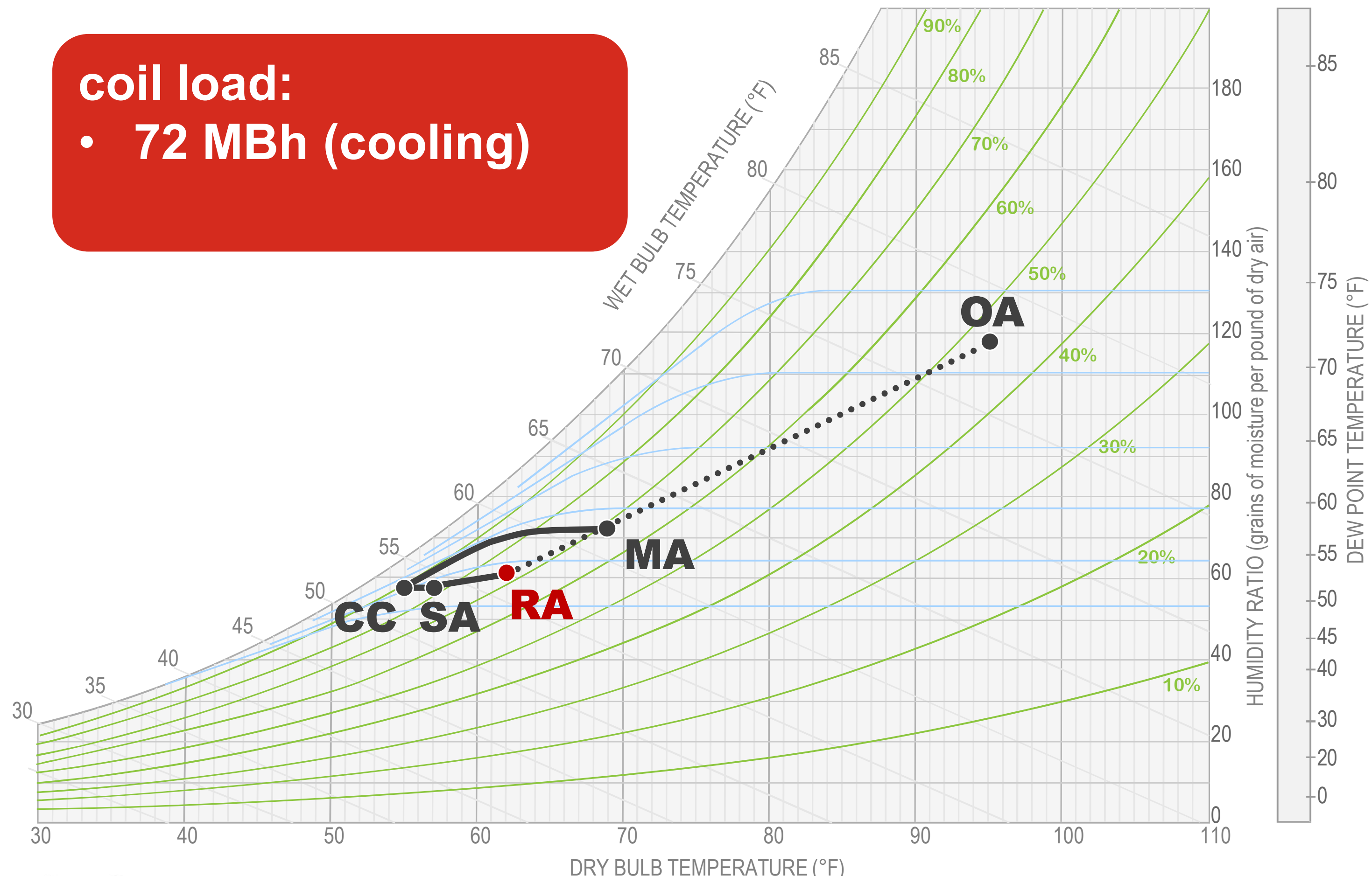
MA 69°F DBT
58°F DPT

CC 55°F DBT
53°F DPT

SA 57°F DBT
53°F DPT

coil load:

- **72 MBh (cooling)**



Source: Trane

example operating room

Humidity-Based Design

$$Q_{space,latent} = 0.69 \times CFM_{SA} \times (W_{space} - W_{SA})$$

$Q_{space,latent}$ = design space latent load (Btu/hr)

CFM_{SA} = supply airflow (cfm)

W_{space} = desired humidity ratio in the space (grains/lb)

W_{SA} = required humidity ratio of the supply air (grains/lb)

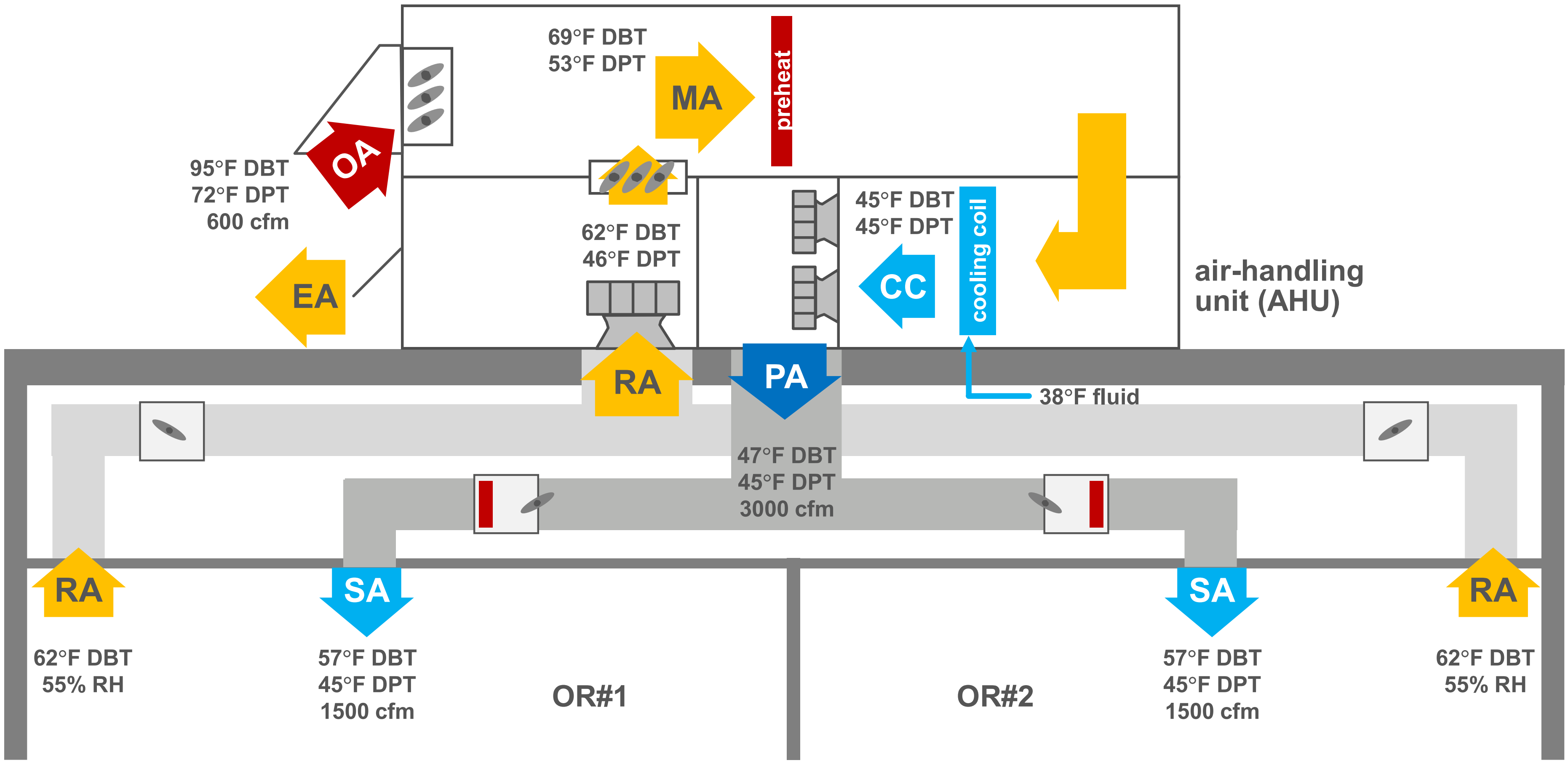
$$1600 \text{ Btu/hr} = 0.69 \times 1500 \text{ cfm} \times (45.5 \text{ gr/lb} - W_{SA})$$

$$W_{SA} = 44.0 \text{ gr/lb} \ (\sim 45°\text{F DPT})$$

Note: The 0.69 in this equation is not a constant; it is a function of the density and latent heat of vaporization the air. At "standard air" conditions and at sea level, these properties result in the value 0.69. Air at other conditions and other elevations will cause this factor to change.

