Commissioning, Operating and Maintaining Air-to-Air Energy Recovery Systems

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Commissioning, Operating and Maintaining Air-to-Air Energy Recovery Systems

- Course Description
- How does one commission energy savings equipment such as air-to-air energy recovery? What are key performance factors that must be measured? When can you simulate and when must you measure? Devices addressed include air-to-air energy recovery plates and wheels, desiccants, run around loops, and water-side economizers.

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Course ID: 0920010385

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General CE hours

LEED-specific hours

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Learning Objectives

- After attending this presentation, participants will be able to:
  - Identify the different types of air-to-air energy recovery systems
  - Distinguish between heat recovery systems and energy recovery systems
  - Describe the types of measurements that must be made in order to commission these systems in the field
  - Explain the importance of operations and maintenance in sustaining energy performance

What is the Purpose of Air-to-Air Energy Recovery?

- Recover energy by exchanging energy but not contaminants between outdoor air and building exhaust streams.
- Ventilation standards ASHRAE 62.1-2016, ASHRAE 62.2-2016, ASHRAE 170-2013 contain minimum requirements for the rate of outdoor air provided to spaces.

When to Use Air-to-Air Energy Recovery?

- When there is a high air exchange in the building
  - Office ~1 ACH
  - High occupancy office space ~2 ACH
  - Hospital Operating Room 12 ACH
  - Research Laboratories 10-12 ACH
  - Hospital patient rooms >2 ACH
- When outdoor air and exhaust air streams are in proximity
- When cost justified or
- When achieves energy design target

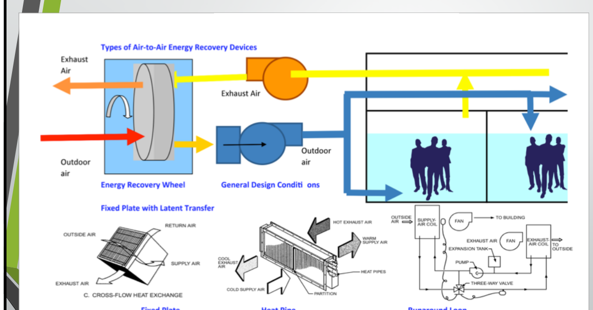
Air-to-Air Energy Recovery Systems

- Types of Systems
- Commissioning Issues
- Operating and Maintaining

Air-to-Air Energy Recovery Common Systems Types

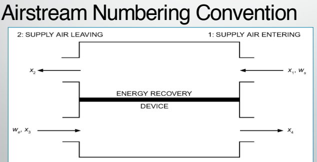
- Heat recovery systems (sensible only)
  - Plates
  - Heat pipes
  - Run around loops
- Energy recovery systems (sensible + latent)
  - Plates with membrane
  - Wheels
  - Liquid Desiccants
  - Twin Towers

Energy Recovery Ventilation – Reducing Energy Use

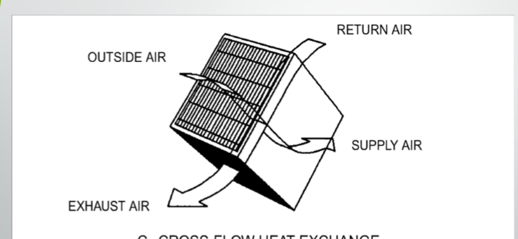


Commissioning Heat Recovery Systems (1)

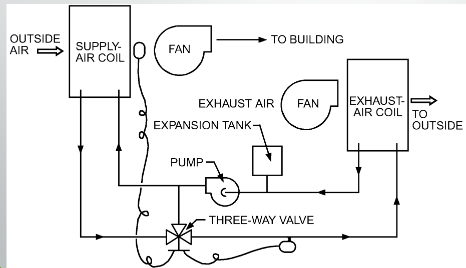
- From 2016 ASHRAE HVAC Systems and Equipment Handbook Chapter 26
- Figure 1. Airstream Numbering Convention



