

# Energy Recovery in Special Situations

Seminar 6: Sustainable Ventilation Systems for Commercial and  
Institutional Buildings  
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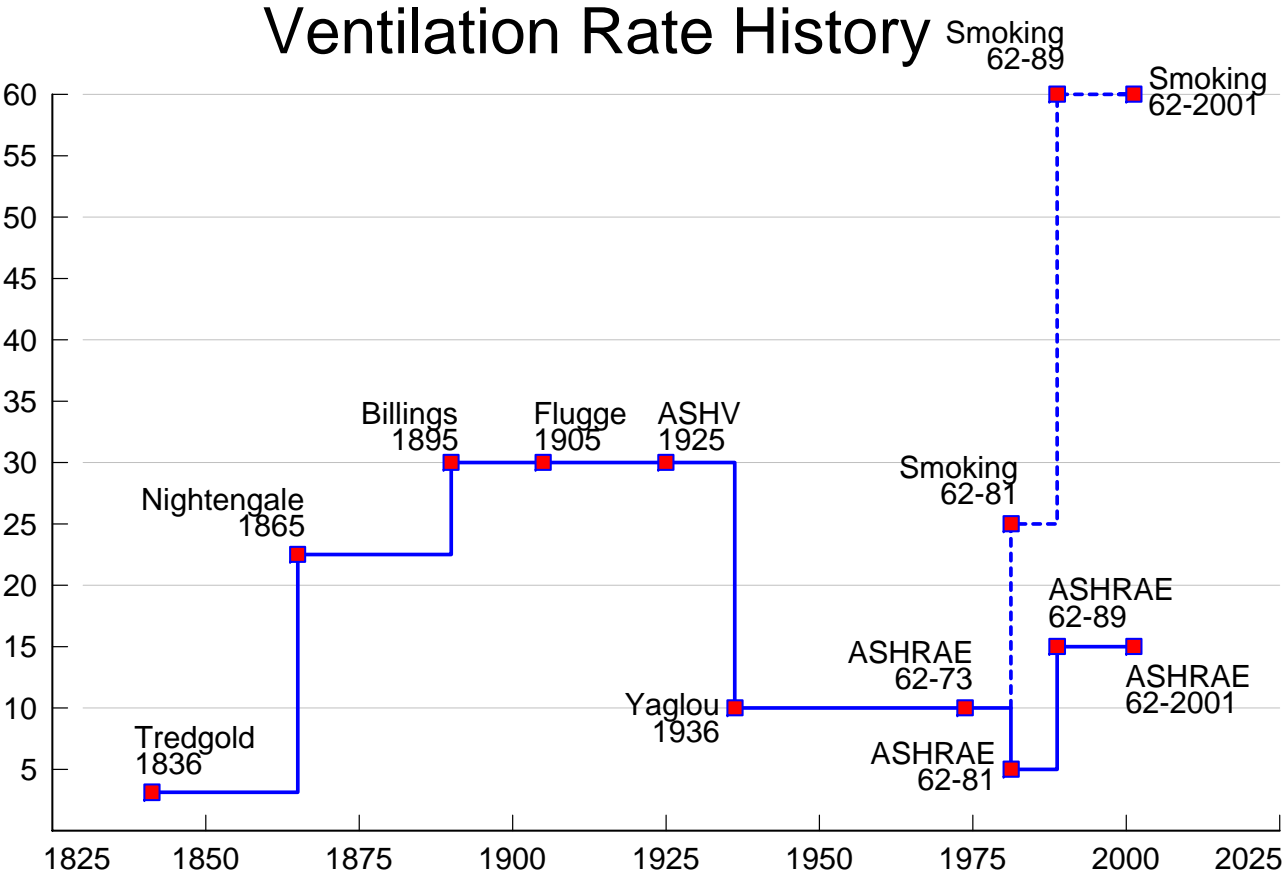


**Research Center**

Contributions from:

U.S. EPA, Research Triangle Park  
Building Performance Equipment

# Green Building Standards and Rating Systems are Driving Ventilation Rates Up Substantially Relative to Required Minimums



# The Energy Cost of Conditioning Outside Air May Be Higher Than Usually Believed

- The US EIA CBECS Survey has a category called “Ventilation Air”
  - It represents the fan energy to move supply air not the cost of conditioning the makeup air
- Conditioning makeup air can be up about 30% of the HVAC cost depending on the type of building and climate zone

# Green Building Ratings & Standards Require Substantial Energy Efficiency Compared to ASHRAE Standard 90.1

- To achieve high energy efficiency in the face of higher ventilation rates, green building designs are likely to increasingly use air-to-air energy recovery to accomplish this goal.
- Natural ventilation will not be able to be used for all climates, seasons, and building types.
  - Mixed mode and ordinary HVAC systems will still be needed to establish indoor comfort.
  - In climates with a heating season, more energy recovery occurs during the heating season than during the cooling season due to the greater average difference between indoor and outdoor temperatures.
  - Air-to-air energy recovery is possible when the indoor conditions are milder than the outdoor conditions