example operating room

Cool + Reheat System



example operating room

Cool + Reheat System

OA 95°F DBT
72°F DPT

RA (space) 62°F DBT
46°F DPT
55% RH
(0.84 space SHR)

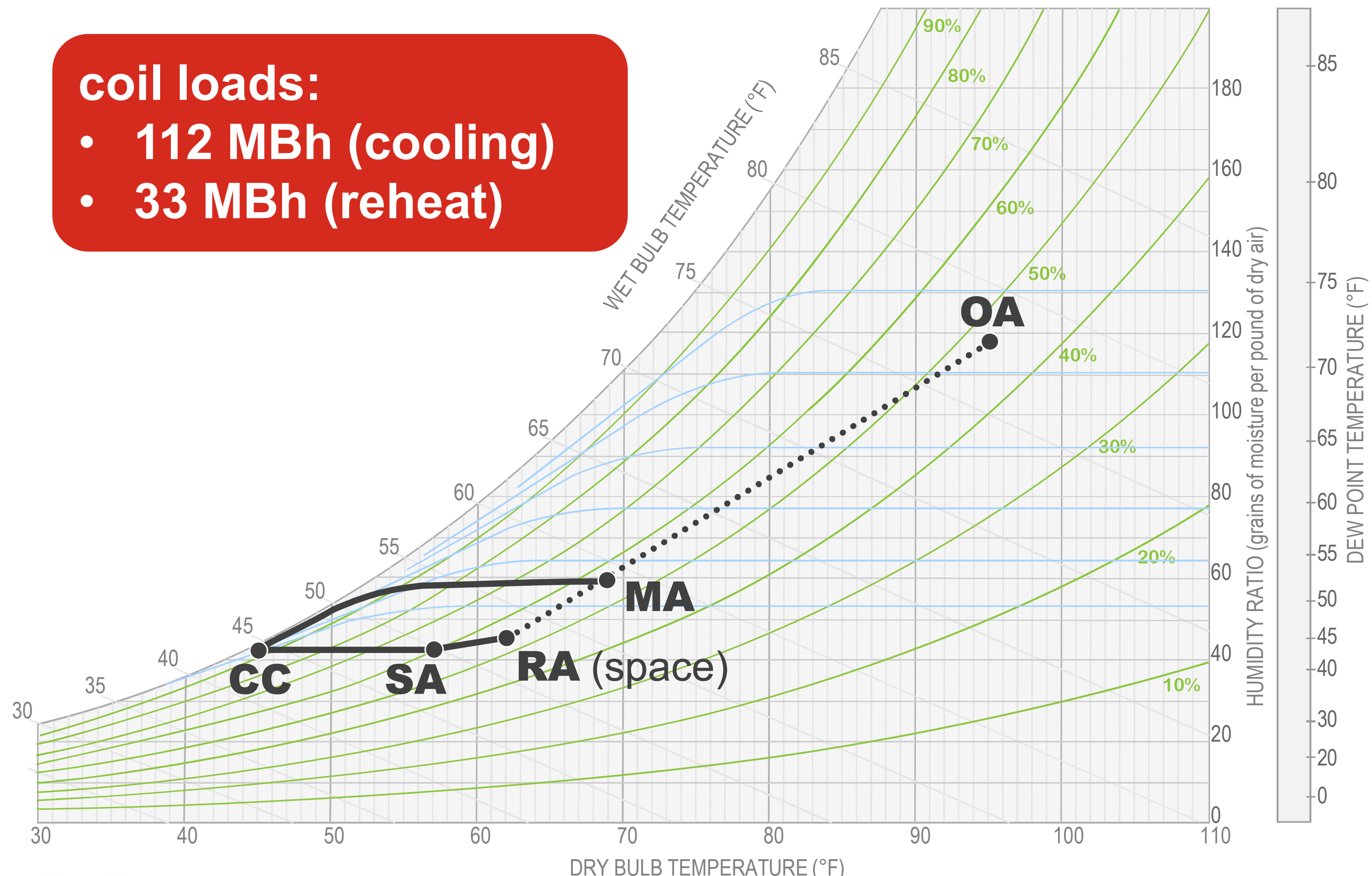
MA 69°F DBT
53°F DPT

CC 45°F DBT
45°F DPT

SA 57°F DBT
45°F DPT

coil loads:

- **112 MBh (cooling)**
- **33 MBh (reheat)**

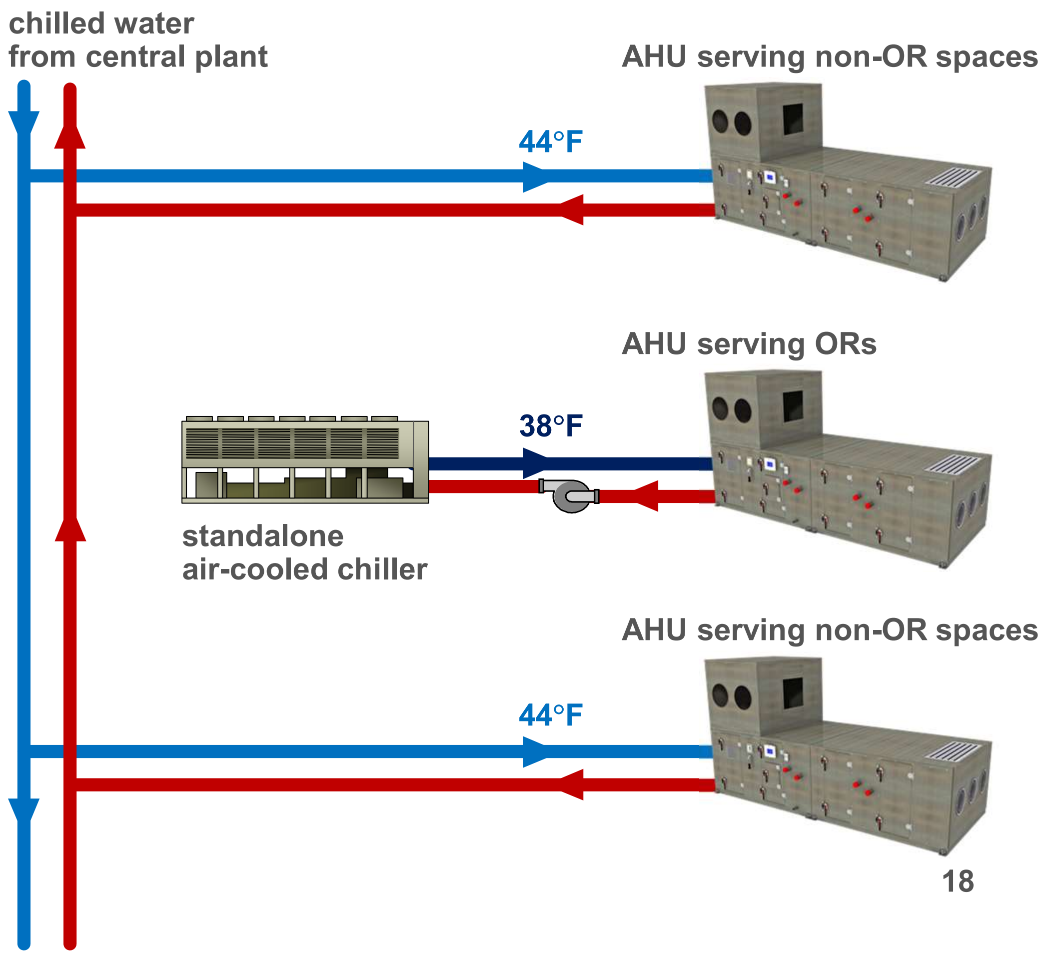


Source: Trane

cool + reheat system

Chiller Plant Configurations

- New standalone chiller
  - Air-cooled or water-cooled

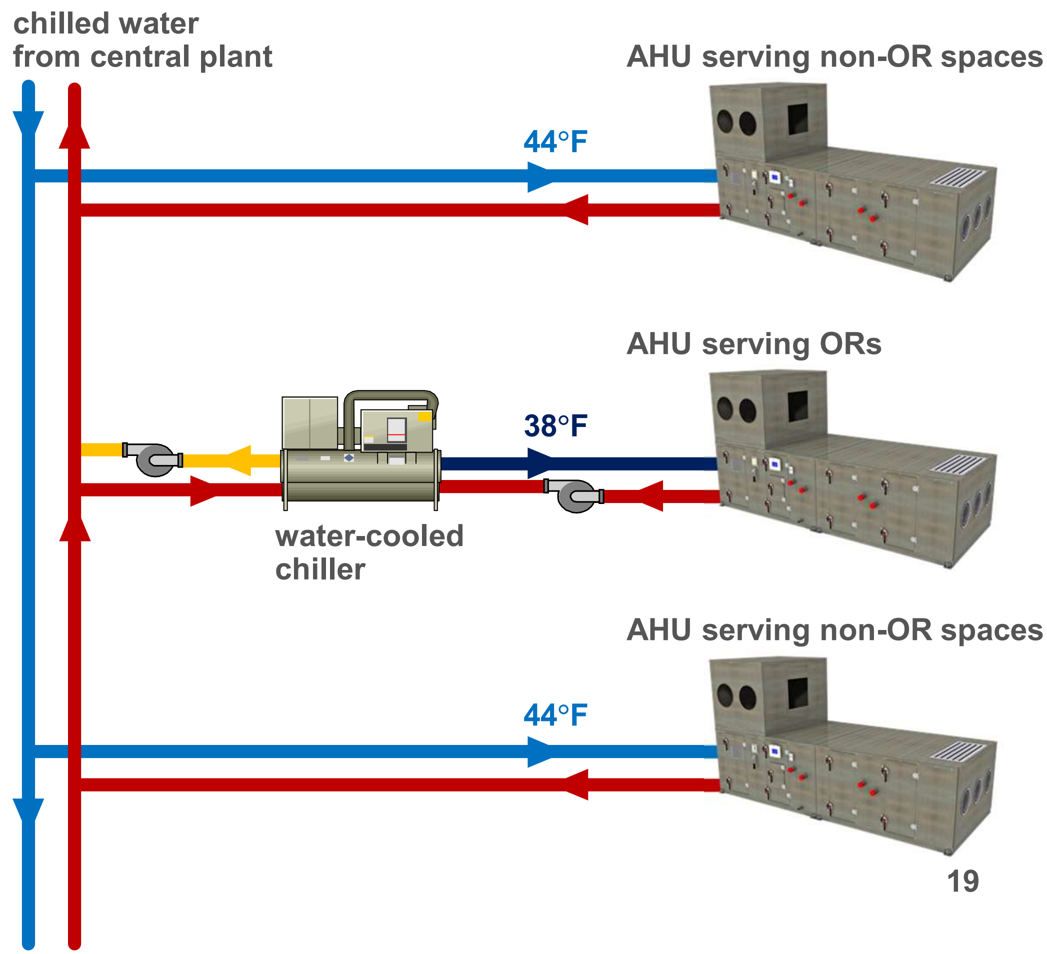


cool + reheat system

Chiller Plant Configurations

or

- New water-cooled chiller using central plant as condenser water



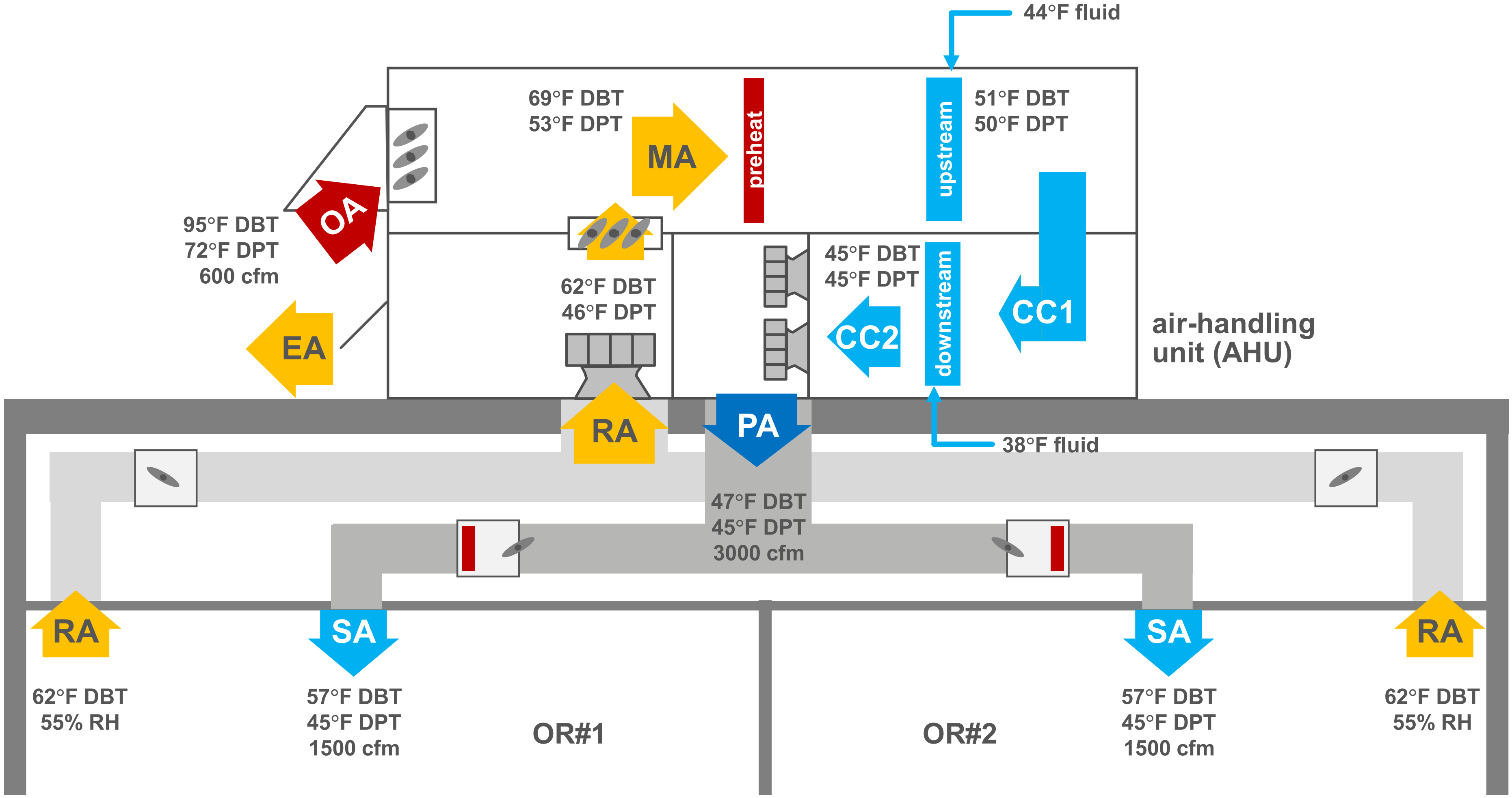
Cool + Reheat System

- Often requires a new chiller to provide cold enough water
  - Example: Air leaving cooling coil = 45°F

- Typically requires reheat even at design conditions
  - Consider options for heat recovery

example operating room

Cool + Reheat System: Two Coils in Series



example operating room

Cool + Reheat System: Two Coils in Series

OA 95°F DBT
72°F DPT

RA (space) 62°F DBT
46°F DPT
55% RH
(0.84 space SHR)

