Dedicated Outdoor Air System (DOAS)

Svein Morner

HGA

smorner@hga.com

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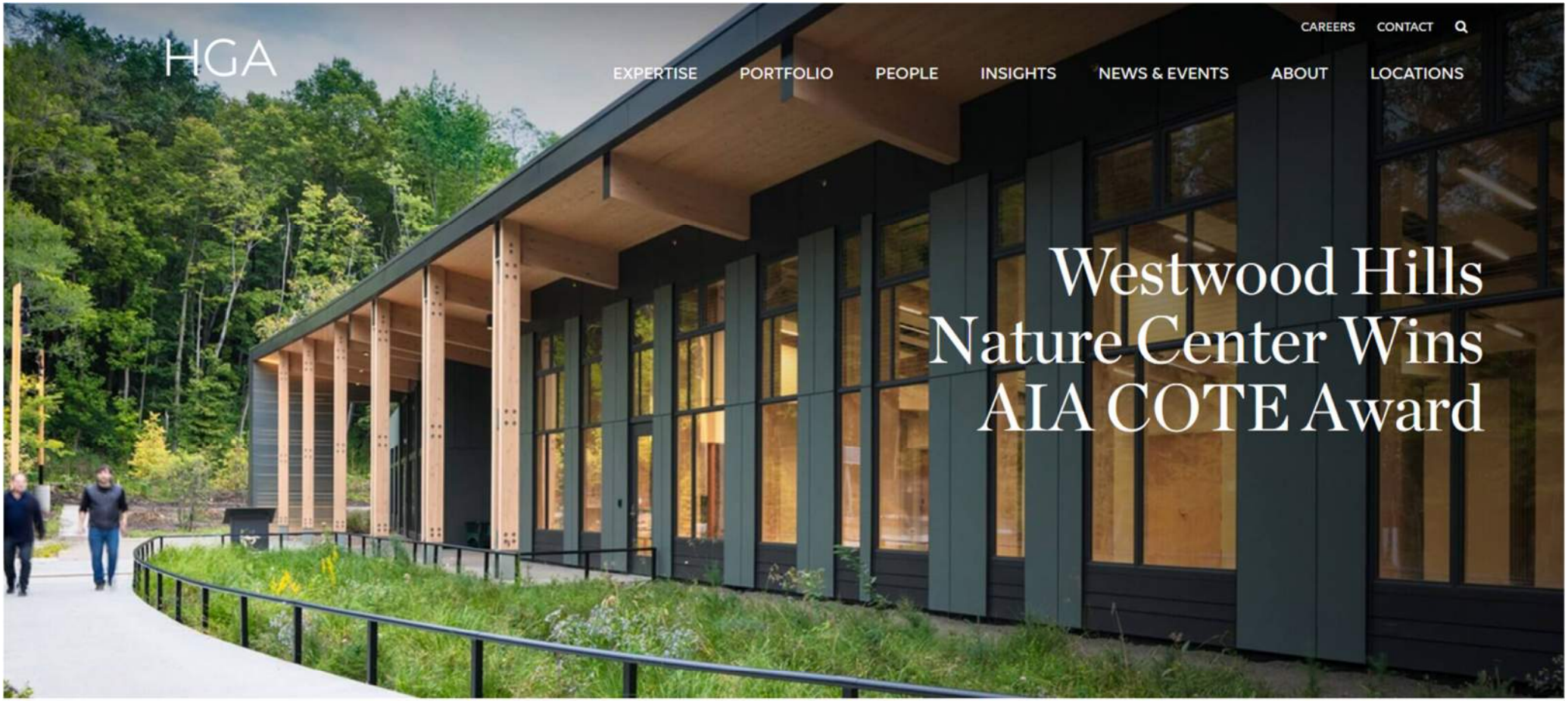


AIA COTE Award Honors Projects for Integrating Design Excellence with Environmental Performance

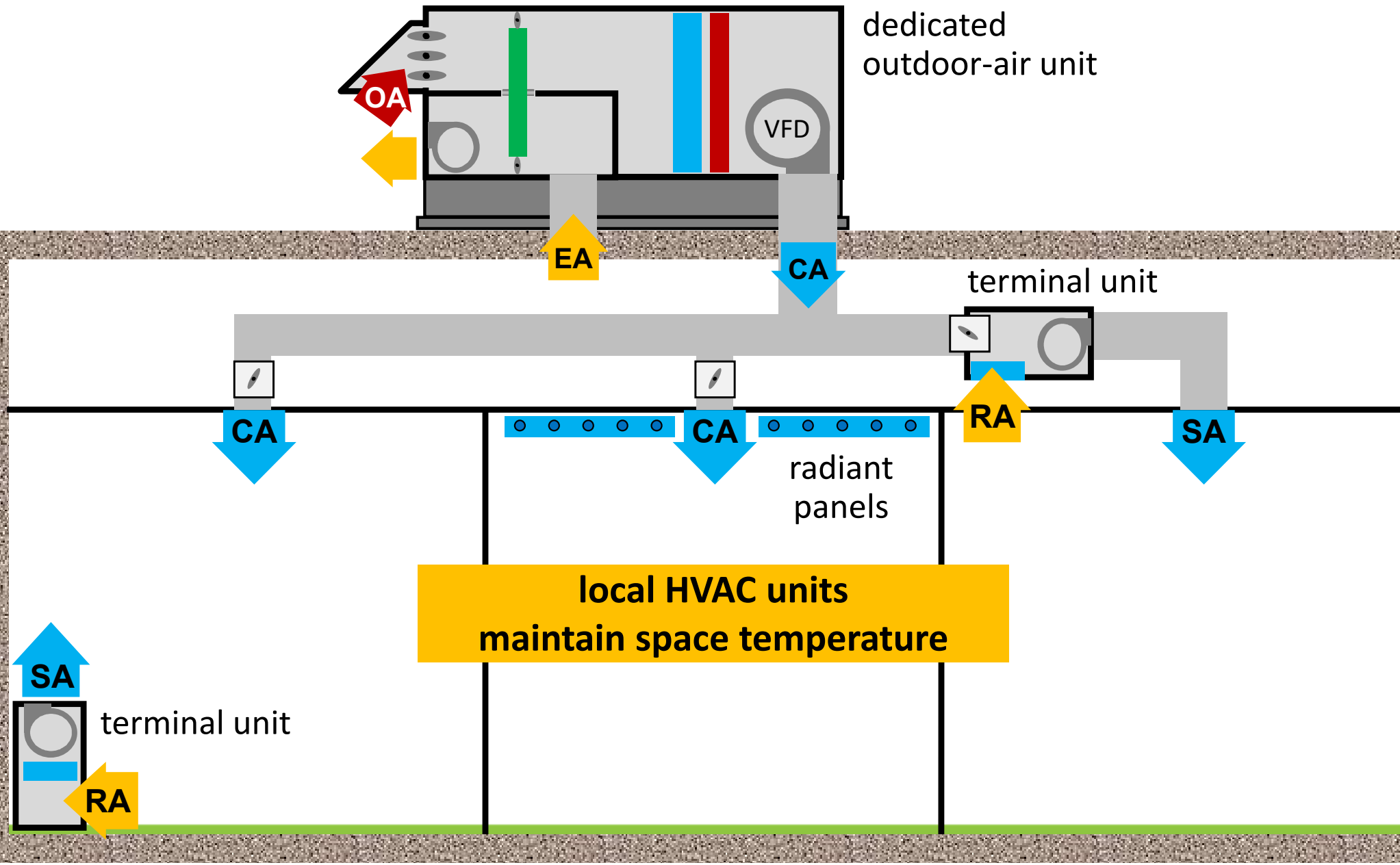
Marlboro Reich Hall Recognized for Outstanding Contemporary Architecture

Climate Forward Report Advocates for the Use of Climate Projections to Inform Design

DOAS Definition

A dedicated outdoor air system (DOAS) uses separate equipment to condition all of the outdoor air brought into a building for ventilation and delivers it to each occupied space, either directly or in conjunction with local or central HVAC units serving those same spaces. The local or central HVAC units are used to maintain space temperature.

condition all the outdoor air brought in for ventilation




Condenser
5 TON
Cooling Coil
Enthalpy
Recovery
Wheel
Exhaust Fan
OA Filter

Purpose of DOAS Guide

- Practical "how to" manual
- Compiles knowledge from various publications and presentations, expert interviews, and field visits
- Focused on what is unique to DOAS, not a “catch-all” design guide
- Counsels engineers how to:
  - Design to best practice
  - Avoid common design mistakes

Layout

- Practical Guide – to be used by design engineers
- Chapter Flow – similar to the design process
- Easy to look up topic
- Takes the process all the way into operation
- Tips and Traps – highlights of good practice, common mistakes or «hot topics»
- Over 60 Pictures and Figures

DOAS Chapters

1. **Introductions**
2. **Outdoor Air and Load Requirements**
3. **System Selection**
4. **Detailed Design Considerations**
5. **Controls**
6. **Construction**
7. **Operation and Maintenance**

Site visits and Interviews

- Many existing DOAS use ~70^{o}F (~20 ^{o}C) supply air temperature and do not take advantage of the «free» cooling
- Many existing DOAS do not achieve dehumidification under some conditions
- Most DOAS do not have a clear objective in regards to dehumidification
- Redundancy requirements can be a deciding factor in critical applications

Outline

Common DOAS Pitfalls:

