Trane Engineers Newsletter Live

Air-to-Air Energy Recovery

Presenters: Ronnie Moffitt, Dennis Stanke, John Murphy, Jeanne Harshaw (host)

Agenda

Air-to-Air Energy Recovery

Presenters: Ronnie Moffitt, Dennis Stanke, John Murphy, Jeanne Harshaw (host)

With the increased focus on reducing energy use in buildings, more projects are considering the use of air-to-air energy recovery. And energy codes are evolving to require energy recovery in more applications. This ENL will discuss the various technologies used for air-to-air energy recovery and the importance of properly controlling these devices in various systems types.

Viewer learning objectives

1. Summarize how to design and control exhaust-air energy recovery to maximize the energy-saving benefits
2. Understand the the various air-to-air energy recovery technologies
3. Understand the advantages and drawbacks of various air-to-air energy recovery technologies
3. Summarize how recent changes to energy codes impact the requirement for using exhaust-air energy recovery in buildings

Agenda

Welcome, introduction

Why recover energy?

- a) Reduce energy use (psychrometrics of EA energy recovery)
- b) Comply with energy codes (ASHRAE Standard 90.1, IECC)
- c) Review the definition of effectiveness

Discuss common technologies (advantages & drawbacks, typical performance)

- a) Coil loop
- b) Heat pipe
- c) Fixed-plate heat exchanger
- d) Fixed-membrane heat exchanger
- e) Total-energy wheel
- f) Comparison of technologies

Proper control and integration into HVAC systems

- a) Show colorful psych chart with hourly weather data
- b) Mild weather (turn device off when hOA < hEA or DBTOA < DBTEA)
- c) Cold weather (modulate capacity to prevent over-heating)
- d) Frost prevention during cold weather
- e) Review operating modes for a mixed-air VAV system

Suggestions for cost-effective application of energy recovery

- a) ASHRAE 90.1-2010 requires exhaust-air energy recovery in more applications
- b) Total-energy recovery devices transfer both sensible heat and water vapor (larger reductions in plant capacity, less susceptible to frosting)
- c) Centralize exhaust to better balance airflows and maximize recovery (DEER unit configuration, Std 62.1 and restroom exhaust)
- d) Minimize cross-leakage with proper fan placement
- e) Importance of proper control (include bypass dampers to enable economizing in mixed-air systems, modulate capacity to prevent over-heating, analyze frost prevention methods)
- f) Specify AHRI-certified components (introduce AHRI 1060 certification program)

Summary

Presenter biographies

Ronnie Moffitt | applications engineering | Trane
Ronnie joined Trane in 1996 and currently is an airside applications engineer whose responsibility is to aid design engineers and Trane sales personnel in the proper design and application of HVAC systems. His primary focus has been dehumidification and air-to-air energy recovery. This includes the development, design and control optimization of desiccants in commercial HVAC systems. He has several patents related to these subjects, and serves on related ASHRAE engineering committees. He is current chairman of the AHRI Air-to-Air Energy Recovery Ventilation Equipment section.

Ronnie led the development of the Trane CDQ system, a winner of the R&D 100 Award for The Most Technologically Significant New Products of 2005. He is a certified Energy Manager (CEM) by Association of Energy Engineers and received his B.S. in Aerospace Engineering from Syracuse University.

John Murphy | applications engineer | Trane
John has been with Trane since 1993. His primary responsibility as an applications engineer is to aid design engineers and Trane sales personnel in the proper design and application of HVAC systems. As a LEED Accredited Professional, he has helped our customers and local offices on a wide range of LEED projects. His main areas of expertise include energy efficiency, dehumidification, dedicated outdoor-air systems, air-to-air energy recovery, psychrometry, and ventilation.

John is the author of numerous Trane application manuals and *Engineers Newsletters*, and is a frequent presenter on Trane's Engineers Newsletter Live series. He also is a member of ASHRAE, has authored several articles for the ASHRAE Journal, and has been a member of ASHRAE's "Moisture Management in Buildings" and "Mechanical Dehumidifiers" technical committees. He was a contributing author of the *Advanced Energy Design Guide for K-12 Schools* and the *Advanced Energy Design Guide for Small Hospitals and Health Care Facilities,* a technical reviewer for the *ASHRAE Guide for Buildings in Hot and Humid Climates*, and a presenter on ASHRAE's "Dedicated Outdoor Air Systems" webcast.

Dennis Stanke | staff applications engineer | Trane
With a BSME from the University of Wisconsin, Dennis joined Trane in 1973, as a controls development engineer. He is now a Staff Applications Engineer specializing in airside systems including controls, ventilation, indoor air quality, and dehumidification. He has written numerous applications manuals and newsletters, has published many technical articles and columns, and has appeared in many Trane Engineers Newsletter Live broadcasts.

An ASHRAE Fellow, he currently serves as Chairman for ASHRAE Standard 189.1, Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings. He recently served as Chairman for ASHRAE Standard 62.1, Ventilation for Acceptable Indoor Air Quality, and he served on the USGBC LEED Technical Advisory Group for Indoor Environmental Quality (the LEED EQ TAG).

TRANE

Air-to-Air Energy Recovery

engineers newsletter LIVE

Ingersoll Rand

EDUCATION PROVIDER

Ingersoll Rand

is a USGBC Education Provider committed to enhancing the professional development of the building industry and LEED Professionals through high-quality continuing education programs.

As a USGBC Education Provider, we have agreed to abide by USGBC-established operational and educational criteria, and are subject to course reviews and audits for quality assurance.

GBCI CMP

Air-to-Air Energy Recovery (Course ID: 0090008664)

Approved for 1.5 GBCI hours for LEED professionals

"Trane" is a Registered Provider with The American Institute of Architects Continuing Education System. Credit earned on completion of this program will be reported to CES Records for AIA members. Certificates of Completion are available on request.

This program is registered with the AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Visit the Registered Continuing Education Programs (RCEP) Website for individual state continuing education requirements for Professional Engineers.

www.RCEP.net

Copyrighted Materials

learning objectives

After today's program you will be able to:

- Design and control exhaust-air energy recovery to maximize the energy-saving benefits
- Identify the advantages and drawbacks of various air-to-air energy recovery technologies
- Comply with recent changes to energy codes regarding the requirements for exhaust-air energy recovery

Today's Presenters

John Murphy
Applications Engineer

Dennis Stanke
Applications Engineer

Ronnie Moffitt
Applications Engineer

Agenda

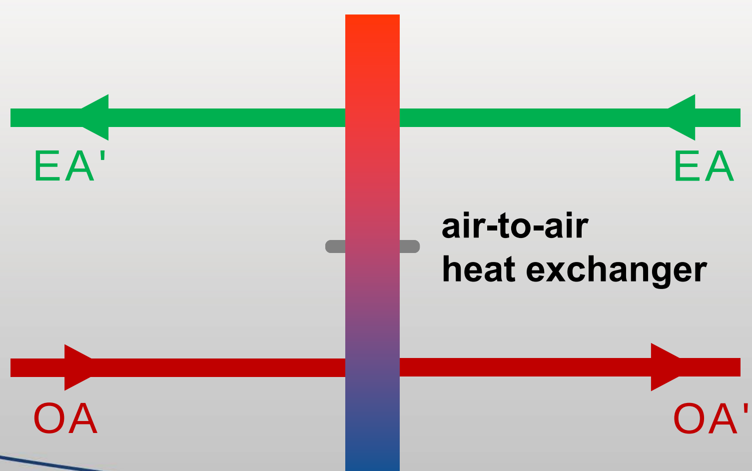
- Why implement exhaust-air energy recovery?
- Common air-to-air energy recovery technologies
- Proper control and integration into HVAC systems
- Suggestions for cost-effective application of energy recovery

Agenda

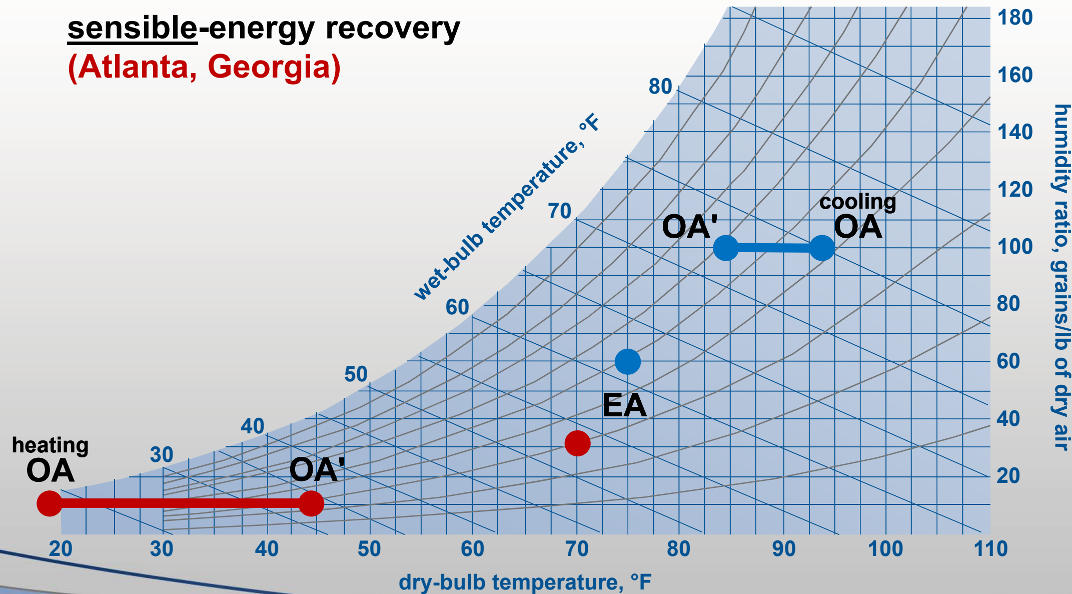
engineers newsletter LIVE

- Why implement exhaust-air energy recovery?
  - Reduce overall system energy use
  - Comply with energy codes
- Common air-to-air energy recovery technologies
- Proper control and integration into HVAC systems
- Suggestions for cost-effective application

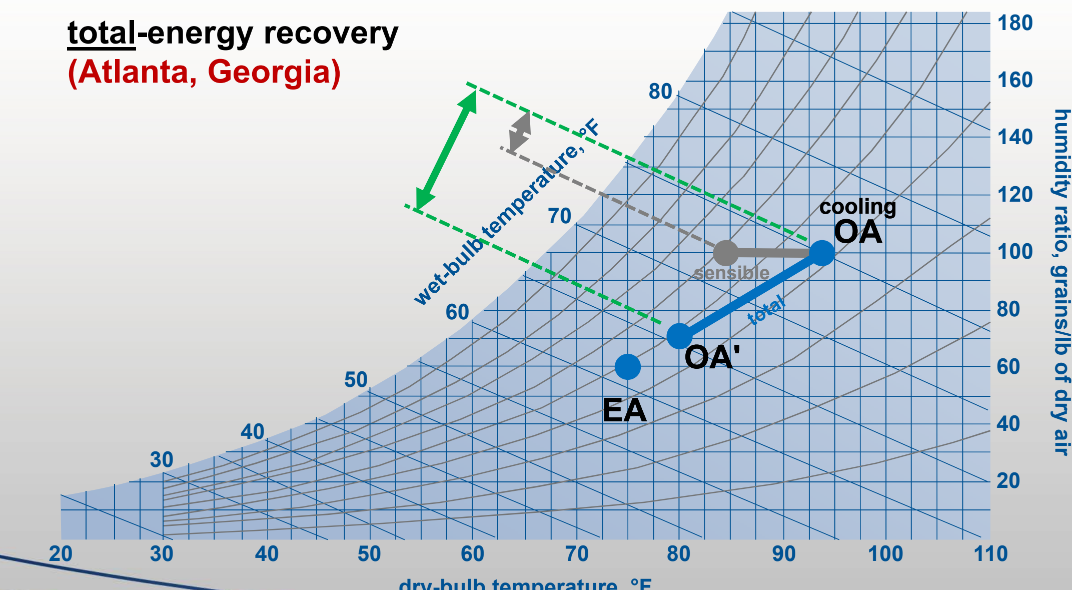
Exhaust-Air Energy Recovery

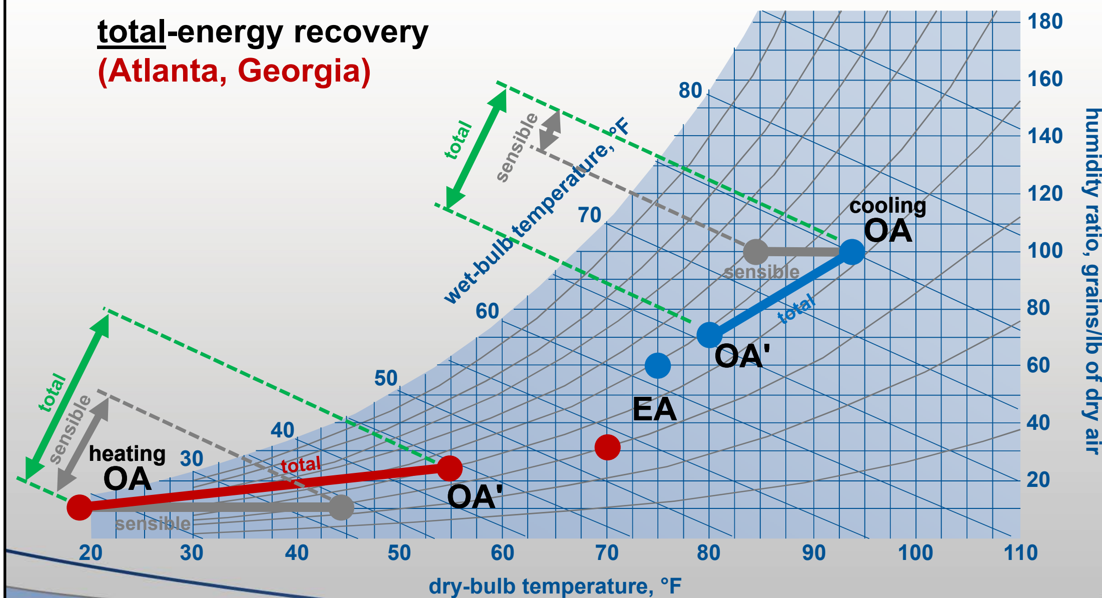


sensible-energy recovery
(Atlanta, Georgia)



total-energy recovery
(Atlanta, Georgia)





Why Use Exhaust-Air Energy Recovery?

Operating Cost

- Reduces cooling and heating energy use
  - Heating energy savings is generally greater than cooling energy savings
- Increases fan energy use

Installed Cost

- Allows downsizing of cooling and heating plants
  - Total-energy recovery typically allows for largest cooling plant reductions
- Added pressure loss may increase fan motor sizes
- May require additional exhaust ductwork

Agenda

engineers newsletter LIVE

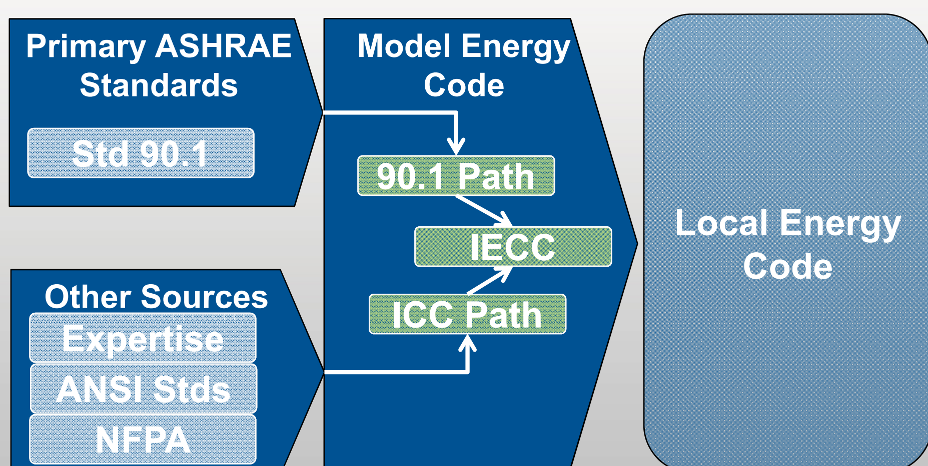
- Why implement exhaust-air energy recovery?
  - Reduce overall system energy use
  - Comply with energy codes
- Common air-to-air energy recovery technologies
- Proper control and integration into HVAC systems
- Suggestions for cost-effective application

Why Recover Energy in Buildings?