# ASHRAE GreenGuide and Energy Recovery

- Energy recovery is known to work well and is in regular use for schools, offices, and in other ordinary situations
- The GreenGuide specifically discusses the use of “heat recovery” as an option for green design in many specialty types of buildings
- A lifecycle costing approach is always recommended
- The energy consumed by the additional pressure drop of the energy-recovery-device is specifically mentioned as something that must be included in the evaluation

# ASHRAE GreenGuide Guidance

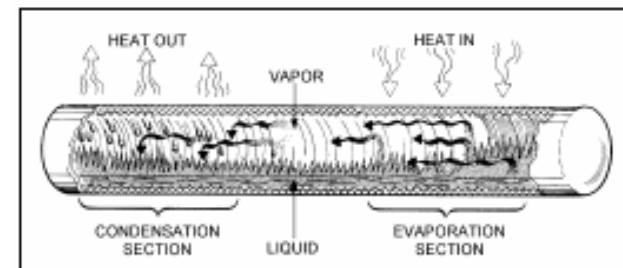
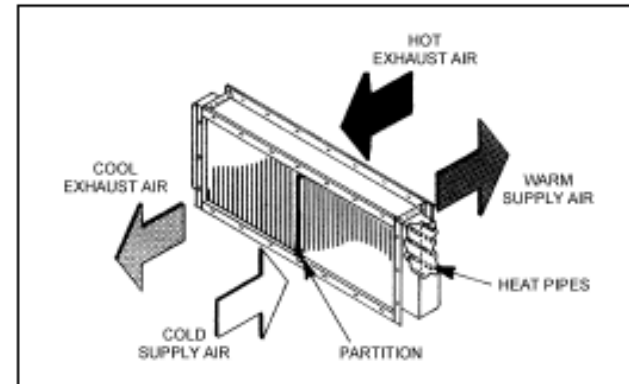
Building Type	Guidance
Performing Arts	DOAS & >50% OA AHU's
Health Care	DOAS
Laboratories	DOAS & >50% OA AHU's
Student Residence Halls, Hotels, Apartments, Condos	DOAS to living spaces. Use toilet exhaust.
Athletic/Recreation Facilities	DOAS & >50% OA AHU's
Swimming Pools	In moderate climates use heat recovery without mechanical cooling

# GreenGuide Guidance Configurations

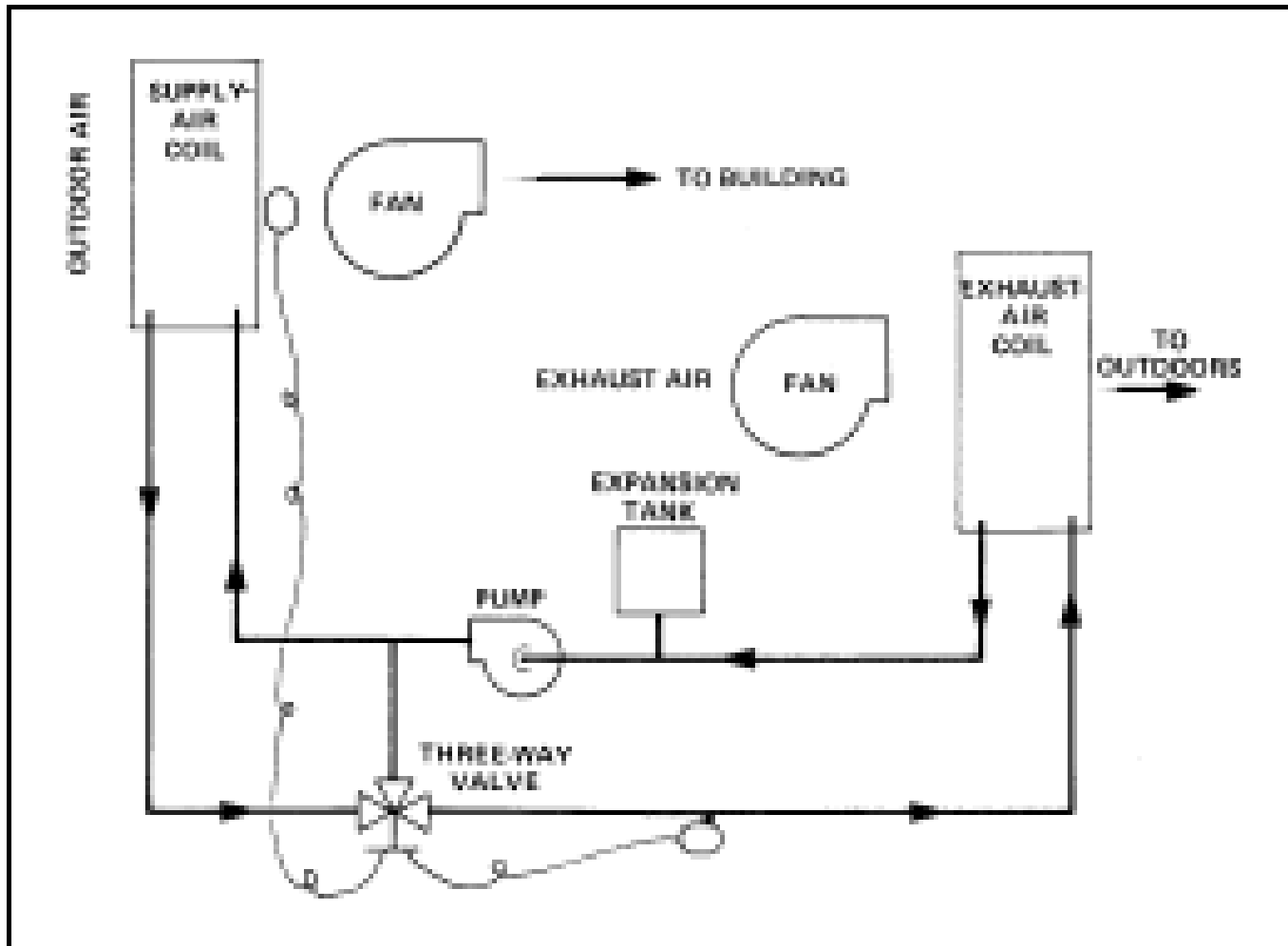
Flat plate: dry, wetted, & membrane	HRV & ERV; evap. Combo
Wheel: Heat & Enthalpy	HRV & ERV
Heat Pipe – internal phase change causes enhanced heat transfer	Sensible only; good for contaminated streams and when proximity is not an issue
Runaround Loop – pumped fluid; no phase change	Sensible only; Heat transfer fluid; good for contaminated streams and when proximity is an issue
Thermosyphon – driven by thermal gradients without pumps	Mentioned but not discussed in GreenGuide
Twin Towers – pumped lines between cooling/heating towers	Mentioned but not discussed in GreenGuide