MA 69°F DBT
53°F DPT

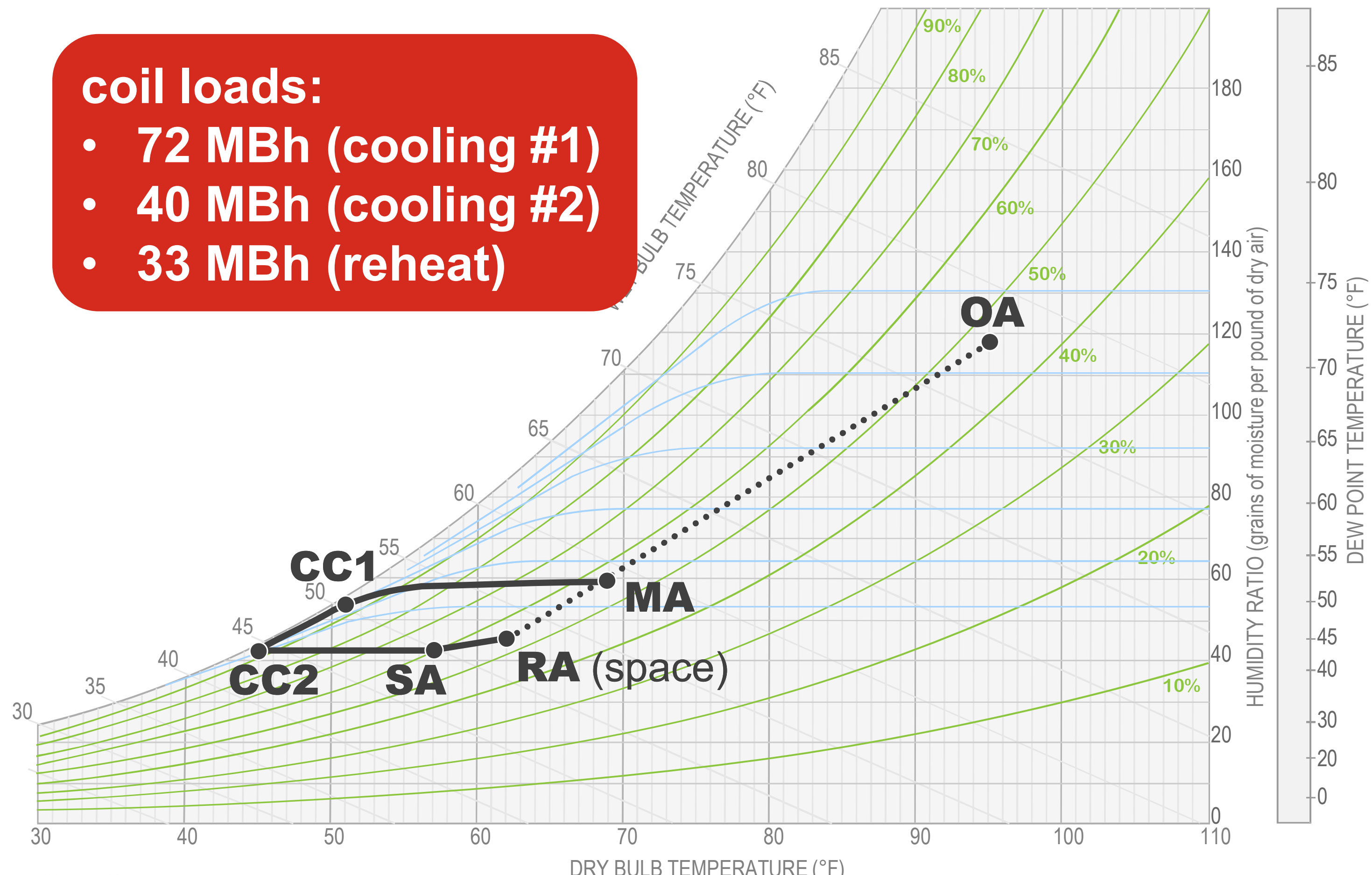
CC1 51°F DBT
50°F DPT

CC2 45°F DBT
45°F DPT

SA 57°F DBT
45°F DPT

coil loads:

- **72 MBh (cooling #1)**
- **40 MBh (cooling #2)**
- **33 MBh (reheat)**



Source: Trane

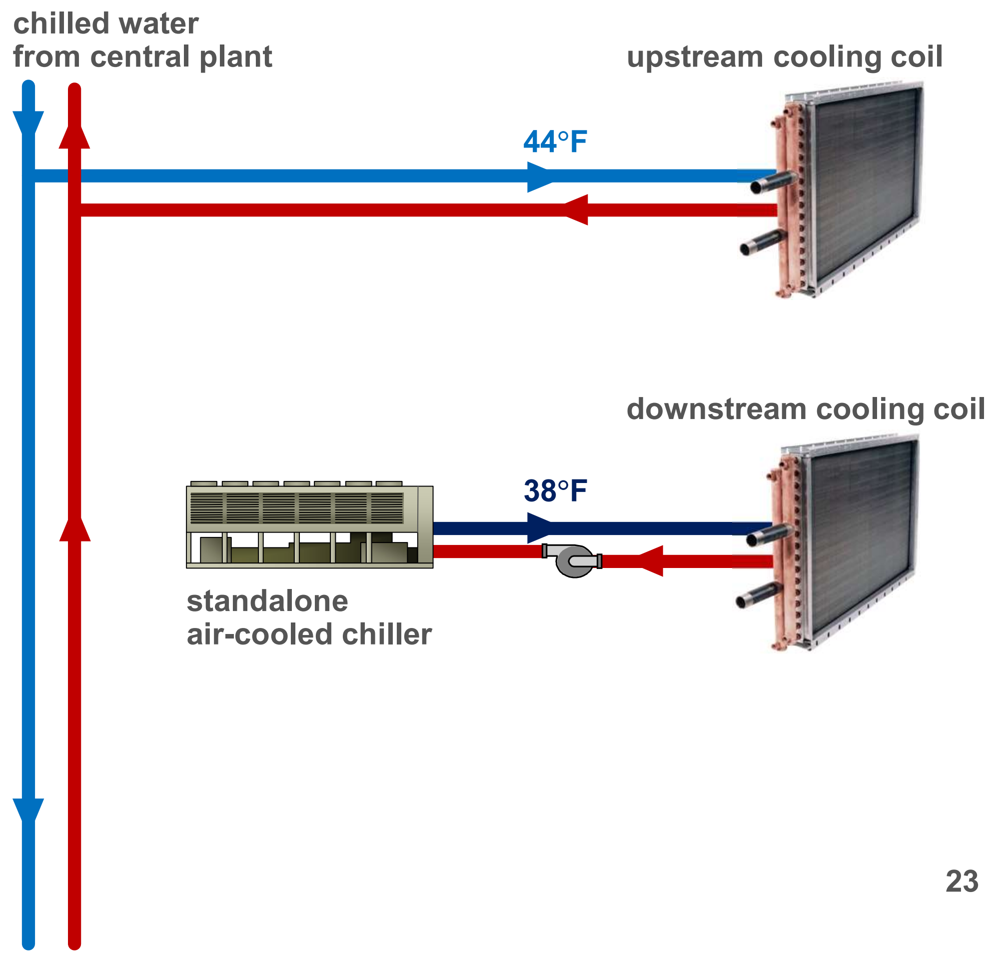
cool + reheat system: two coils in series

Chiller Plant Configurations

- New standalone chiller serving downstream cooling coil
    - Existing central plant serving upstream cooling coil

or

- New water-cooled chiller, using central plant as condenser water, serving downstream cooling coil



