Trends in Energy Recovery Technologies

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PRESENTATION AGENDA

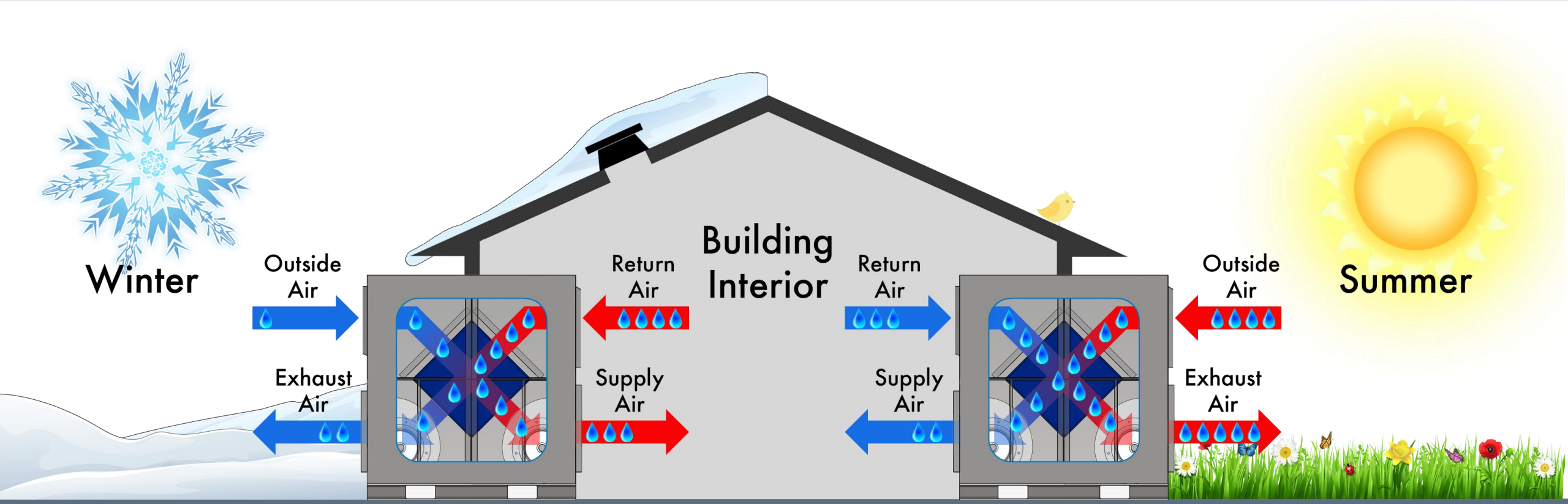
Part 1: Why Energy Recovery?

Part 2: Codes & Standards

Part 3: HVAC and ERV Equipment Options

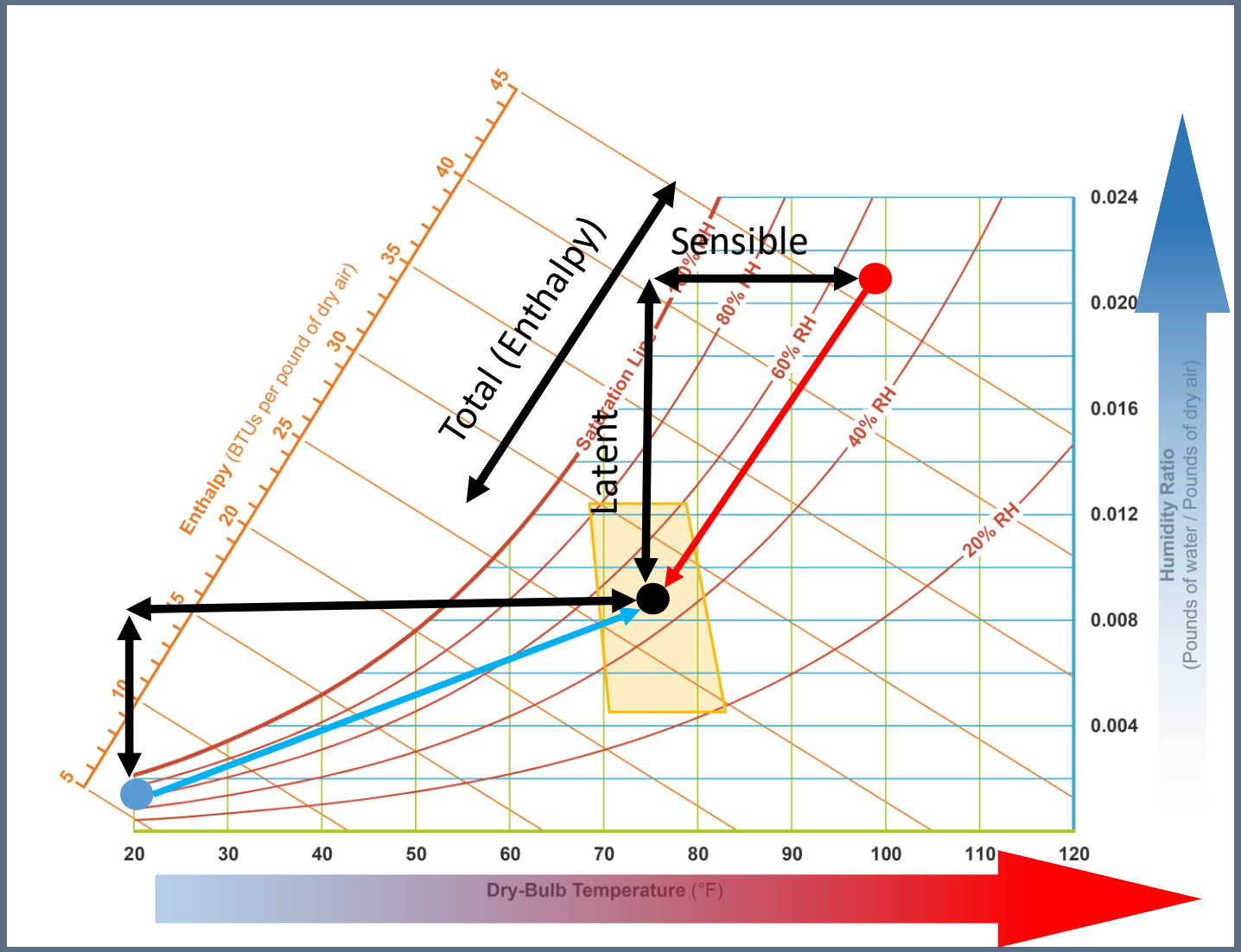
Part 4: Climate Considerations

Ventilate with Energy Recovery



Humidifies in winter & dehumidifies in summer, reducing energy costs & providing fresh air & optimal indoor comfort

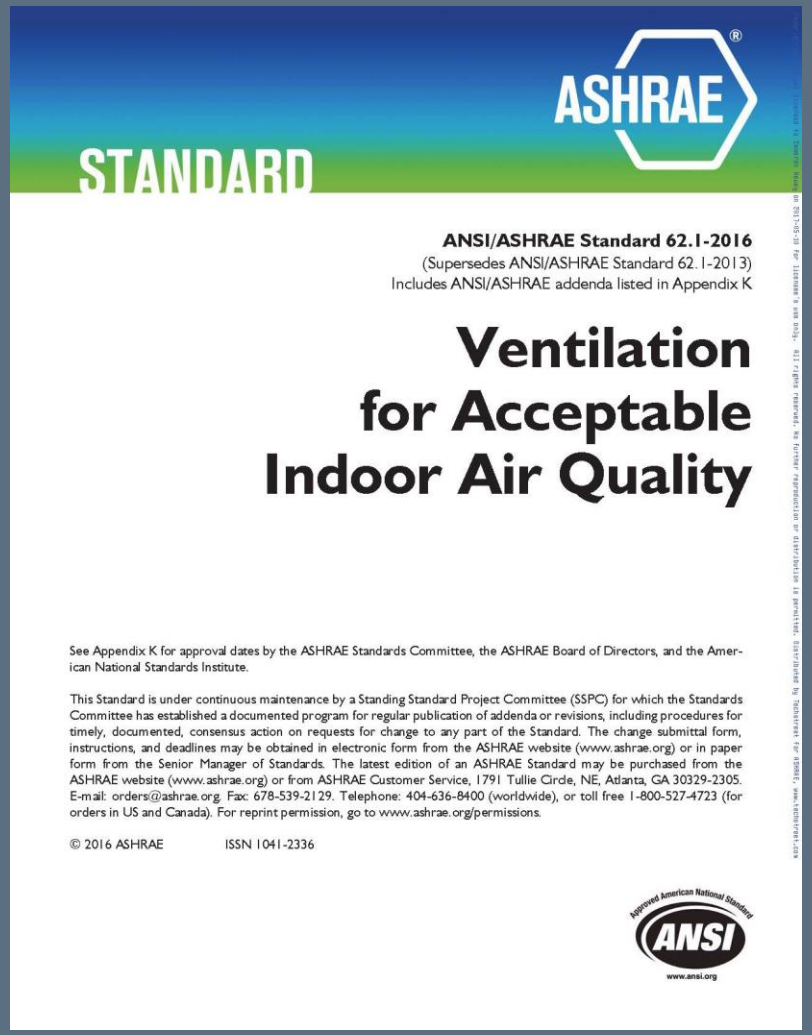
Effectiveness - Psychrometrics



North American Ventilation and ERV Codes & Standards

ASHRAE 62.1

Standard of Ventilation for Acceptable Indoor Air Quality



STANDARD

ASHRAE

ANSI/ASHRAE Standard 62.1-2016
(Supersedes ANSI/ASHRAE Standard 62.1-2013)
Includes ANSI/ASHRAE addenda listed in Appendix K

Ventilation for Acceptable Indoor Air Quality

See Appendix K for approval dates by the ASHRAE Standards Committee, the ASHRAE 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. The change submittal form, instructions, and deadlines may be obtained in electronic form from the ASHRAE website (www.ashrae.org) or in paper form from the Senior Manager of Standards. The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. 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.

 ISSN 1041-2336

Approved American National Standard
ANSI
www.ansi.org

ASHRAE Definition of Acceptable IAQ

"Air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction."

ASHRAE 62.1-2016

Standard of Ventilation for Acceptable Indoor Air Quality

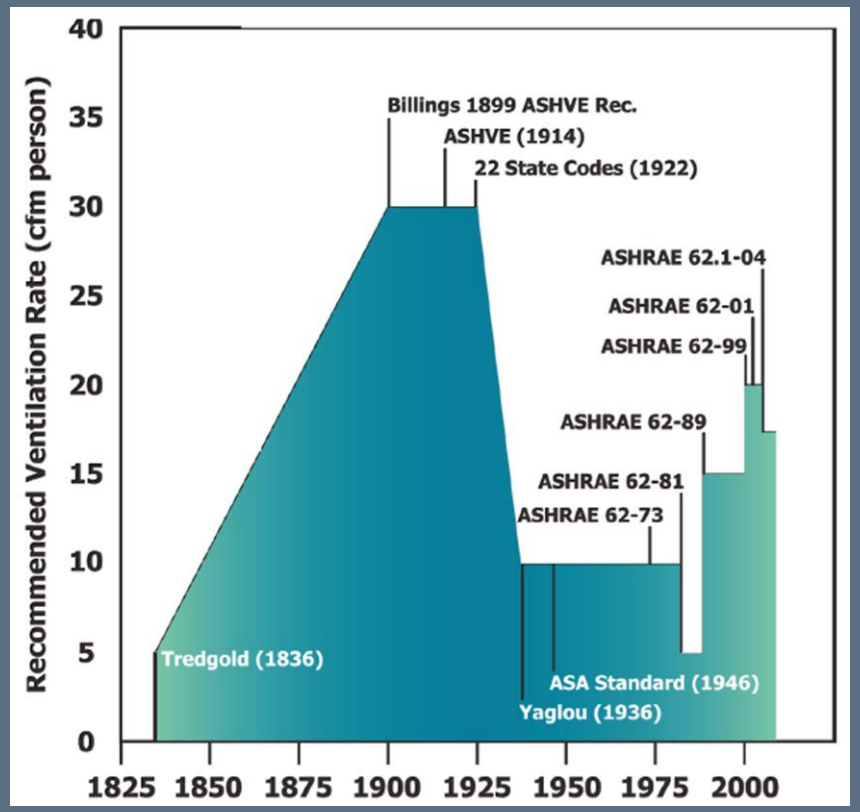


TABLE 6.2.2.1 Minimum Ventilation Rates in Breathing Zone *(Continued)*
(Table 6.2.2.1 shall be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p cfm/person	People Outdoor Air Rate R_p L/s·person	Area Outdoor Air Rate R_a cfm/ft²	Area Outdoor Air Rate R_a L/s·m²	Notes	Default Values: Occupant Density (see Note 4) #/1000 ft² or #/100 m²	Default Values: Combined Outdoor Air Rate (see Note 5) cfm/person	Default Values: Combined Outdoor Air Rate (see Note 5) L/s·person	Air Class
Residential									
Dwelling unit	5	2.5	0.06	0.3	F,G, H	F			1
Common corridors	—	—	0.06	0.3	H				1
Retail									
Sales (except as below)	7.5	3.8	0.12	0.6		15	16	7.8	2
Mall common areas	7.5	3.8	0.06	0.3	H	40	9	4.6	1
Barbershop	7.5	3.8	0.06	0.3	H	25	10	5.0	2
Beauty and nail salons	20	10	0.12	0.6		25	25	12.4	2
Pet shops (animal areas)	7.5	3.8	0.18	0.9		10	26	12.8	2
Supermarket	7.5	3.8	0.06	0.3	H	8	15	7.6	1
Coin-operated laundries	7.5	3.8	0.12	0.6		20	14	7.0	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3	H	65	8	4.3	1
Office Buildings									
Breakrooms	5	2.5	0.12	0.6		50	7	3.5	1
Main entry lobbies	5	2.5	0.06	0.3	H	10	11	5.5	1
Occupiable storage rooms for dry materials	5	2.5	0.06	0.3		2	35	17.5	1
Office space	5	2.5	0.06	0.3	H	5	17	8.5	1
Reception areas	5	2.5	0.06	0.3	H	30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3	H	60	6	3.0	1
Multiuse assembly	7.5	3.8	0.06	0.3	H	100	8	4.1	1