# Heat Pipe Concept

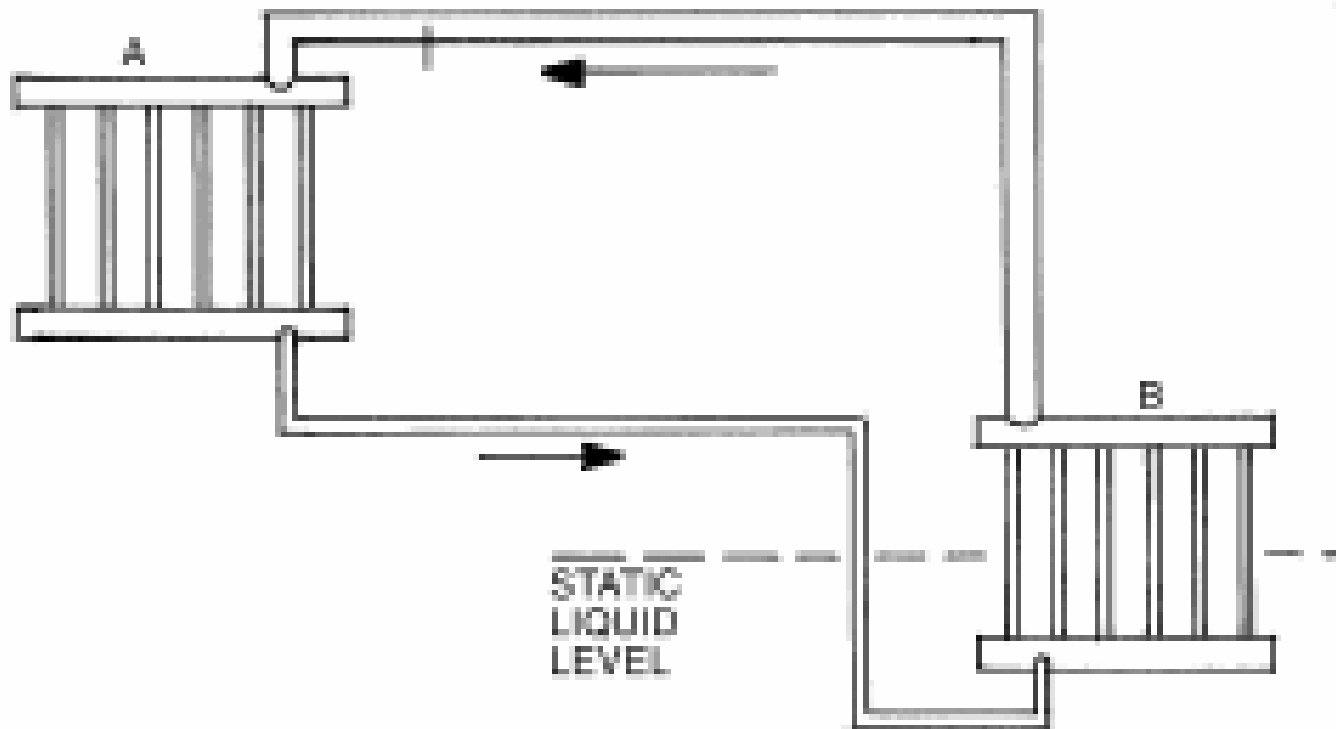
- No pump is required
- Phase change of working fluid enhances heat transfer
- Proximity is needed