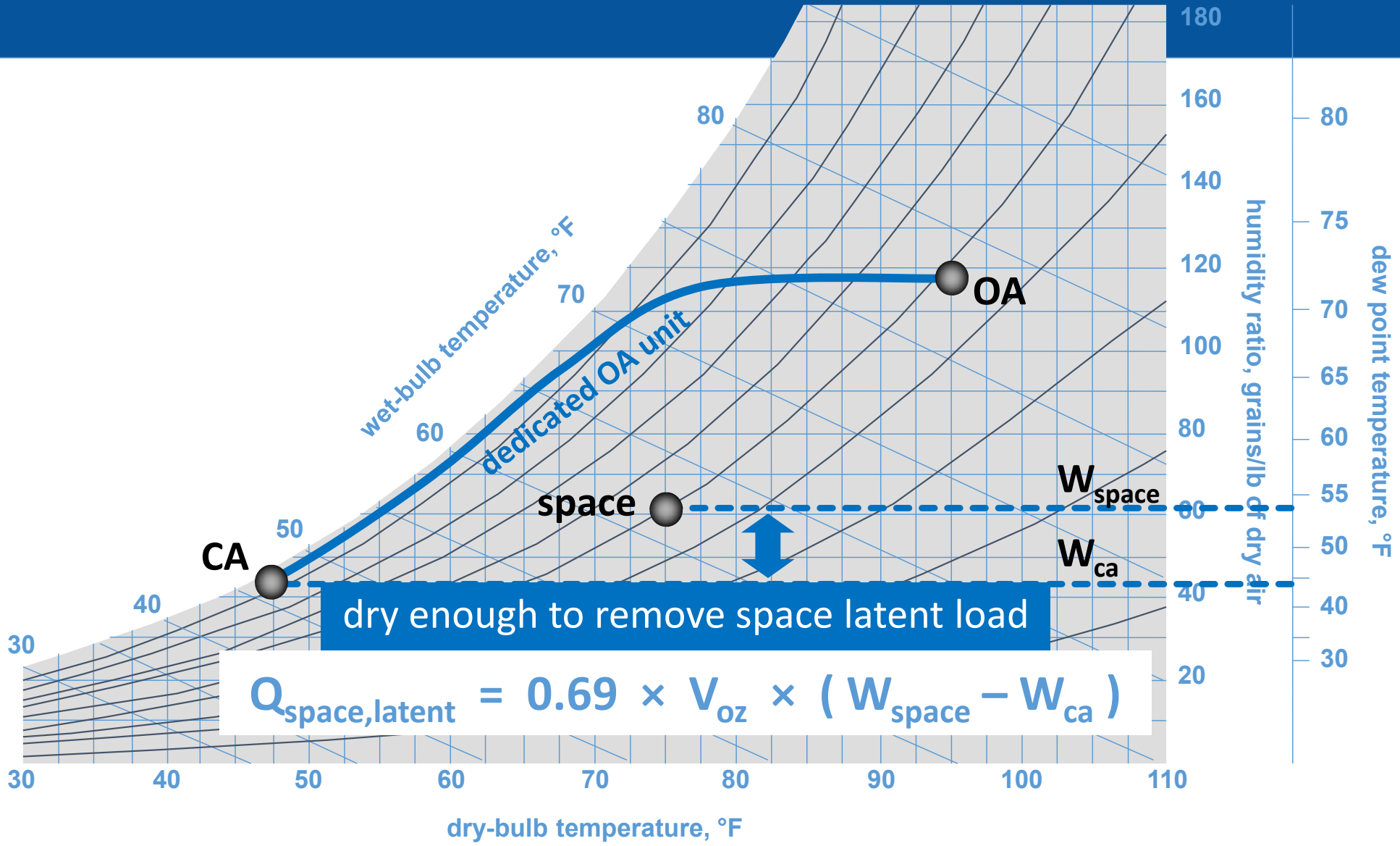
1. Not enough dehumidification
2. Fear of over-cooling spaces
3. Interrupted or insufficient ventilation
4. No exhaust-air energy recovery

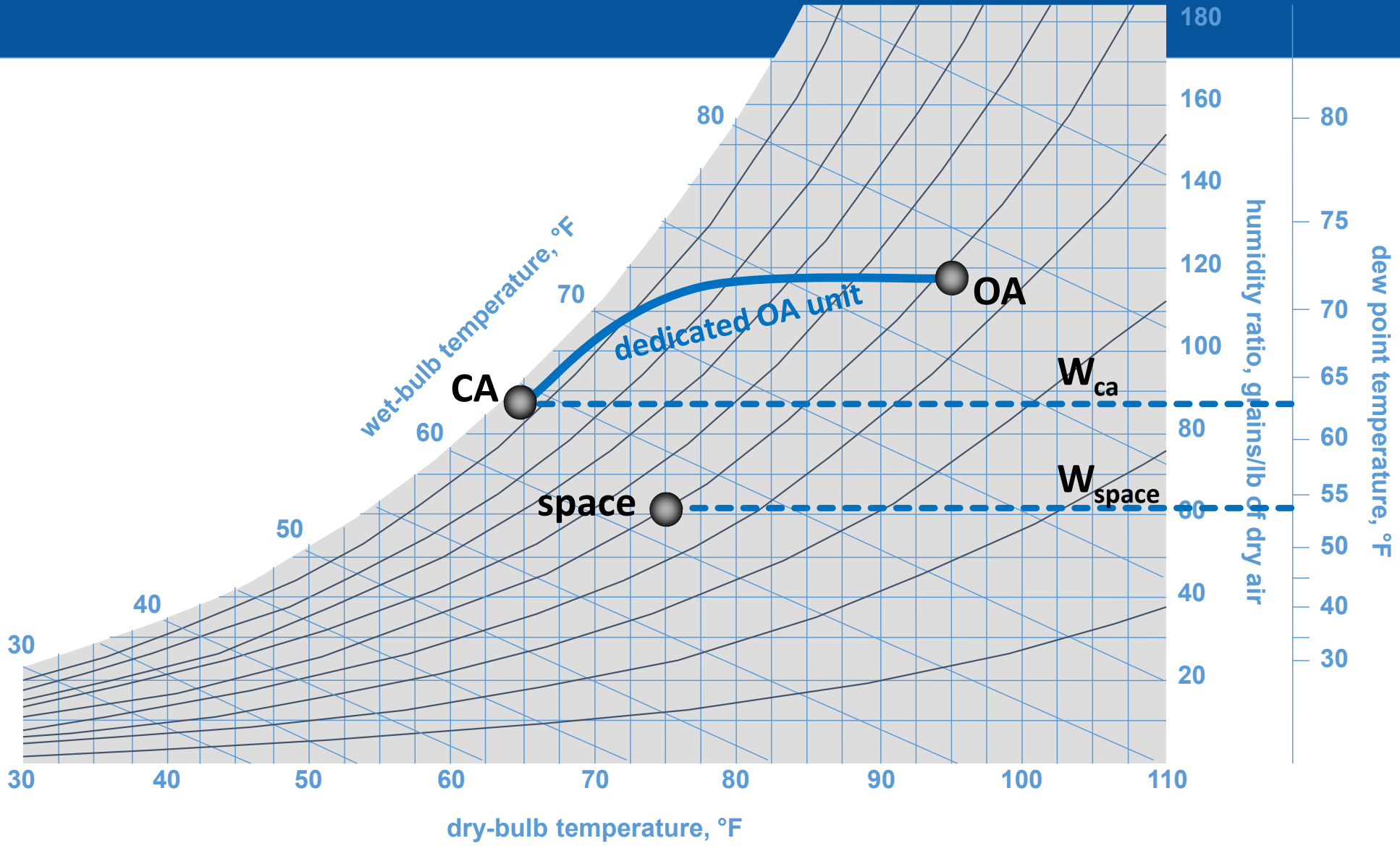
5. ASHRAE Standard 90.1 compliance (if time/interest)