ASHRAE 62.1-2016

Four Classes of Air

	Class 1	Class 2	Class 3	Class 4
Environment	Office/Apartment	Laundry room/Nail salon	Kitchen/Bathroom exhaust	Lab Fume Hood
% Recirculation	No limit	Less than 10%	Less than 5%	0%

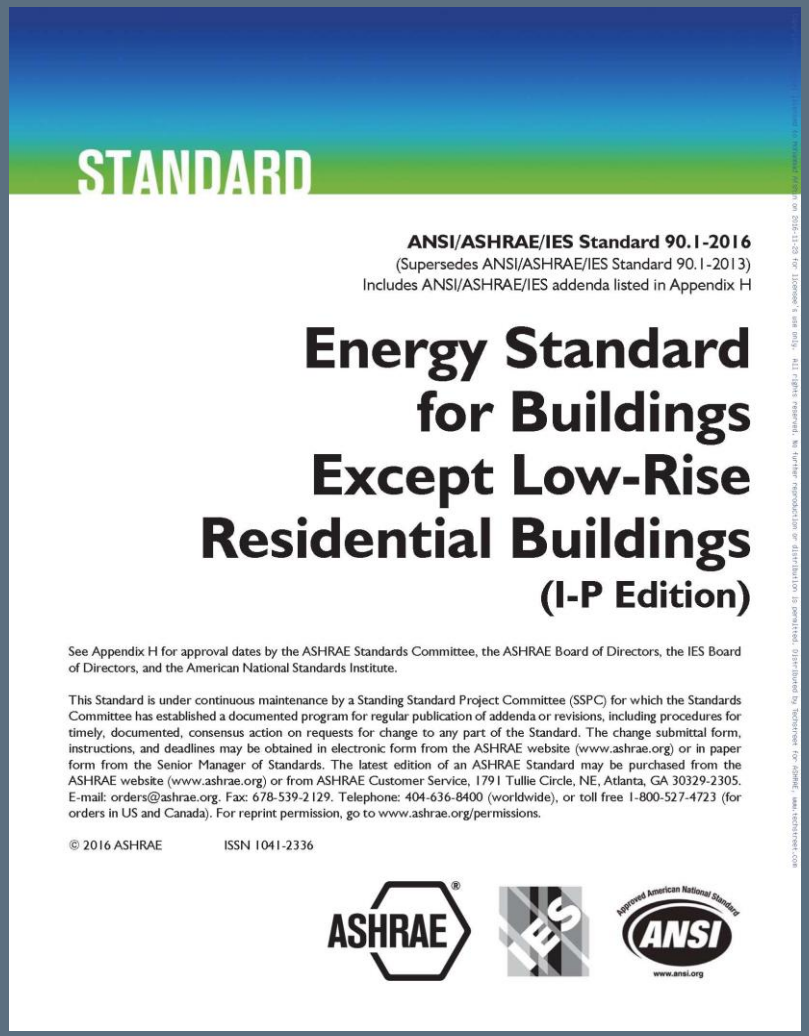
TABLE 5.16.1 Airstreams or Sources

Description	Air Class
Diazo printing equipment discharge	4
Commercial kitchen grease hoods	4
Commercial kitchen hoods other than grease	3
Laboratory hoods	4 [a]
Residential kitchen hoods	3
Hydraulic elevator machine room	2

a. Air Class 4 unless determined otherwise by the Environmental Health and Safety professional responsible to the owner or to the owner's designee

ASHRAE 90.1

Standard that provides minimum requirements for energy efficiency in buildings

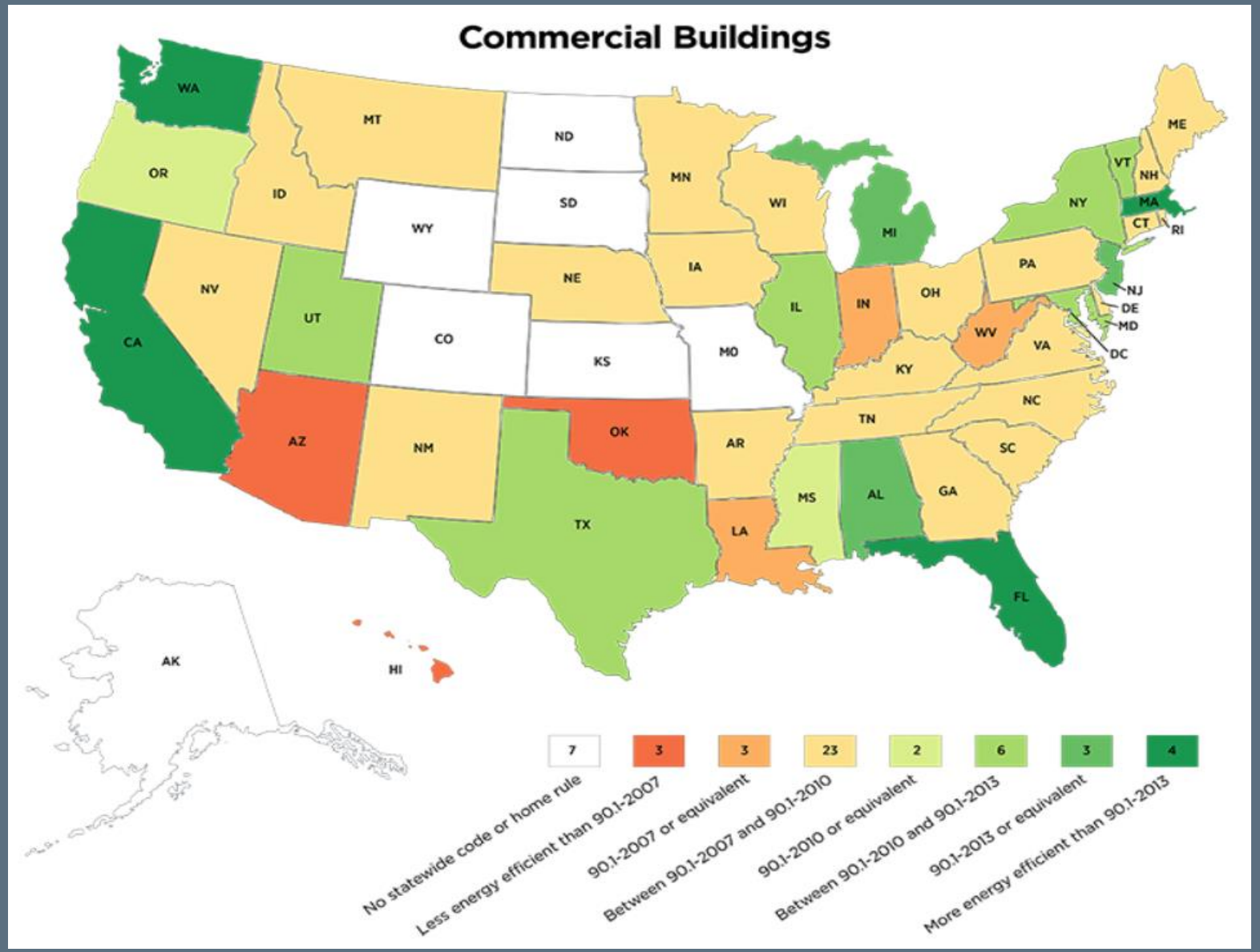


6.5.6.1 Exhaust Air Energy Recovery.

Energy recovery systems required (by table 6.5.6.1) shall have at least **50% enthalpy recovery ratio.**

(This) shall mean **a change in the enthalpy of the *outdoor air* supply equal to 50% of the difference between the *outdoor air* and return air enthalpies** at design conditions.

US States Adoption of ASHRAE 90.1 Codes



<u>90.1 2010</u>

50% *Total* Energy Recovery Effectiveness

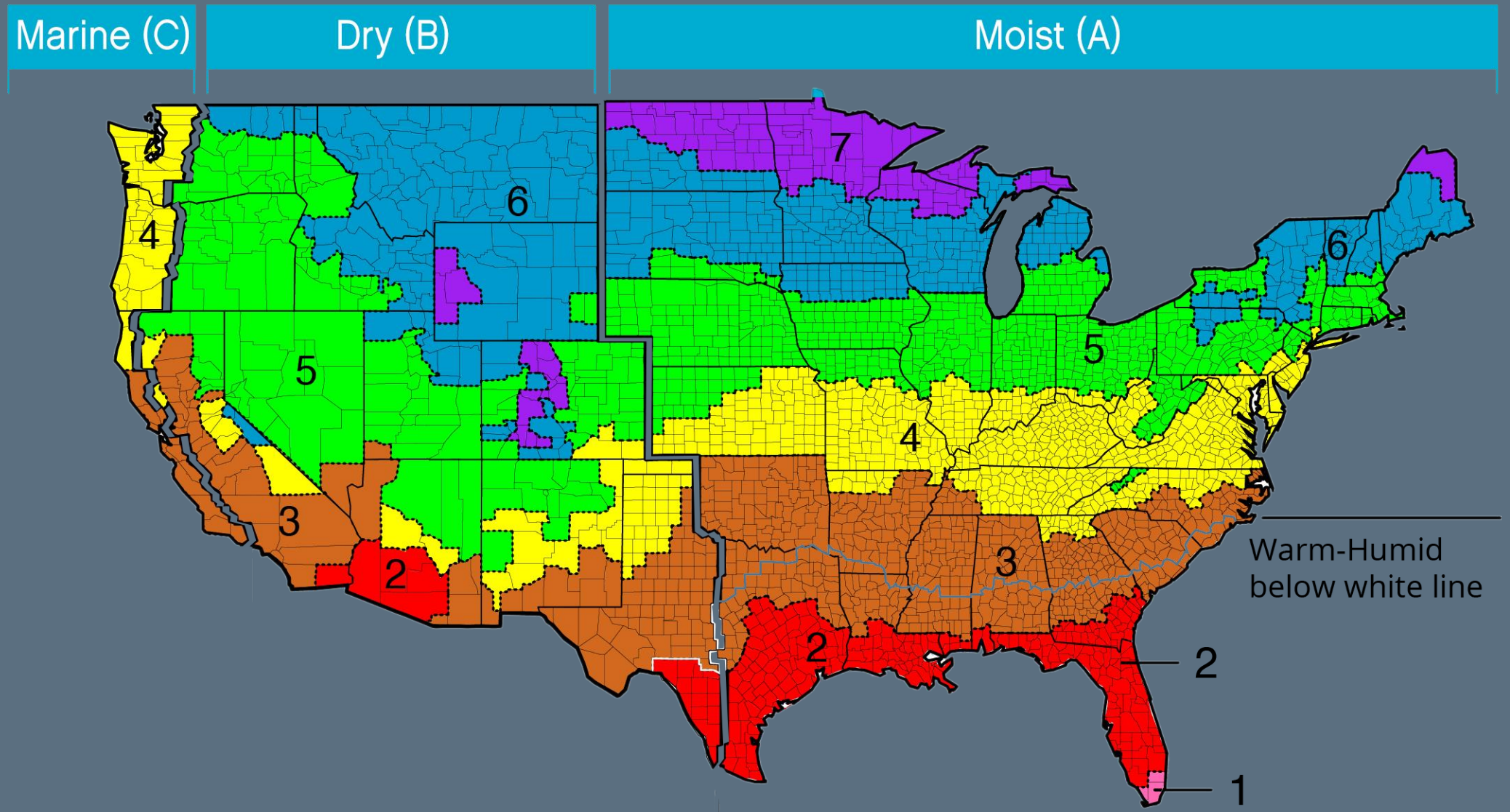
White= No code

Orange= 2007

Yellow= Transition to 2010

Green= Transition to 2013

ASHRAE Climate Zone Map



ASHRAE 90.1-2010

TABLE 6.5.6.1 Energy Recovery Requirement

Zone	% *Outdoor Air* at Full Design Airflow Rate					DOAS
	≥30% and < 40%	≥40% and < 50%	≥50% and < 60%	≥60% and < 70%	≥70% and < 80%	≥80%
	Design Supply Fan Airflow Rate (cfm)					
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	≥5000	≥5000
1B, 2B,5C	NR	NR	≥26000	≥12000	≥5000	≥4000
6B	≥11000	≥5500	≥4500	≥3500	≥2500	≥1500
1A, 2A, 3A, 4A, 5A, 6A	≥5500	≥4500	≥3500	≥2000	≥1000	>0
7,8	≥2500	≥1000	>0	>0	>0	>0

NR—Not required

ASHRAE 90.1-2013, Table 6.5.6.1

Table 6.5.6.1-1 Energy Recovery Requirement (systems operating less than 8,000 hours/year) – non continuous operation								
Climate Zone	% Outdoor Air at Full Design Airflow Rate							
	≥10% and >20%	≥20% and >30%	≥30% and >40%	≥40% and >50%	≥50% and >60%	≥60% and >70%	≥70% and >80%	≥80%
	Design Supply Fan Airflow Rate (cfm)							
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	NR	NR	NR	NR
1B, 2B, 5C	NR	NR	NR	NR	≥26,000	≥12,000	≥5,000	≥4,000
6B	≥28,000	≥26,500	≥11,000	≥5,500	≥4,500	≥3,500	≥2,500	≥1,500
1A, 2A, 3A, 4A, 5A, 6A	≥26,000	≥16,000	≥5,500	≥4,500	≥3,500	≥2,000	≥1,000	≥0