# Runaround Loop Concept



# Unidirectional Thermosyphon



UNIDIRECTIONAL LOOP  
(Transfers energy only from B to A)

# Twin Tower Concept

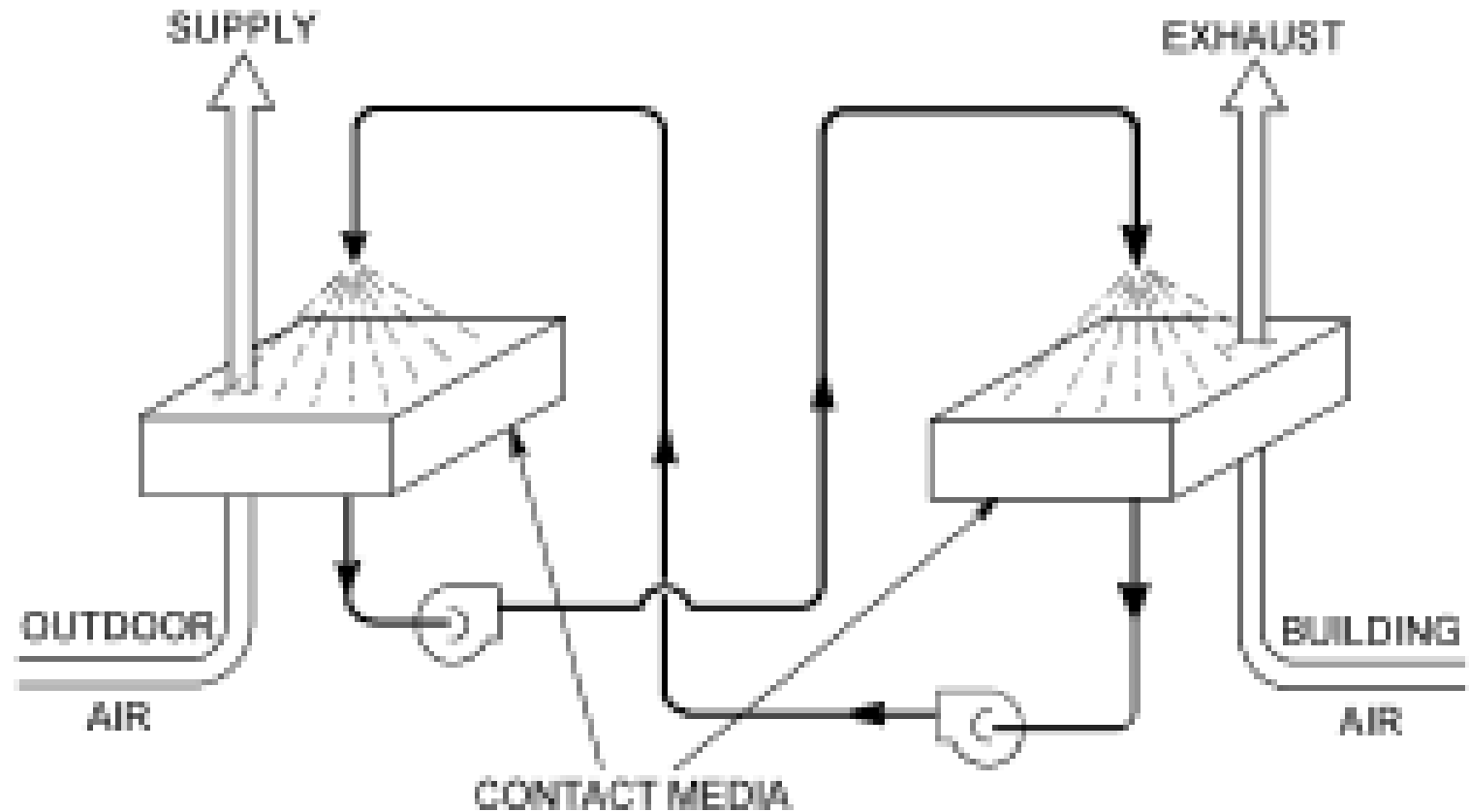


Fig. 21 Twin Tower Enthalpy Recovery Loop

# Chapter 44 Selection Table

Table 2 Comparison of Air-to-Air Energy Recovery Devices

	Fixed Plate	Rotary Wheel	Heat Pipe	Runaround Coil Loop	Thermosiphon	Twin Towers
Airflow arrangements	Counterflow Cross-flow Parallel flow	Counterflow Parallel flow	Counterflow Parallel flow	Counterflow Parallel flow	Counterflow Parallel flow	
Equipment size range, cfm	50 and up	50 to 70,000	100 and up	100 and up	100 and up	
Type of heat transfer (typical effectiveness)	Sensible (50 to 80%) Total (55 to 85%) Treated paper and poly membrane	Sensible (50 to 80%) Total (55 to 85%)	Sensible (45 to 65%)	Sensible (55 to 65%)	Sensible (40 to 60%)	Sensible (40 to 60%)
Face velocity, fpm (most common design velocity)	100 to 1000 (200 to 1000)	500 to 1000	400 to 800 (450 to 550)	300 to 600	400 to 800 (450 to 550)	300 to 450
Pressure drop, in. of water (most likely pressure)	0.02 to 1.8 (0.1 to 1.5)	(0.25 to 1.0)	(0.4 to 2.0)	(0.4 to 2.0)	(0.4 to 2.0)	0.7 to 1.2
Temperature range	-70 to 1500°F	-70 to 200°F	-40 to 95°F	-50 to 900°F	-40 to 104°F	-40 to 115°F
Typical mode of purchase	Exchanger only Exchanger in case Exchanger and blowers Complete system	Exchanger only Exchanger in case Exchanger and blowers Complete system	Exchanger only Exchanger in case Exchanger and blowers Complete system	Coil only Complete system	Exchanger only Exchanger in case	Complete system
Unique advantages	No moving parts Low pressure drop Easily cleaned	Latent (moisture mass) transfer Compact large sizes Low pressure drop	No moving parts except tilt Fan location not critical Allowable pressure differential up to 60 in. of water	Exhaust airstream can be separated from supply air Fan location not critical	No moving parts Exhaust airstream can be separated from supply air Fan location not critical	Latent transfer from remote airstreams Multiple units in a single system Efficient microbiological cleaning of both supply and exhaust airstreams