- Save energy and operating costs
- Comply with:
  - Energy codes (IECC), following either ASHRAE Standard 90.1 or ICC requirements
  - Green-building codes (IgCC-based), following either Standard 189.1 or ICC requirements
  - Energy label (ENERGY STAR) or building rating systems (LEED®)

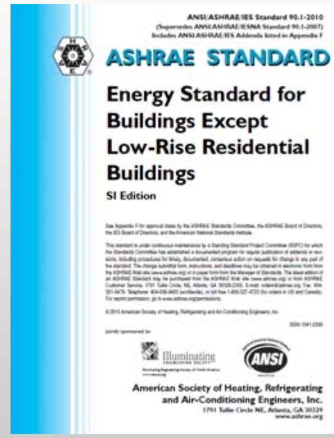
- **IECC**—International Energy Conservation Code
- **ICC**—International Code Council (ICC) requirements
- **IgCC**—International green Construction Code

how standards fit with
Energy Codes



What is Standard 90.1?

- An ANSI standard in mandatory-language, co-sponsored by ASHRAE, USGBC, and IES, that:
  - Provides minimum design energy requirements for commercial and high-rise residential buildings
  - It does not apply to low-rise residential
  - It covers building envelope, HVAC, water heating, power and lighting



Standard 90.1-2007, Section 6.5.6.1
Exhaust-Air Energy Recovery

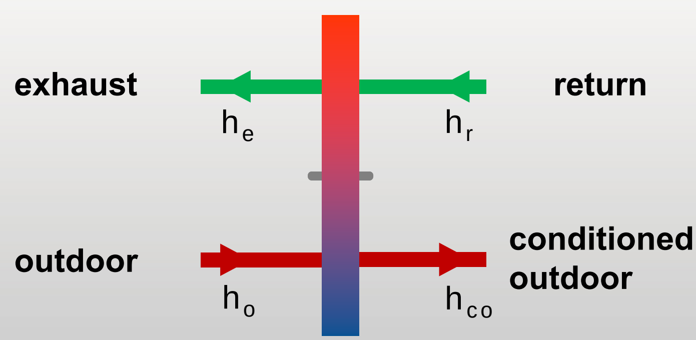
Individual fan systems that have both a design supply air capacity of 5000 cfm or greater and have a minimum *outdoor air* supply of 70% or greater of the design supply air quantity shall have an energy recovery system with at least 50% recovery effectiveness. Fifty percent energy recovery effectiveness 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 at design conditions. Provision shall be made to bypass or control the heat recovery system to permit air economizer operation as required by Section 6.5.1.1.

Standard 90.1-2007, Section 6.5.6.1
Exhaust-Air Energy Recovery

- Must recover energy in any system with both:
  - Design supply airflow of 5,000 cfm or more
  - Minimum outdoor airflow 70% or more of design supply airflow
- Must meet "energy recovery effectiveness" ≥ 50% (*vent load-reduction ratio* = $(h_o - h_{co})/(h_o - h_r) \geq 0.50$)
- Bypass or control requirements to avoid heat recovery during air economizer operation

defined by ASHRAE Standard 90.1
"Energy Recovery Effectiveness" (ERE)

$$\text{ERE} = \frac{(h_o - h_{co})}{(h_o - h_r)}$$



ERE = ventilation load-reduction ratio ≥ 0.50

Standard 90.1-2010, Section 6.5.6.1
Exhaust-Air Energy Recovery

Each fan system shall have an energy recovery system when the system's supply air flow rate exceeds the value listed in Table 6.5.6.1 based on the climate zone and percentage of *outdoor air* flow rate at design conditions. Energy recovery systems required by this section shall have at least 50% energy recovery effectiveness. Fifty percent energy recovery effectiveness 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. Provision shall be made to bypass or control the energy recovery system to permit air economizer operation as required by 6.5.1.1.

Standard 90.1-2010, Section 6.5.6.1
Exhaust-Air Energy Recovery

- Must recover energy in any system with good potential, which depends upon supply airflow, minimum outdoor airflow (**≥30%**) and climate, as shown in Table 6.5.6.1
- Must meet "energy recovery effectiveness" ≥ 50% (*vent load-reduction ratio* = $(h_o - h_{co})/(h_o - h_r) \geq 0.50$)
- Bypass or control requirements to avoid heat recovery during air economizer operation

Standard 90.1-2010, Section 6.5.6.1
Exhaust-Air Energy Recovery

TABLE 6.5.6.1 Energy Recovery Requirement (I-P)

Climate Zone	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and <80%	≥80%
	% Outdoor Air at Full Design Flow							
	Design Supply Fan Flow, cfm						Std 90.1-2007	
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	NR	NR	≥5000	≥5000
1B, 2B, 5C	NR	NR	NR	NR	≥26000	≥12000	≥5000	≥4000
6B	NR	NR	≥11000	≥5500	≥4500	≥3500	≥2500	≥1500
1A, 2A, 3A, 4A, 5A, 6A	NR	NR	≥5500	≥4500	≥3500	≥2000	≥1000	≥0
7, 8	NR	NR	≥2500	≥1000	≥0	≥0	≥0	≥0

Std 90.1-2010 – More Stringent

Standard 90.1-2013, expected Section 6.5.6.1
Exhaust-Air Energy Recovery

TABLE 6.5.6.1 Energy Recovery Requirement (I-P)

Climate Zone	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and <80%	≥80%
	% Outdoor Air at Full Design Flow							
	Design Supply Fan Flow, cfm						Std 90.1-2013	
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	NR	NR	NR	NR
1B, 2B, 5C	NR	NR	NR	NR	≥26,000	≥12,000	≥5000	≥4000
6B	≥28000	≥26500	≥11,000	≥5500	≥4500	≥3500	≥2500	≥1500
1A, 2A, 3A, 4A, 5A, 6A	≥26000	≥16000	≥5500	≥4500	≥3500	≥2000	≥1000	≥0
7, 8	≥4500	≥4000	≥2500	≥1000	≥0	≥0	≥0	≥0

Std 90.1-2013 | **Std 90.1-2010 and Std 90.1-2013**

Standard 90.1-2010, Section 6.5.6.1
Exhaust-Air Energy Recovery Exceptions

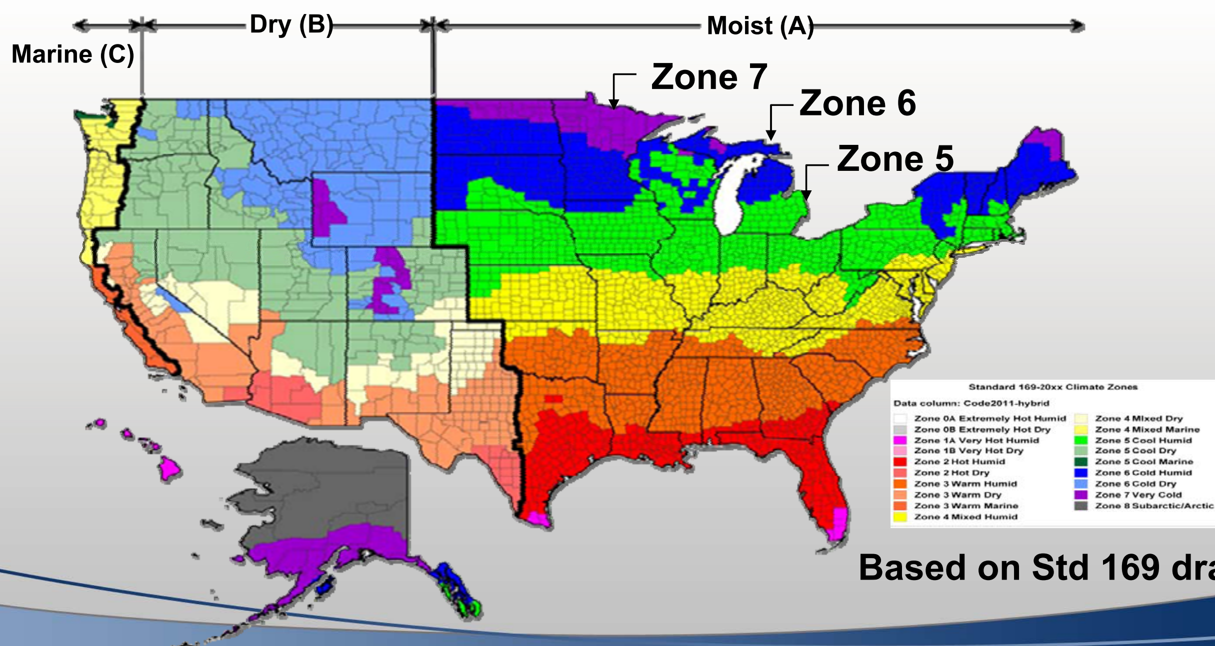
a. Laboratory systems meeting 6.5.7.2.
b. Systems serving spaces that are not cooled and that are heated to less than 60°F.
c. Systems exhausting toxic, flammable, paint, or corrosive fumes or dust.
d. Commercial kitchen hoods used for collecting and removing grease vapors and smoke.
e. Where more than 60% of the *outdoor air* heating energy is provided from site-recovered or site-solar energy.
f. Heating energy recovery in climate zones 1 and 2.

Standard 90.1-2010, Section 6.5.6.1 (cont.)
Exhaust-Air Energy Recovery Exceptions

g. Cooling energy recovery in climate zones 3C, 4C, 5B, 5C, 6B, 7, and 8.
h. Where the largest source of air exhausted at a single location at the building exterior is less than 75% of the design *outdoor air* flow rate.
i. Systems requiring dehumidification that employ energy recovery in series with the cooling coil.
j. Systems expected to operate less than 20 hrs per week at the *outdoor air* percentage covered by Table 6.5.6.1

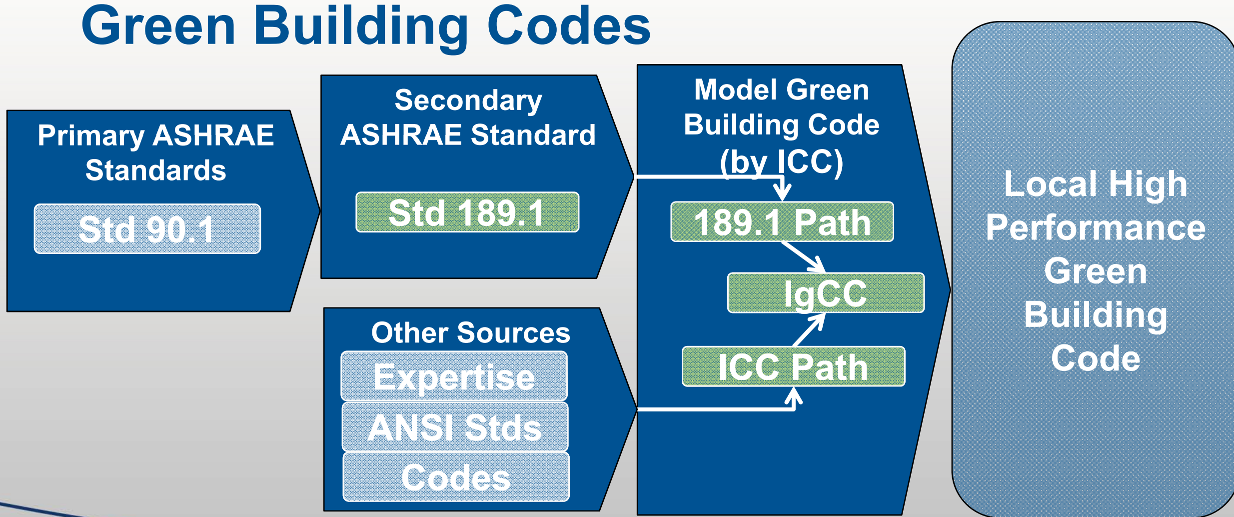
Standard 90.1-2010, Section 6.5.6.1
Exhaust-Air Energy Recovery

- Some exceptions to exhaust-air ER requirements:
  - a. Laboratory systems meeting 6.5.7.2 (e.g., certain VAV lab exhaust and supply systems)
  - e. Systems where site-recovered or site-solar heat provides >60% of the energy needed to heat outdoor air
  - g. Cooling energy recovery in cool, dry climates (zone 3C, 4C, 5B, 5C, 6B, 7, and 8)
  - i. Dehumidification systems using energy recovery in series with the cooling coil



Based on Std 169 draft

how standards fit with
Green Building Codes



What is Standard 189.1?

- An ANSI standard in mandatory-language, co-sponsored by ASHRAE, USGBC, and IES, that:
  - Provides minimum design requirements for high-performance green buildings (HPGB)
  - Applies to the same buildings as Std 90.1 and Std 62.1
  - It covers building site, water use, energy use, indoor environmental quality, environmental impact

Standard 189.1, Section 7.4.3.6
Exhaust-Air Energy Recovery

7.4.3.6 Exhaust-Air Energy Recovery. The exhaust-air energy recovery requirements defined in Section 6.5.6.1 of ANSI/ASHRAE/IES Standard 90.1 shall be used except that the energy recovery effectiveness shall be 60% and the requirements of Table 7.4.3.6 shall be used instead of those of Table 6.5.6.1 of ANSI/ASHRAE/IES Standard 90.1.