1. Min. OA requirement now 10%
2. Split into 2 tables for continuous & non-continuous operation

ASHRAE 90.1-2013, Table 6.5.6.1-2

Table 6.5.6.1-2 Energy Recovery Requirement (systems operating equal to or greater than 8,000 hours/year) continuous operation.								
Climate Zone	% Outdoor Air at Full Design Airflow Rate							
	≥10% and >20%	≥20% and >30%	≥30% and >40%	≥40% and >50%	≥50% and >60%	≥60% and >70%	≥70% and >80%	≥80%
	Design Supply Fan Airflow Rate (cfm)							
3C	NR	NR	NR	NR	NR	NR	NR	NR
1B, 2B, 3B, 4C, 5C	NR	≥19,500	≥9,000	≥5,000	≥4,000	≥3,000	≥1,500	≥0
1A, 2A, 3A, 4B, 5B	≥2,500	≥2,000	≥1,000	≥500	≥0	≥0	≥0	≥0
4A, 5A, 6A, 6B, 7, 8	≥0	≥0	≥0	≥0	≥0	≥0	≥0	≥0

ASHRAE 90.1-2016 – Exceptions

Exceptions to 6.5.6.1

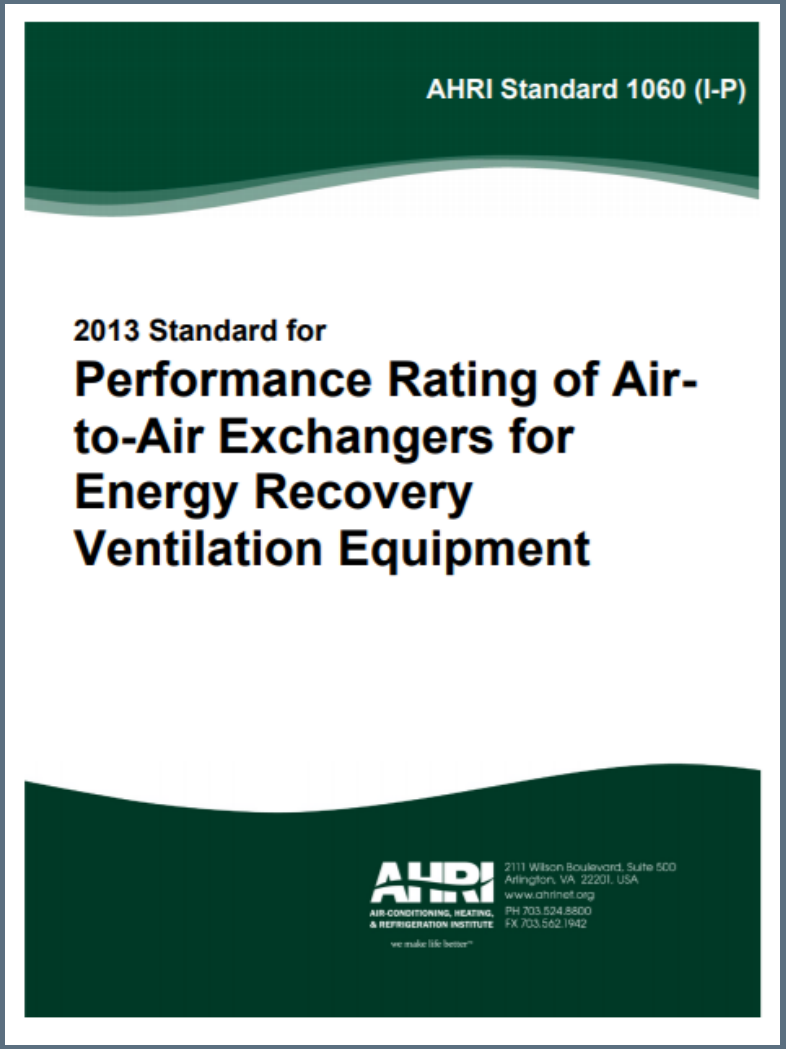
1. Laboratory *systems* meeting Section 6.5.7.3.
2. *Systems* serving *spaces* that are not cooled and that are heated to less than 60°F.
3. Where more than 60% of the *outdoor air* heating *energy* is provided from *site-recovered energy* or *site-solar energy*.
4. Heating *energy* recovery in Climate Zones 0, 1, and 2.
5. Cooling *energy* recovery in Climate Zones 3C, 4C, 5B, 5C, 6B, 7, and 8.
6. Where the sum of the airflow rates exhausted and relieved within 20 ft of each other is less than 75% of the design outdoor airflow rate, excluding exhaust air that is
   a. used for another *energy* recovery *system*,
   b. not allowed by ASHRAE Standard 170 for use in *energy* recovery *systems* with leakage potential, or
   c. of Class 4 as defined in ASHRAE Standard 62.1.
7. *Systems* requiring dehumidification that employ *energy* recovery in series with the cooling coil.
8. *Systems* expected to operate less than 20 hours per week at the *outdoor air* percentage covered by Table 6.5.6.1-1.

Free cooling and economizing must be used when applicable

Energy Recovery Options

AHRI 1060

Standard for Performance Rating of Air-to-Air Exchangers



SCOPE OF THE CERTIFICATION PROGRAM

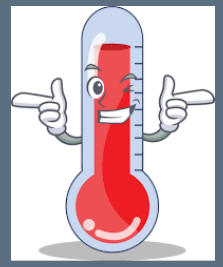
The certification program includes Air-to-Air Heat Exchangers for use in Air-to-Air Energy Recovery Ventilation Equipment, rated at or above 50 scfm but below or equal to 5,000 scfm at AHRI Standard Rating Conditions.

In addition, Air-to-Air Heat Exchangers for use in Air-to-Air Energy Recovery Ventilation Equipment rated above 5,000 scfm are included if the participant's basic model group(s) for those models include at least one model rated at or above 50 scfm but below or equal to 5,000 scfm.

AHRI 1060 – Key Performance Metrics

Performance:

- $Sensible\ Effectiveness$
- $Latent\ Effectiveness$
- $Total\ Effectiveness$
- $Pressure\ Drop$

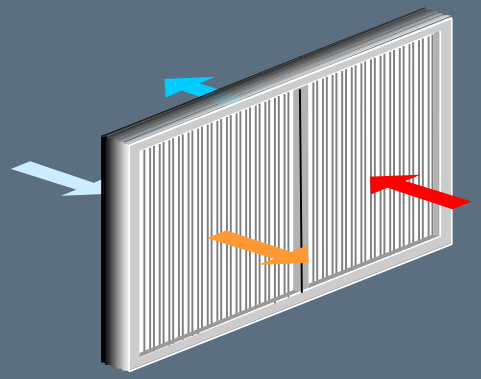


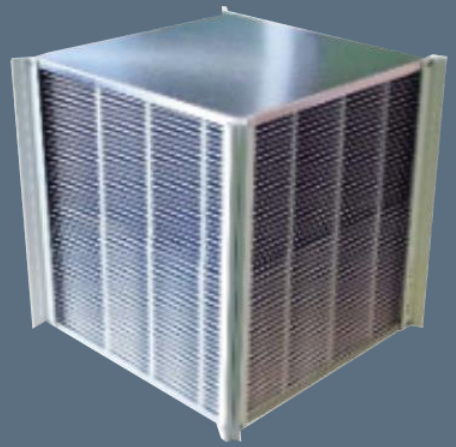
Leakage:

- $Exhaust\ Air\ Transfer\ Ratio\ (EATR) - Cross\ Contamination$
- $Outdoor\ Air\ Correction\ Factor\ (OACF) - Cross\ Leakage$