Limitations	Latent available in hygroscopic units only	Cold climates may increase service Cross-air contamination possible	Effectiveness limited by pressure drop and cost Few suppliers	High effectiveness requires accurate simulation model	Effectiveness may be limited by pressure drop and cost Few suppliers	Few suppliers
Cross-leakage	0 to 5%	1 to 10%	0%	0%	0%	0.025%
Heat rate control (HRC) schemes	Bypass dampers and ducting	Wheel speed control over full range	Tilt angle down to 10% of maximum heat rate	Bypass valve or pump speed control over full range	Control valve over full range	Control valve or pump speed control over full range

# Barriers to Wider Use of Energy Recovery in Green Buildings

## Discussed in Recent Forums

- Addressed with Software Tools
  - Uncertainty about the value proposition (lifecycle costing; price vs. quantity produced)
  - Uncertainty about technology selection and sizing
- Addressed with Frequency of Use, Case Studies, Manufacturing Improvements, Local Support
  - Fear that downsized plant will not meet customer demand if energy recovery device malfunctions (reliability; mean time to repair)
  - No customer pull; lack of experience; not required by standards or codes

## Special Situations Where Energy Recovery May Be Possible If Done Properly

- Unbalanced Situations – lack of qualified exhaust air
- Spatial constraints – proximity and profile
- Potential for odorous or hazardous materials in exhaust stream
- Presence of particulates in exhaust stream

# Balance and Effectiveness

- Optimal effectiveness is achieved if equal mass flows are used for inlet and exhaust flows
  - Other uses of exhaust in a building (toilets, kitchen hoods) prevent operation at the optimal situation making the unit exhaust starved
  - Solution 1: Get more exhaust – if possible use toilet exhaust – if the leakage is low enough use may be permissible
  - Solution 2: Downsize the ERD to make the outside air equal to the exhaust that is available and bypass the extra OA. This helps with the first cost.

# Spatial Constraints – Profile

- Customers don't want rooftop equipment to be visible from ground level
- Enthalpy wheels are generally oriented in a low profile orientation
- Other technologies can also be low profile