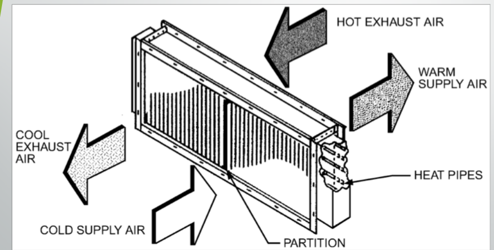
Cross Flow Plate



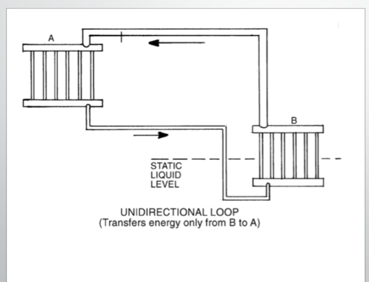
Run Around Loop



Heat Pipe



Thermal Siphon



Heat Transfer – Sensible Effectiveness

- From Figure 1, the sensible effectiveness ε_s of a heat recovery ventilator is given as
- $$\varepsilon_s = \frac{q_s}{q_{s,max}} = \frac{m_s c_{ps}(t_2 - t_1)}{C_{min}(t_3 - t_1)} = \frac{m_s c_{pe}(t_3 - t_4)}{C_{min}(t_3 - t_1)} \quad (2a)$$
- *where*

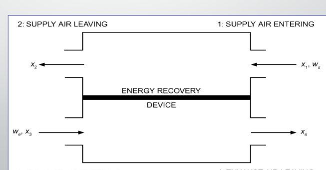
ε_s = sensible effectiveness
t_1 = dry-bulb temperature at location 1 in Figure 1, °F
m_s = supply dry air mass flow rate, lb/min
m_e = exhaust dry air mass flow rate, lb/min
C_{min} = smaller of $c_{ps}m_s$ and $c_{pe}m_e$
c_{ps} = supply moist air specific heat Btu/lb · °F
c_{pe} = exhaust moist air specific heat Btu/lb · °F

Commissioning Heat Recovery Systems (2)

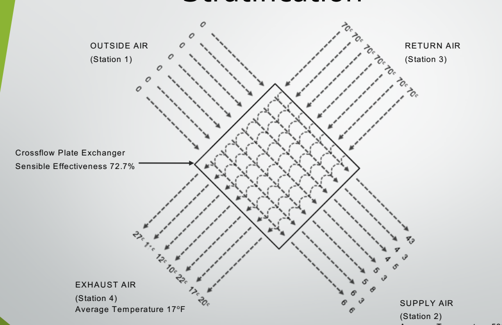
- Should measure t_1, t_2, t_3, t_4, m_s, m_e
- Note that airstreams may be stratified!

OUTSIDE AIR	
Dry-bulb	95°F [35°C]
Wet-bulb	78°F [26°C]

ROOM AIR	
Dry-bulb	70°F [21°C]
Wet-bulb	58°F [14°C]

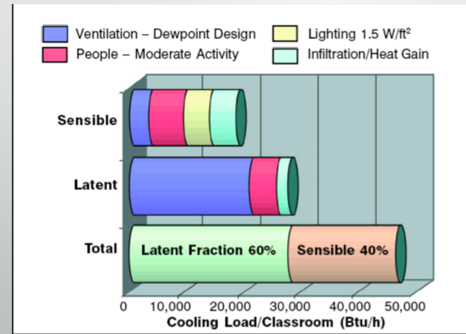


Stratification

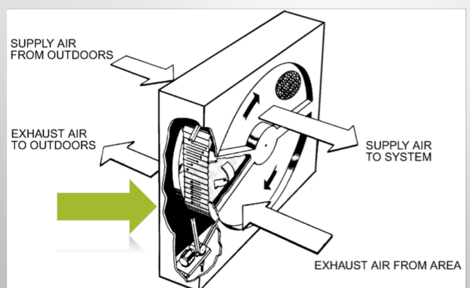


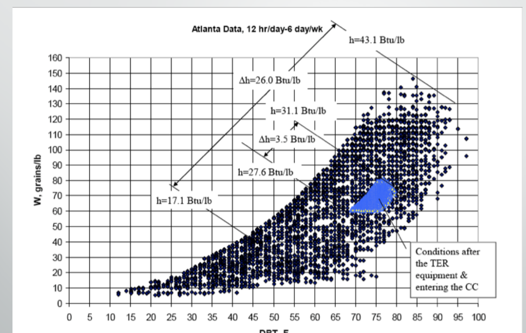
Commissioning Heat Recovery Systems (3)