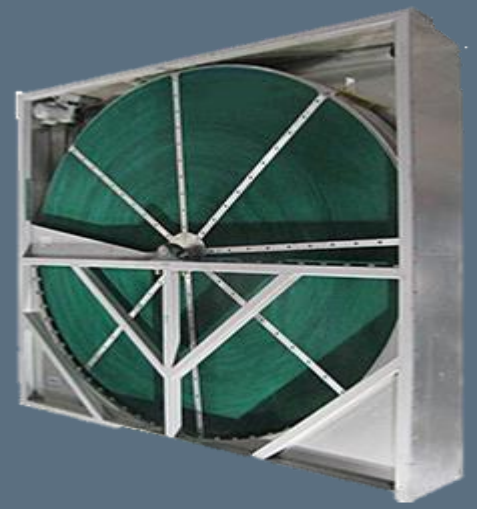
Energy Recovery Technologies

Sensible Devices



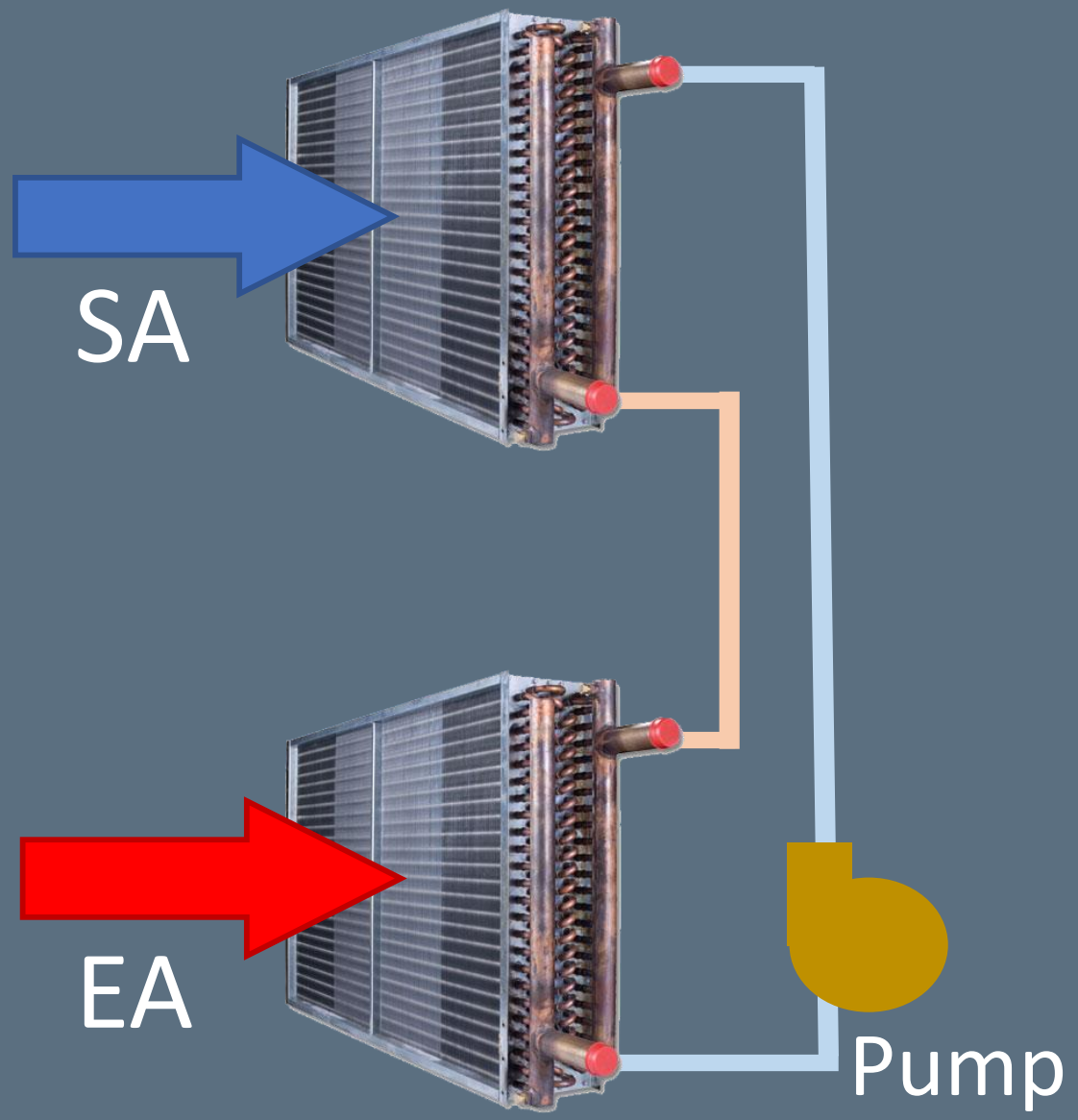


Enthalpy Devices



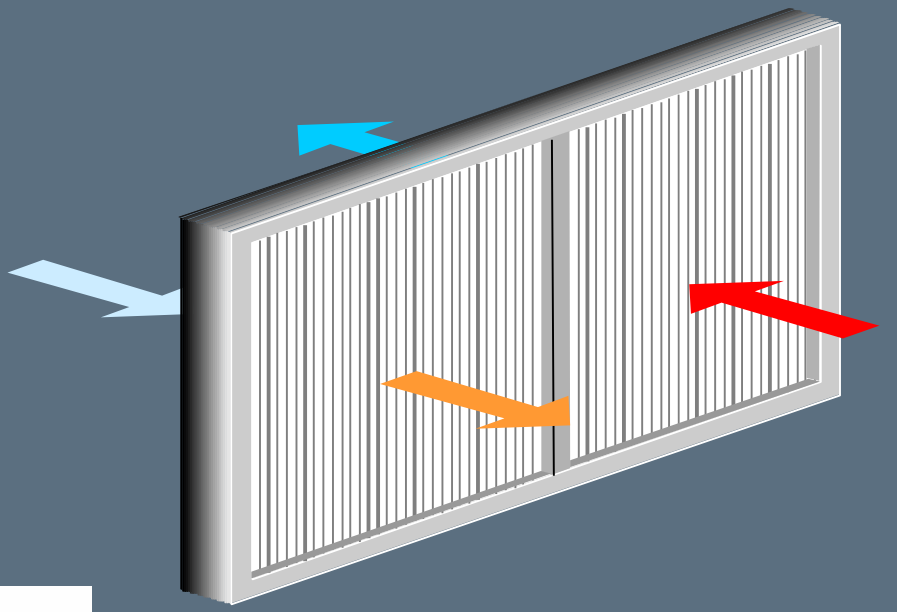
Run-Around Loops

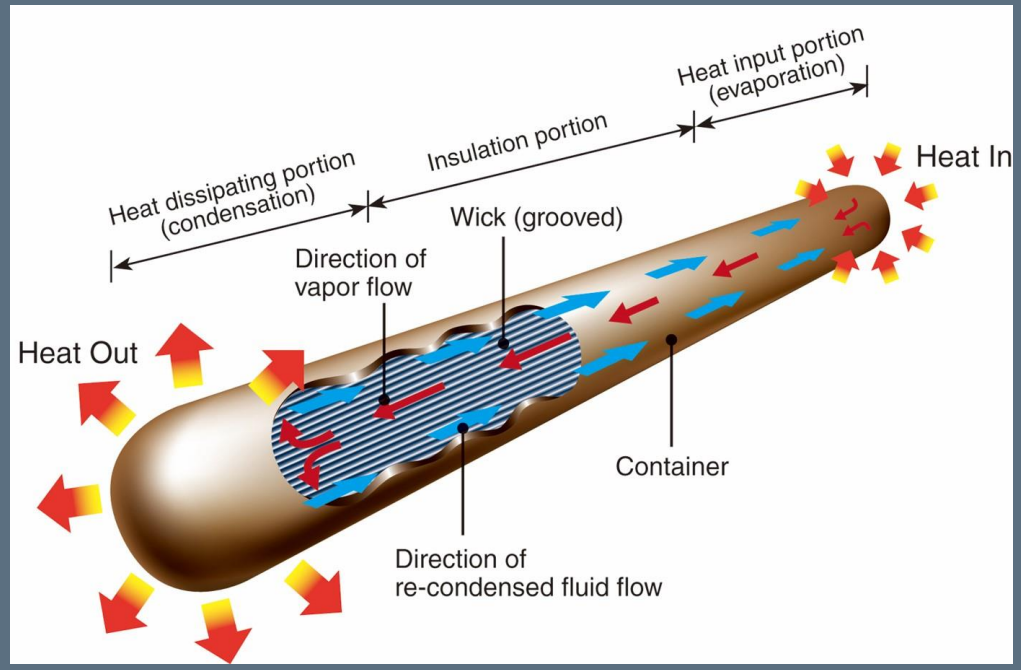
- Minimum of 2 coils (1 per airstream)
- Supply and Exhaust air streams may be completely separate: Can be used in class 4 air applications
- Retrofit applications
- Sensible only recovery
- 30%-40% Effectiveness
- Does not meet 90.1 in most climates



Heat Pipes

- Coils need to be adjacent or close
- Sensible only recovery
- 30%-40% Effectiveness
- Does not meet 90.1 in most climates



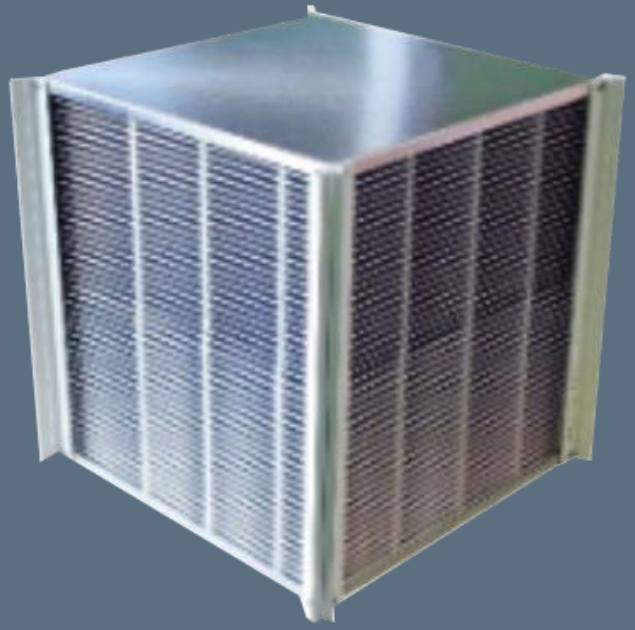


Fixed Plate Exchangers

- Transfers Heat and/or Humidity between two airstreams
- Air tunnels must be adjacent
- No moving part between the two airstreams
- Cross-over of 0-5%.
- OACF of 1.0 to 1.1
- Passive Energy Recovery Device: No moving part
- 40%-70% Effectiveness

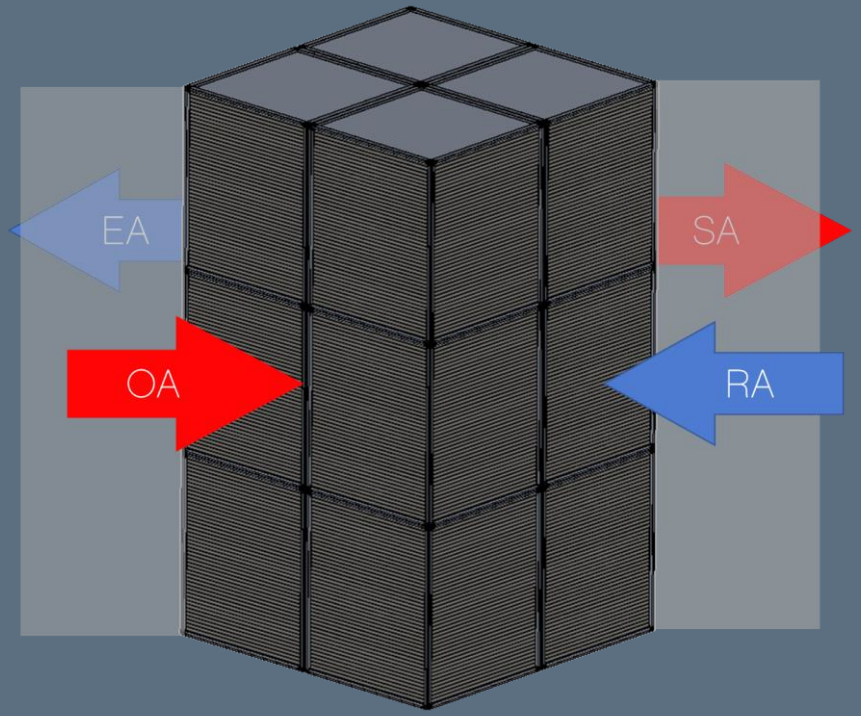
Enthalpy Exchanger

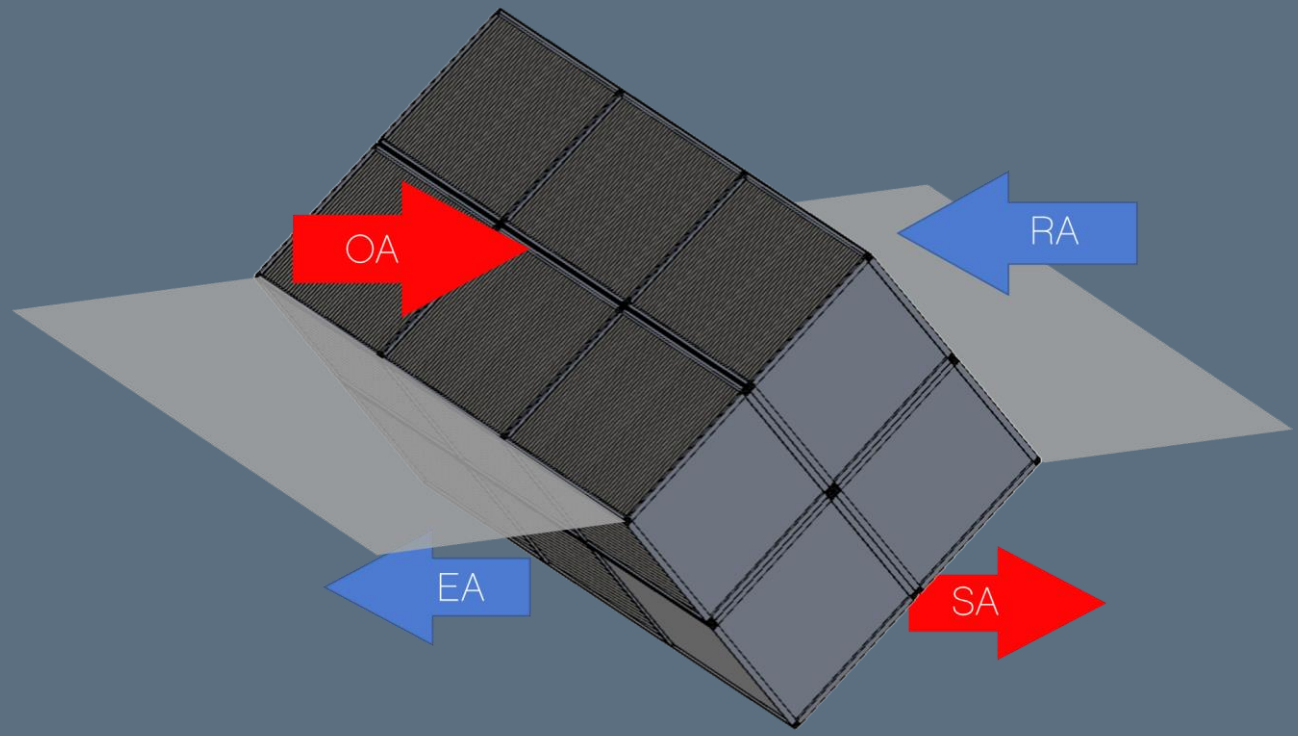
Sensible Exchanger



Fixed Plate Exchangers

Flow Configurations

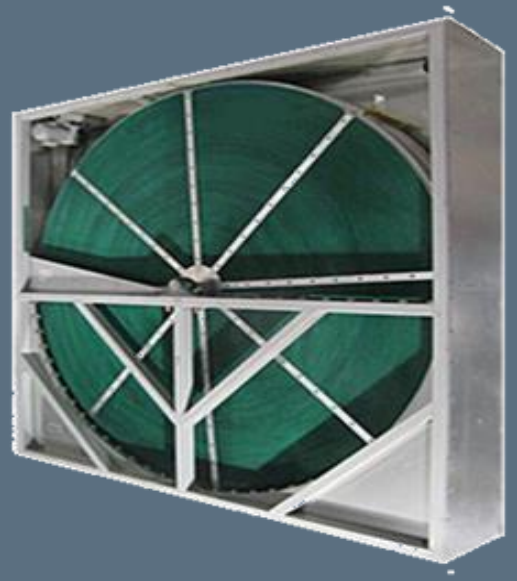




Rotary Energy Recovery Devices

- Heat and/or humidity transfer
- Adjacent air tunnels
- Cross-over of 1-10%
- OACF of 0.95 to 1.5
- Fixed aspect ratio (circle)
- Compact size at high flow rates:

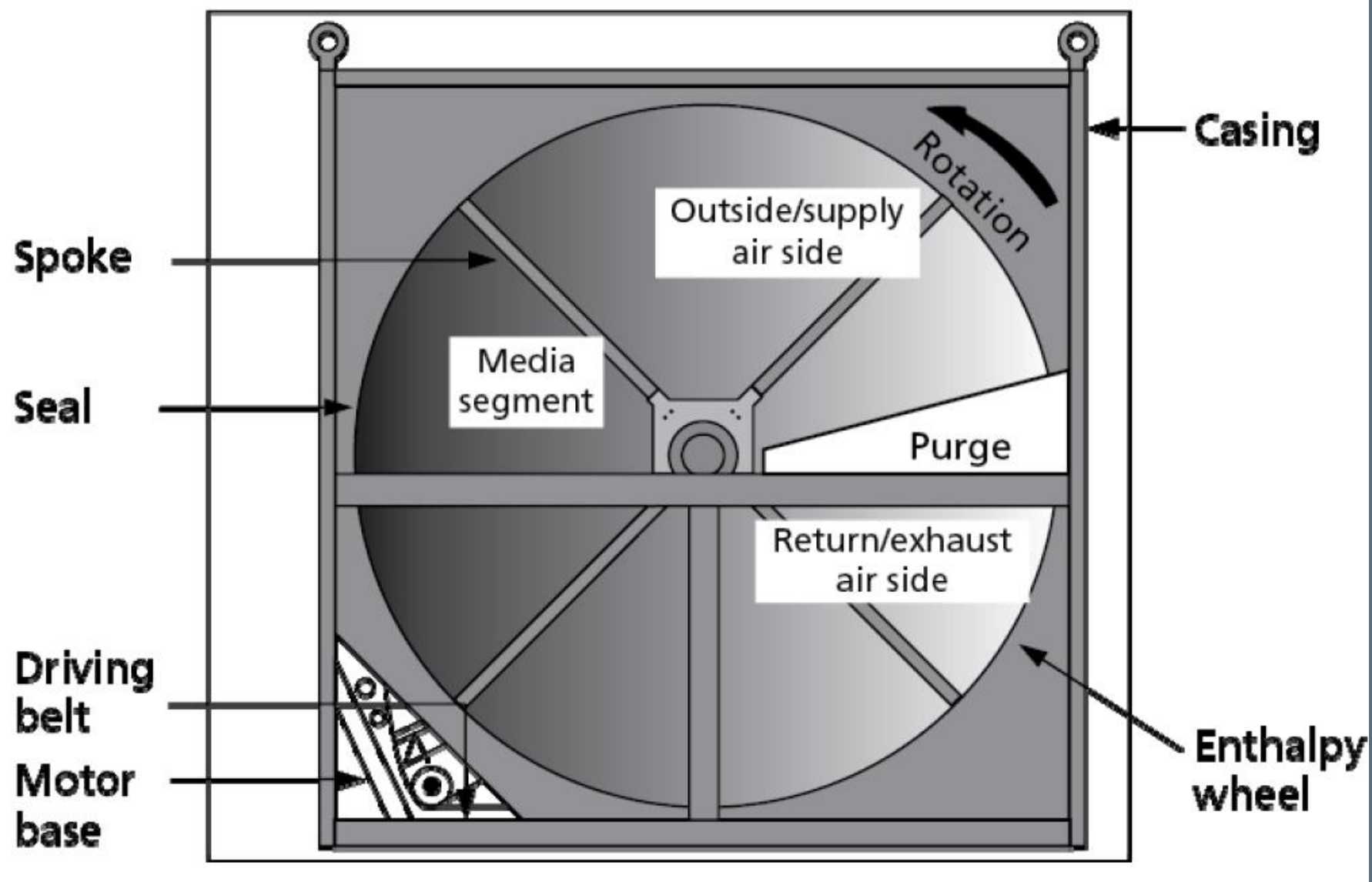
  Wheel thickness: 4”-12”
- Active energy recovery device
- 45%-80% Effectiveness