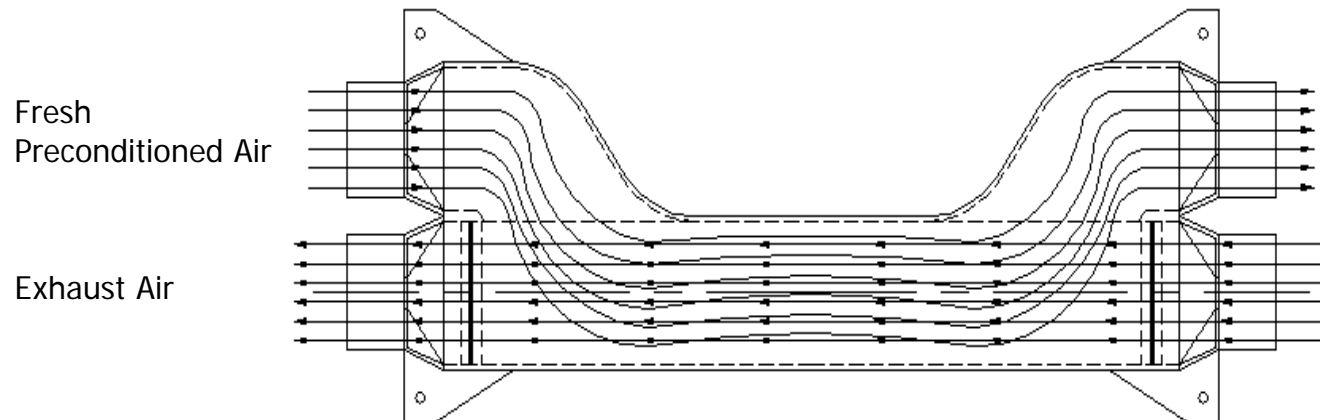
# Spatial Constraints - Proximity

- The desired position for exhaust vents is not near the air intake position
- Use a configuration with a pumped solution between the exhaust and inlet locations – e.g., a runaround loop
- Exhausts may be manifolded to aggregate the air so as to nearly balance the supply air

# Odorous But Non-Toxic Exhausts

- Use a technology that has essentially a reliable zero leakage rate (e.g., flat-plate HRV)
- Keep the supply side at positive pressure relative to the exhaust side under all building operation conditions
  - use blow-through on the supply side and draw-through on the exhaust side
- Use a device with a small leakage rate but a purge stream to dilute any crossover air (e.g., enthalpy wheel)

# Example



# Hazardous Exhaust

- Laboratory Hoods – high outside air rates, high conditioning expense, and potential for hazardous materials in the exhaust
- EPA Labs21 Program has generated much guidance
- Manifold multiple hood exhausts and use a technology such as a runaround loop to precondition outside air

# Example: Runaround Loop in a Laboratory Situation

- Pumped Glycol System
- Fan pressure drop expense should be less than value of energy recovered



# Particulates in Flow

## Low Companion VOCs

- Difficult if particles can agglomerate or condense out on the device
- Particle separation methods can remove large particles
- Laminar flow elements have boundary layers which can keep small particles moving through the ERD device
- Periodic blowout/backflushing may be needed

# Particulates in Flow With Condensable VOCs

- With condensable VOCs
  - FOG in kitchen exhaust; cannot cool the exhaust air
  - Must use a whole building approach to “temper” incoming air and deliver it to the zone of influence of the hood without causing discomfort to kitchen personnel
  - Some emerging technology to catalytically remove or scrub condensed material; this may permit future energy recovery with the cleaner exhaust

# Conclusions

- Green building rating systems and future standards are increasingly mandating energy recovery
- Technology maturation and selection tool availability have improved greatly
- As the volume of manufacture of components increases, lifecycle costs should continue to drop
- Many applications have become routine
- Many of the special situations once thought impossible can increasingly be handled

Thank you.

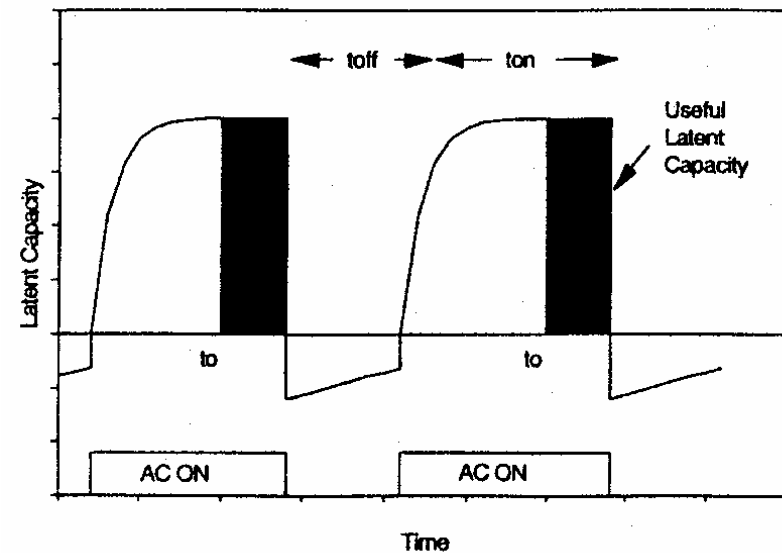
Any Questions?