- Parasitic power and energy losses (examples)
  - Airside pressure drops including filters
  - Pump energy in runaround loops
- Control issues (examples)
  - Frosting
  - Condensing
  - Transferring energy in wrong direction (example: 55˚ F outdoor air when zone requires cooling)

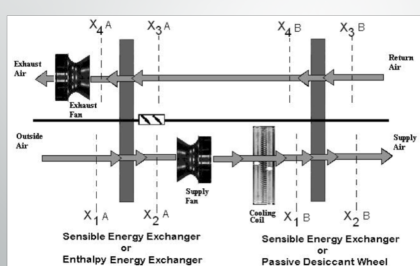


Rotary Energy Recovery Wheel

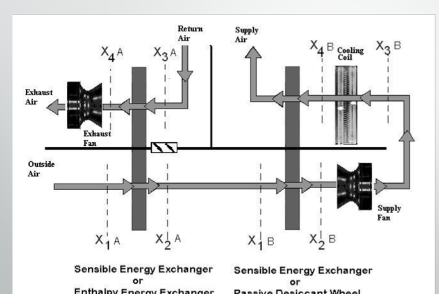




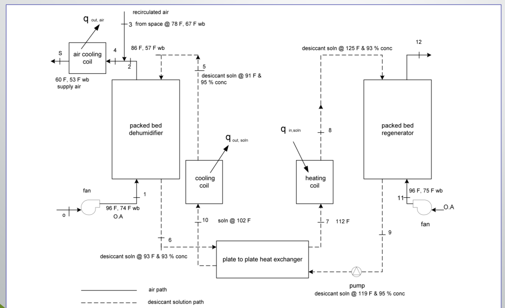
Multiple Energy Recovery Exchangers in Parallel Mode



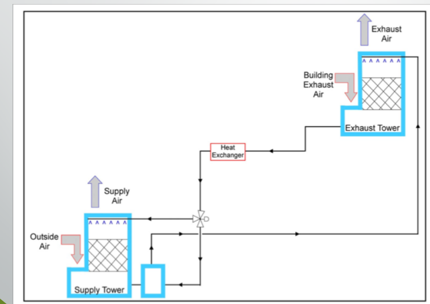
Multiple Energy Recovery Exchangers in Series Mode



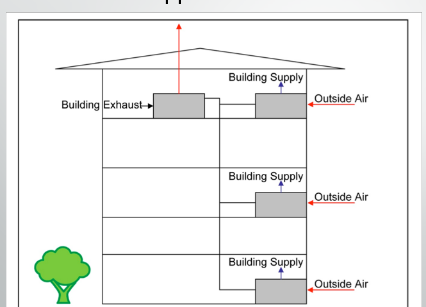
Liquid Desiccant System



Twin Tower Loops



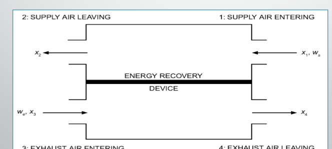
Twin Tower Application



Commissioning Energy Recovery Systems (1)

From 2016 ASHRAE HVAC Systems and Equipment Handbook Chapter 26

Figure 1. Airstream Numbering Convention



Energy Transfer – Total Effectiveness

- The total effectiveness ε_t of an energy recovery ventilator is given as
- $$\varepsilon_t = \frac{q_t}{q_{t,max}} = \frac{m_s(h_2 - h_1)}{m_{min}(h_3 - h_1)} = \frac{m_e(h_3 - h_4)}{m_{min}(h_3 - h_1)} \quad (6a)$$
- *where*