Enthalpy Wheel

Sensible Wheel

Rotary Energy Recovery Devices - Anatomy

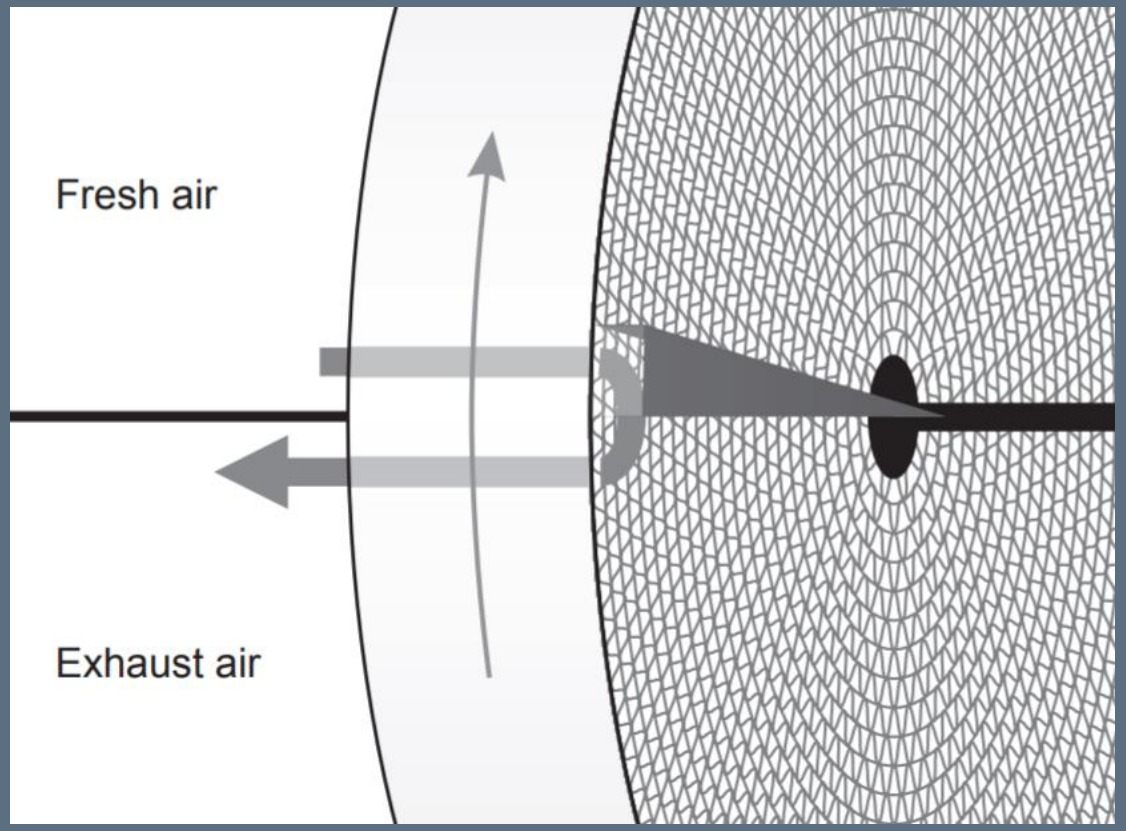


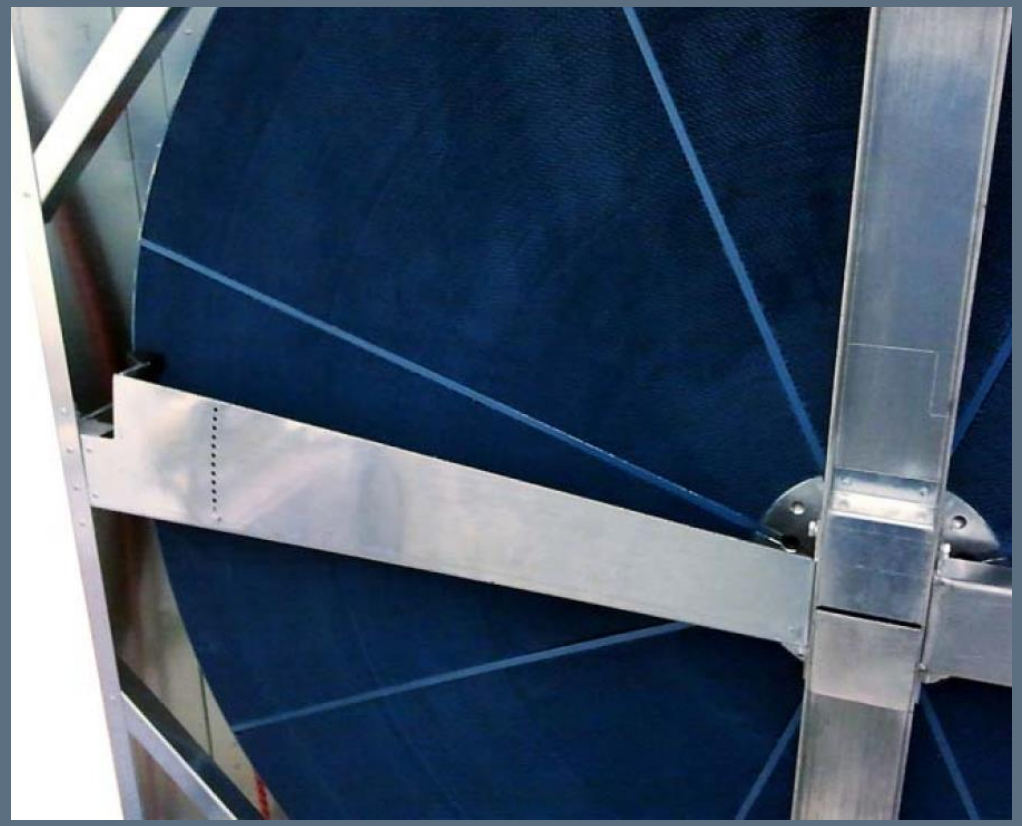
Rotary Energy Recovery Devices - Leakage

- Heat and mass transfer media moves between airstreams
- Air leakage mechanisms:
  - Air trapped in the media channels goes to the other airstream
  - Air leaks though the seal
- Draw through exhaust/blow through supply fan arrangement may be used to reduce leakage, but watch for OACF

Rotary Energy Recovery Devices – Leakage

Purge Section





Purge Section Reduces the Carry Over
Purge Section Significantly increases the OACF

Summary

Technology / Metric	Enthalpy Wheels	Enthalpy Plate	Heat Pipe	Run Around Loop
Performance (TRE)	45%-80%	45%-70%	30%-40%	30%-40%
EATR	1%-10%	0%-5%	0%-1%	0% (Separate Channels)
OACF	0.95-1.5	0-1.06	0.99-1.01	1.0
Moving Parts	Motor/Belt/Bearing	None	None	Pump
Application	High Flow Rate Compact Size	Low cross contamination -Low maintenance	Low Cross Contamination	Class 4 Air Retrofit

Maintaining Energy Recovery

Technology / Maintenance	Heat Pipe/Run Around Loop	Enthalpy Wheels	Enthalpy Plates
Cleaning Cycle:	Once every 12 months	Once every 12 months	Once every 2 years
Maintenance:	Clean the coils/Check refrigerant pressure/Check the pump	Check desiccant coating bearings/belts and motor	Clean exchanger media
Method:	Hot water & mild detergents	Vacuum or low-pressure water (depending on manufacturer)	Vacuum or low-pressure water (depending on manufacturer)

Proper filtration is the best way to maintain all energy recovery devices

Climate Considerations

Frost Control

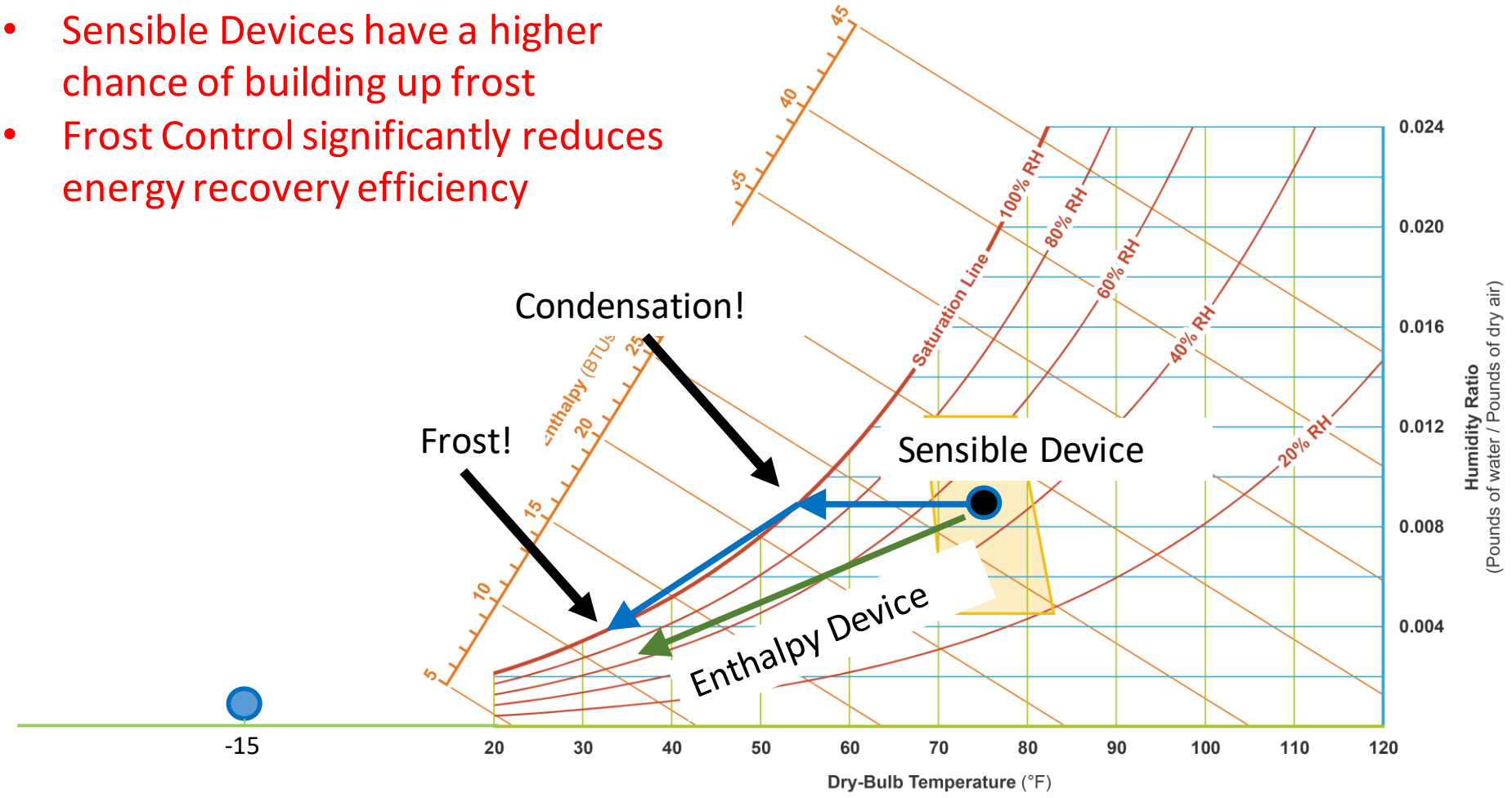
- All ERV devices may need frost control in extreme winter conditions

- Frost threshold depends on:
  - Type of the device
  - Indoor humidity
  - Device sensible and latent performance

- 5 frost control strategies:
  - Face and Bypass (Plate Exchangers and Heat Pipes)
  - Electric pre-heat (All)
  - Exhaust-only (Plate Exchangers)
  - Exhaust Re-circulation (Plate Exchangers)
  - Speed Control (Rotary Devices)