Standard 189.1-2011, Section 7.4.3.6
Exhaust-Air Energy Recovery

- Must use recovery energy based on energy recovery potential, which depends on climate, outdoor airflow (**≥10%**) and supply airflow per Table 7.4.3.6
- Must meet "energy recovery effectiveness" ≥ **60%** (*vent load-reduction ratio* = $(h_o - h_{co})/(h_o - h_r) \geq 0.60$)
- Must include bypass or control requirements to avoid heat recovery during air economizer operation

Standard 189.1-2011 vs. Standard 90.1-2010
Exhaust-Air Energy Recovery

TABLE 7.4.3.6 Energy Recovery Requirement (I-P)

Climate Zone	*% Outdoor Air at Full Design Flow*							
	≥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 Flow, cfm							
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	NR	NR	≥5000	≥5000
1B, 2B, 5C	NR	NR	NR	NR	≥26,000	≥12,000	≥5000	≥4000
6B	NR	≥22500	≥11,000	≥5500	≥4500	≥3500	≥2500	≥1500
1A, 2A, 3A, 4A, 5A, 6A	≥30000	≥13000	≥5500	≥4500	≥3500	≥2000	≥1000	≥0
7, 8	≥4000	≥4000	≥2500	≥1000	≥0	≥0	≥0	≥0
	Std 189.1-2011		**Std 90.1-2010 and Std 189.1-2011**					

ASHRAE Standard 84

- Defines method of testing air-to-air heat exchangers

AHRI Standard 1060

- Defines conditions and procedures for rating and certifying performance defined by ASHRAE Standard 84 and AHRI Standard 1060

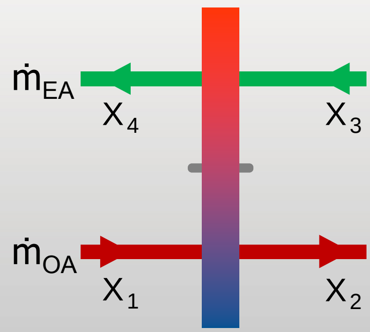
Effectiveness

sensible effectiveness

$$\varepsilon_S = \frac{\dot{m}_{OA}}{\dot{m}_{min}} \times \frac{(T_1 - T_2)}{(T_1 - T_3)}$$

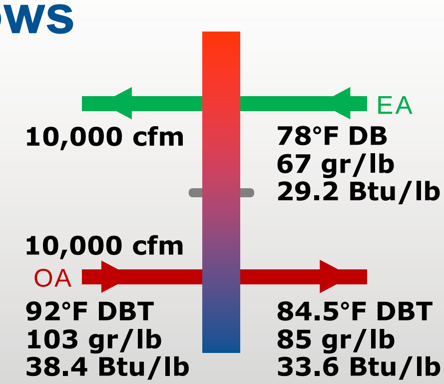
total effectiveness

$$\varepsilon_T = \frac{\dot{m}_{OA}}{\dot{m}_{min}} \times \frac{(h_1 - h_2)}{(h_1 - h_3)}$$



$\dot{m}_{min}$ = smaller of $\dot{m}_{OA}$ or $\dot{m}_{EA}$

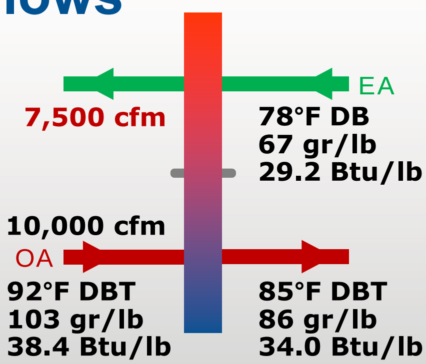
Equal Airflows



$$\varepsilon_T = \frac{10{,}000 \text{ cfm}}{10{,}000 \text{ cfm}} \times \frac{(38.4 - 33.6)}{(38.4 - 29.2)} = 52\%$$

$Q_T = 4.5 \times 10{,}000 \text{ cfm} \times (38.4 - 33.6 \text{ Btu/lb}) = 216 \text{ MBh}$

Unequal Airflows



$$\varepsilon_T = \frac{10{,}000 \text{ cfm}}{7{,}500 \text{ cfm}} \times \frac{(38.4 - 34.0)}{(38.4 - 29.2)} = 64\%$$

compared to 52% with equal airflows

$$Q_T = 4.5 \times 10{,}000 \text{ cfm} \times (38.4 - 34.0 \text{ Btu/lb}) = 200 \text{ MBh}$$

compared to 216 MBh with equal airflows

sponge in large bucket of water

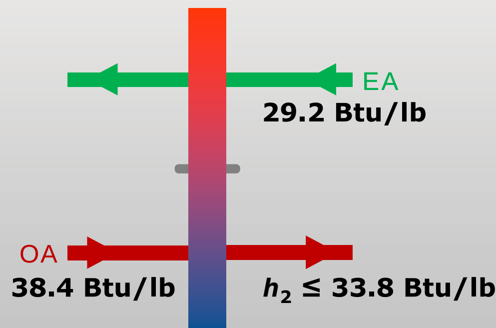
- More water absorbed
- Less effective
  (does not absorb all water in bucket)

sponge in small puddle of water

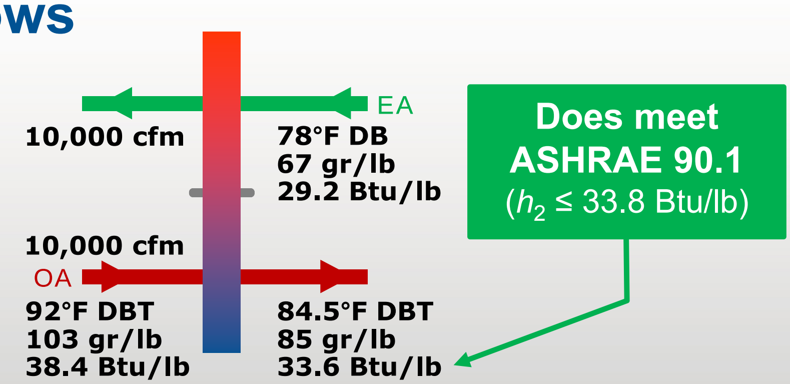
- Less water absorbed
- More effective
  (absorbs all water in puddle)

ASHRAE 90.1-2010, Section 6.5.6.1
Exhaust-Air Energy Recovery

*"Fifty percent energy recovery **effectiveness** 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."*



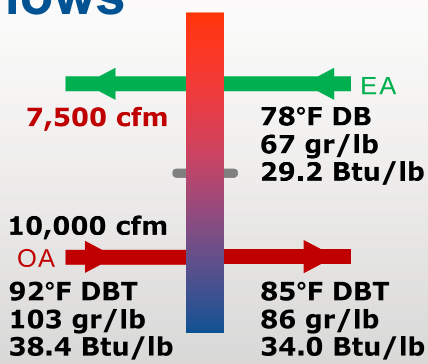
Equal Airflows



$$\varepsilon_T = \frac{10{,}000 \text{ cfm}}{10{,}000 \text{ cfm}} \times \frac{(38.4 - 33.6)}{(38.4 - 29.2)} = 52\%$$

52% ventilation load reduction

Unequal Airflows



Does not meet ASHRAE 90.1
($h_2 \leq 33.8$ Btu/lb)

$$\varepsilon_T = \frac{10{,}000 \text{ cfm}}{7{,}500 \text{ cfm}} \times \frac{(38.4 - 34.0)}{(38.4 - 29.2)} = 64\%$$

48% ventilation load reduction

"As-Applied" vs. "Rated" Effectiveness

- Be careful not to confuse the enthalpy reduction (or ventilation load reduction) required by ASHRAE 90.1 with "rated" effectiveness per ASHRAE 84 / AHRI 1060
- Strive for equal airflows
  - Bring back as much exhaust air as possible

Agenda

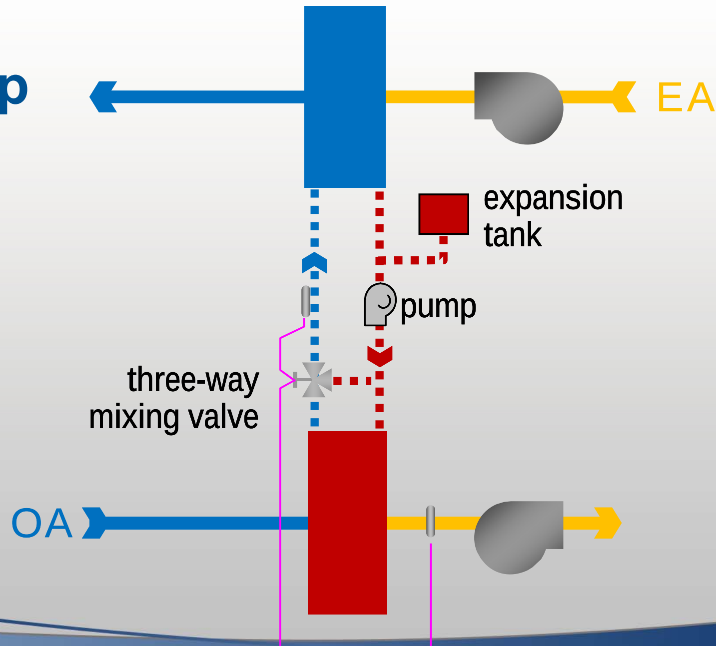
engineers newsletter LIVE

- Why implement exhaust-air energy recovery?
- Common air-to-air energy recovery technologies
  - Coil loop
  - Heat pipe
  - Fixed-plate heat exchanger
  - Fixed-membrane heat exchanger
  - Total-energy wheel
- Proper control and integration into HVAC systems
- Suggestions for cost-effective application

Energy Recovery Technology Comparison

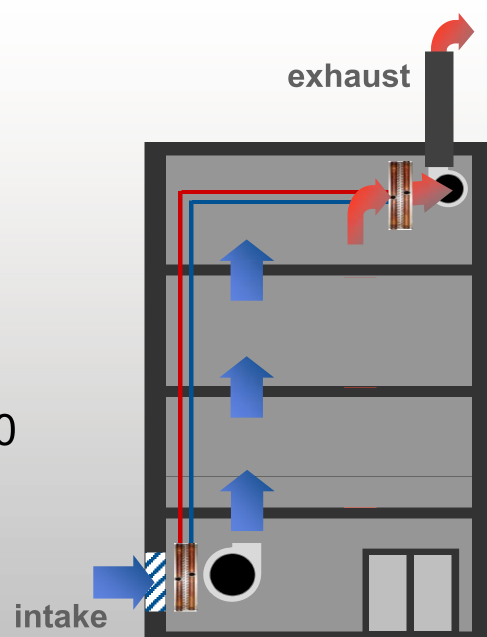
- Coil loop
- Heat pipe
- Fixed-plate heat exchanger
- Fixed-membrane heat exchanger
- Total-energy wheel

Coil Loop



coil loop
Typical Applications

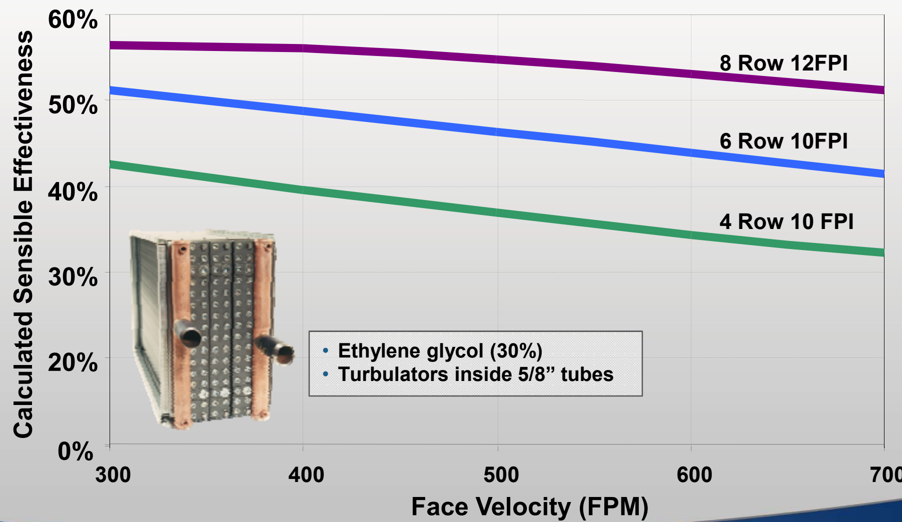
- When need to totally isolate ventilation from exhaust air
- No cross contamination
- Hospitals or labs with high ventilation/exhaust rates (8760 hours/year)
- Greater benefits in heating-dominated climates



coil loop
How Much Energy Recovered

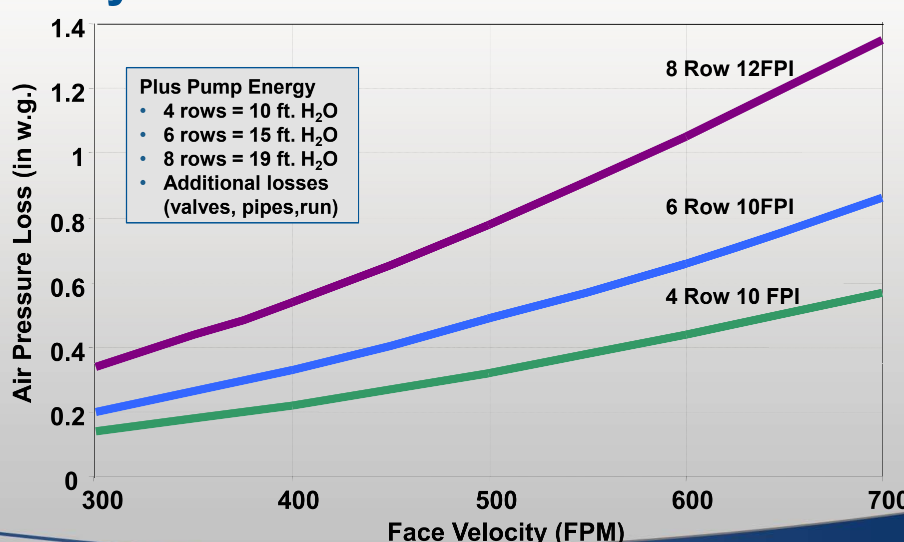
Typical Coil Loop
Sensible
Effectiveness

35% to 55% sensible heat recovered



coil loop
Energy Recovery At What Cost

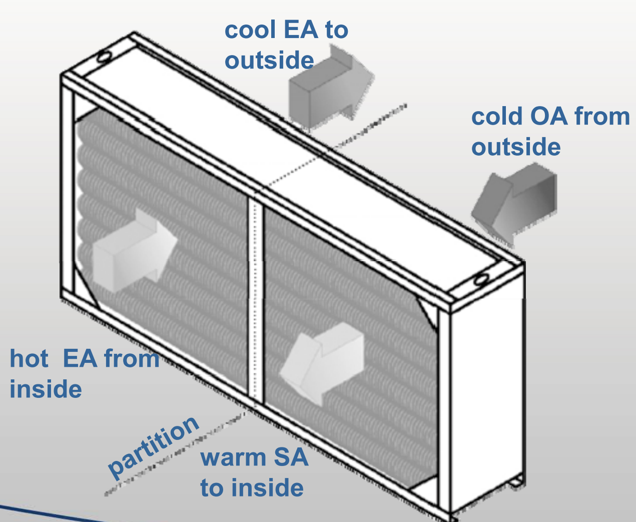
Typical Coil Loop
Air Pressure Drop
per Coil



Coil Loop Considerations

- Sensible recovery only, no stream-to-stream leakage, ducts may be separated
- Ventilation load-reduction is usually **too low**
  - 10-20% in moist climates, 35-55% in dry & cold climates
- Std 90.1 exceptions may allow coil loops, e.g.:
  - Exception c: Systems exhausting toxic fumes
  - Exception h: Systems with multiple small exhaust paths