Backup

# ERV's Help Mitigate Compressor Cycling Effects and Improve Humidity Control

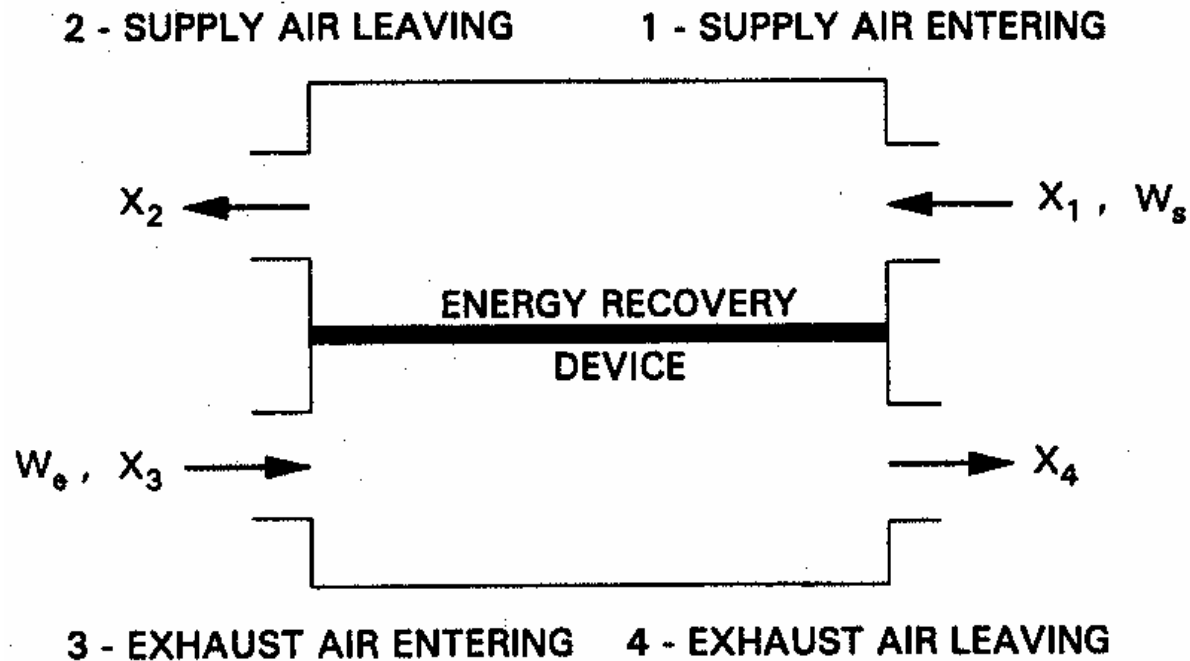
- Preconditioning the outside air keeps the HVAC coil cooler during compressor-off periods
- Downsizing the HVAC coil using "System Effective EER" concepts leads to smaller coil area and therefore less end of cycle re-evaporation into the supply air while the outside air is on but the compressor-off

ASHRAE Transactions: Research, Vol. 102,  
No. 1, Paper 3958, pp. 266-274, 1996.



*Figure 1* Condensate removal and evaporation at quasi-steady cyclic conditions.