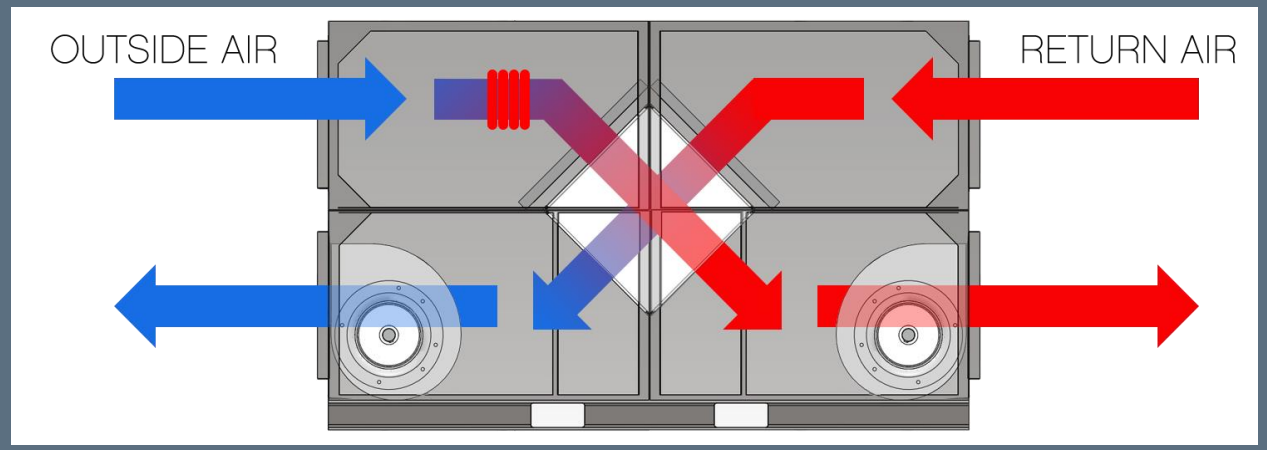
Energy Recovery in Cold Climates

- Sensible Devices have a higher chance of building up frost
- Frost Control significantly reduces energy recovery efficiency