Heat Pipe

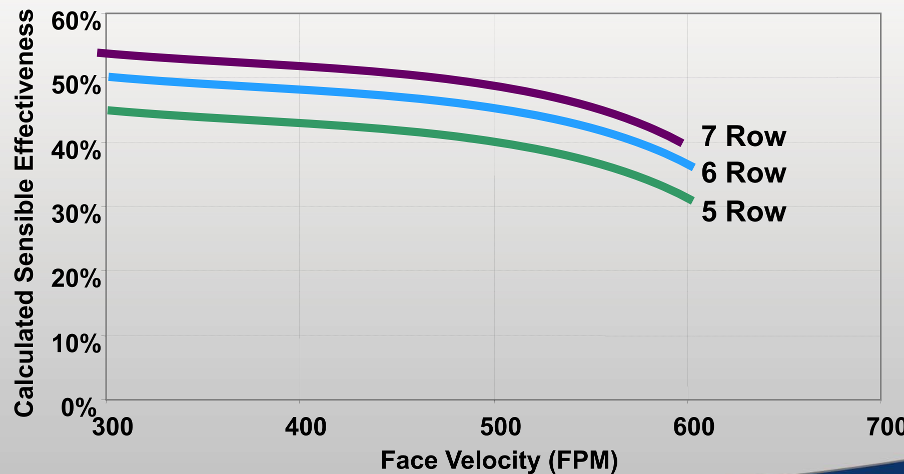


- Capacity modulation via bypass dampers or tilt control
- Very low cross-leakage
- No pumps

heat pipe
How Much Energy Recovered

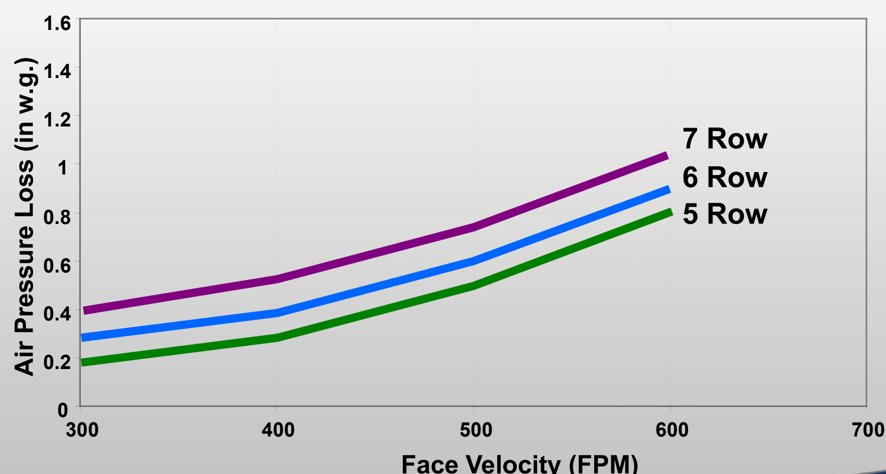
Heat Pipe
Sensible
Effectiveness

30% to 52% sensible heat recovered



heat pipe
Energy Recovery At What Cost

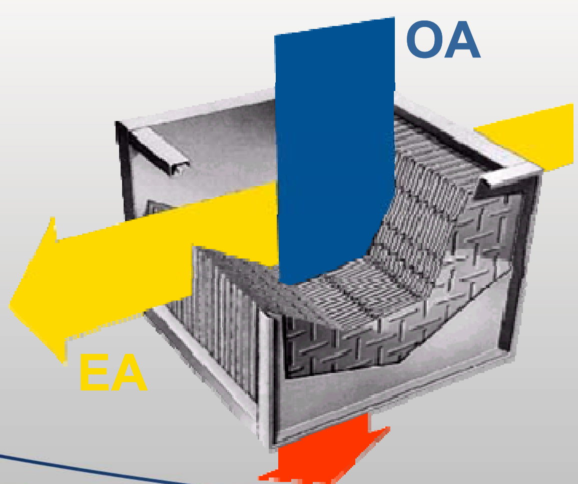
Typical Coil Loop
Air Pressure Drop
per Coil



Heat Pipe Considerations

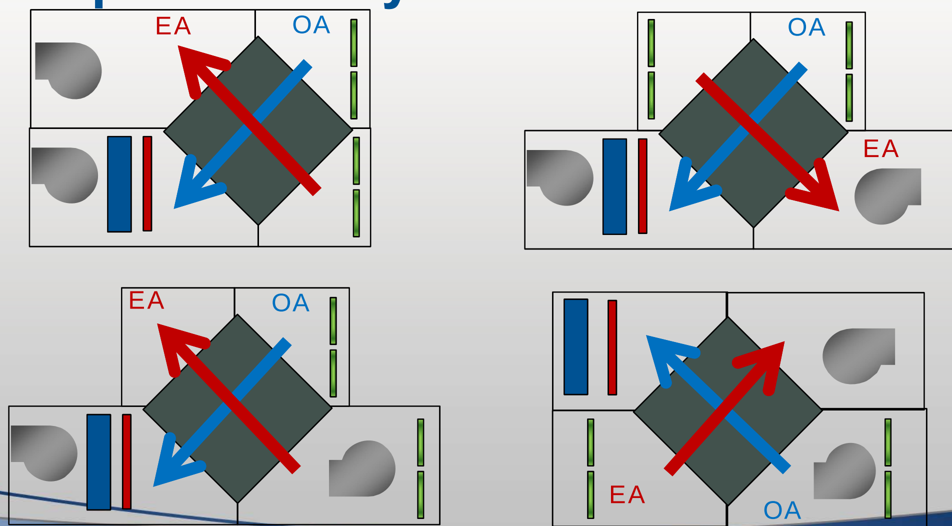
- Sensible recovery only, some leakage possible, ducts must be adjacent
- Ventilation load-reduction is **too low**
  - 10-20% in moist climates, 30-50% in dry & cold climates
- Std 90.1 exceptions may allow use of heat pipes, e.g.:
  - Exception b: Uncooled spaces, heated to <60ºF

Fixed-Plate Heat Exchanger

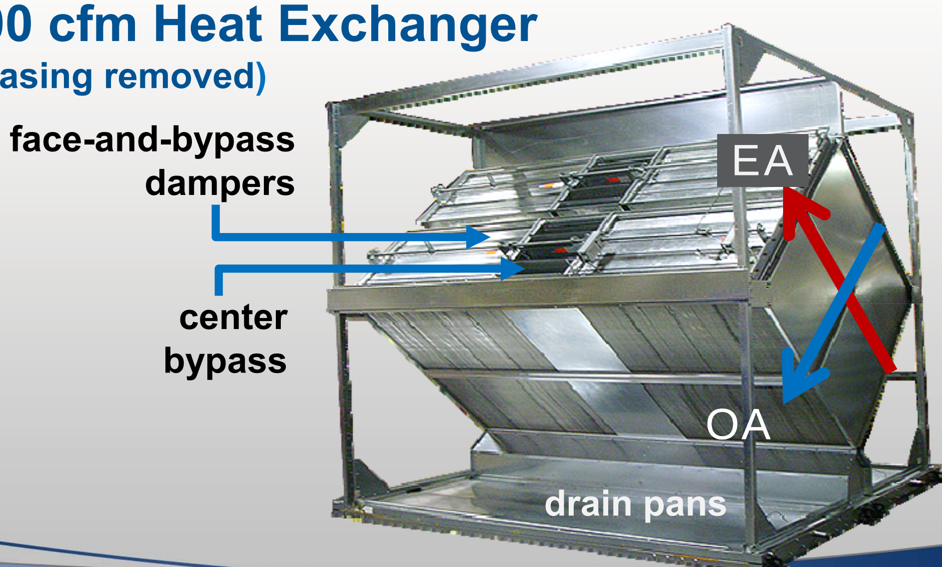


- Cross-flow aluminum plates
- Dimpled or channeled plates
- Handle high pressure up to 10” diff
- High temperatures
- Corrosion resistant
- Capacity modulation using face-and-bypass dampers
- Little or no cross-leakage
- Most susceptible to frosting

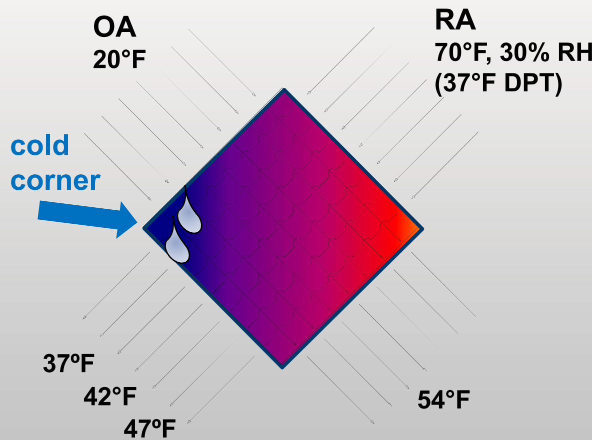
fixed-plate heat exchanger
Example AHU Layouts



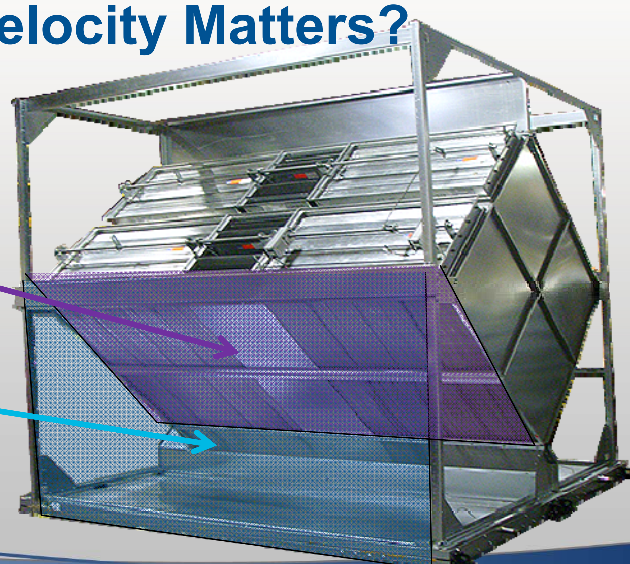
fixed-plate heat exchanger
20,000 cfm Heat Exchanger
(AHU casing removed)



fixed-plate heat exchanger
Non-Uniform Temperature Across Exchanger



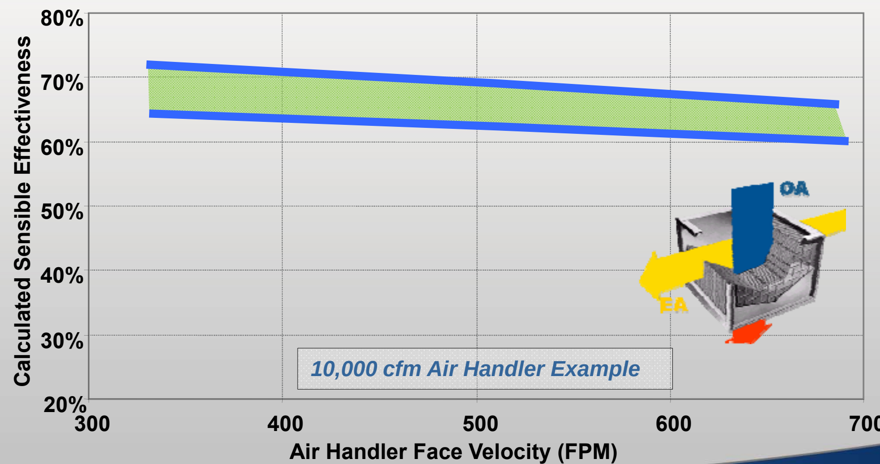
fixed-plate heat exchanger
Which Face Velocity Matters?



fixed-plate heat exchanger
How Much Energy Recovered

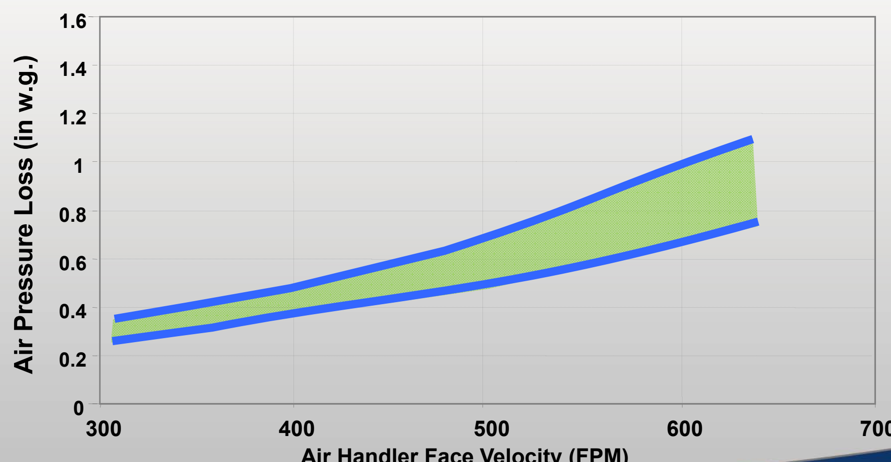
Air-to-Air
Plate Exchanger
Sensible
Effectiveness

60% to 70% sensible heat recovered



fixed-plate heat exchanger
Energy Recovery At What Cost

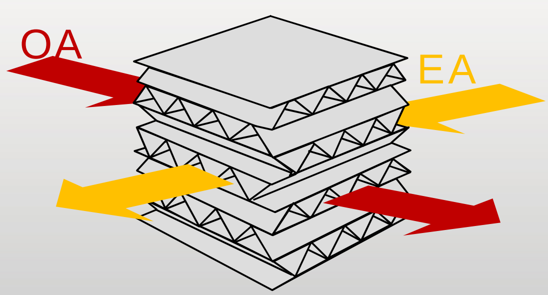
Air-to-Air
Plate Exchanger
Air Pressure Drop



Fixed-Plate Considerations

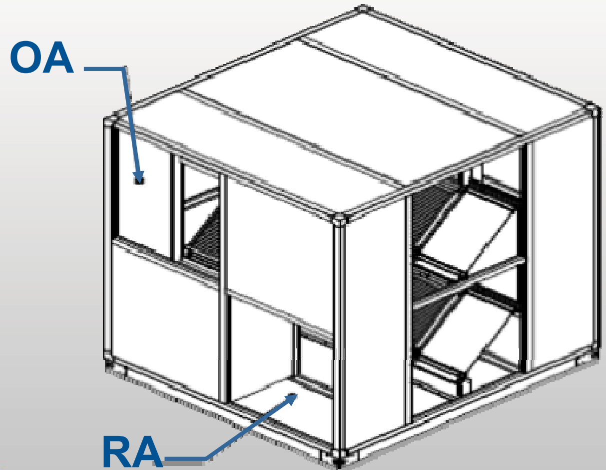
- Sensible recovery only, some leakage possible, ducts must be adjacent
- Ventilation load-reduction varies over wide range
  - 20% to 30% in moist climates is **too low**
  - 55% to 70% in dry & cold climates is **high enough**
- Std 90.1 exceptions may allow fixed-plate exchangers
  - Exception j: Systems that operate less than 20 hours per week at design minimum OA flow

Fixed-Membrane Heat Exchanger



- Membrane material in layers
- Water vapor permeable
- Capacity modulation using external bypass dampers
- Little cross-leakage