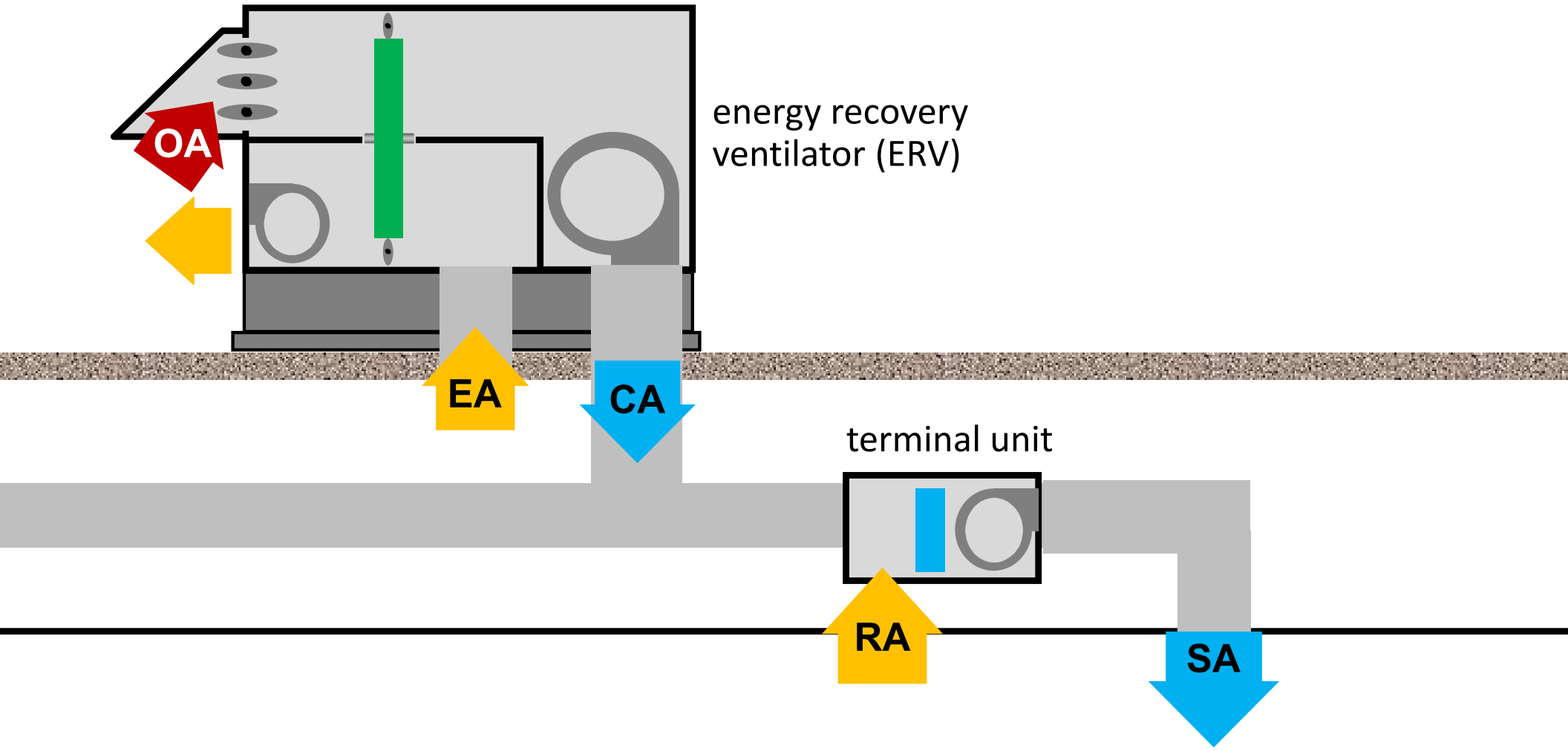
Outline

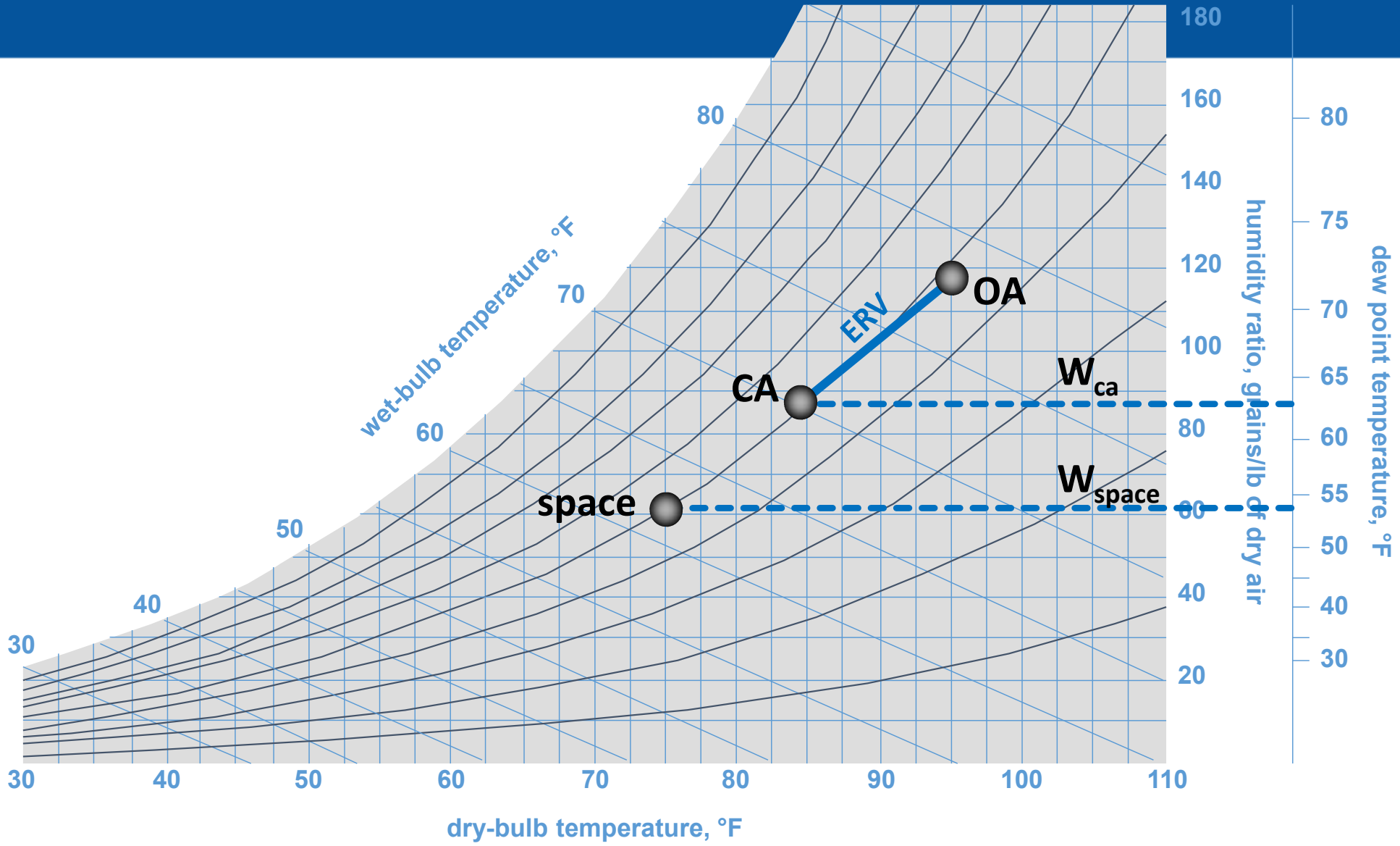
Common DOAS Pitfalls:

1. **Not enough dehumidification**
2. Fear of over-cooling spaces
3. Interrupted or insufficient ventilation
4. No exhaust-air energy recovery
5. ASHRAE Standard 90.1 compliance


wet-bulb temperature, °F
dedicated OA unit
OA
space
CA
W_{space}
W_{ca}
dry enough to remove space latent load
$Q_{space,latent} = 0.69 \times V_{oz} \times (W_{space} - W_{ca})$
dry-bulb temperature, °F
humidity ratio, grains/lb of dry air
dew point temperature, °F


wet-bulb temperature, °F
dedicated OA unit
OA
CA
W_{ca}
space
W_{space}
humidity ratio, grains/lb of dry air
dew point temperature, °F
dry-bulb temperature, °F
30
40
50
60
70
80
90
100
110
20
120
140
160
180
55
65
75


OA
energy recovery
ventilator (ERV)
EA
CA
terminal unit
RA
SA


wet-bulb temperature, °F
dry-bulb temperature, °F
humidity ratio, grains/lb of dry air
dew point temperature, °F
ERV
OA
CA
space
W_{ca}
W_{space}
30
40
50
60
70
80
90
100
110
20
40
60
80
100
120
140
160
180
30
40
50
55
60
65
70
75
80

Not Enough Dehumidification

- Dehumidify OA to a dew point drier than the space

Outline

Common DOAS Pitfalls:

1. Not enough dehumidification
2. **Fear of over-cooling spaces**
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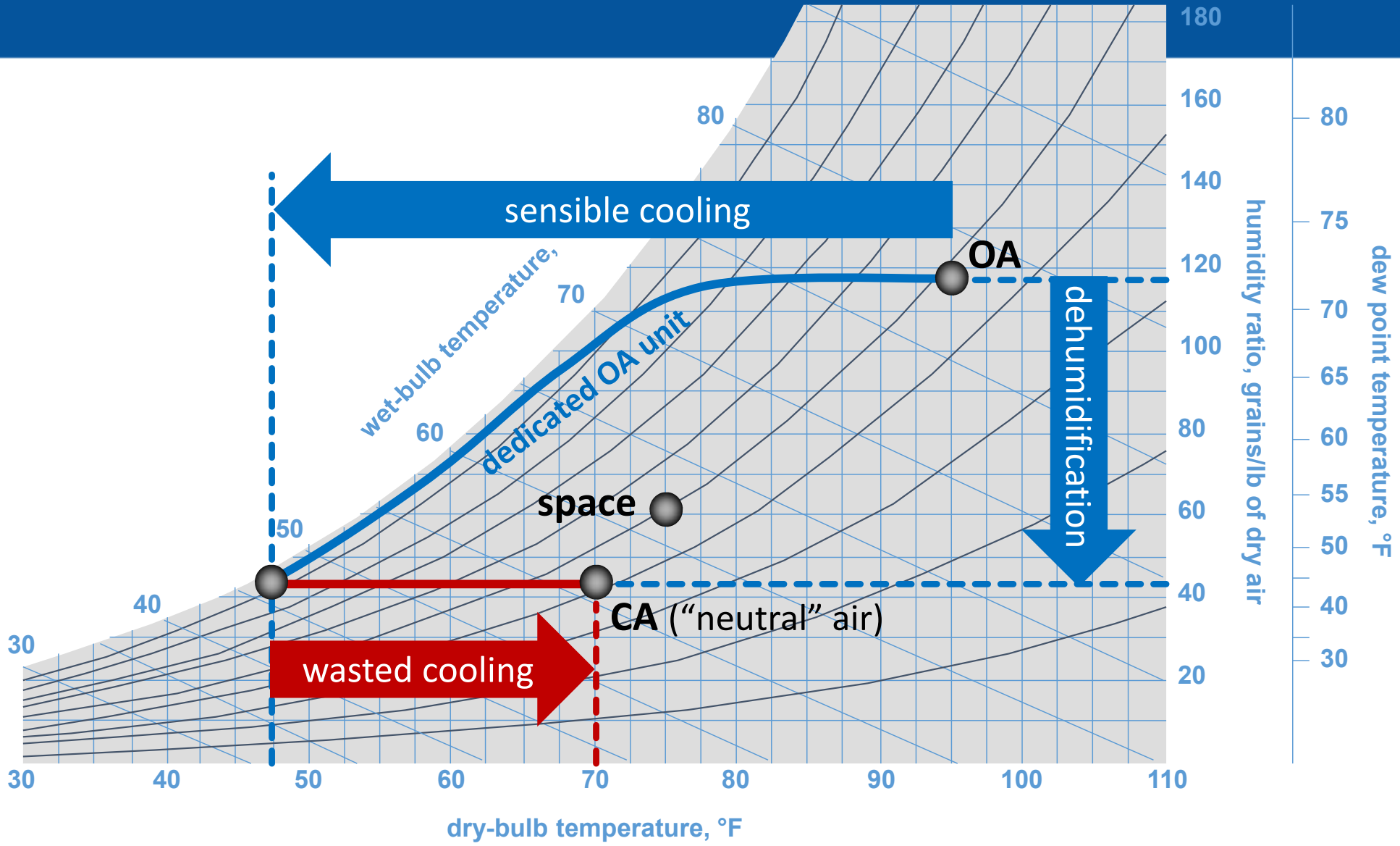
5. ASHRAE Standard 90.1 compliance


sensible cooling
OA
dehumidification
wet-bulb temperature,
dedicated OA unit
space
CA ("neutral" air)
wasted cooling
dry-bulb temperature, °F
humidity ratio, grains/lb of dry air
dew point temperature, °F
30
40
50
60
70
80
90
100
110
20
40
60
80
100
120
140
160
180
30
40
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55
60
65
70
75
80

ASHRAE Standard 90.1

6.5.2.6 Ventilation Air Heating Control

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 (16°C)*** *when representative building loads or outdoor air temperature indicate that the majority of zones require cooling.*

ASHRAE Standard 90.1-2016 (Section 6.5.2.6)

Fear of Over-Cooling Spaces

Example: K-12 school classroom (age 9+)

- Sensible heat gain from people = **250 Btu/h/person**
- Minimum ventilation rate (V_{oz}) = 13 cfm/person
  (using default occupant density from ASHRAE Standard 62.1-2016)
- Space temperature setpoint (DBT_{space}) = 73°F