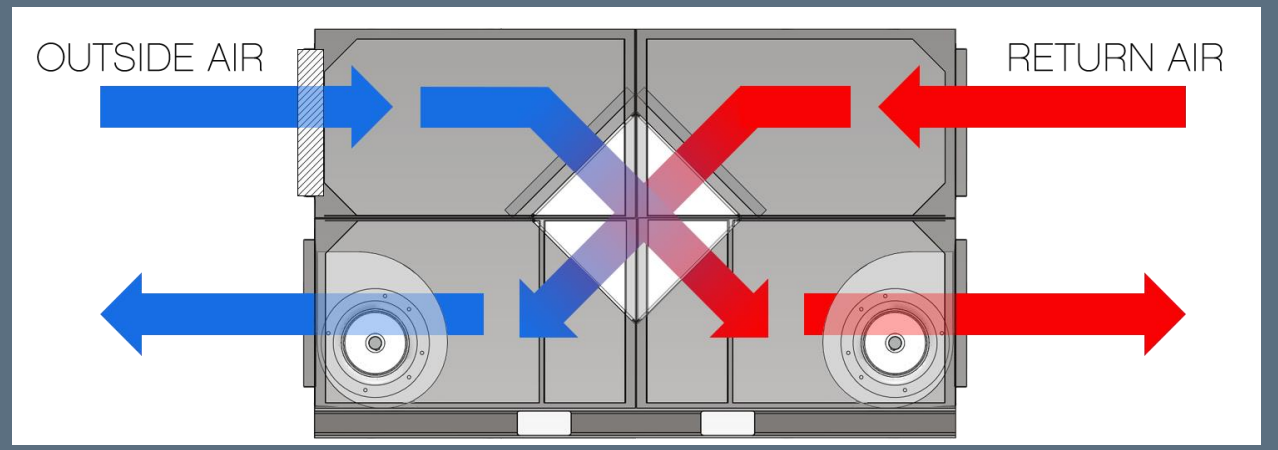


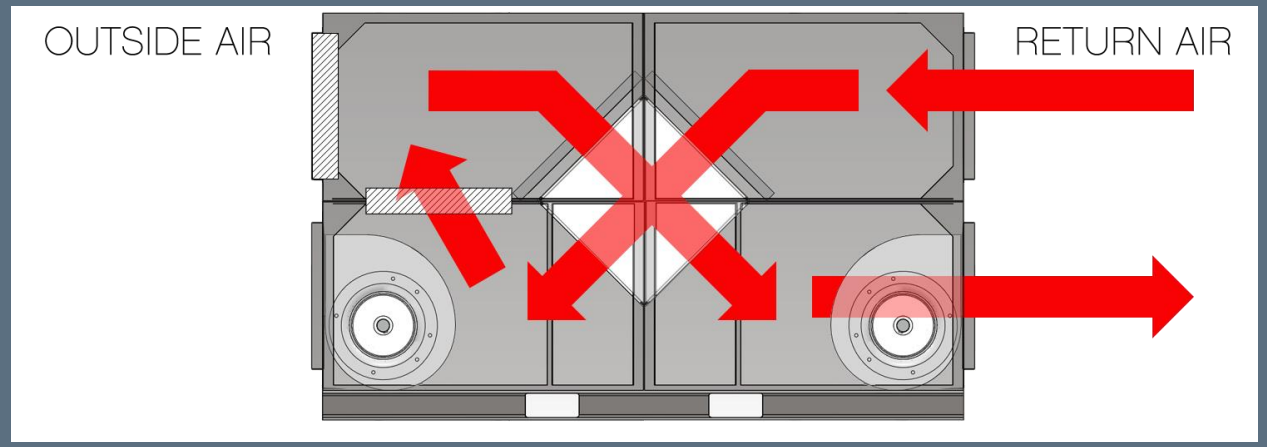
Frost Control – Fixed Plate Exchangers

Pre-Heat Coil

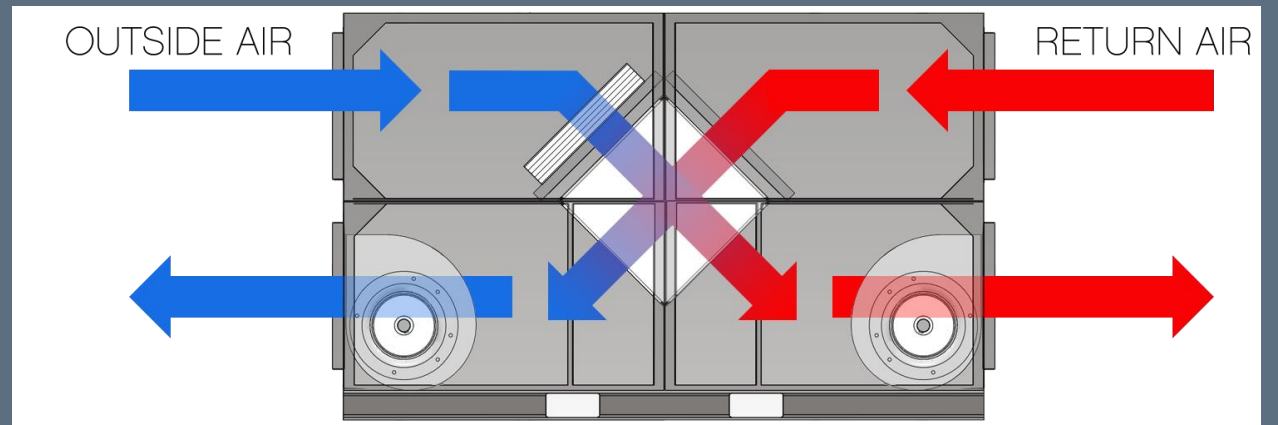


Exhaust-Only



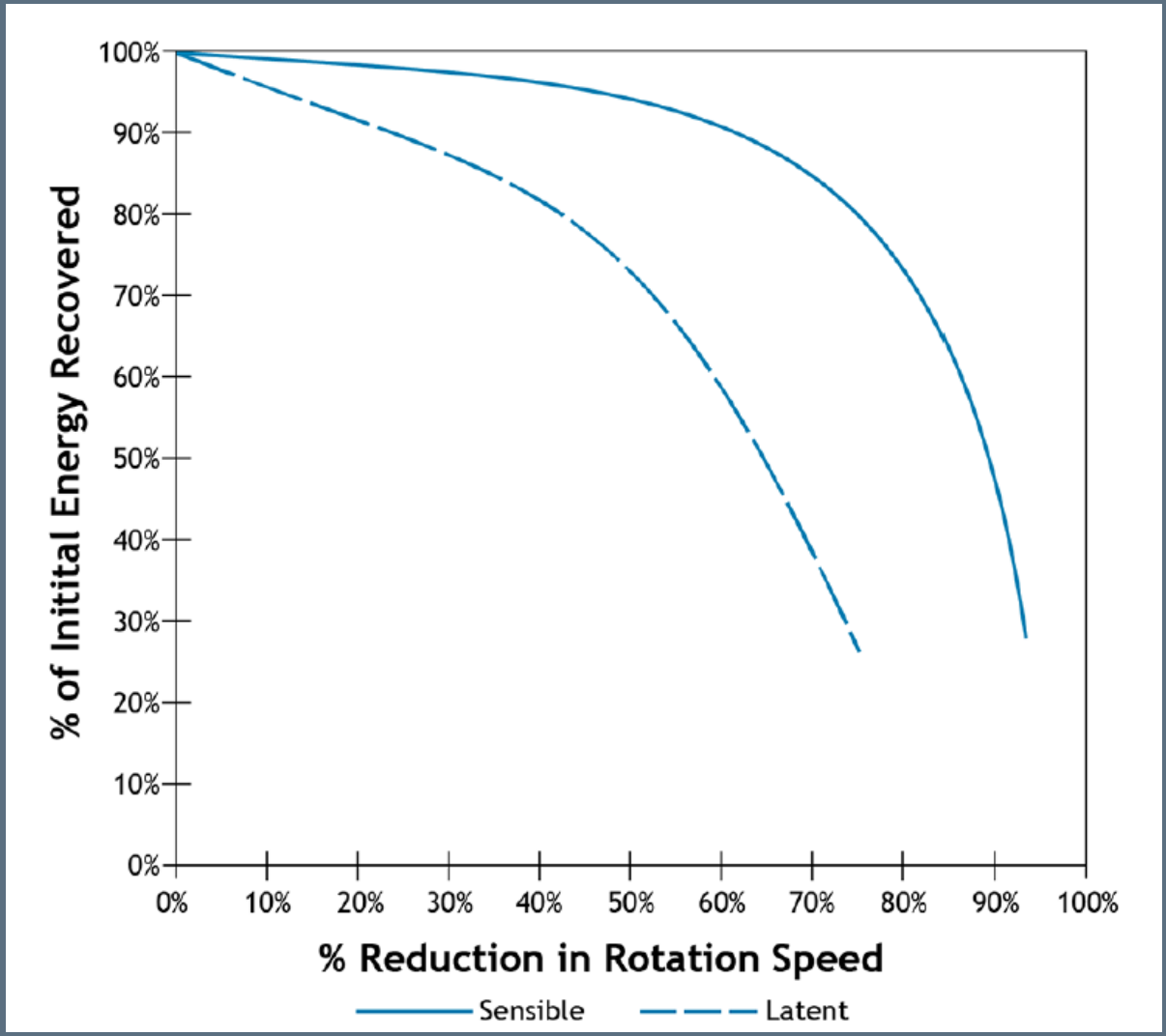


Recirculation Damper



Face and Bypass Damper

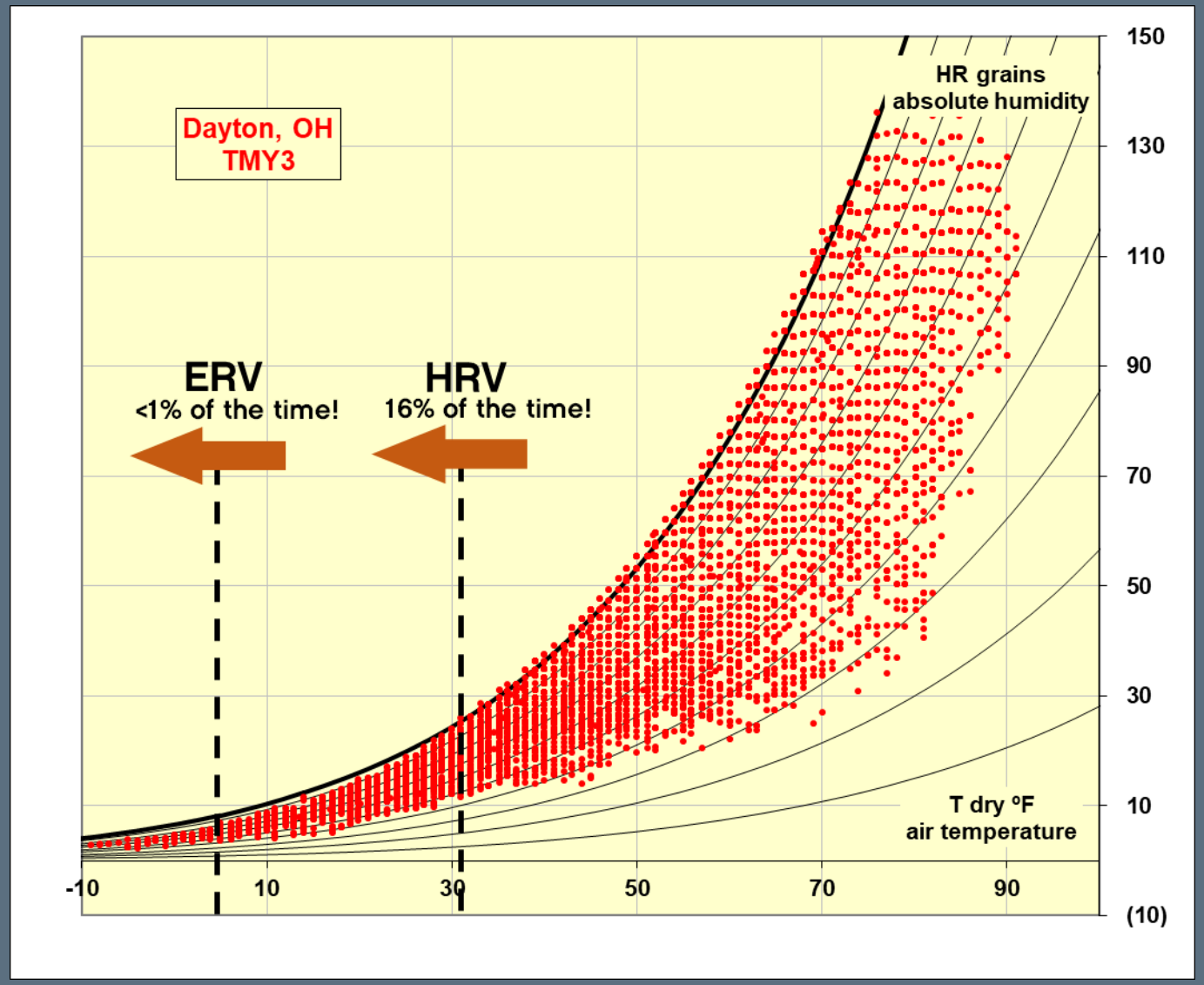
Frost Control – Rotary Devices



Frost Threshold Comparison

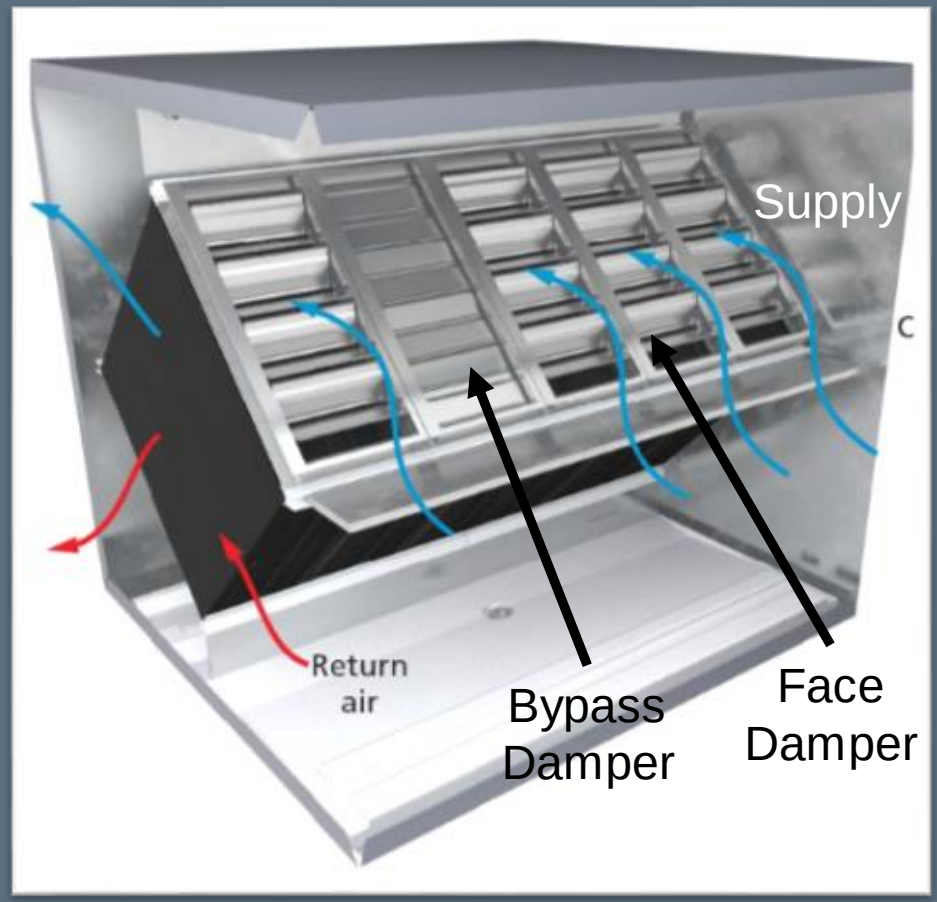
Technology:	Enthalpy Wheels	Heat Pipes	Enthalpy Plates	Sensible Plates
Typical Frost Threshold:	-15 F	15	0 to 15	35 F
Frost Control:	Reduce wheel speed	Face and Bypass/Exhaust-only/Recirculation/Pre-heat		

Dayton Climate



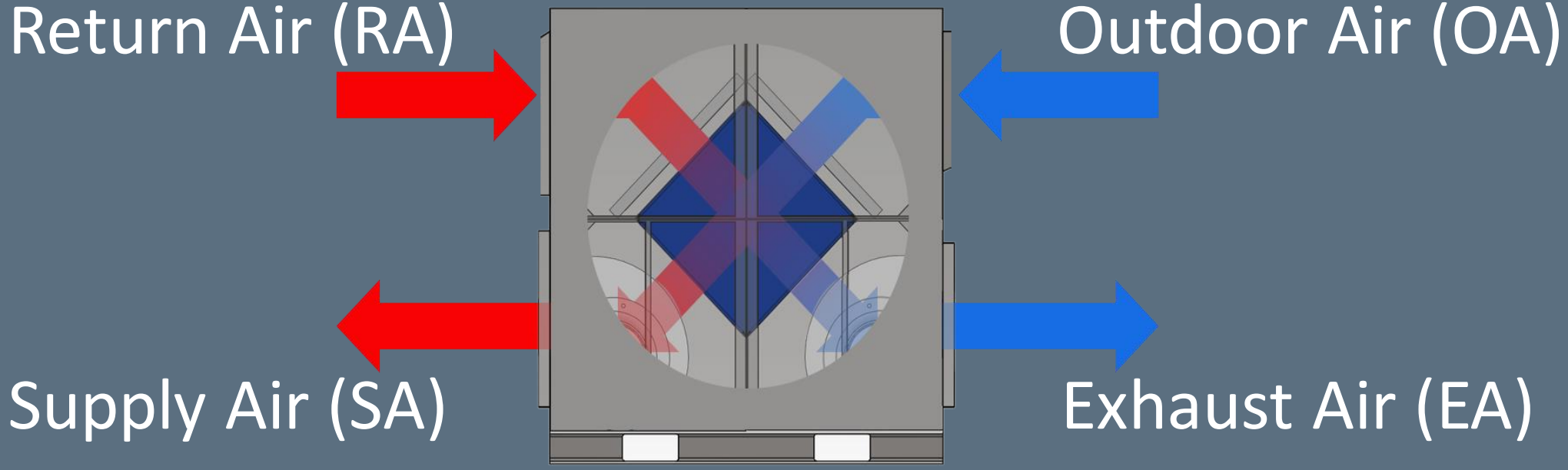
Free Cooling & Economizing

- ERV devices must allow for free cooling in shoulder seasons (OA= 55-65 F)
- Bypassing the ERV device is the most common strategy
- Face and bypass dampers modulate air passing through ERV
- An enthalpy setpoint on the supply air may be used to modulate face and bypass dampers



Thank You!

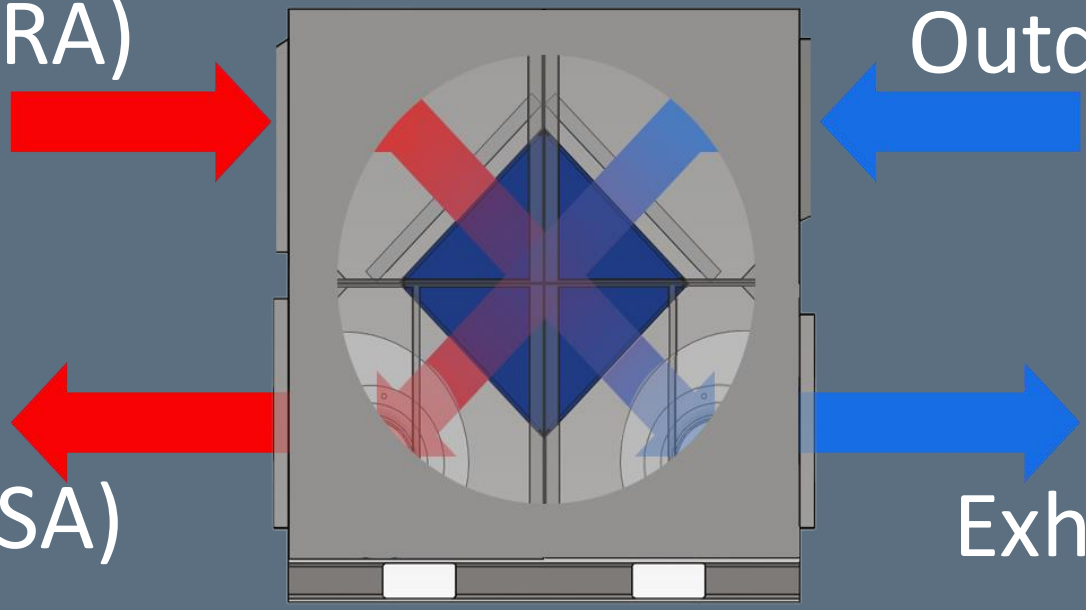
Sensible Effectiveness



$$\varepsilon_s = \frac{\dot{m}_{SA}}{\dot{m}_{min}} \times \frac{T_{OA} - T_{SA}}{T_{OA} - T_{RA}}$$

Sensible Effectiveness

Return Air (RA)
10,000 CFM
75 F
50% RH



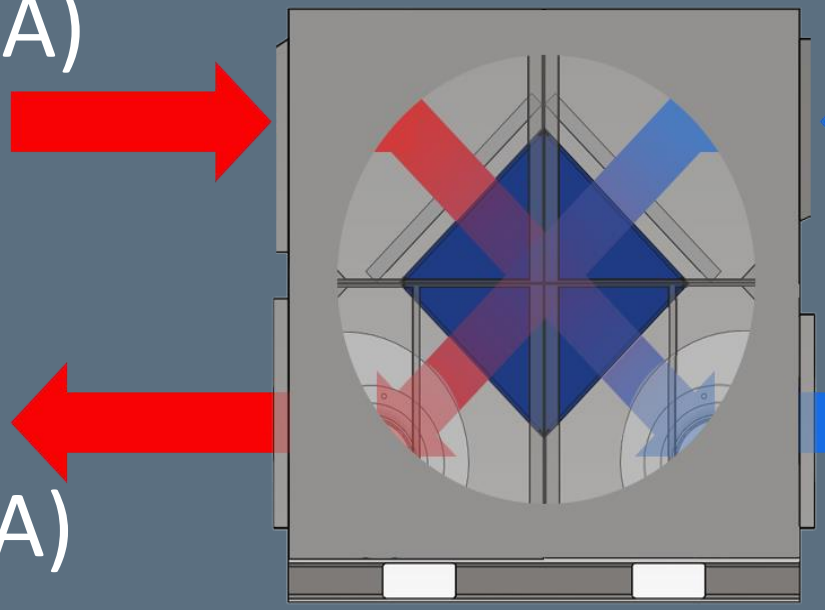
Outdoor Air (OA)
10,000 CFM
0 F
80% RH

Supply Air (SA)
10,000 CFM
55 F
50% RH

Exhaust Air (EA)

$$\varepsilon_s = \frac{\dot{m}_{SA}}{\dot{m}_{min}} \times \frac{T_{SA} - T_{OA}}{T_{RA} - T_{OA}} = 1 \times \frac{55 - 0}{75 - 0} = 73\%$$

Latent Effectiveness

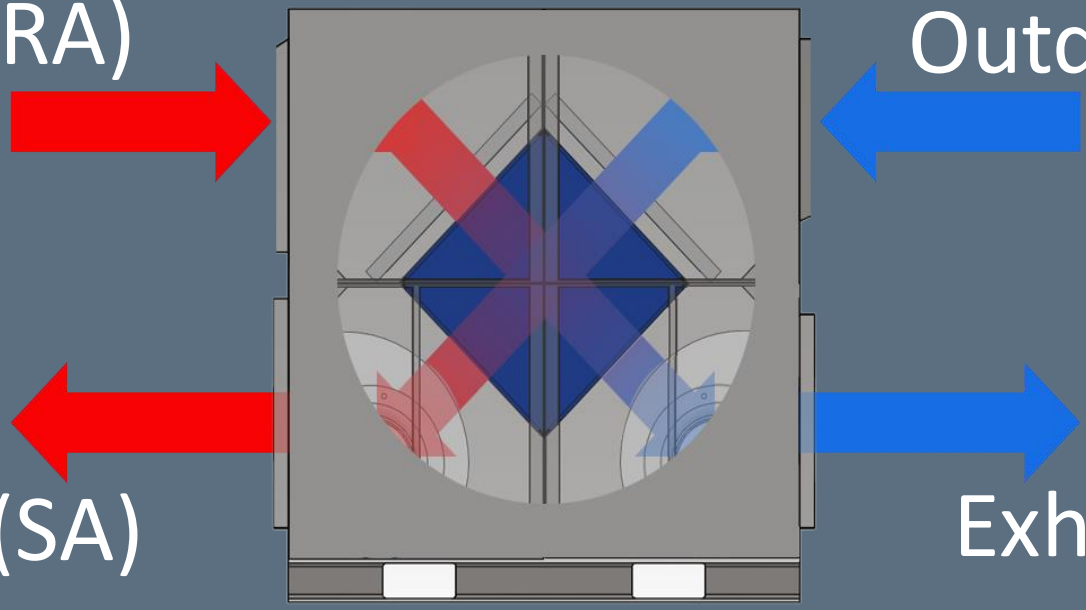


$$\varepsilon_l = \frac{\dot{m}_{SA}}{\dot{m}_{min}} \times \frac{W_{SA} - W_{OA}}{W_{RA} - W_{OA}}$$