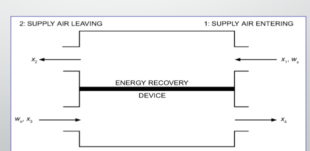
  ε_t = total effectiveness
  h = enthalpy at locations indicated in Figure 1, Btu/lb
  m_s = supply dry air mass flow rate, lb/min
  m_e = exhaust dry air mass flow rate, lb/min
  m_{min} = smaller of m_s and m_e

Commissioning Energy Recovery Systems (2)

- Should measure h_1, h_2, h_3, h_4, m_s, m_e

OUTSIDE AIR	
Dry-bulb	95°F [35°C]
Wet-bulb	78°F [26°C]

#3: ROOM AIR	
Dry-bulb	75°F [24°C]
Wet-bulb	63°F [17°C]



Commissioning Energy Recovery Systems (3)

- Parasitic power and energy losses (examples)
  - Airside pressure drops including filters
  - Motor energy in wheels
- Control issues (examples)
  - Frosting
  - Condensing
  - Transferring energy in wrong direction (example: 55° F outdoor air when zone requires cooling)

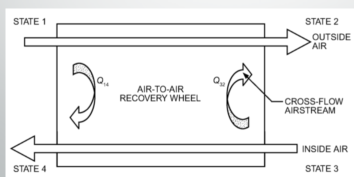
Commissioning Energy Recovery Systems (4)

Monthly Climatic Design Conditions

		Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours	Tavg	5.5	-8.7	-7.6	-2.8	3.4	9.9	15.2	18.7	18.2	13.7	7.7	1.8	-4.8
	Sd		6.48	5.97	5.39	3.86	4.03	3.74	2.70	3.07	3.74	4.06	5.09	6.03
	HDD10.0	2541	579	493	398	201	52	4	0	0	8	96	249	460
	HDD18.3	4792	838	727	657	448	261	107	28	41	144	330	494	718
	CDD10.0	885	0	0	0	3	50	160	269	253	121	24	4	0
	CDD18.3	95	0	0	0	0	1	13	39	36	6	0	0	0
	CDH23.3	806	0	0	0	1	27	148	314	268	48	1	0	0
	CDH26.7	152	0	0	0	0	4	28	56	55	9	0	0	0

Commissioning Energy Recovery Systems (5)

Air Leakage in Energy Recovery Units



Commissioning Energy Recovery Systems (6)

- EATR (Exhaust air transfer ratio)
- $$\text{EATR} = \frac{c_2 - c_1}{c_3 - c_1} \qquad (20)$$
- OACF (Outside air correction factor)
- $$\text{OACF} = \frac{m_1}{m_2} \qquad (21)$$
- Both of these are device and pressure dependent

Commissioning Energy Recovery Systems (7)

- Should measure h_1, h_2, h_3, h_4, m_s, m_e, P_1, P_2, P_3, P_4, RPM_{wheel}

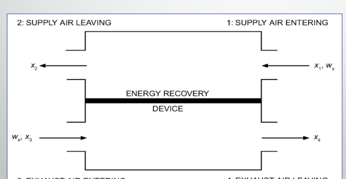


Plate Type Systems O&M

- Operating Issues
  - Parasitic power – pressure drops consuming fan energy
  - Control issues - sequencing
    - Frosting
    - Condensing
    - Transferring energy in wrong direction
- Maintenance Issues
  - Performance – changing filters, controls calibration
  - Cleaning should be minimal if good filtration!
  - Follow manufacturer's instructions – not everything is to be washed

Heat Pipe Systems O&M

- Operating Issues
  - Parasitic power – pressure drops consuming fan energy
  - Control issues – tilt control or other
    - Frosting
    - Condensing
    - Not transferring energy because of tilt
- Maintenance Issues
  - Performance – changing filters, controls calibration, tilt control mechanism, loss of working fluid
  - Cleaning should be minimal if good filtration!