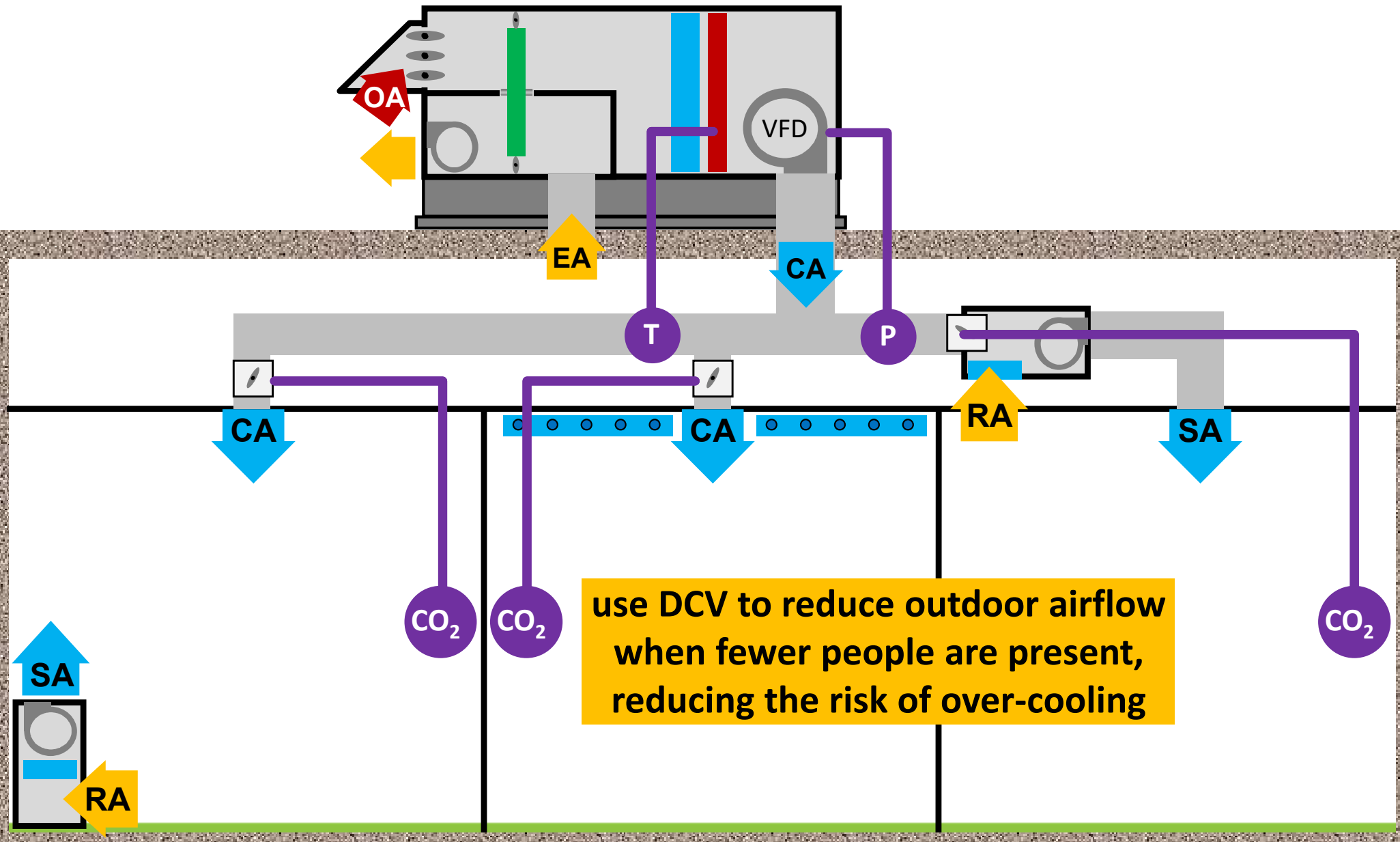
If conditioned air (CA) from DOAS is delivered at 55°F…

$$Q_{CA,sensible} = 1.085 \times V_{oz} \times (DBT_{space} - DBT_{CA})$$
$$= 1.085 \times 13\ cfm/p \times (73°F - 55°F)$$
$$= \mathbf{254\ Btu/h/person}$$

Fear of Over-Cooling Spaces

- Deliver conditioned OA cold (not “neutral”), if possible
- To avoid overcooling space at part-load conditions:
  - Implement demand-controlled ventilation to reduce outdoor airflow as population changes
  - Activate heat in the local HVAC unit (few zones, WSHP)
  - Reheat dehumidified air in dedicated OA unit using recovered energy, but only when necessary

reheat dehumidified air only as much as needed to avoid over-cooling

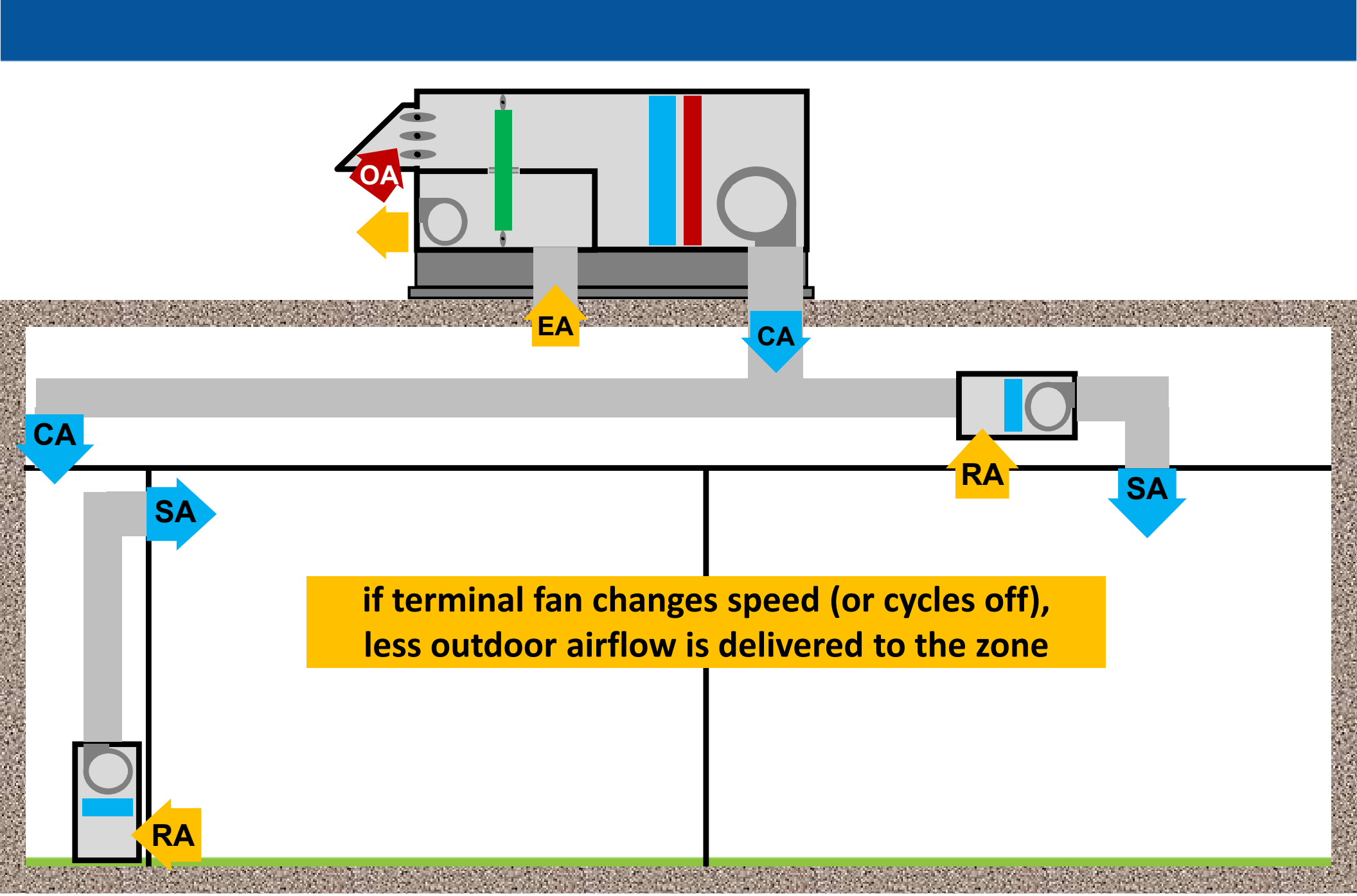


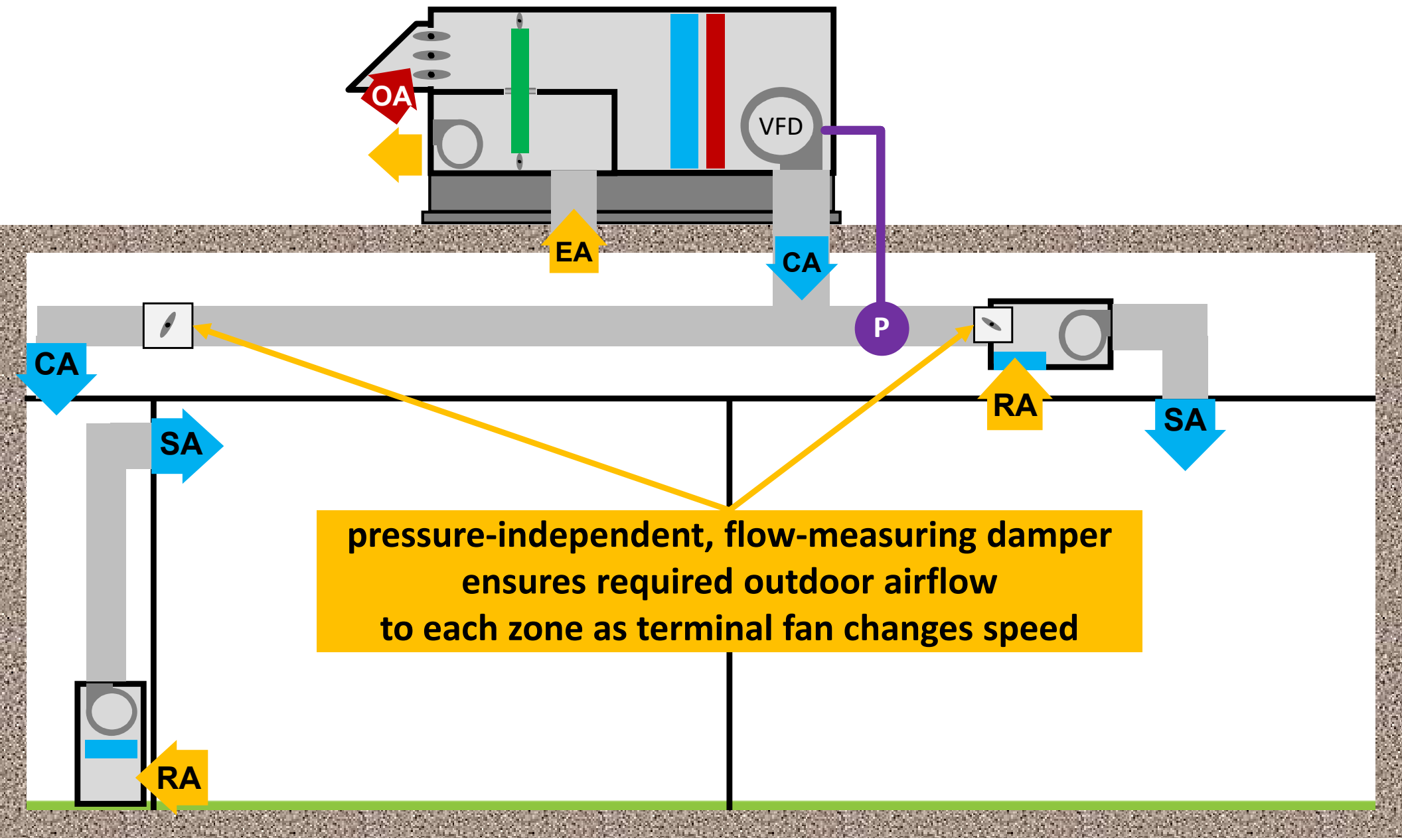
use DCV to reduce outdoor airflow when fewer people are present, reducing the risk of over-cooling