Latent Effectiveness

Return Air (RA)
10,000 CFM
75 F
0.0092 lb/lb

Outdoor Air (OA)
10,000 CFM
0 F
0.00063 lb/lb

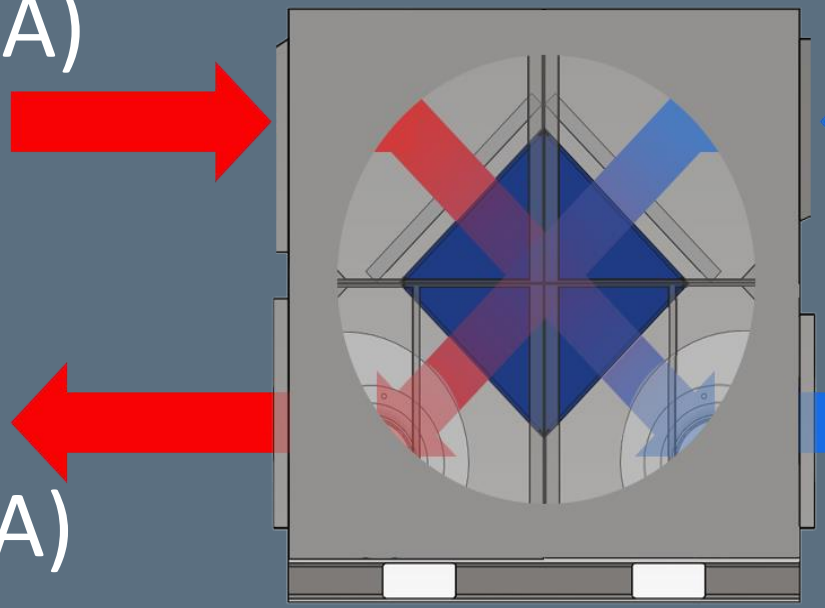


Supply Air (SA)
10,000 CFM
55 F
0.0049 lb/lb

Exhaust Air (EA)

$$\varepsilon_s = \frac{\dot{m}_{SA}}{\dot{m}_{min}} \times \frac{W_{SA} - W_{OA}}{W_{RA} - W_{OA}} = 1 \times \frac{0.0049 - 0.00063}{0.0092 - 0.00063} = 50\%$$

Total Effectiveness

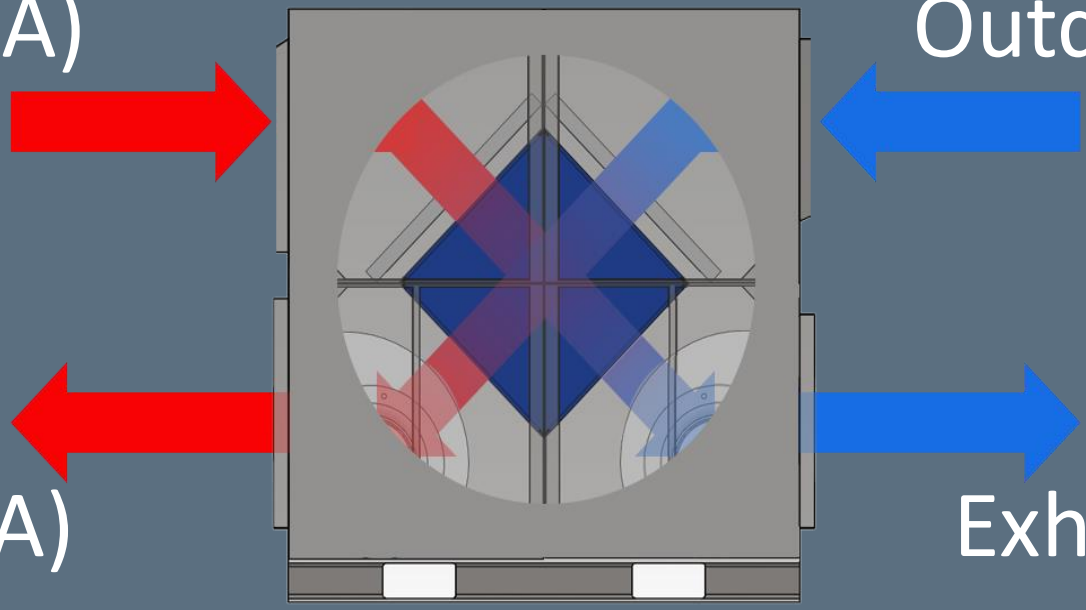


$$\varepsilon_l = \frac{\dot{m}_{SA}}{\dot{m}_{min}} \times \frac{h_{SA} - h_{OA}}{h_{RA} - h_{OA}}$$

Enthalpy Recovery Ratio (90.1)

Return Air (RA)

Outdoor Air (OA)

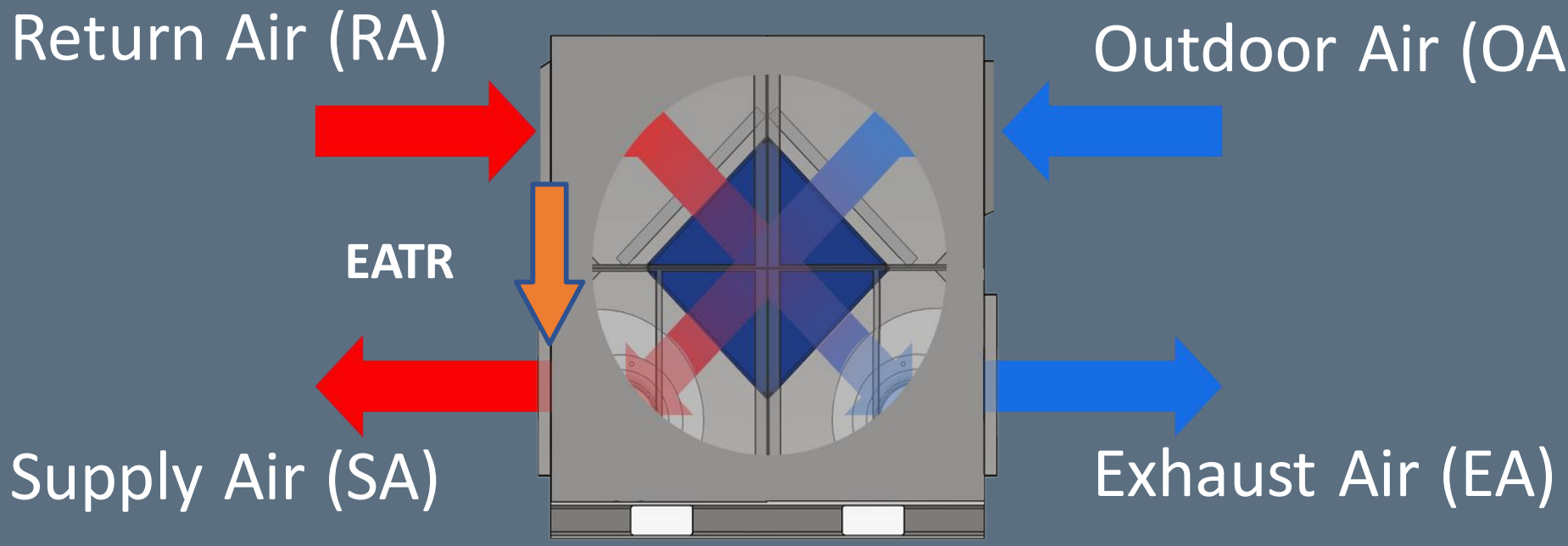


Supply Air (SA)

Exhaust Air (EA)

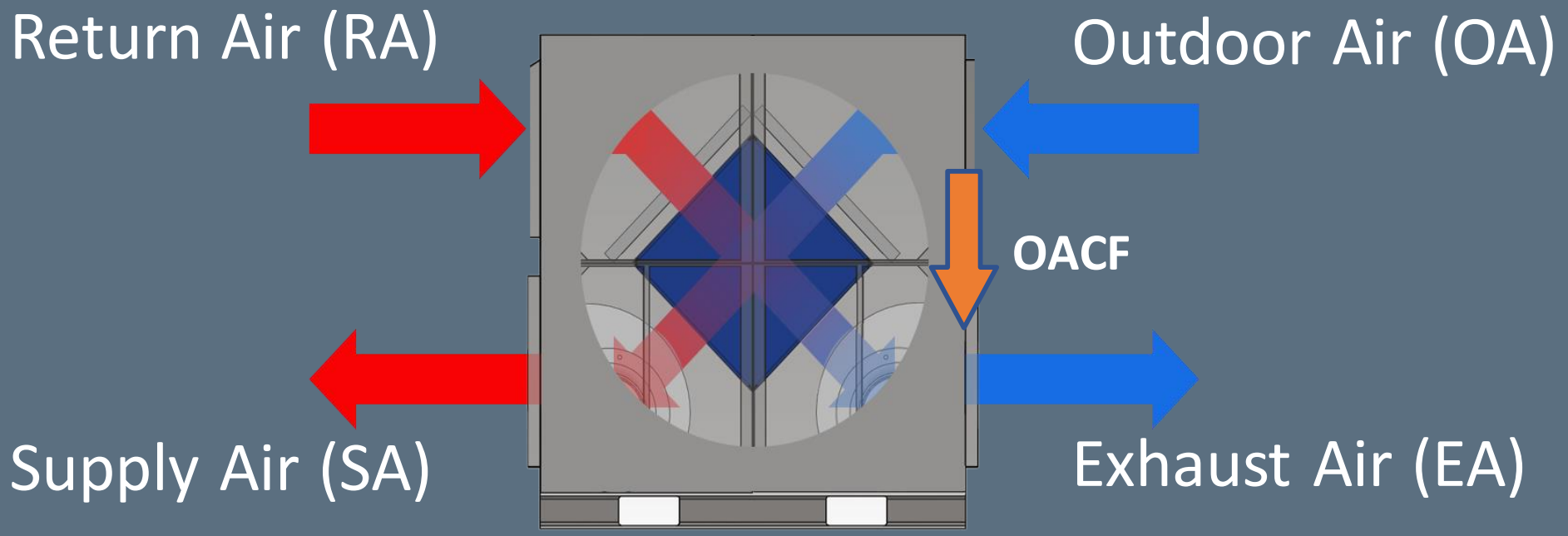
$$\varepsilon = \frac{h_{SA} - h_{OA}}{h_{RA} - h_{OA}}$$

Exhaust Air Transfer Ratio (EATR)



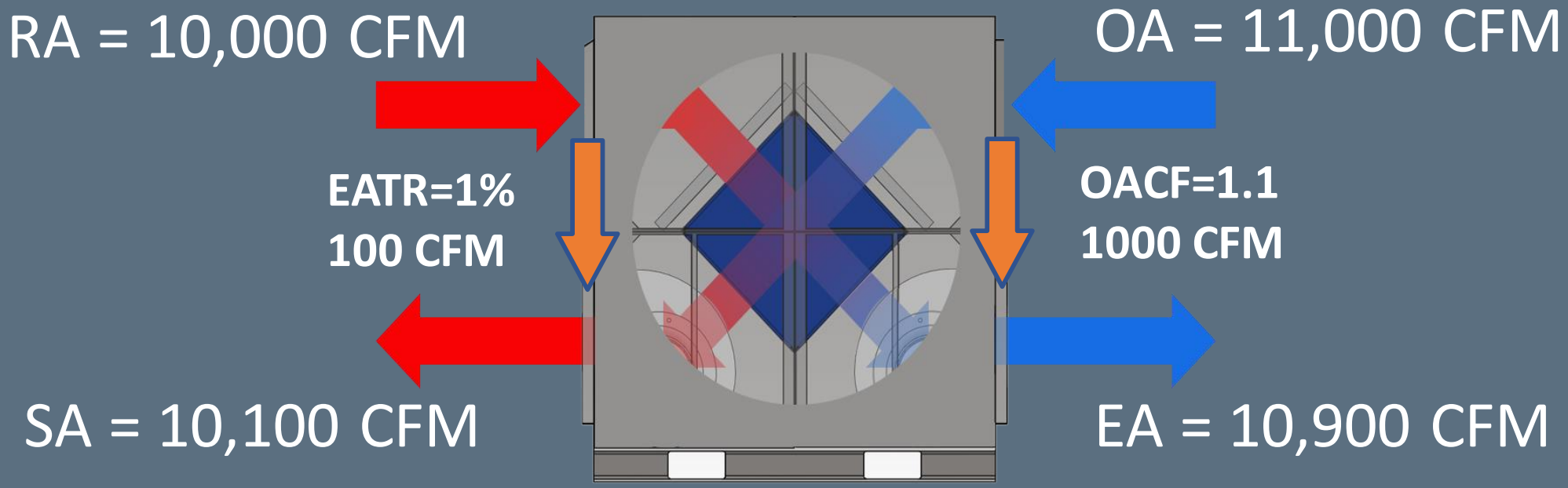
$$EATR = \frac{C_{SA} - C_{OA}}{C_{RA} - C_{OA}}$$

Outdoor Air correction Factor (OACF)



$$OACF = \frac{CFM_{OA}}{CMF_{SA}}$$

Outdoor Air correction Factor (OACF)



Supply Fan Must be sized = CFM_{SA} x OACF
Some products have OACF up to 1.7!
Minimum Cross Contamination = CFM_{OA} x EATR

Fixed Plate Exchangers

Flow Configurations