Cool + Reheat System: Two Coils in Series

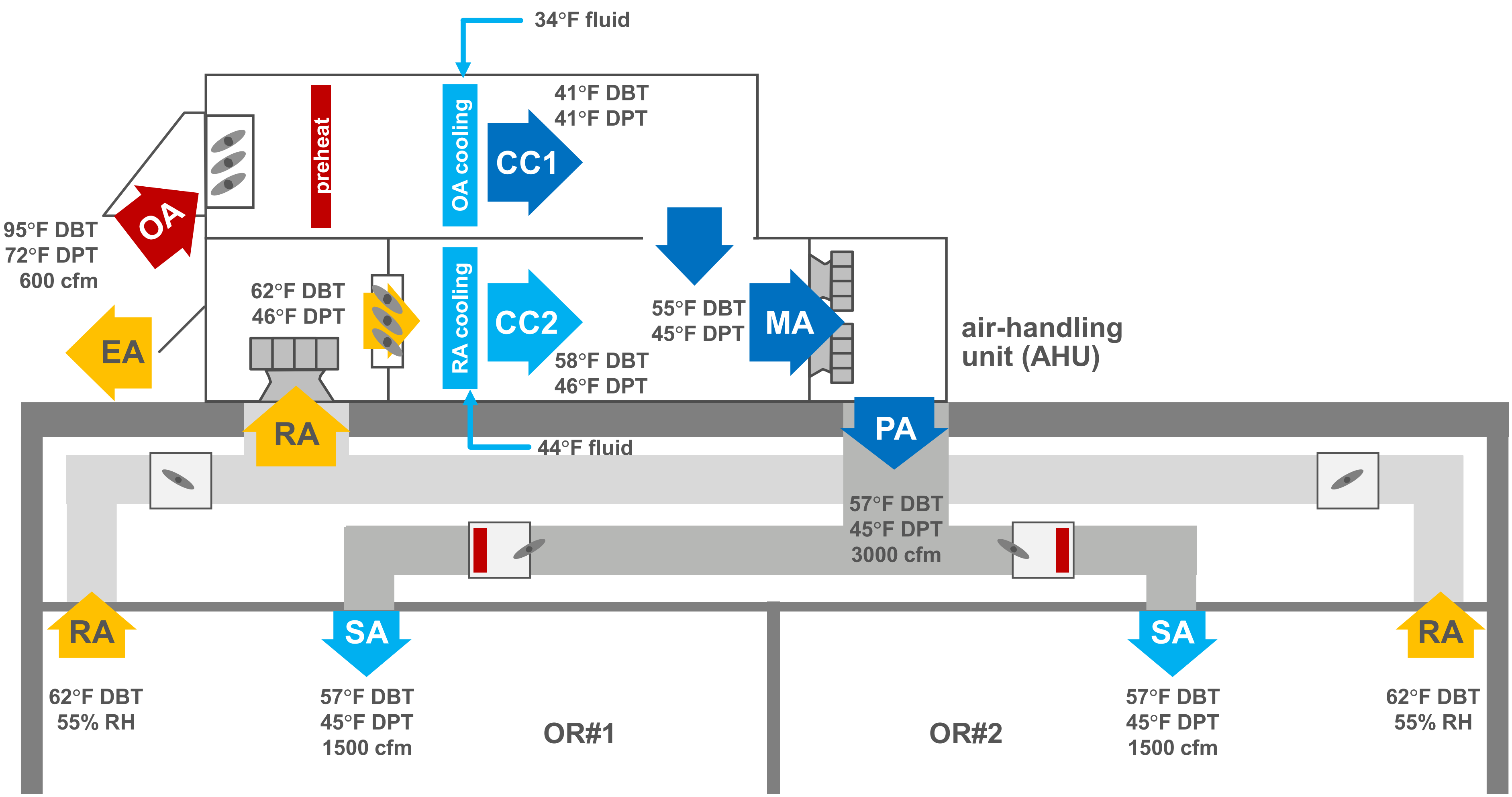
- Allows for a smaller new chiller to serve downstream cooling coil
  - Example: Capacity required of downstream cooling coil = 40 MBh

- Uses existing central plant to serve upstream cooling coil
  - Example: Capacity required of upstream cooling coil = 72 MBh

- Typically requires reheat even at design conditions
  - Consider options for heat recovery

example operating room

Dual-Path AHU



example operating room

Dual-Path AHU

OA 95°F DBT
72°F DPT

CC1 41°F DBT
41°F DPT

RA (space) 62°F DBT
46°F DPT
55% RH
(0.84 space SHR)

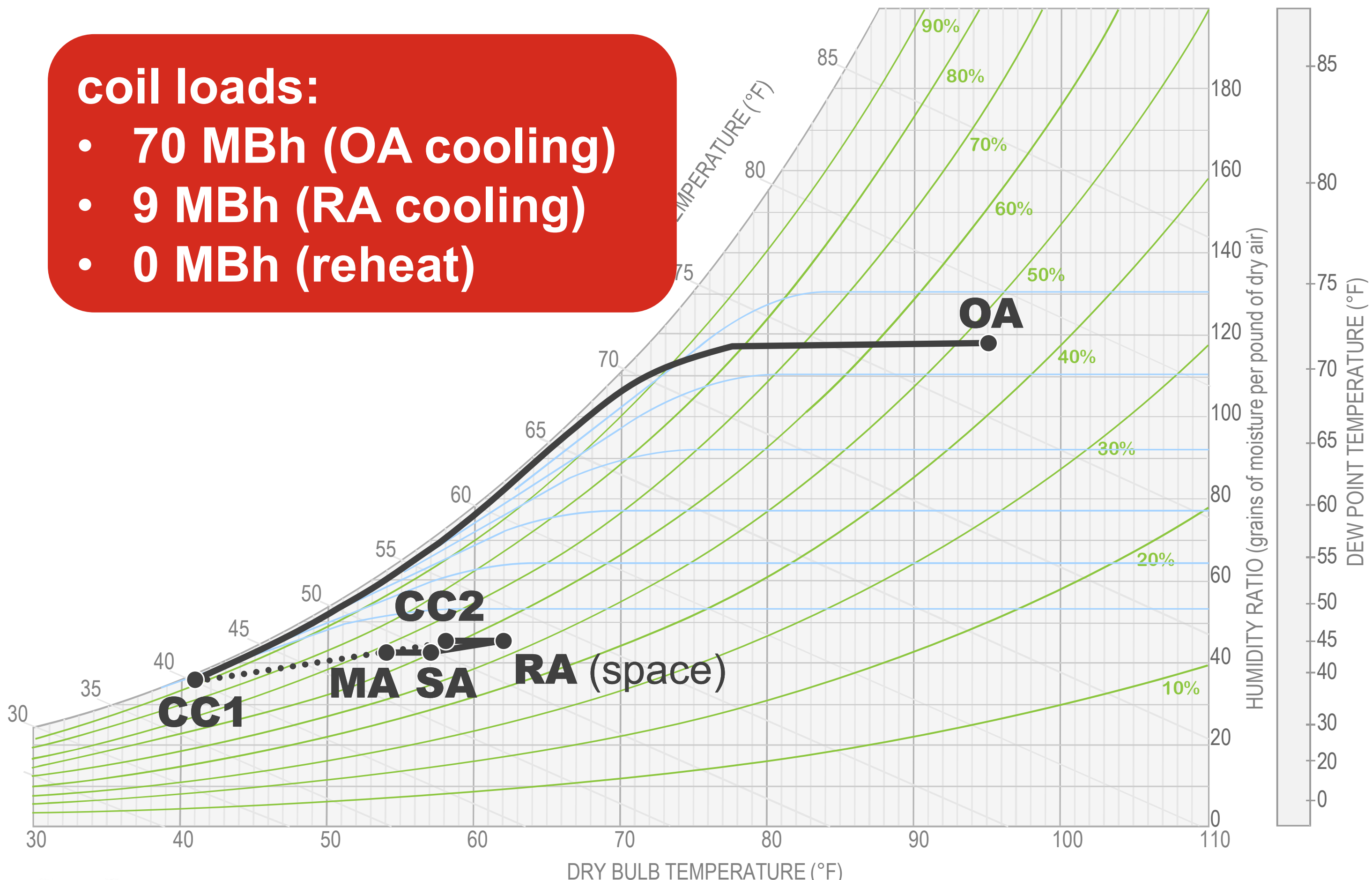
CC2 58°F DBT
46°F DPT

MA 55°F DBT
45°F DPT

SA 57°F DBT
45°F DPT

coil loads:

- **70 MBh (OA cooling)**
- **9 MBh (RA cooling)**
- **0 MBh (reheat)**



Source: Trane

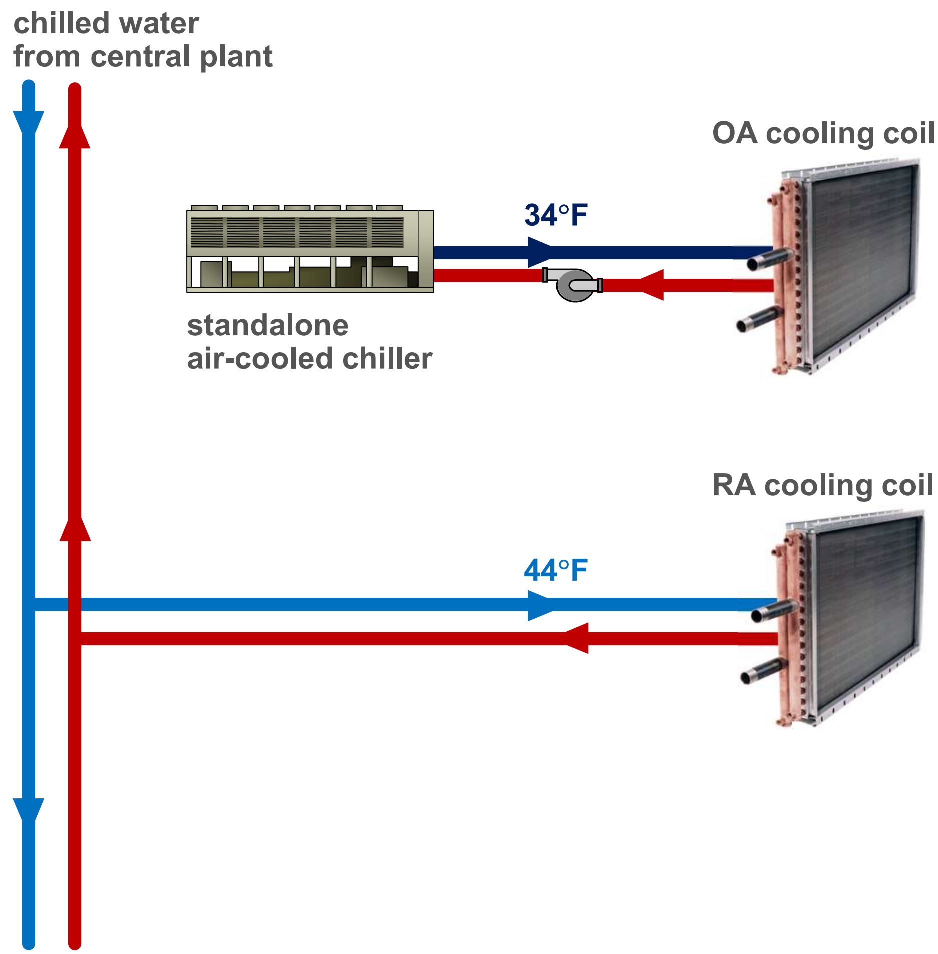
dual-path AHU

Chiller Plant Configurations

- New standalone chiller serving OA cooling coil
  - Existing central plant serving RA cooling coil

or

- New water-cooled chiller, using central plant as condenser water, serving OA cooling coil

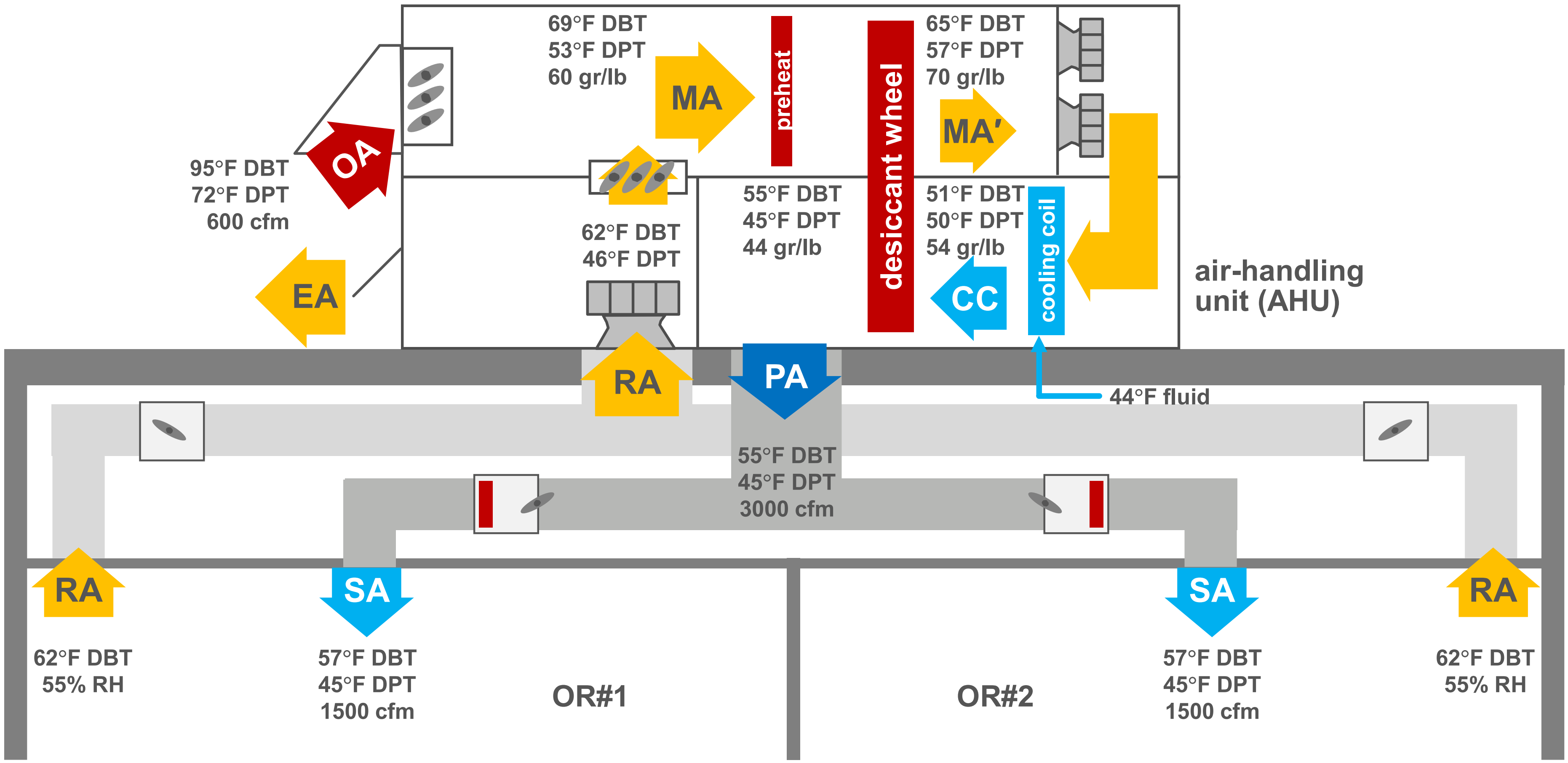


Dual-Path AHU

- Often avoids need for reheat at design conditions
  - Reheat still likely at some part-load conditions
- Requires less overall cooling capacity than Cool + Reheat systems
  - Example: 79 MBh versus 112 MBh for Cool + Reheat systems
- Requires new chiller to make very cold water
  - Example: Air leaving OA cooling coil = 41°F
  - Likely can use water from existing central plant to serve RA cooling coil