Outline

Common DOAS Pitfalls:

1. Not enough dehumidification
2. Fear of over-cooling spaces
3. **Interrupted or insufficient ventilation**
4. No exhaust-air energy recovery
5. ASHRAE Standard 90.1 compliance

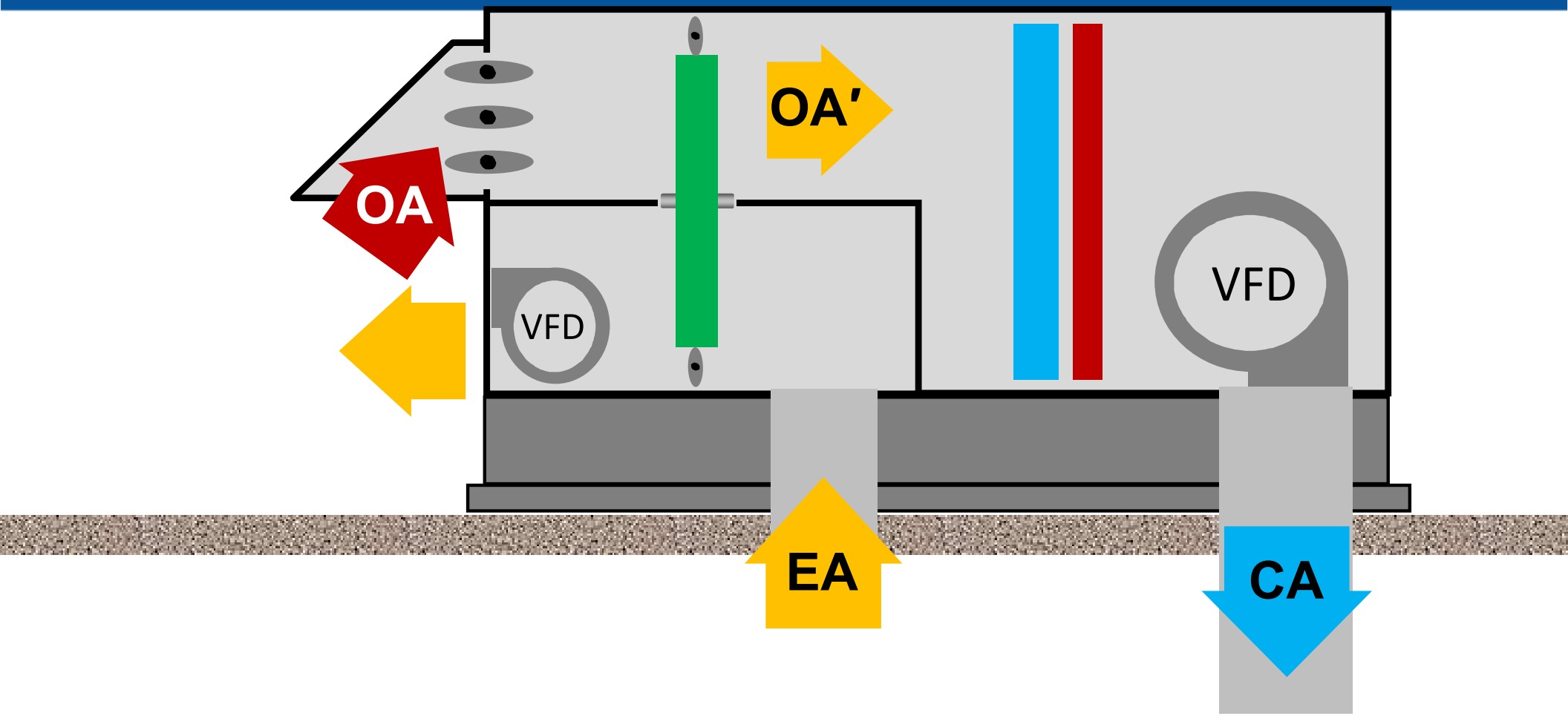

OA
EA
CA
CA
RA
SA
SA
RA
if terminal fan changes speed (or cycles off),
less outdoor airflow is delivered to the zone


OA
VFD
EA
CA
P
CA
SA
RA
SA
RA
pressure-independent, flow-measuring damper
ensures required outdoor airflow
to each zone as terminal fan changes speed