Fixed-Membrane Heat Exchanger

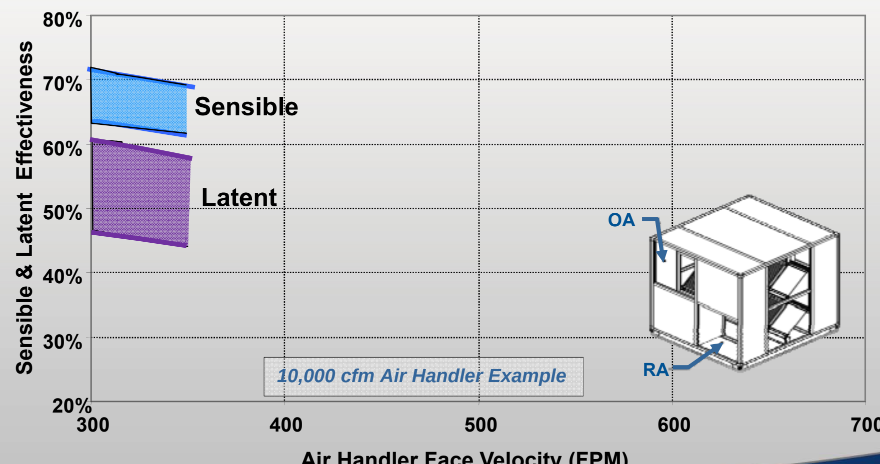


- Smaller cores only (500 cfm range)
- Limited fan arrangements
- Low pressure differential (2 to 4 in. H_2O maximum)
- Large footprint required
- Transitions add another 1.0 to 1.5 in. H_2O pressure loss (> 2000 cfm)

fixed-membrane heat exchanger
How Much Energy Recovered

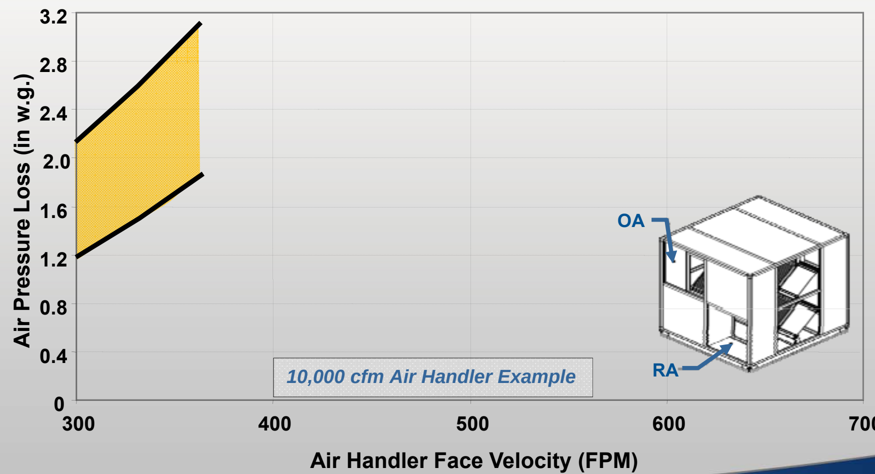
Bank of Membrane Exchangers
Sensible & Latent Effectiveness

Sensible: 62-70%
Latent: 45–54%



fixed-membrane heat exchanger
Energy Recovery At What Cost

Bank of Membrane Exchangers
Air Pressure Drop



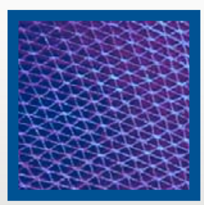
Fixed-Membrane Considerations

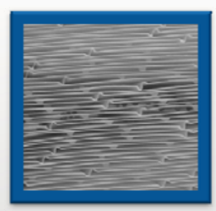
- Total energy recovery, low leakage, adjacent ducts
- Ventilation load-reduction varies widely
  - 35% to 60% in moist climates
  - 55% to 70% in dry & cold climates
- Probably meet Std 90.1 (50%) in most locations and Std 189.1 (60%) in some locations
- Low core airflows limit unit size

Total-Energy Wheel

- Desiccant rotor rotating 20-60 rpm between exhaust and outdoor air
- Capacity modulation using bypass dampers
- Some cross-leakage
- Self cleaning (dry particles)
- Less susceptible to frosting than sensible-recovery technologies

total-energy wheel
Media Types

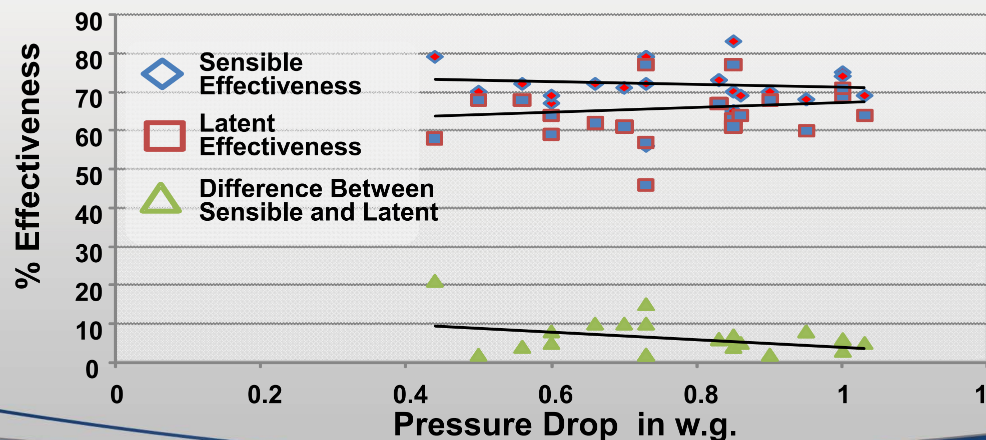




	Aluminum	Synthetic fiber	Polymer
Weight	heaviest	Mid	lightest
Bearing maintenance	annual	← large I small →	none
Desiccant loading	good	best	good
Corrosion resistance	good	best	better
Common depth	6”, 8”, 12”	4”, 6”	1.5”, 3”

total-energy wheel
How Much Energy Recovered

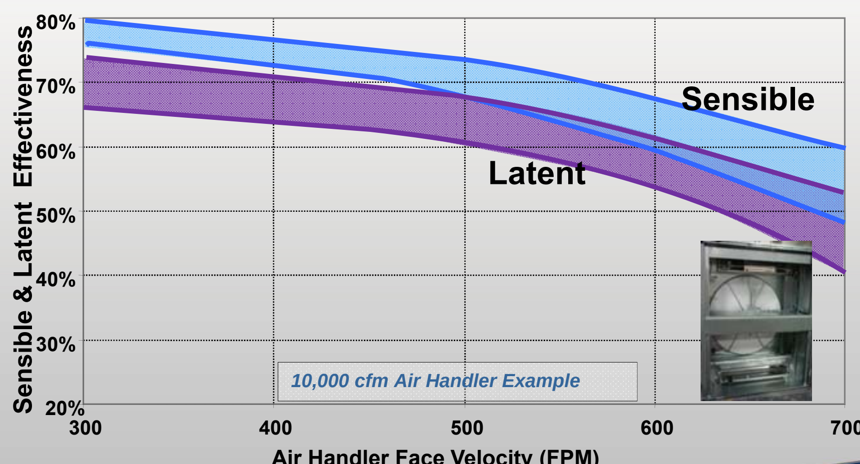
AHRI 1060 Directory Data



total-energy wheel
How Much Energy Recovered

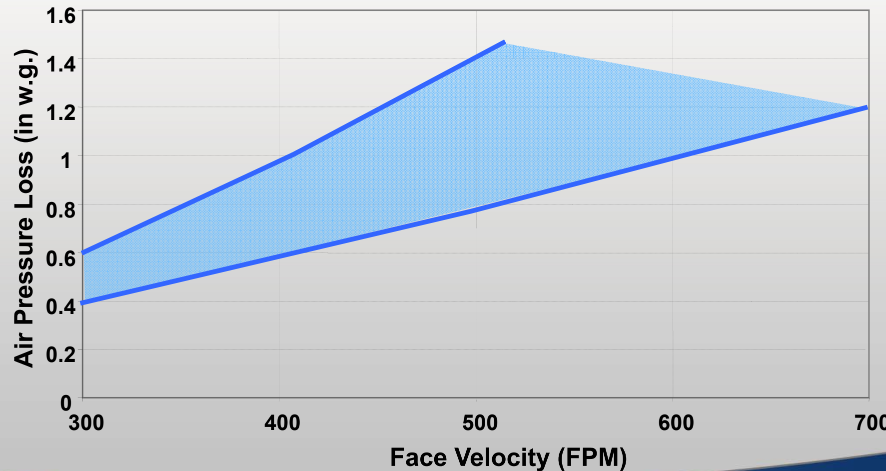
Sensible & Latent Effectiveness

Sensible: 60-76%
Latent: 55-71%



total-energy wheel
Energy Recovery At What Cost

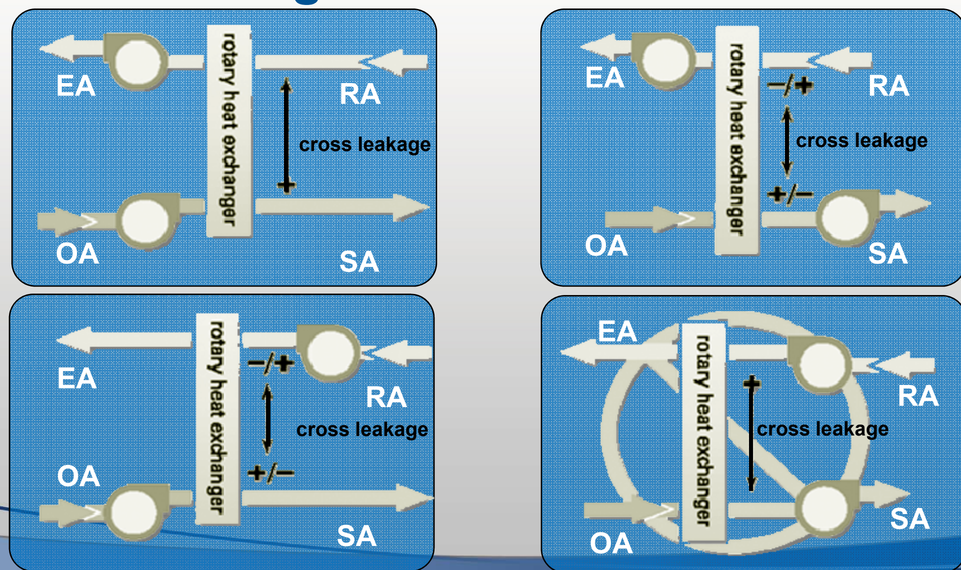
Energy Wheel
Air Pressure Drop



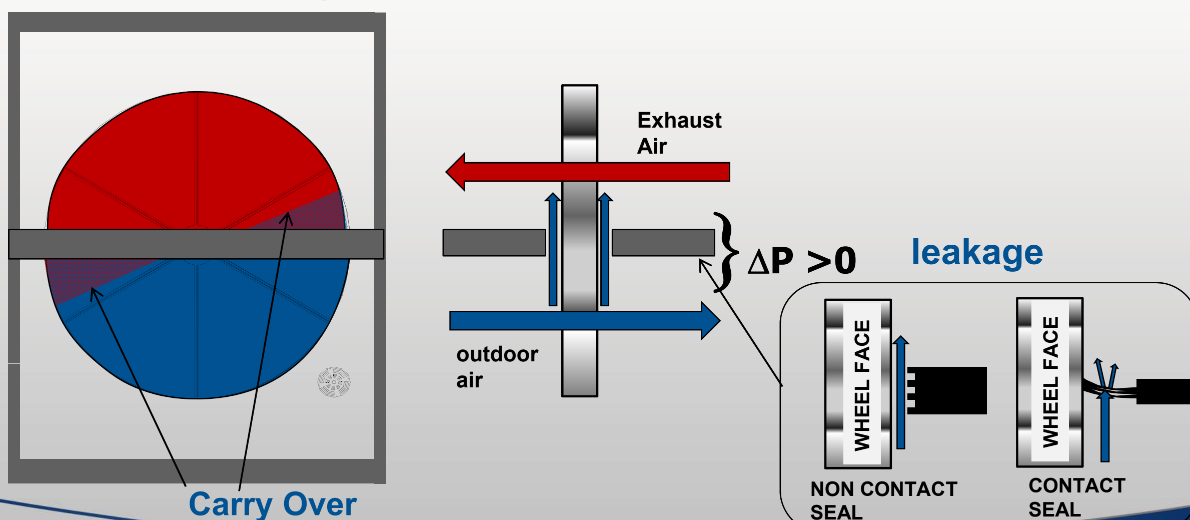
total-energy wheel
Energy Recovery At What Cost
Motor Power

Media type	Motor horsepower
Aluminum	1/3—5 hp
Synthetic fiber	1/4—2 hp
Polymer	1/80—1/3 hp

total-energy wheel: at what cost
Cross Leakage



total-energy wheel: at what cost
Cross Leakage

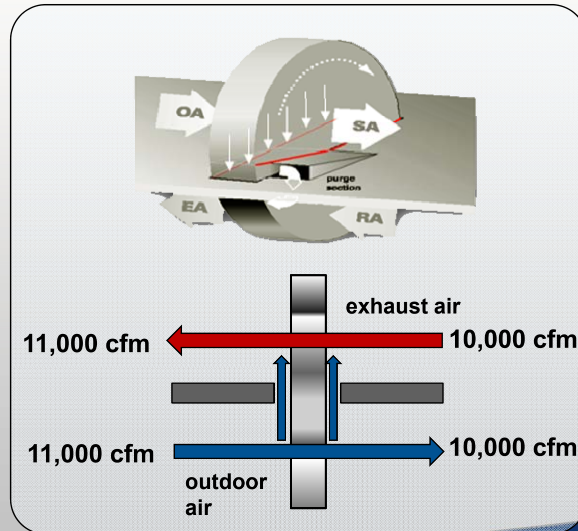


total-energy wheel
Cross-Leakage Measurements

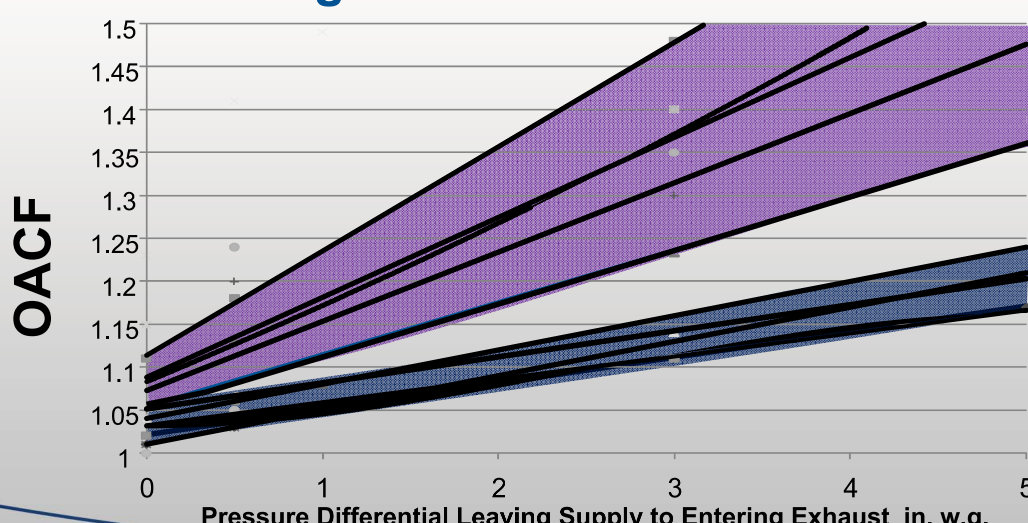
Outside Air Correction Factor
Ratio of outdoor air flow to supply air flow

OACF = OA cfm/SA cfm

Exhaust Air Transfer Ratio
The percentage of supply air that is exhaust air



total-energy wheel
Cross-Leakage Measurements

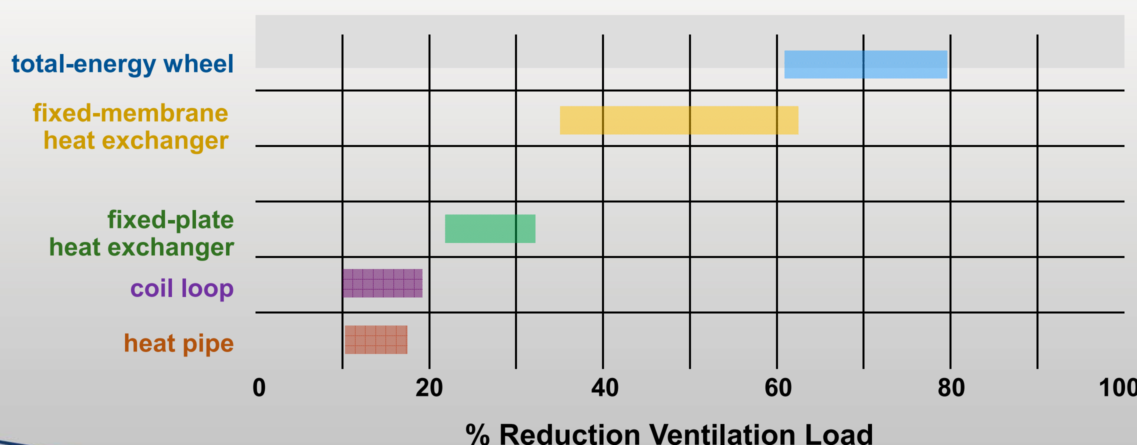


Total Energy Wheel Considerations

- Total energy recovery, must manage leakage, adjacent ducts
- Ventilation load-reduction (60% to 80% in all climates) meets Std 90.1 (50%) and Std 189.1 (60%)
- Proper fan placement can control pressures to reduce potential leakage