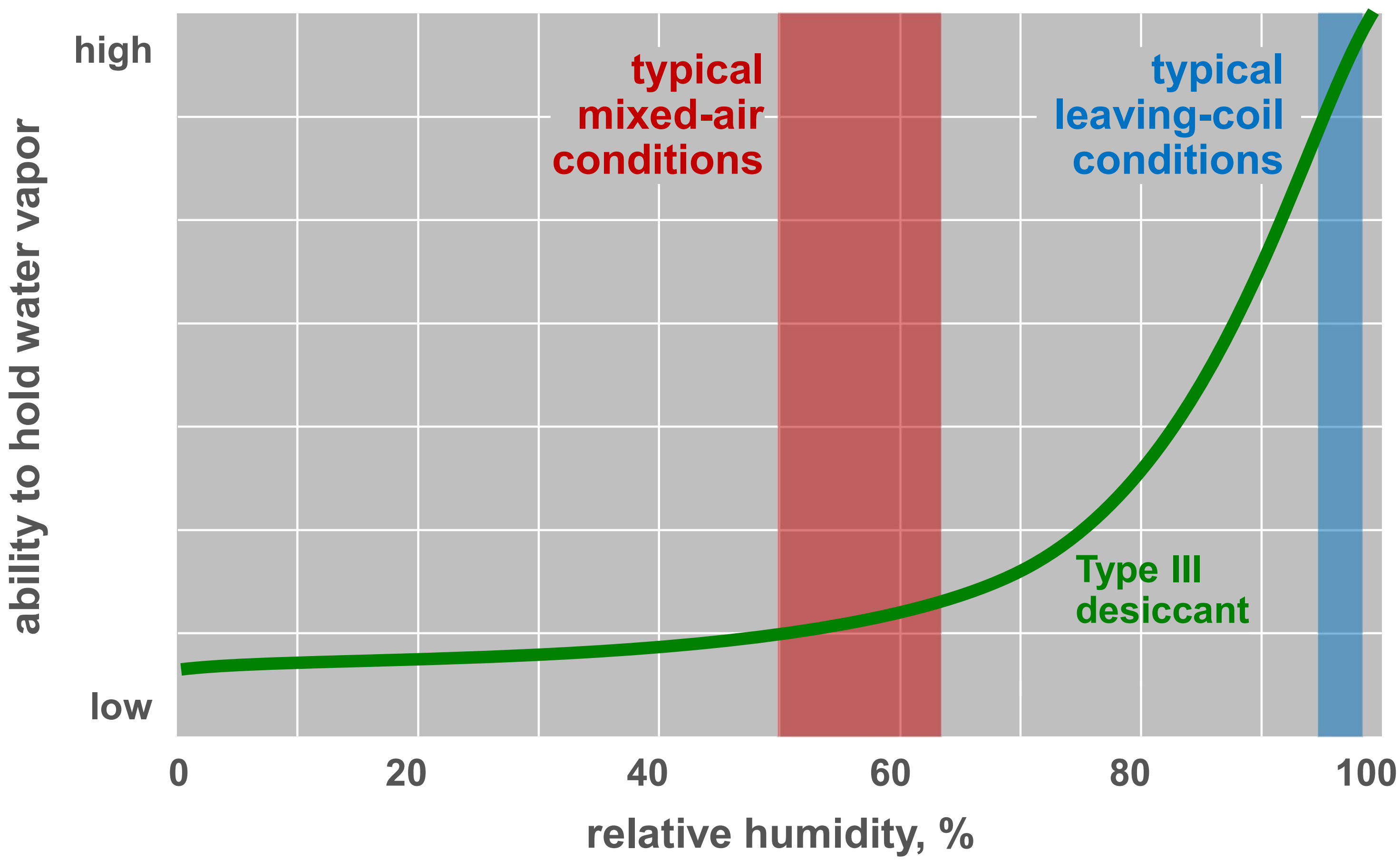
example operating room

Series Desiccant Wheel



series desiccant wheel

How It Works



example operating room

Series Desiccant Wheel

OA 95°F DBT
72°F DPT

RA (space) 62°F DBT
46°F DPT
55% RH
(0.84 space SHR)