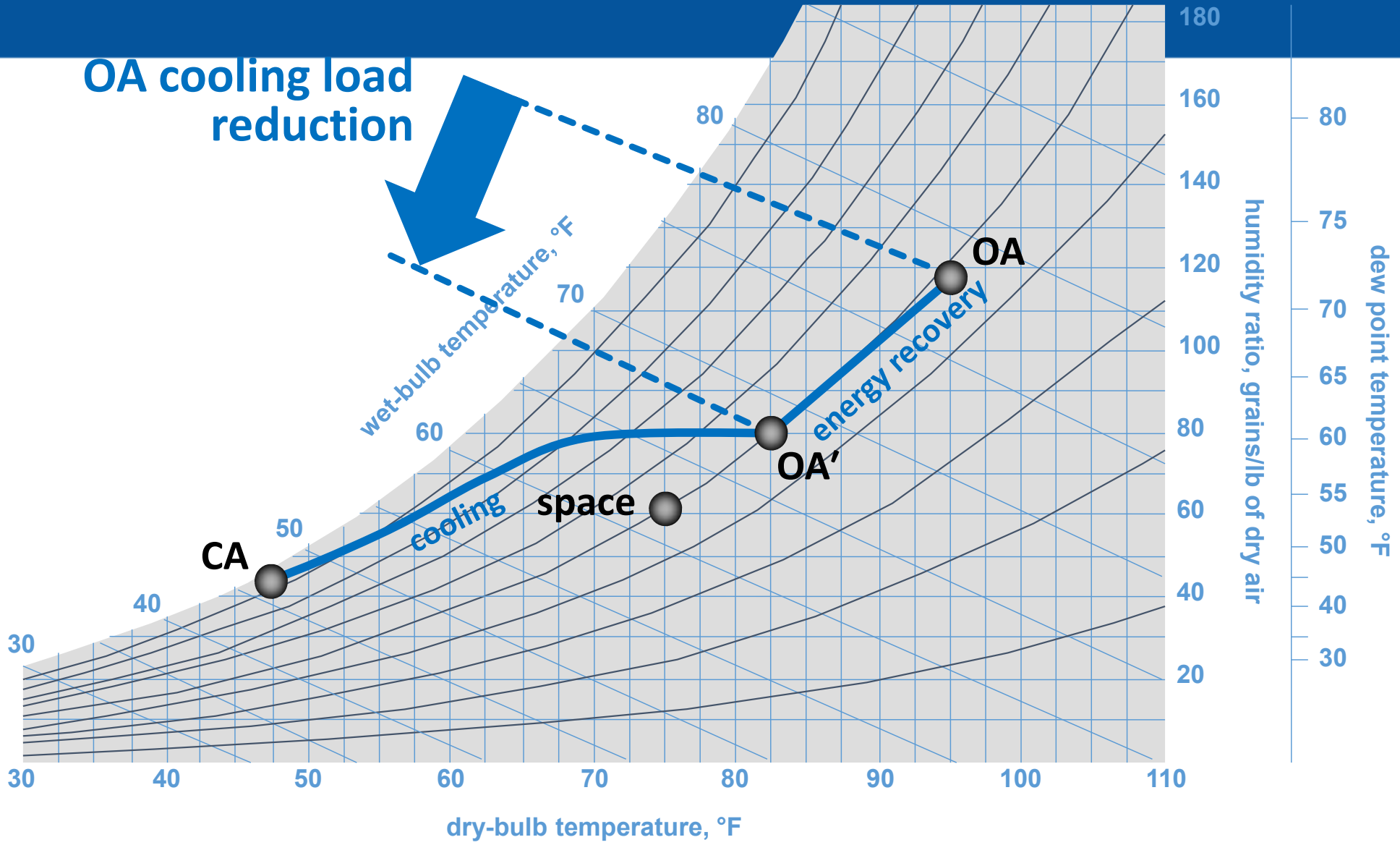
Outline

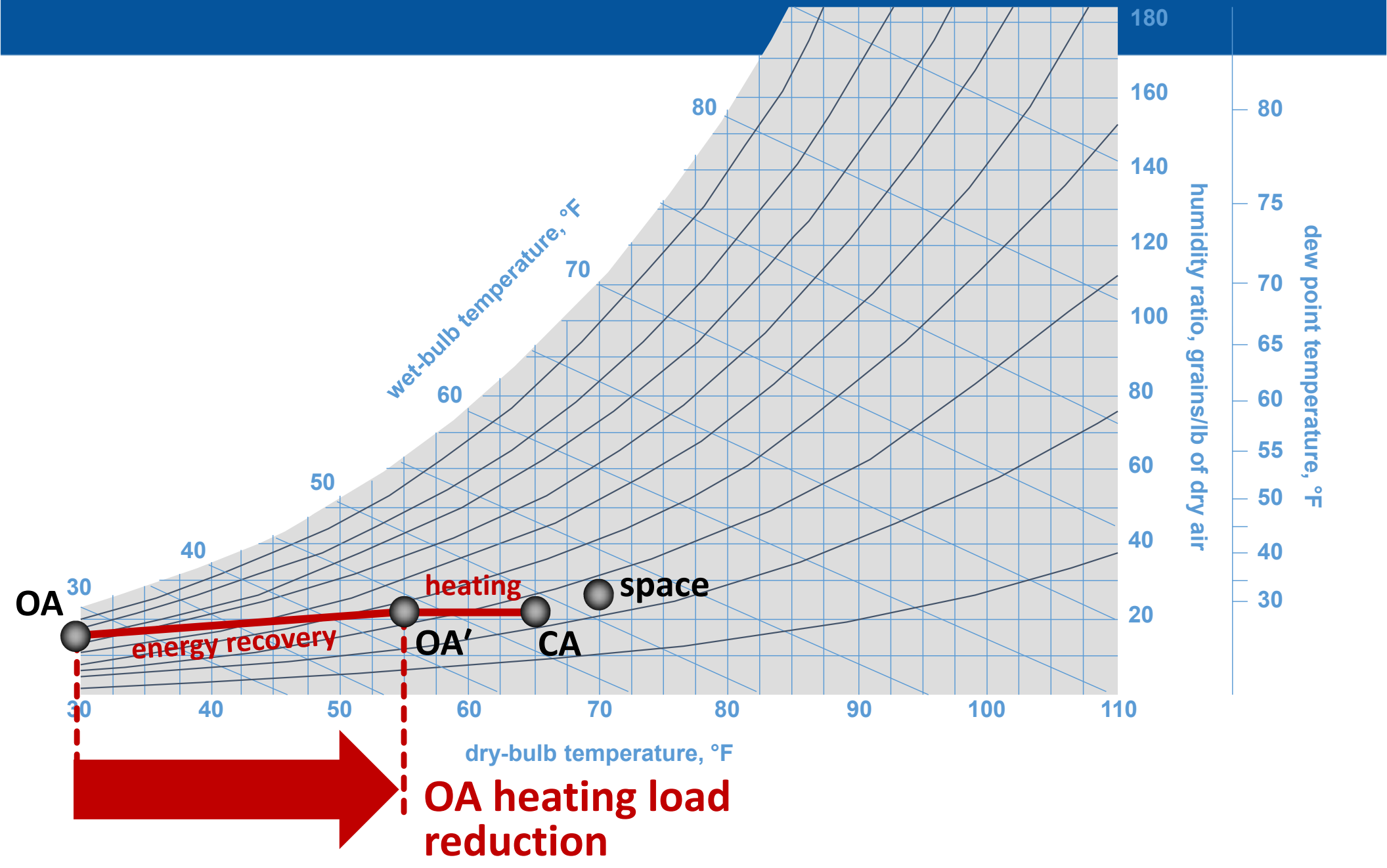
Common DOAS Pitfalls:

1. Not enough dehumidification
2. Fear of over-cooling spaces
3. Interrupted or insufficient ventilation
4. **No exhaust-air energy recovery**
5. ASHRAE Standard 90.1 compliance


OA
OA'
VFD
VFD
EA
CA

OA cooling load reduction




wet-bulb temperature, °F
30
40
50
60
70
80
humidity ratio, grains/lb of dry air
20
40
60
80
100
120
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160
180
dew point temperature, °F
30
40
50
55
60
65
70
75
80
dry-bulb temperature, °F
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40
50
60
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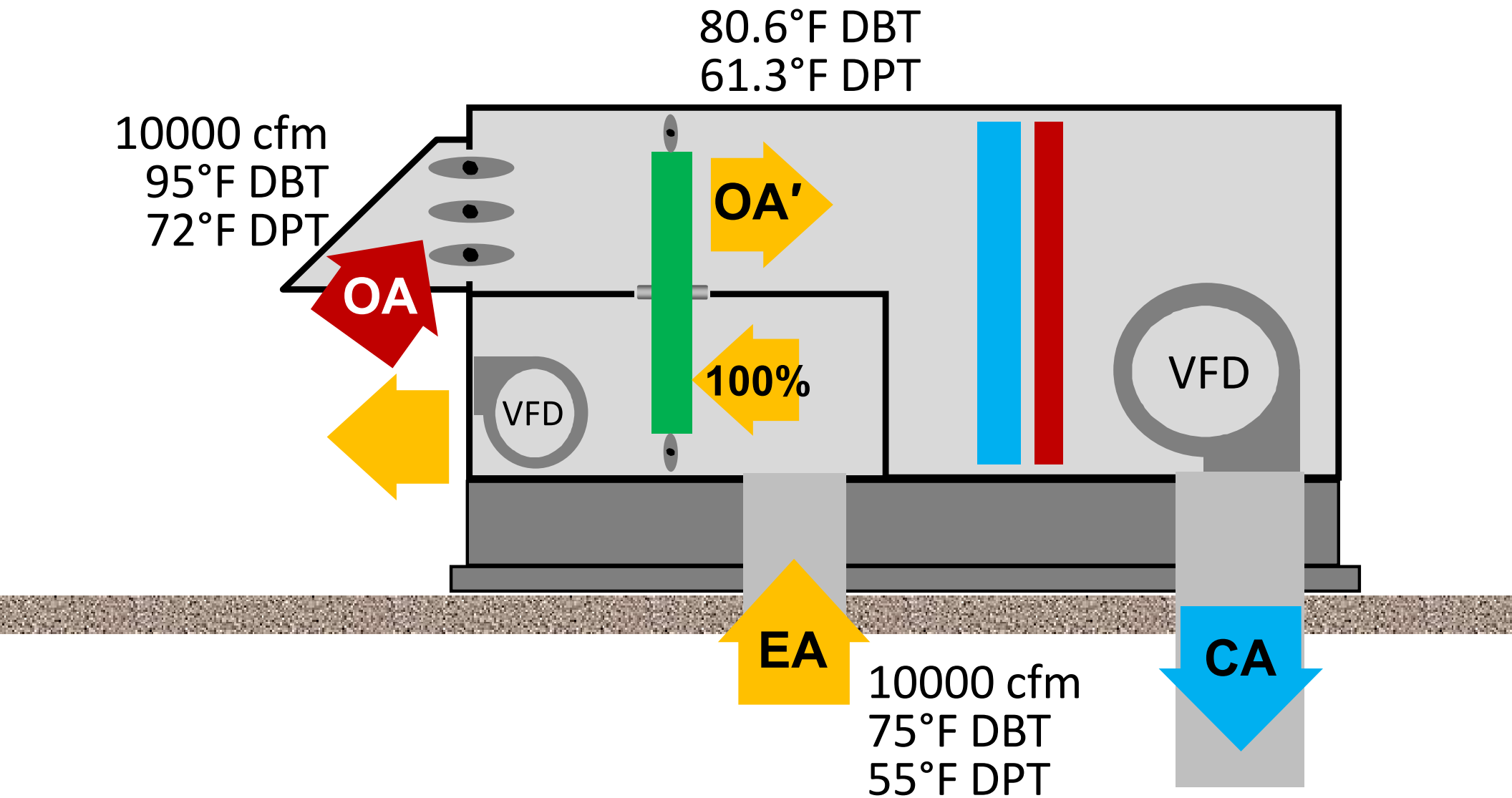
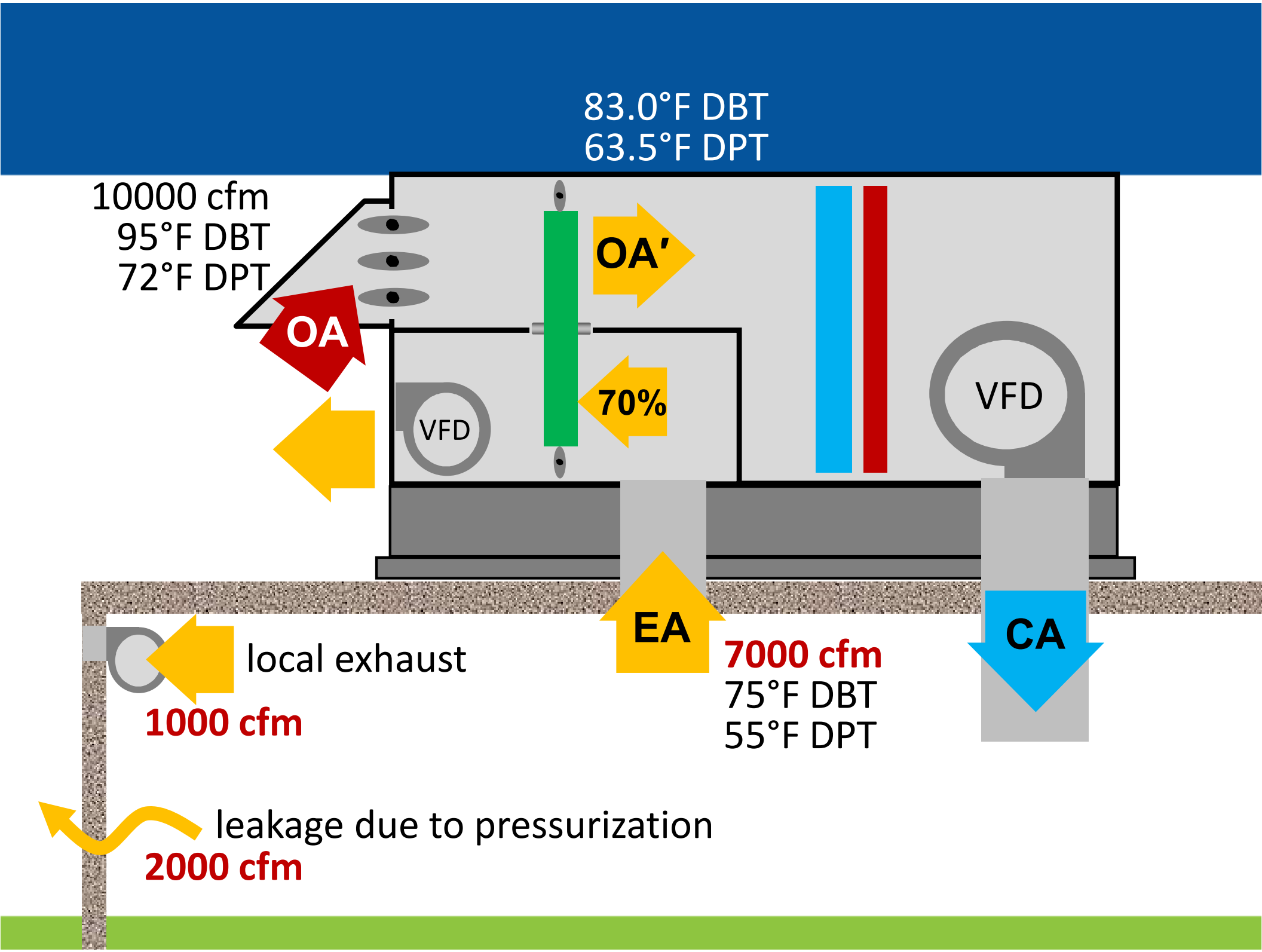
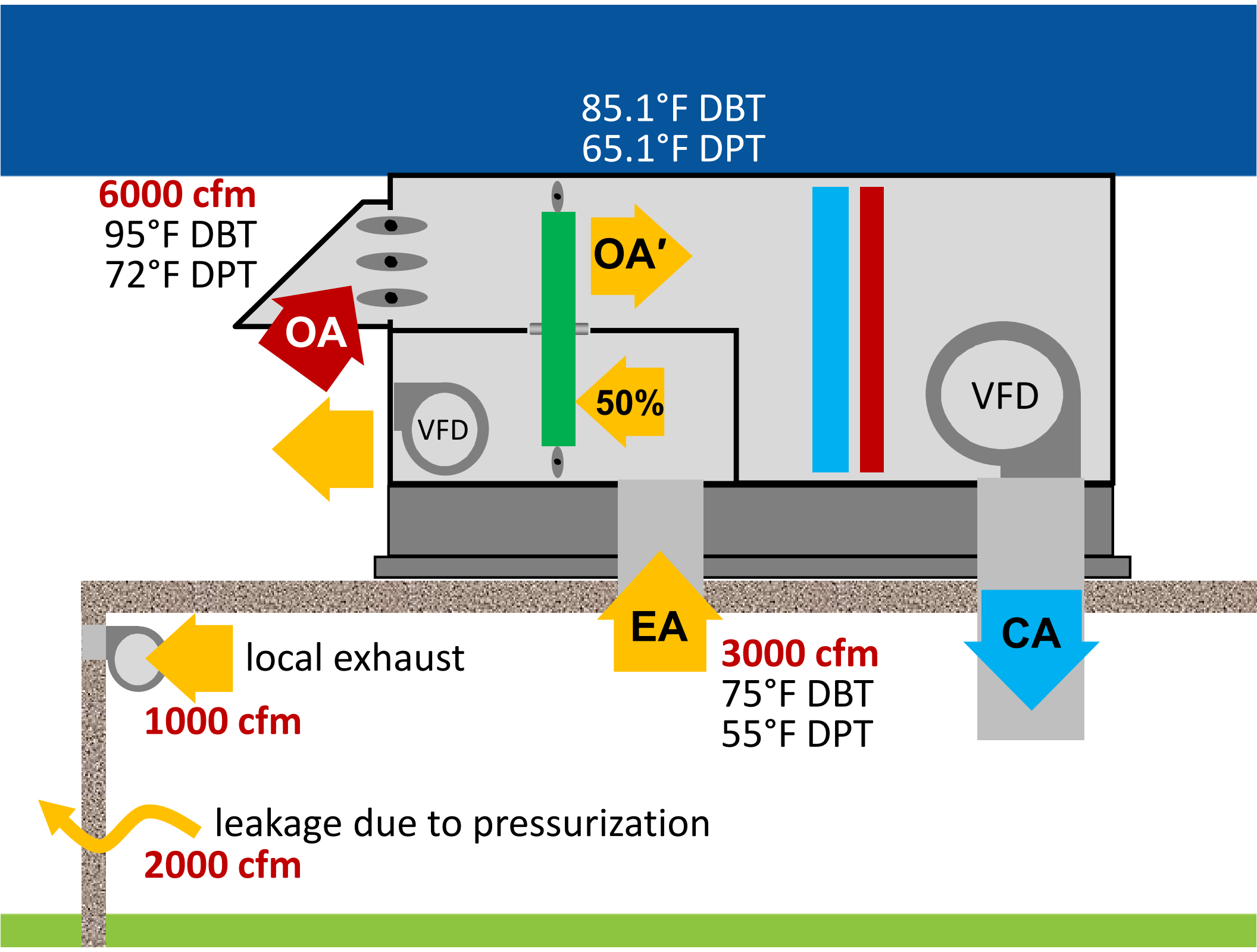
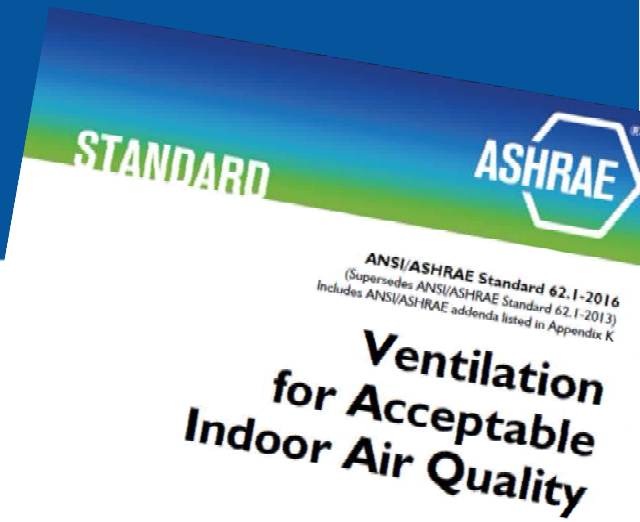
80
90
100
110
OA
energy recovery
OA'
heating
CA
space
OA heating load reduction