Run Around Loop Systems O&M

- Operating Issues
  - Parasitic power – pressure drops consuming fan energy and pumping energy for fluid
  - Control issues – variable pumping or 3-way valve control
    - Transfer fluid freezing
    - Condensing
    - Transferring energy in wrong direction
- Maintenance Issues
  - Performance – changing filters, controls calibration, variable speed pumps, corrosion, working fluid
  - Airside cleaning should be minimal if good filtration!

Wheel Type Systems O&M

- Operating Issues
  - Parasitic power – pressure drops consuming fan energy and wheel motor
  - Control issues – wheel speed, bypass dampers, or other
    - Frosting
    - Condensing
    - Transferring energy in wrong direction
- Maintenance Issues
  - Performance – changing filters, controls calibration, belt and motor on wheel, dampers if installed
  - Follow manufacturer's instructions on cleaning!

Conclusions

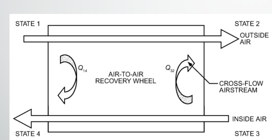
- Each type of system has unique commissioning challenges
- Operating issues include:
  - Parasitic power consumption
  - Controls setup – frosting, condensing, transfer, temperature
- Maintenance issues include
  - Maintaining performance
  - Keeping clean
- Re-commission systems periodically (2-5 years) to assure performance

Exhaust Air Leakage in ERV

How much is too much?

How much is expected?

Air Leakage in Energy Recovery Units



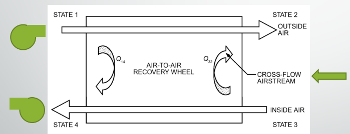
Leakage From Exhaust back into Building

$Q_{32} = Q_2 (EATR / 100)$
EATR is Exhaust Air Transfer Ratio

Fan Position Determines Leakage

- Four fan arrangements that I have seen
- There can be many others
- 1 – minimizes exhaust leakage
- 2 - maximum exhaust leakage
- 3 – typical arrangement in many built up systems
- 4 - some small packaged units have this arrangement

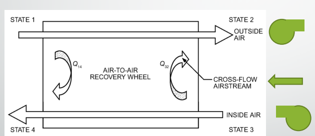
Air Leakage in Energy Recovery Units Fan Position 1



Minimize Q32

In this arrangement airstream 1-2 must be positive to airstream 3-4 even if one fan fails

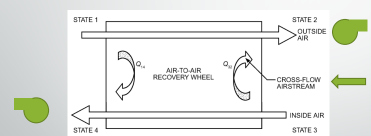
Air Leakage in Energy Recovery Units Fan Position 2



Maximize Q32

In this arrangement airstream 1-2 must be negative to airstream 3-4 even if one fan fails

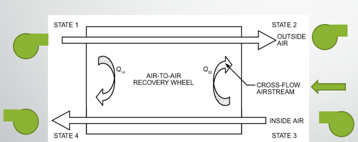
Air Leakage in Energy Recovery Units Fan Position 3



Unknown Q32

In this arrangement knowledge of all operating pressure conditions must be known to make a prediction

Air Leakage in Energy Recovery Units Fan Position 4

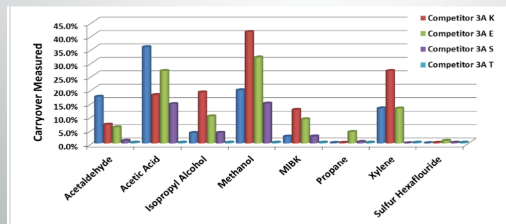


Unknown Q32

Carryover

- Carryover can be reduced to less than 0.1% of the exhaust airflow with a purge section but cannot be completely eliminated
- 2016 ASHRAE Handbook 26.10

Carryover



data courtesy of Charlene Bayer, PhD

Performance Ratings

- ASHRAE Standard 84
- AHRI Standard 1060

- Tests are performed with balanced airflows and $p_2 - p_3 = 0$
- Published EATR will reflect those conditions

Questions?