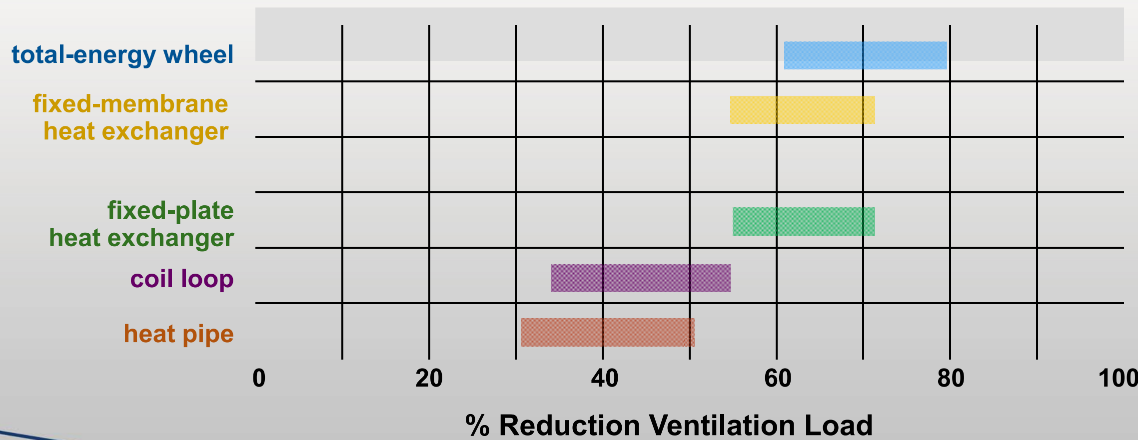
Comparison of Energy-Recovery Technologies

Reduction in Ventilation Cooling Load:
Region A "Moist"



Comparison of Energy-Recovery Technologies

Reduction in Ventilation Heating and Cooling Load:
Region B "Arid"



Comparison of Energy-Recovery Technologies
Recovery Efficiency Ratio

recovery efficiency ratio (RER): **a ratio of the energy recovered divided by the energy expended in the energy recovery process***

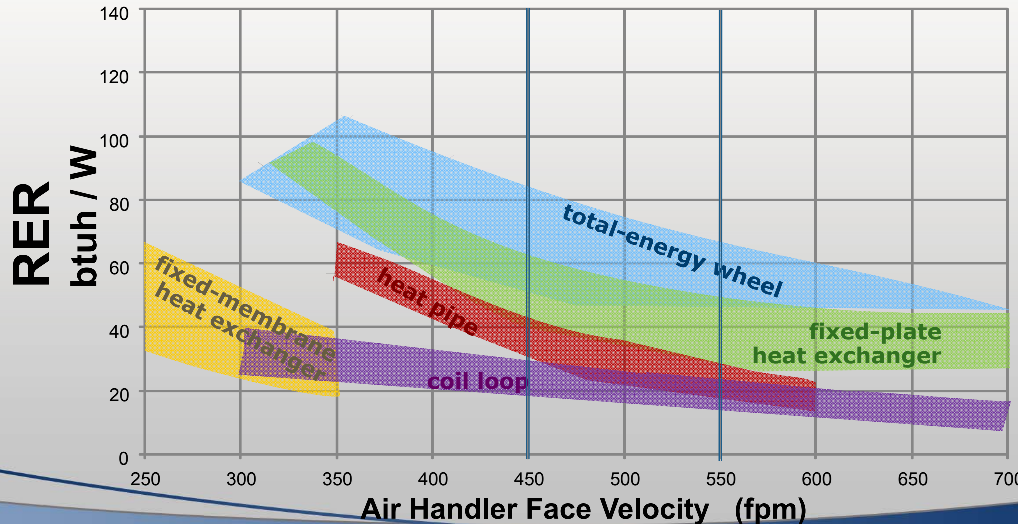
BTUH / W (cooling) or W / W (heating)

Power required	Coil loop	Heat pipe	Plate exchanger	Membrane cores	Energy wheel
Fan: Pressure Loss	●	●	●	●	●
Fan: Leakage/Purge					●
Component: Motor or Pump	●				●

***RER is defined by ASHRAE Std 84-2008 and AHRI Guideline V**

Comparison of Energy-Recovery Technologies

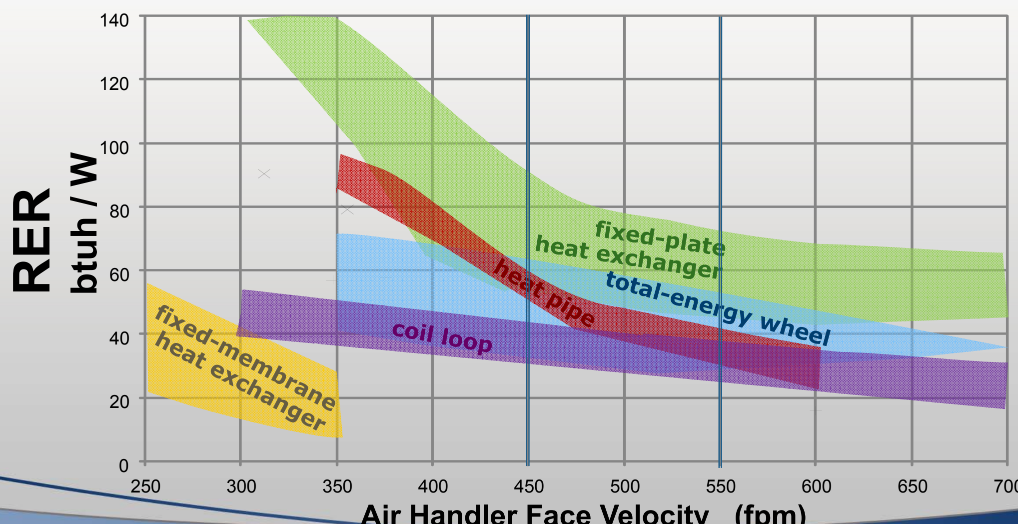
RER Cooling: Region A "Moist"



Based on
10,000 cfm
95ºF / 78ºF
OA 75ºF
55%RH RA

Comparison of Energy-Recovery Technologies

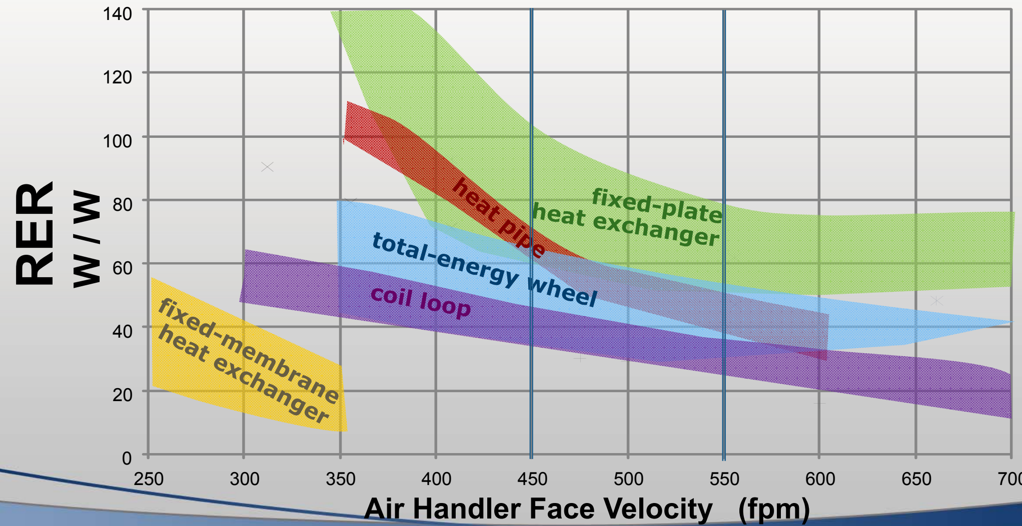
RER Cooling: Region B "Arid"



Based on
10,000 cfm
105ºF OA
75ºF 55%
RH RA

Comparison of Energy-Recovery Technologies

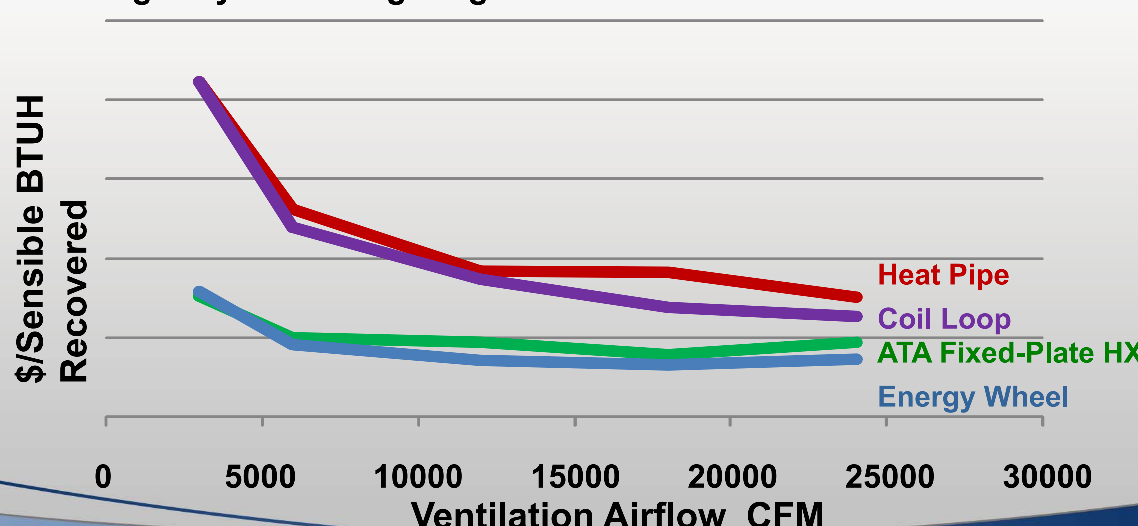
COP Coefficient of Performance: Heating



Based on
10,000 cfm
10ºF OA
70ºF no
frosting

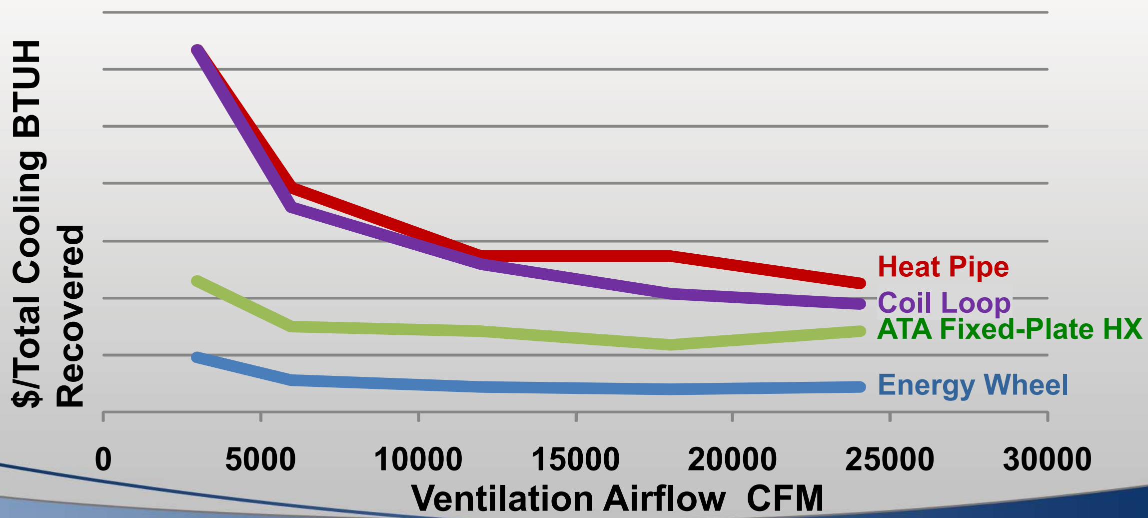
Installed Price Addition (AHU)

Heating Only or Cooling: Region B “Arid”



Installed Price Addition (AHU)

Cooling: Region A "Moist"



Conclusion: Which technology?

- Is cross leakage a concern?
  - Toxic, fume hoods, isolation rooms, etc.
    - ➔ Coil loop
  - Animal laboratory, natatorium
    - ➔ Fixed-plate HX, coil loop, heat pipe

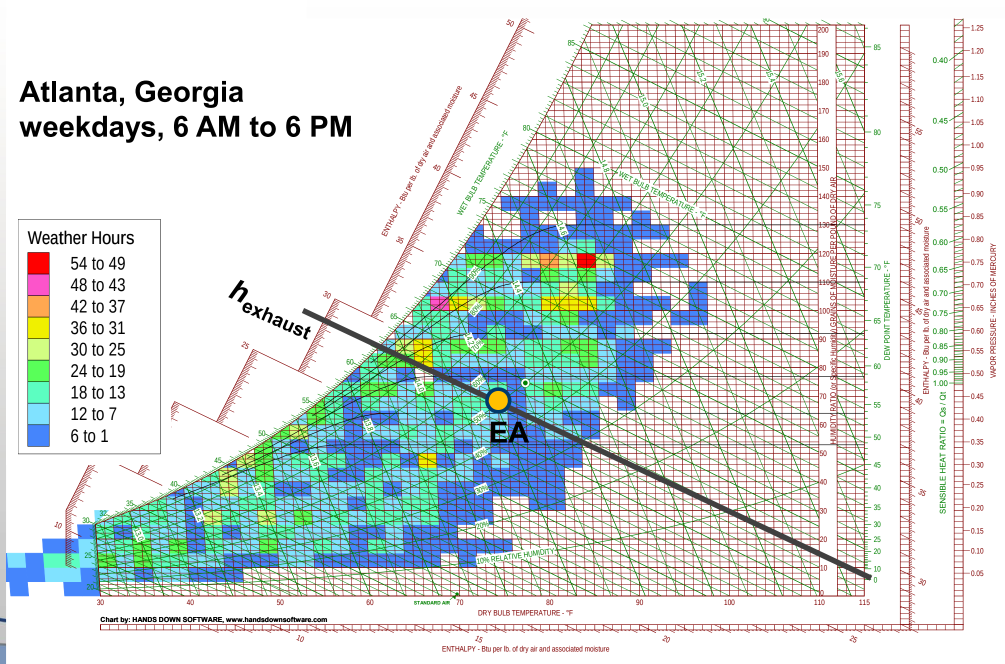
Conclusion: Which technology?