80.6°F DBT
61.3°F DPT
10000 cfm
95°F DBT
72°F DPT
OA
OA'
100%
VFD
VFD
EA
CA
10000 cfm
75°F DBT
55°F DPT


83.0°F DBT
63.5°F DPT
10000 cfm
95°F DBT
72°F DPT
OA
OA'
70%
VFD
VFD
EA
CA
local exhaust
1000 cfm
7000 cfm
75°F DBT
55°F DPT
leakage due to pressurization
2000 cfm


85.1°F DBT
65.1°F DPT
6000 cfm
95°F DBT
72°F DPT
OA
OA'
50%
VFD
VFD
EA
CA
local exhaust
1000 cfm
3000 cfm
75°F DBT
55°F DPT
leakage due to pressurization
2000 cfm

ASHRAE Standard 62.1



5.16.3.2.5 *Class 2 air* [which includes restrooms] *shall not be recirculated or transferred to Class 1 spaces.*

Exception: *When using any energy recovery device, recirculation from leakage, carryover, or transfer from the exhaust side of the energy recovery device is permitted. Recirculated Class 2 air* ***shall not exceed 10% of the outdoor air intake flow****."*

ASHRAE Standard 62.1-2016 (Section 5.16.3.2.5)

Conclusions

- Dehumidify OA to a dew point drier than the space
- Deliver conditioned OA cold (not “neutral”), if possible
- Implement DCV and reheat dehumidified air in dedicated OA unit using recovered energy, but only when necessary
- Deliver conditioned OA directly to spaces or use flow-measuring dampers to ensure proper ventilation as operating conditions change
- Centralize exhaust to better balance airflows and maximize exhaust-air energy recovery

Sample Projects

- Oregon Forest Edge Elementary School
- Sun Prairie High School

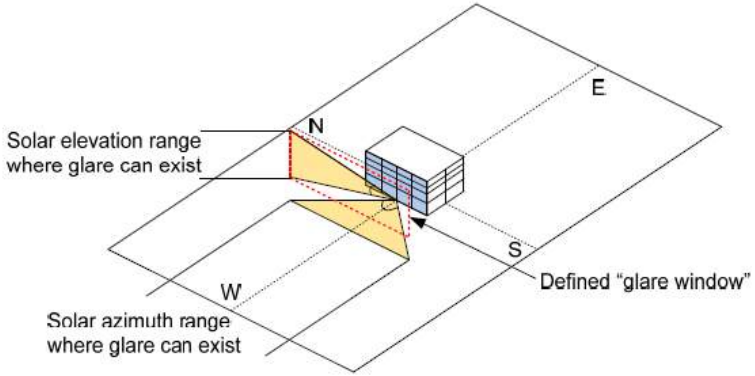
Oregon Forest Edge (Wisconsin)

Net Zero Energy School

Interesting Design Elements

- DOAS
- No natural gas connection
- Electrochromic glazing
- ECM motor pump skid for geo pumps
- Submetering of loads
- Solar PV roof
- Advanced lighting control
- Lithium ion battery (125kW/250kWh

Electrochromic Glass



Geothermal Pump Skid

Sun Prairie High School (Wisconsin)

DOAS

Questions

- Svein Morner
- smorner@hga.com

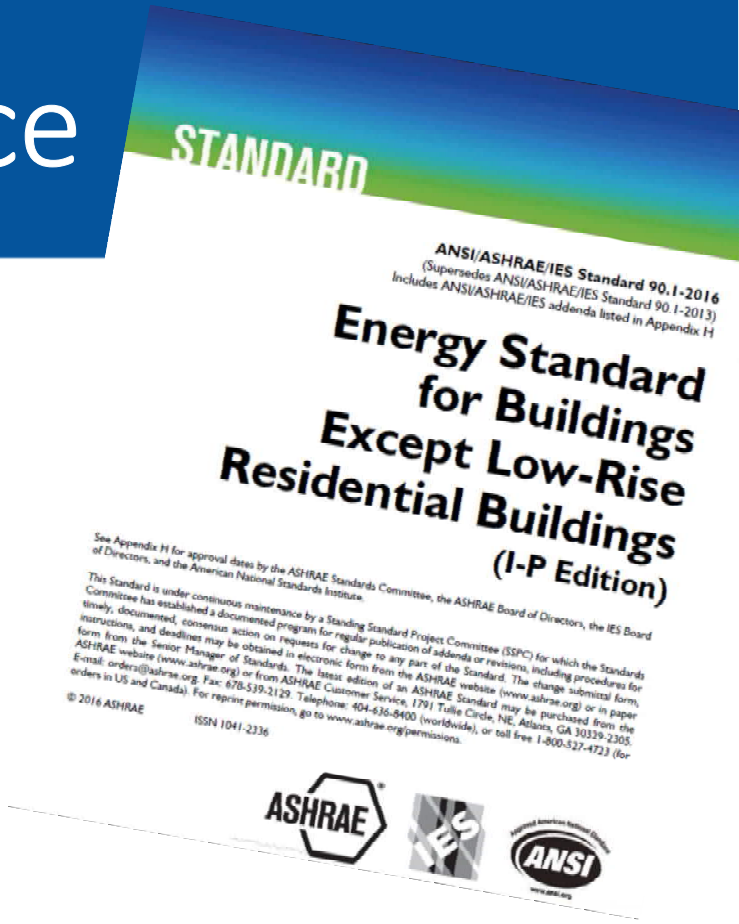
Outline

Common DOAS Pitfalls:

1. Not enough dehumidification
2. Fear of over-cooling spaces
3. Interrupted or insufficient ventilation
4. No exhaust-air energy recovery
5. **ASHRAE Standard 90.1 compliance**

ASHRAE 90.1 Compliance

- Minimum equipment efficiency (AHRI Standard 920)
- Fan power limit
- Economizer exceptions
- Exhaust-air energy recovery
- Limit on heating above 60°F (16°C)



Minimum Equipment Efficiencies

Equipment efficiency levels defined in this section [Section 6.4.1] and Tables 6.8.1-1 through 6.8.1-13 are based on industry rating standards, such as those of the Air-Conditioning, Heating, and Refrigeration Institute (AHRI).

Although Sections 6.4.1.1 and 6.4.1.2 include many types of HVACR equipment, ***not every type of HVACR equipment that might be used in a project is covered****. This section [Section 6.4.1.3] clarifies that the use of HVACR equipment not covered by these sections does not prohibit compliance with the Standard. Equipment not covered by these sections is not regulated by this standard, but may be regulated by other standards, codes, or federal regulations.*

Standard 90.1-2013 User's Manual (pages 6-14 and 6-18)

Minimum Equipment Efficiencies

- Until AHRI Standard 920 was published in June 2013, there was no rating standard for DX dedicated OA equipment, so ASHRAE 90.1 did not include minimum efficiency requirements for this class of equipment
- Minimum efficiency requirements were added to Standard 90.1 in the 2016 version

Dedicated outdoor air systems (DOAS) ... are used in many buildings covered by ASHRAE 90.1. However, ***the current ASHRAE 90.1 standard has no minimum energy efficiency requirements for this equipment****. Through AHRI, manufacturers of DOAS developed Standard 920 to establish common rating conditions for these products. This proposal establishes for the first time a product class for DOAS.*

addendum CD to ASHRAE Standard 90.1-2013

Minimum Equipment Efficiencies

Equipment Type	Subcategory	Minimum efficiency	Test procedure
Air-cooled (dehumidification mode)		4.0 ISMRE	AHRI Standard 920-2015
Air-source heat pump (dehumidification mode)		4.0 ISMRE	
Water-cooled (dehumidification mode)	cooling tower condenser water	4.9 ISMRE	
	chilled water	6.0 ISMRE	
Water-source heat pump (dehumidification mode)	ground-source, closed loop	4.8 ISMRE	
	groundwater-source	5.0 ISMRE	
	water-source	4.0 ISMRE	
Air-source heat pump (heating mode)		2.7 ISCOP	
Water-source heat pump (heating mode)	ground-source, closed loop	2.0 ISCOP	
	groundwater-source	3.2 ISCOP	
	water-source	3.5 ISCOP	

ASHRAE Standard 90.1-2016 (Tables 6.8.1-15 and -16)

Fan Power Limitation

6.5.3.1 Fan System Power and Efficiency

6.5.3.1.1 Each HVAC system *having a total fan system motor nameplate horsepower* ***exceeding 5 hp*** *at fan system design conditions shall not exceed the allowable fan system motor nameplate horsepower (Option 1) or fan system bhp (Option 2) as shown in Table 6.5.3.1-1.*

ASHRAE Standard 90.1-2016 (Section 6.5.3.1.1)

Fan Power Limitation

QUESTION: *A wing of an elementary school building is served by eight WSHPs, each equipped with a ¾-hp fan motor and serving a single classroom. Ventilation air is supplied directly to each classroom by a dedicated outdoor-air system. Each classroom requires 500 cfm of outdoor air, so the DOAS delivers the total of 4000 cfm of conditioned outdoor air using a 5-hp fan. Does this system need to comply with section 6.5.3.1?*

ANSWER: ***Each WSHP is a separate fan system*** *because each has a separate cooling and heating source. The* ***power of the DOAS fan must be allocated to each heat pump*** *on a cfm-weighted basis.*

Standard 90.1-2013 User's Manual (Example 6-CCC)

Fan Power Limitation

DOAS delivers 500 cfm to each classroom, so 1/8th (500 cfm / 4000 cfm) of the DOAS fan power is added to the fan power for each WSHP:

1/8th of 5 hp = 5/8 hp

3/4 hp (WSHP) + 5/8 hp (allocated DOAS) = 1 3/8 hp

ANSWER [continued] ***…***

In this instance, even with the DOAS fan allocated, ***each WSHP fan system is less than the 5 hp threshold*** *in Section 6.5.3, so the system* ***does not need to comply*** *with Section 6.5.3.1.*

Standard 90.1-2013 User's Manual (Example 6-CCC)

Economizers

6.5.1 Economizers. *Each cooling system shall include either an air economizer or fluid economizer meeting the requirements of Sections 6.5.1.1 through 6.5.1.5.*

ASHRAE Standard 90.1-2016 (Section 6.5.1)

Notable exceptions for DOAS:

1. Individual fan-cooling units < 54,000 Btu/hr (4.5 tons)

The requirement is based on the [capacity of the] *fan-coil unit and not the capacity of a central chilled-water plant or VRF system condensing unit capacity.*

ASHRAE 90.1-2013 User's Manual (page 6-57)

6. Residential with system capacity < 270,000 Btu/hr
8. Systems that operate < 20 hours/week
10. Install higher-efficiency cooling equipment

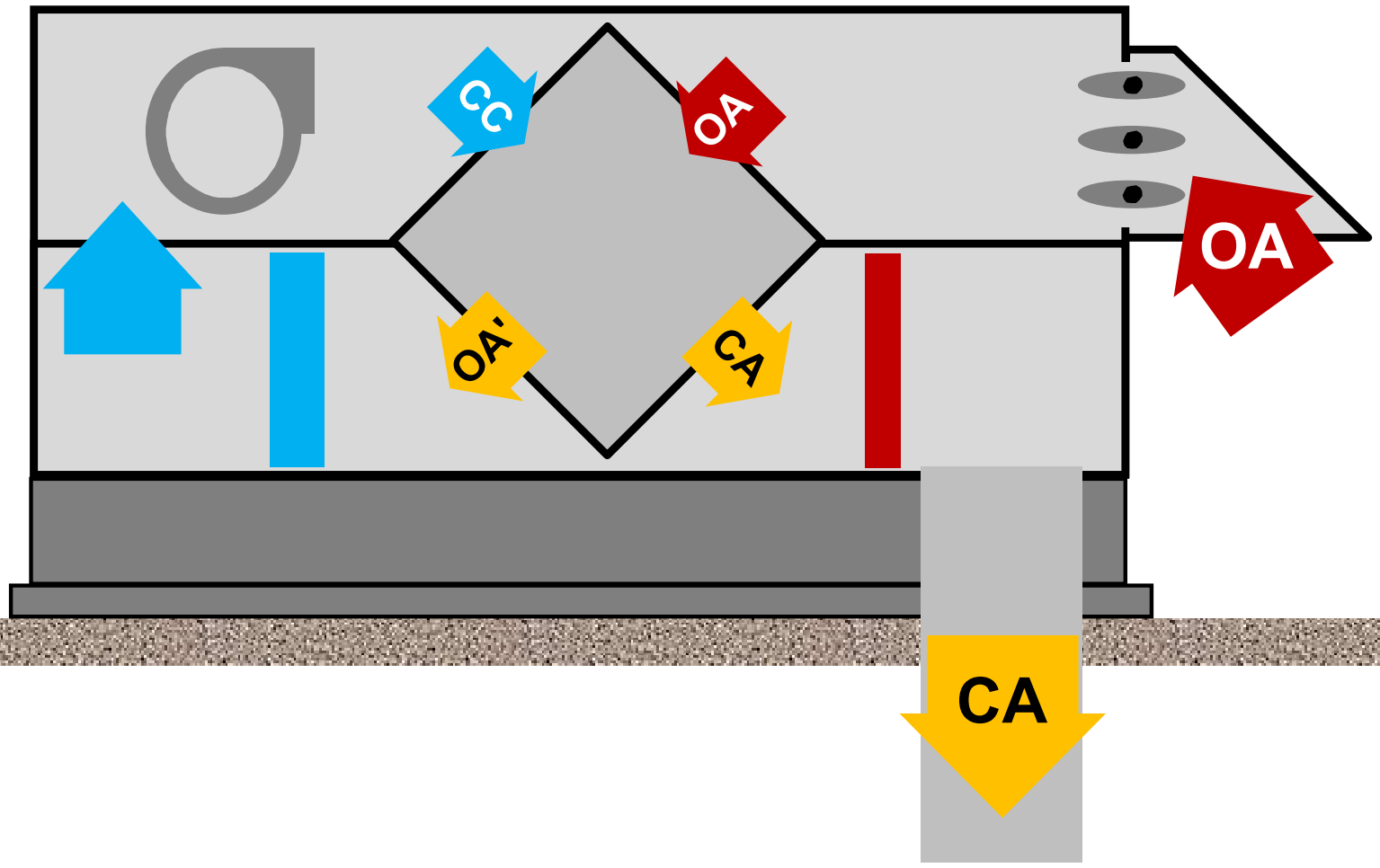
DOAS Reheat/Heating Limit

6.5.2.6 Ventilation Air Heating Control

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 (16°C)*** *when representative building loads or outdoor air temperature indicate that the majority of zones require cooling.*

ASHRAE Standard 90.1-2016 (Section 6.5.2.6)

fixed-plate
heat exchanger*



* could also be a heat pipe, coil loop, or sensible heat wheel

OA cooling load reduction