MA 69°F DBT
53°F DPT

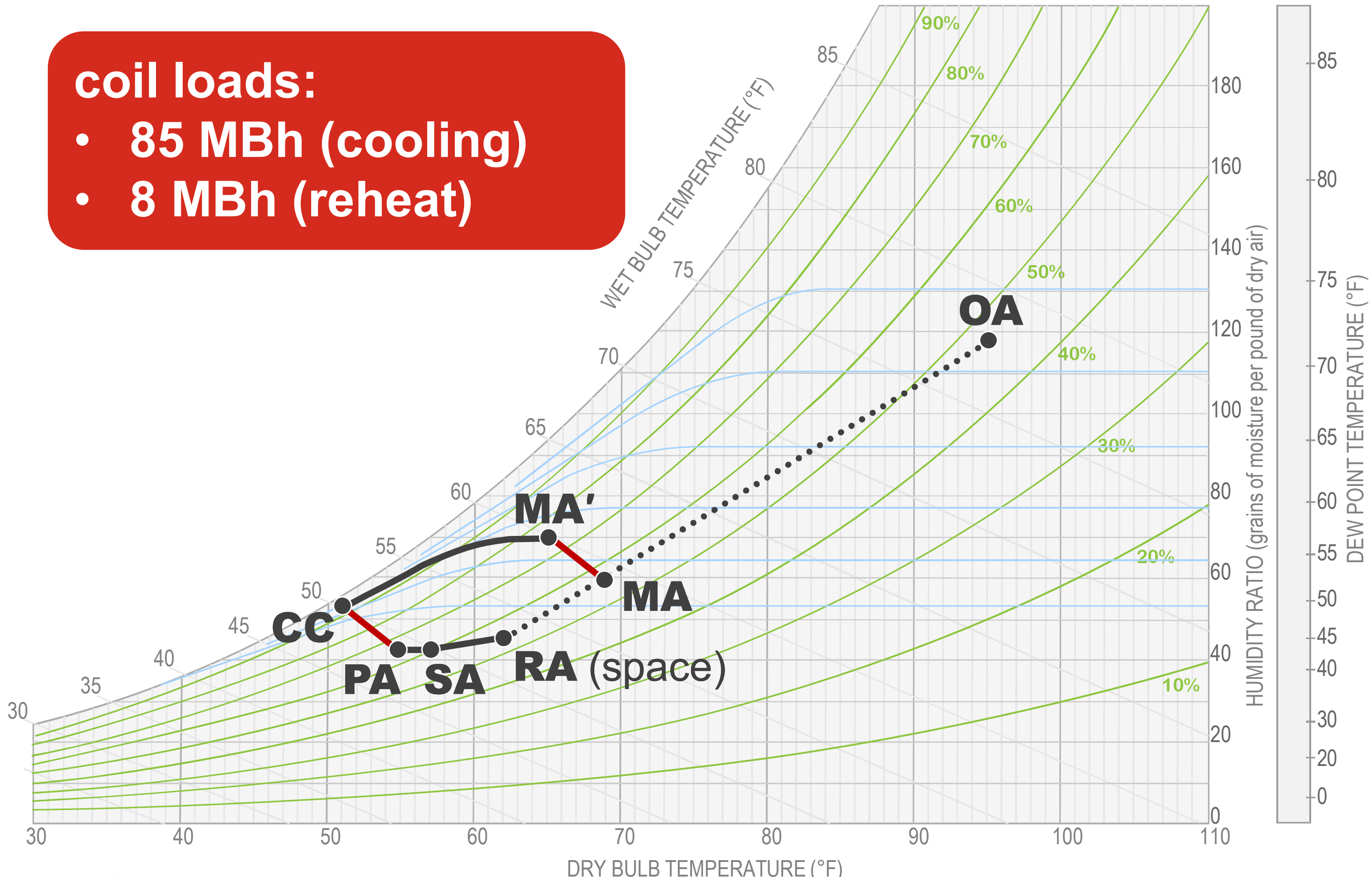
MA′ 65°F DBT
57°F DPT

CC 51°F DBT
50°F DPT

PA 55°F DBT
45°F DPT

SA 57°F DBT
45°F DPT

coil loads:
- **85 MBh (cooling)**
- **8 MBh (reheat)**



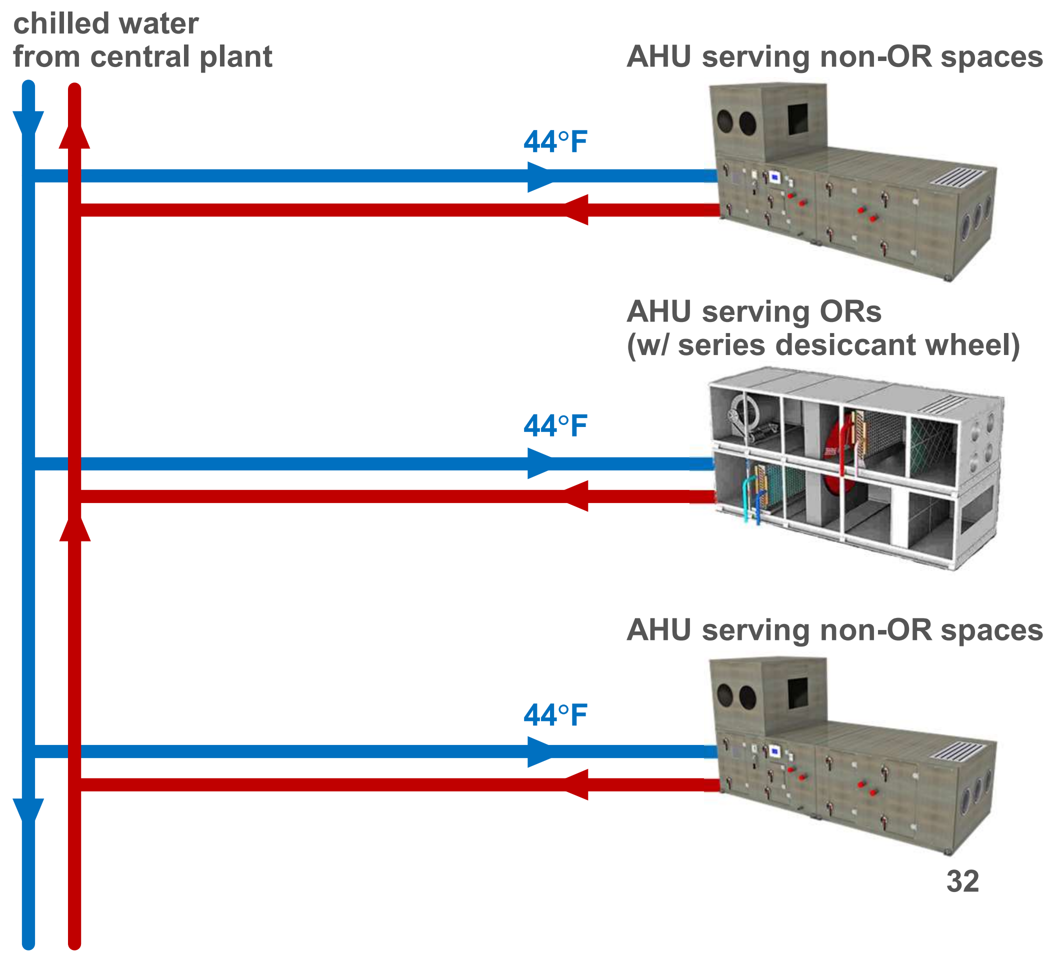
Source: Trane

series desiccant wheel
Chiller Plant Configurations

- New chiller might not be required, if existing central plant has sufficient capacity

or

- Smaller new chiller supplying conventional fluid temperature



Series Desiccant Wheel

- Requires less overall cooling capacity <u>and</u> not-as-cold of a fluid temperature than Cool + Reheat systems
  - Example: 85 MBh with 44°F fluid vs. 112 MBh with 38°F fluid for Cool + Reheat

- Existing central plant might be able to provide all required cooling capacity
  - No new chiller required
  - No separate water distribution (no glycol)
  - Smaller electrical service

- Reduces (or avoids) need for reheat at design conditions
  - Reheat (or low-temperature preheat) still likely at some part-load conditions

Comparison of System Alternatives (Design Load)

	space RH	cooling coil(s), MBh	fluid supply temperature, °F	reheat coils, MBh
temperature-based design	74%	72	44	0
cool + reheat (single coil)	55%	112	38	33
cool + reheat (series coils)	55%	(112)		33
upstream coil		72	44	
downstream coil		40	38	
dual-path AHU	55%	(79)		0
OA coil		70	34	
RA coil		9	44	
series desiccant wheel	55%	85	44	8

Summary

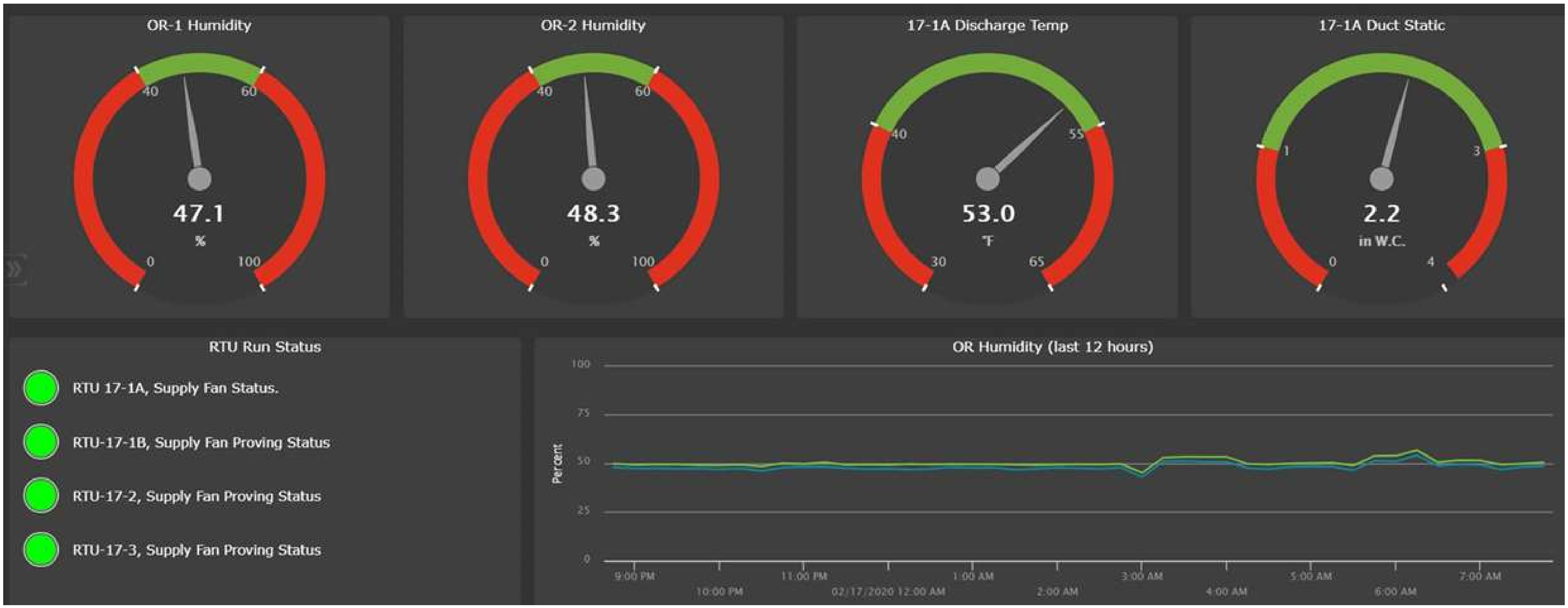
- Need to consider both temperature and humidity in HVAC system design
- Solutions available for using existing central plant capacity or new equipment
- Opportunities to optimize system energy performance
  - Series desiccant wheel or dual-path AHU
  - Heat recovery (airside or waterside)
  - Reset control strategies (occupied/unoccupied airflows, supply-air DPT)

For More Information

- ANSI/ASHRAE/ASHE Standard 170-2021, *Ventilation of Health Care Facilities*. Available from www.ashrae.org
- ASHRAE, Inc. *HVAC Design Manual for Hospitals and Clinics*. 2013. Available from www.ashrae.org
- Moffitt, R. "Taking the Heat Out of Desiccants." *HPAC Engineering* 79(3). March 2007.
- Murphy, J. "Temperature and Humidity Control in Surgery Rooms." *ASHRAE Journal* 48(6). June 2006. Available from www.ashrae.org
- Murphy, J. "Advances in Desiccant-Based Dehumidification" *Engineers Newsletter*, ADM-APN016-EN. Trane. 2005. Available from www.trane.com

Questions?

Monitoring / Documenting Temperature and Humidity



Monitoring / Documenting Temperature and Humidity