- Comfort cooling/heating application
  - Dry or arid climate
    - ➔ Fixed-plate heat exchanger
  - Humid or mixed climate
    - ➔ Total-energy wheel
  - Reduced footprint required
    - ➔ Coil loop, heat pipe

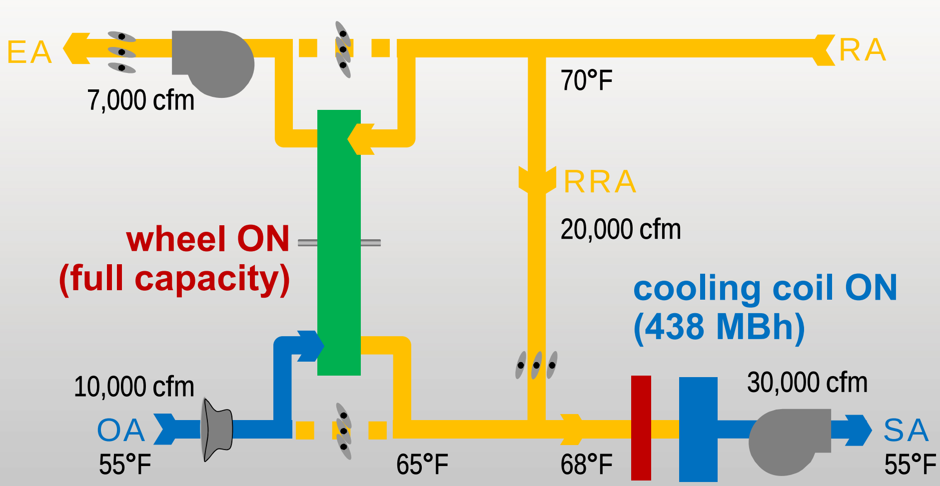
Agenda

engineers newsletter LIVE

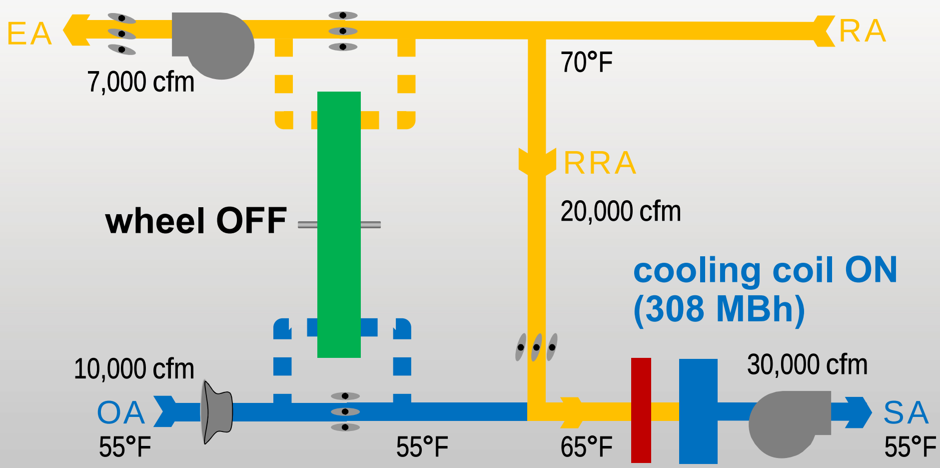
- Why implement exhaust-air energy recovery?
- Common air-to-air energy recovery technologies
- Proper control and integration into HVAC systems
  - On/off
  - Capacity modulation
  - Frost prevention
- Suggestions for cost-effective application



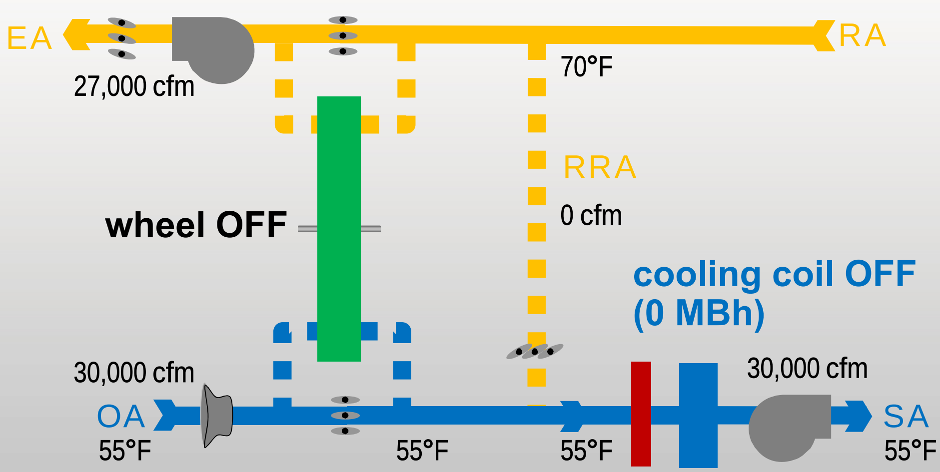
Control During Mild Weather



Control During Mild Weather

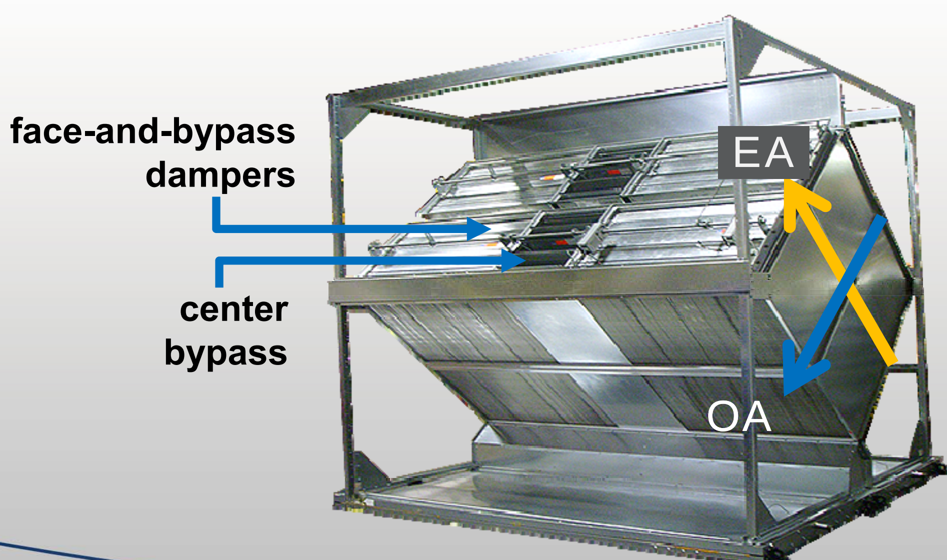


Control During Mild Weather



On/Off Control Methods

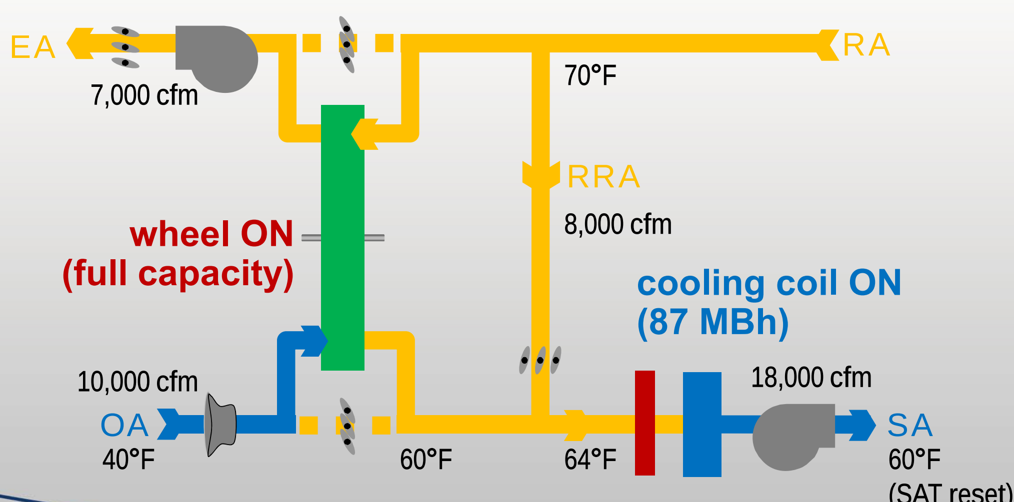
Coil loop	▪ Turn off pump
Heat pipe	
Fixed-plate heat exchanger	▪ Face-and-bypass dampers
Fixed-membrane heat exchanger	
Total-energy wheel	▪ Turn off wheel



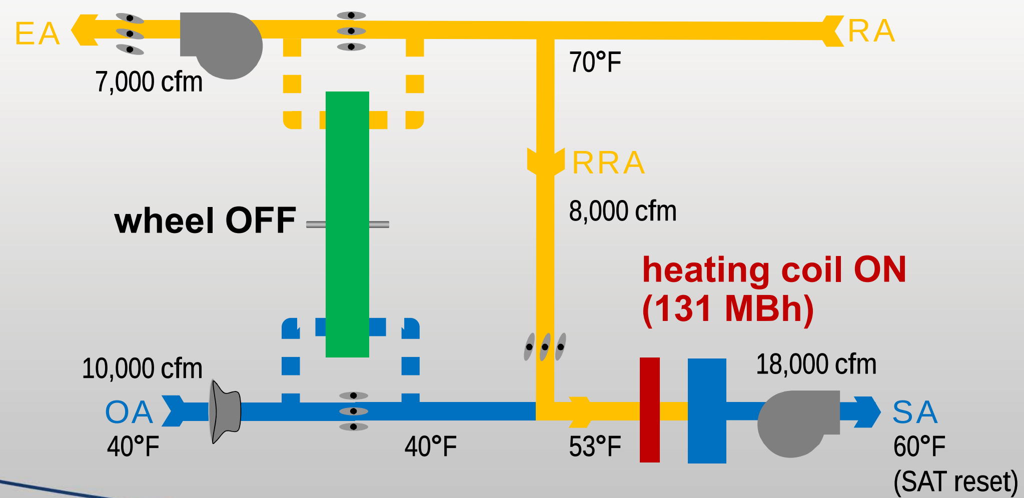
On/Off Control Methods

Coil loop	▪ Turn off pump
Heat pipe	▪ Face-and-bypass dampers ▪ Some use solenoid valve(s)
Fixed-plate heat exchanger	▪ Face-and bypass dampers
Fixed-membrane heat exchanger	▪ Face-and-bypass dampers
Total-energy wheel	▪ Turn off wheel

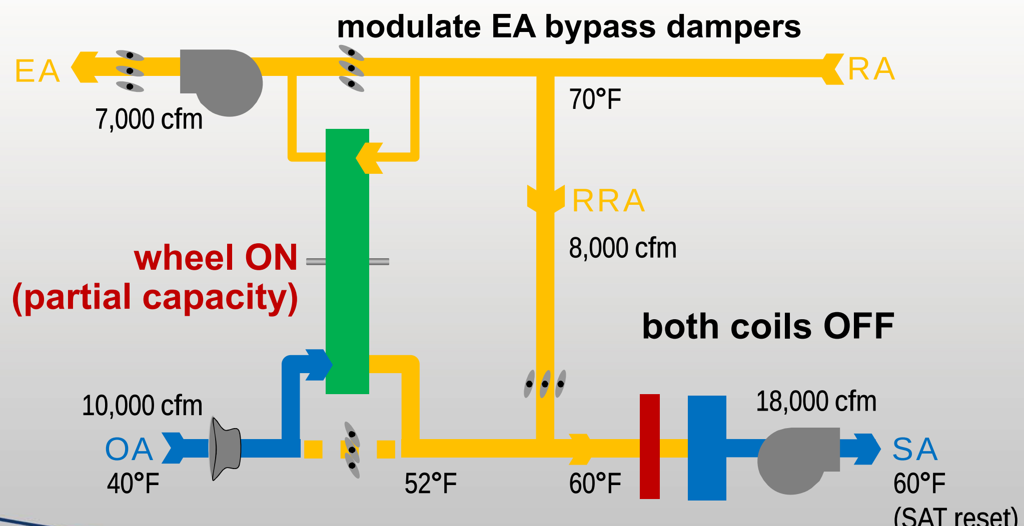
Control During Heating



Control During Heating



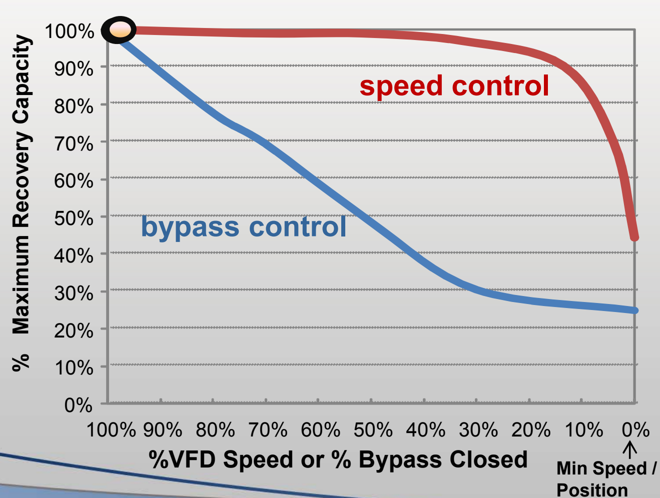
Control During Heating



Capacity Modulation Methods

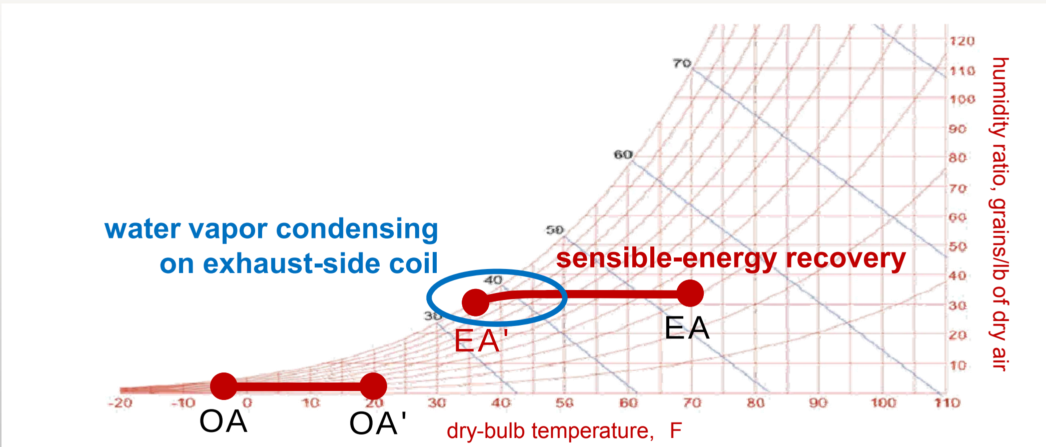
Coil loop	▪ Three-way mixing valve ▪ Vary pump speed
Heat pipe	▪ Face-and-bypass dampers ▪ Some use solenoid valve(s) ▪ Tilt mechanism
Fixed-plate heat exchanger	▪ Face-and-bypass dampers
Fixed-membrane heat exchanger	▪ Face-and-bypass dampers
Total-energy wheel	▪ Exhaust-side bypass damper ▪ Vary wheel speed