# Generalized ERV Equations

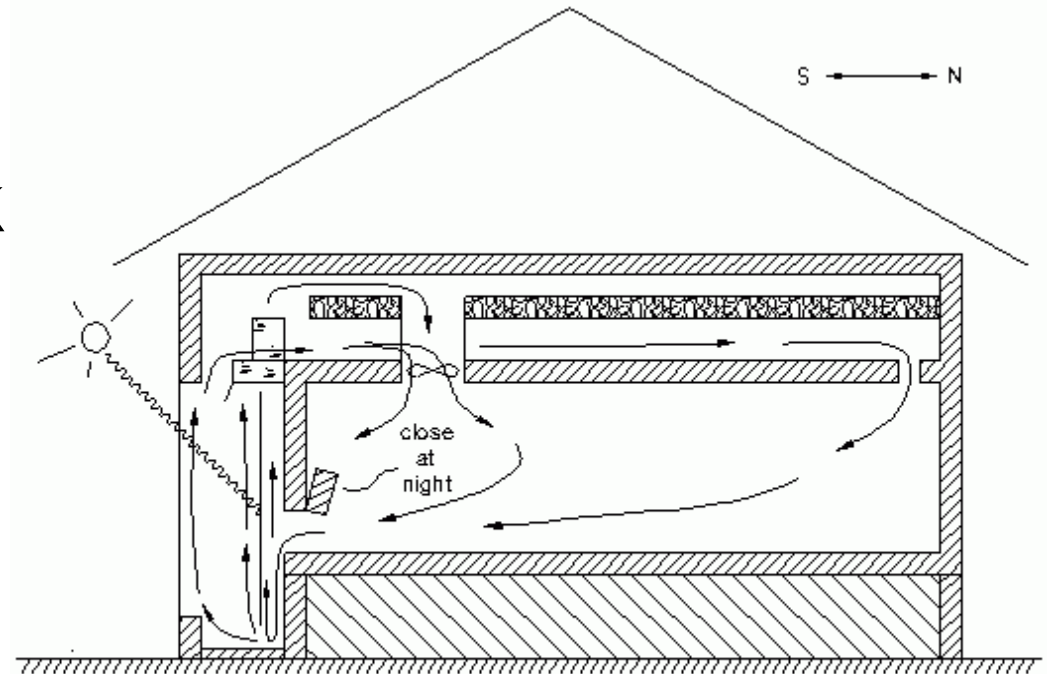


$$X_2 = X_1 + \varepsilon \cdot (W_{\min} / W_s) (X_3 - X_1)$$

$$X_4 = X_3 - \varepsilon \cdot (W_{\min} / W_e) (X_1 - X_3)$$

# Air Thermosyphon

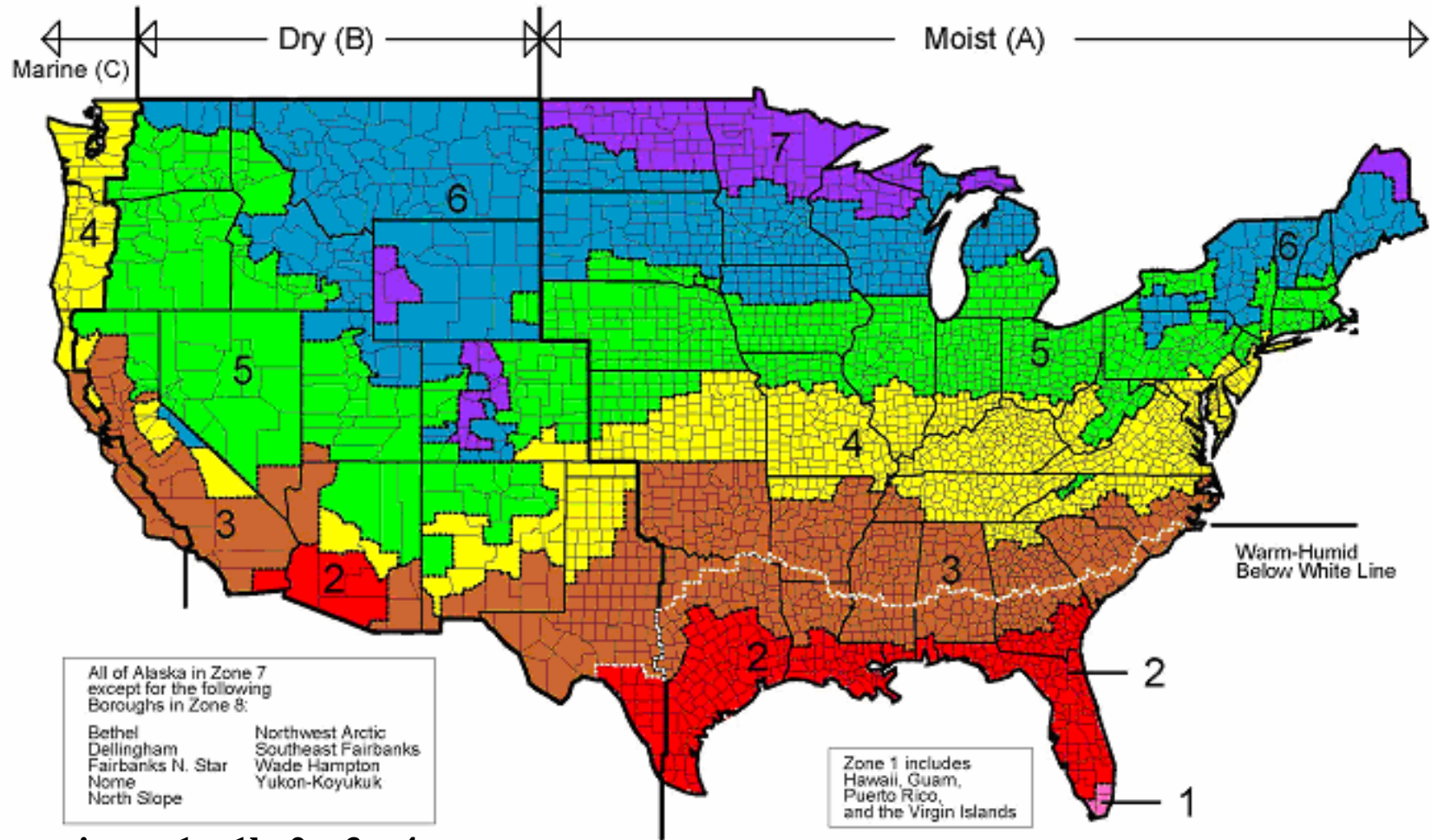
- Solar-heat induced circulation
- Preferably no fan
- Usually has check valve for “off” periods



*David Delaney, Ottawa, November 6, 2004*

Emergency configuration for fan failure

# CLIMATE ZONES



**No economizer – 1a, 1b, 2a, 3a, 4a**

**Economizer – 2b, 3b, 3c, 4b, 4c, 5, 6, 7, 8**