wheel
Comparison of Capacity Control Methods

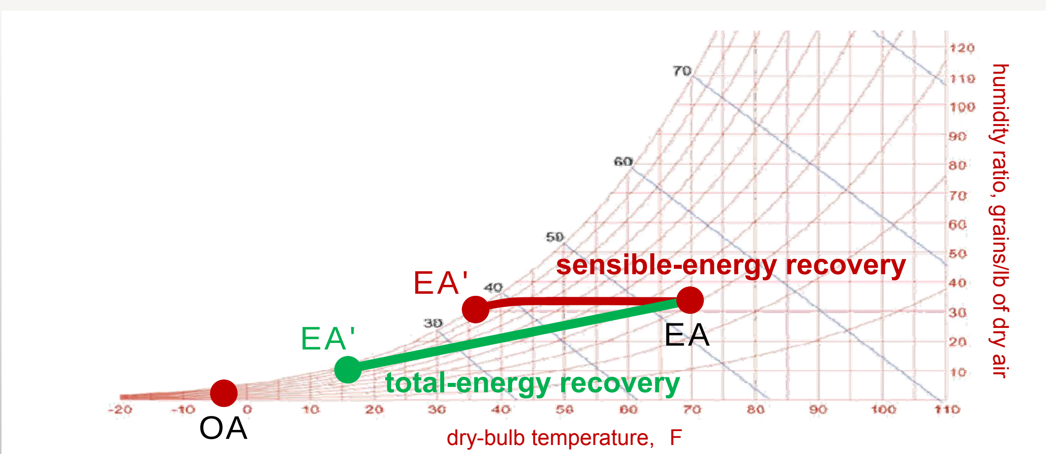


	Bypass control	Speed control
Cost	✓	
Control	✓	
Energy	✓	
Motor duty	✓	

Frosting



frosting
Total- vs. Sensible-Energy Recovery



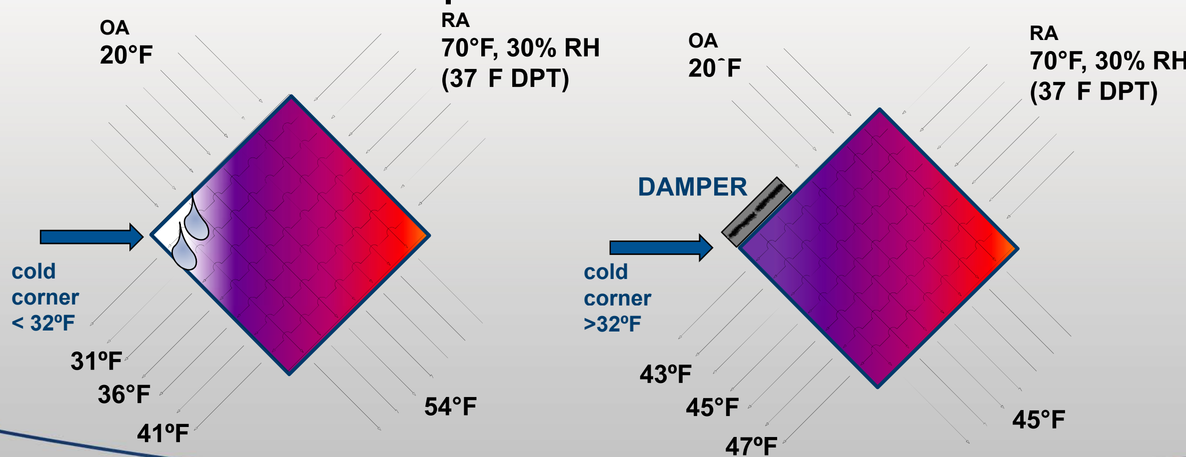
Frost Prevention Methods

Coil loop	▪ Three-way mixing valve
Heat pipe	▪ Face-and-bypass dampers
Fixed-plate heat exchanger	▪ Frost damper
Fixed-membrane heat exchanger	▪ Face-and-bypass dampers
Total-energy wheel	▪ Supply-side bypass damper

fixed-plate heat exchanger

Frost Prevention

Frost Avoidance Damper



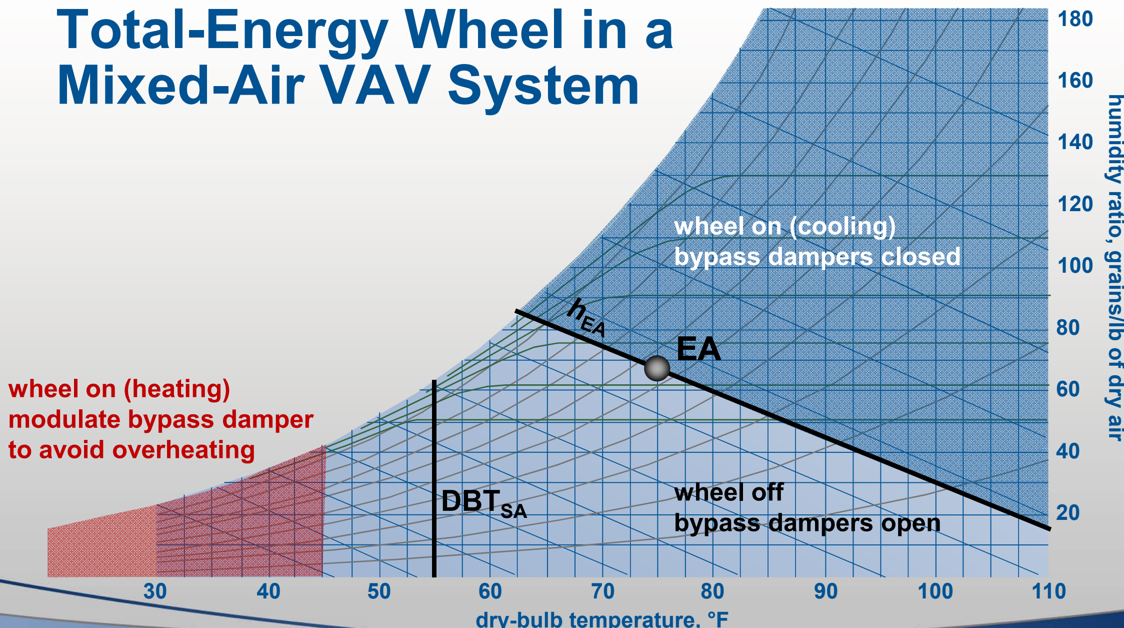
fixed-plate heat exchanger
Frost Prevention

- Fixed-*plate* (sensible) heat exchangers begin to experience frosting when entering OA drops < 25°F
- Use frost damper to minimize frosting (keeps higher temperature in the "cold corner")

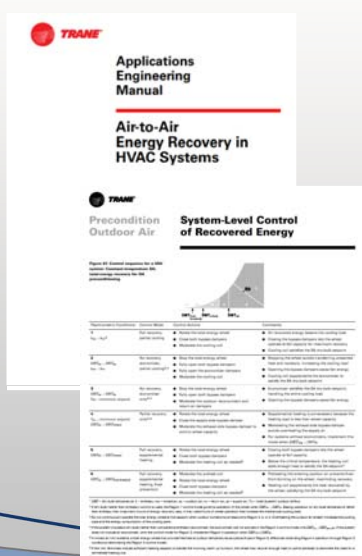
Frost Prevention Methods

Coil loop	▪ Three-way mixing valve ▪ OA or EA preheat
Heat pipe	▪ Face-and-bypass dampers ▪ OA or EA preheat
Fixed-plate heat exchanger	▪ Frost damper ▪ OA or EA preheat
Fixed-membrane heat exchanger	▪ Face-and-bypass dampers ▪ OA or EA preheat
Total-energy wheel	▪ Supply-side bypass damper ▪ OA or EA preheat

Total-Energy Wheel in a Mixed-Air VAV System



System Control Modes



Air-to-Air Energy Recovery in HVAC Systems, Trane application manual, SYS-APM003-EN

- Sensible- or total-energy recovery
- Mixed-air or dedicated OA system
- Constant- or variable-air volume
- DBT- or enthalpy-based control
- Airside economizers
- Energy recovery capacity control
- Frost prevention

Agenda

engineers newsletter LIVE

- Why implement exhaust-air energy recovery?
- Common air-to-air energy recovery technologies
- Proper control and integration into HVAC systems
- Suggestions for cost-effective application

Suggestions

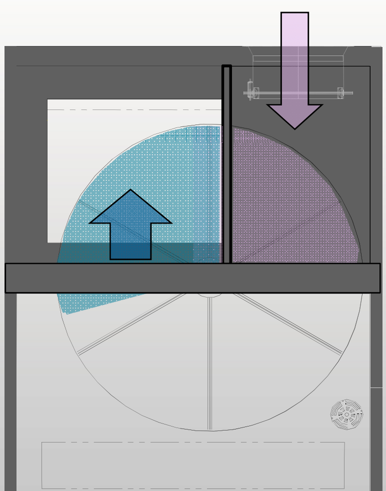
- ASHRAE 90.1-2010 (and 189.1-2011) requires exhaust-air energy recovery in more applications
- Total-energy recovery transfers both sensible heat and water vapor (latent heat)
  - Allows for larger cooling plant reductions
  - Less susceptible to frost, so greater heating energy savings

Suggestions

- Maximize energy recovery effectiveness
  - Centralize exhaust to better balance airflows and maximize recovery
  - Minimize cross-leakage with fan placement

maximizing energy recovery

Dual Exhaust Energy Recovery

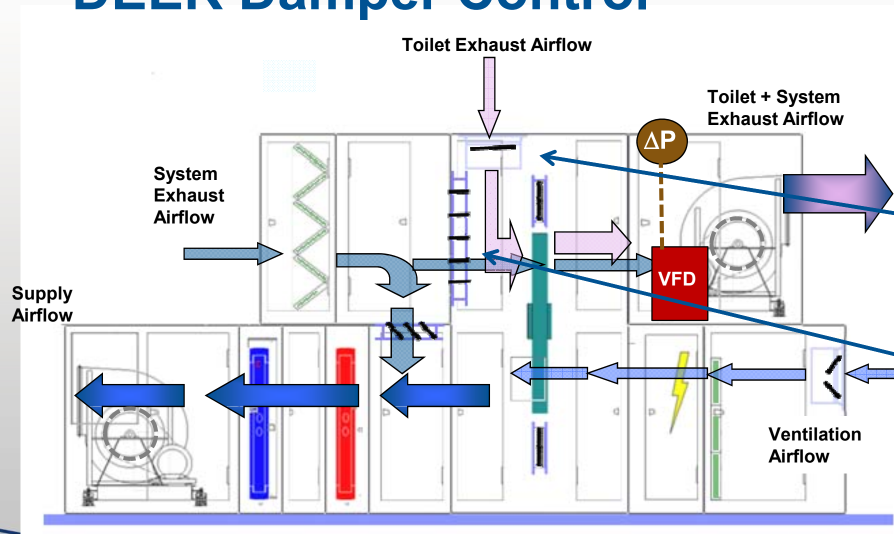


- Toilet exhaust air is isolated from return air
- Divider panel divides toilet and system exhaust air
- Toilet exhaust enters the first portion of the energy wheel
- System exhaust enters second portion of wheel
- System exhaust air purges wheel of toilet exhaust air

Toilet Exhaust Air Flow = Fixed amount set by code requirements

System Exhaust Air Flow = Varies to meet building pressure requirements

DEER Damper Control



Exhaust Fan
Fan speed modulates to control building pressure

Toilet Damper
Traq damper modulates to maintain code required toilet exhaust air flow

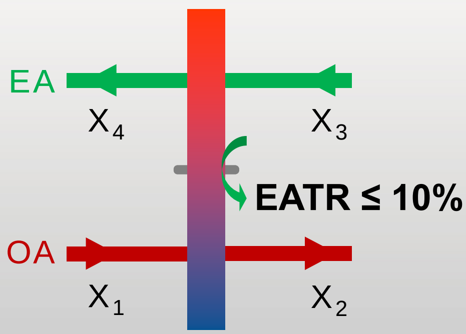
Balancing Damper
When toilet damper is 100% open, balancing damper modulates from minimum position to close to maintain toilet exhaust air flow

ASHRAE Standard 62.1-2010, Section 5.16.3.2.5
Recirculation of Toilet Exhaust

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

Exception: *When using an 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."*

Exhaust Air Transfer Ratio (EATR)



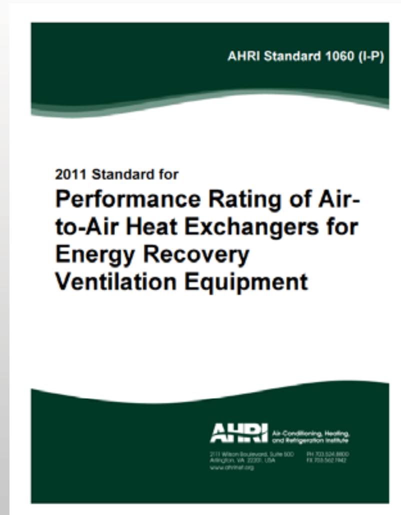
- Defined by ASHRAE Standard 84
- Certified by AHRI Standard 1060

Suggestions

- Proper control is very important
  - Turn device OFF during mild weather to avoid wasting energy
  - Modulate capacity during cold weather to prevent over-heating
  - Include bypass dampers to enable economizing in mixed-air systems
  - Don’t forget about frost prevention

Suggestions

- Specify/purchase AHRI-certified components
  - Trustworthy performance data, fewer third-party or field performance tests
  - More accurate sizing for improved design and application of air-handling equipment


AHRI Standard 1060 (I-P)

2011 Standard for
Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Ventilation Equipment

AHRI Air-Conditioning, Heating, and Refrigeration Institute

references for this broadcast
Where to Learn More

www.trane.com/EN

www.trane.com/ENL

Past program topics include:

- ASHRAE Standards 189.1, 90.1, 62.1
- High-performance VAV Systems
- Chilled-water plants
- Air distribution
- WSHP/GSHP systems
- Control strategies
- USGBC LEED®
- Energy and the environment
- Acoustics
- Ventilation
- Dehumidification
- Ice storage
- Central geothermal systems

EDUCATION PROVIDER

GBCI CMP

LEED Continuing Education Courses

on-demand, no charge, 1.5 CE credits

- ASHRAE Standards 62.1 and 90.1 and VAV Systems
- ASHRAE Standard 62.1: Ventilation Rate Procedure
- ASHRAE Standard 90.1-2010
- ASHRAE Standard 189.1-2011
- High-Performance VAV Systems
- Dedicated Outdoor Air Systems
- Ice Storage Design and Control
- Energy Saving Strategies for WSHP/GSHP Systems

GBCI CMP

EDUCATION PROVIDER

www.trane.com/ContinuingEducation

2013 Engineers Newsletter Live Programs

- Single-zone VAV Systems
- ASHRAE Standard 62.1
- Variable-speed Chiller Plant Operation

TRANE

Air-to-Air Energy Recovery

engineers newsletter LIVE

Ingersoll Rand

Bibliography

October 2012

Air-to-Air Energy Recovery

Industry Publications

Air-Conditioning, Heating, and Refrigeration Institute (AHRI). *ANSI/AHRI Standard 1060-2011: Performance Rating of Air-to-Air Heat Exchangers for Energy Recovery Equipment*. Available at www.ahrinet.org

Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory of Certified Product Performance available at www.ahridirectory.org

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). *ANSI/ASHRAE/IESNA Standard 90.1-2010: Energy Standard for Buildings Except Low-Rise Residential Buildings*. Available at www.ashrae.org/bookstore

American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE). *Standard 90.1-2010 User's Manual*. Available at www.ashrae.org/bookstore

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). *ANSI/ASHRAE/USGBC/IES Standard 189.1-2011: Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings*. Available at www.ashrae.org/bookstore

Trane Application Manual

Murphy, J. and B. Bradley. *Air-to-Air Energy Recovery in HVAC Systems*, application manual SYS-APM003-EN, 2008. Order from www.trane.com/bookstore

Analysis Software

Trane Air-Conditioning and Economics (TRACE™ 700). Available at www.trane.com/TRACE