Energy Recovery Systems

Greg Drensky
Vice President
Jacco & Associates

Agenda:

- Who is Jacco?
- What is energy recovery?
- Why use energy recovery?
- What types of energy recovery are there?
- What applications do they fit?

Who is Jacco

- Established 1968
  - Hudson, Ohio
  - Columbus, Ohio
  - Toledo, Ohio
- Focused on the Engineered Environment
  - Systems Knowledgeable
    - HVAC Systems
    - Service & Maintenance
    - Parts
- Full Circle Support
- 30 Minute Design

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Who is Jacco

- Operations
  - Brenda Homjak
  - Mike Spangler
  - Chad Russell
  - Mike Mueller
- Contractor Owning Experience
  - Maggie Sawicki
  - Rick Baker
  - Dan Duignan
- Engineering Owning Experience
  - Greg Drensky
  - Jerry Cohen
- Owning Experience
  - Steve Leister
  - Gloria Schwartz
  - Jeff Watson

Purpose Statement

The purpose of our Company is to solve our customers problems, in the most economical way, at all times optimizing the owning experience.

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Who is Jacco

- 30 Minute Design
  - –Unit Performance
  - –Drawing
  - –Weights
  - –Electrical
  - –Specifications?
  - –Sequence of Operation?
  - –Cartoon?
  - –Narrative?

Who is Jacco

2016 Seminars

Seminars	Instructor	Date
Psychrometrics	Jerry Cohen	13-Jan
The Refrigeration Cycle	Jerry Cohen	10-Feb
Best Practices for VRF Systems - Design	Greg Drensky	9-Mar
Best Practices for VRF Systems - Installation	Steve Leister	13-Apr
Best Practices for Applied Rooftop Systems, Applications & Installation	Jerry Cohen	11-May
Applying Energy Recovery Systems	Greg Drensky	14-Sep
OFCC Applicable Systems - Pro's & Con's	Greg Drensky	12-Oct
Applying Building Pressure & Air Flow Measurement Instrumentation	Greg Drensky	9-Nov
Controlling HVAC Systems with Special Emphasis on Sequence of Operations	Jerry Cohen	14-Dec

Announcement!

RUUD®

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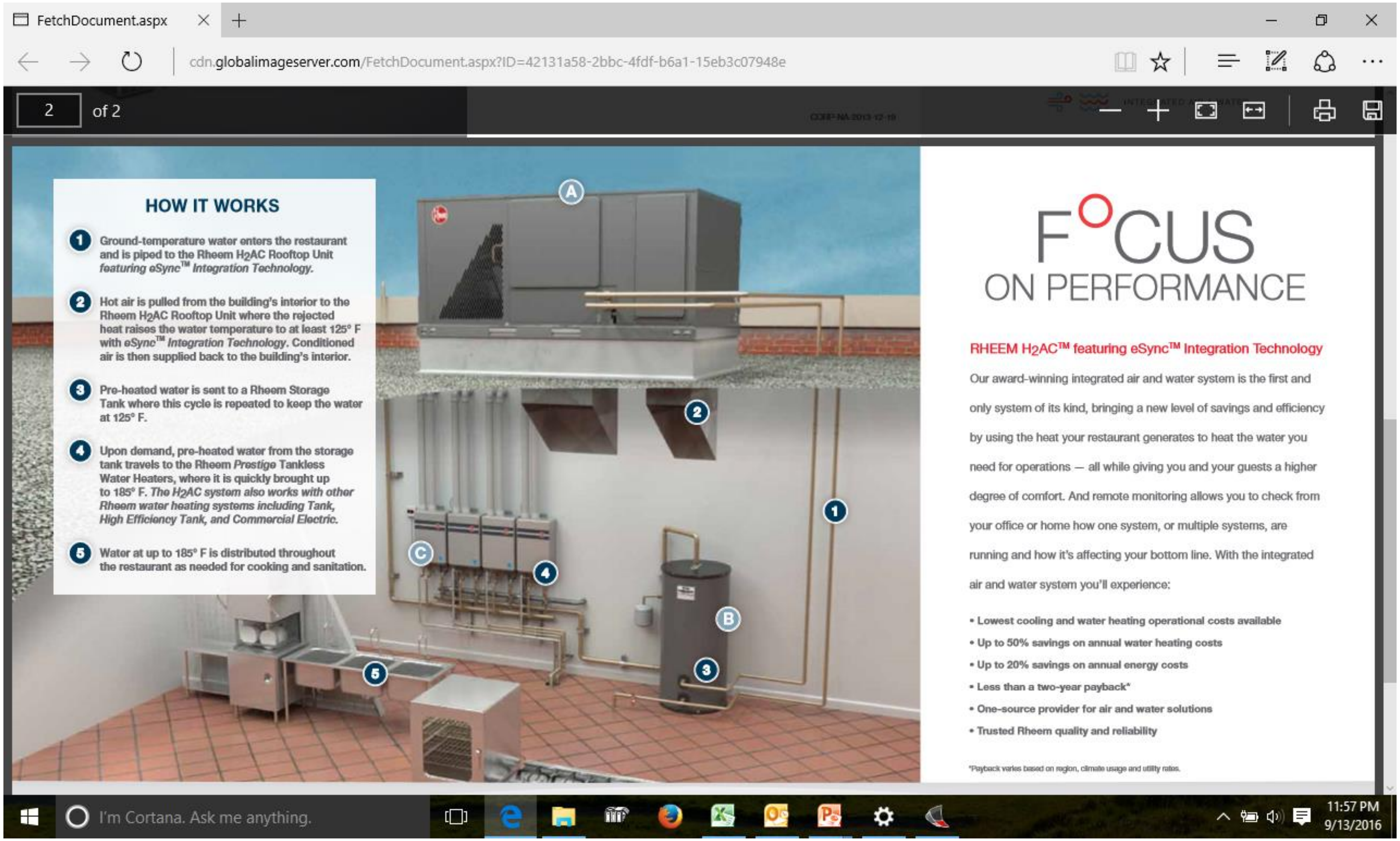
RUUD:

- Established 1920
- 3-25 Ton RTUs, 6-20 Ton Split Systems
- Multiple Efficiency Levels
- Slide Out Drain Pan & Blower
- Copeland Scroll Compressors
- Microchannel Coils
- AL/SS Heat Exhangers
- VFDs
- CAV
- Hot Gas Reheat
- Horizontal/Vertical Connections
- $10-12M Stock, 4 Week Standard Lead Time

RUUD:



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HOW IT WORKS
1 Ground-temperature water enters the restaurant and is piped to the Rheem H2AC Rooftop Unit featuring eSync™ Integration Technology.
2 Hot air is pulled from the building's interior to the Rheem H2AC Rooftop Unit where the rejected heat raises the water temperature to at least 125° F with eSync™ Integration Technology. Conditioned air is then supplied back to the building's interior.
3 Pre-heated water is sent to a Rheem Storage Tank where this cycle is repeated to keep the water at 125° F.
4 Upon demand, pre-heated water from the storage tank travels to the Rheem Prestige Tankless Water Heaters, where it is quickly brought up to 185° F. The H2AC system also works with other Rheem water heating systems including Tank, High Efficiency Tank, and Commercial Electric.
5 Water at up to 185° F is distributed throughout the restaurant as needed for cooking and sanitation.
FOCUS ON PERFORMANCE
RHEEM H2AC™ featuring eSync™ Integration Technology
Our award-winning integrated air and water system is the first and only system of its kind, bringing a new level of savings and efficiency by using the heat your restaurant generates to heat the water you need for operations — all while giving you and your guests a higher degree of comfort. And remote monitoring allows you to check from your office or home how one system, or multiple systems, are running and how it's affecting your bottom line. With the integrated air and water system you'll experience:
• Lowest cooling and water heating operational costs available
• Up to 50% savings on annual water heating costs
• Up to 20% savings on annual energy costs
• Less than a two-year payback*
• One-source provider for air and water solutions
• Trusted Rheem quality and reliability
*Payback varies based on region, climate usage and utility rates.
I'm Cortana. Ask me anything.
11:57 PM
9/13/2016

What Is Energy Recovery?

- Ability to transfer energy from one air stream to another
- Proven technology over past decades and thousands of installations
- Reduction of required mechanical heating & cooling
- Temper OA conditions to simplify controlling to a point

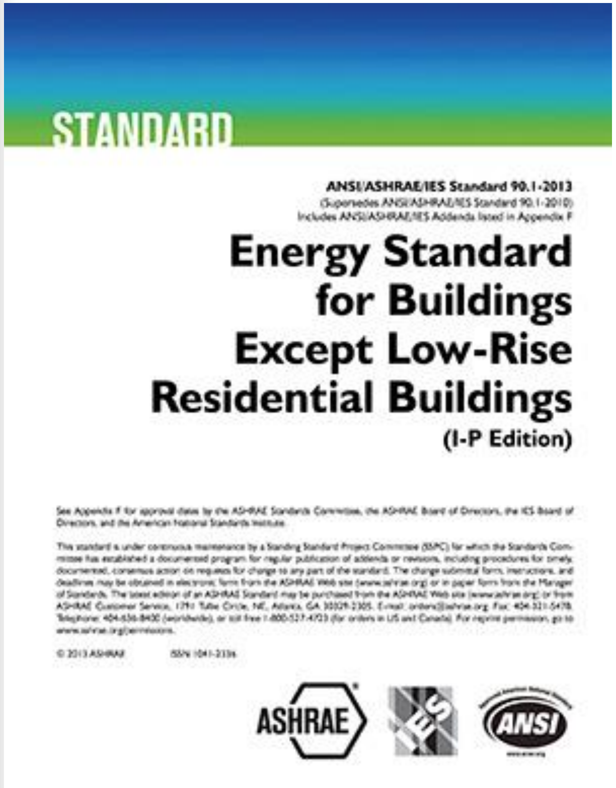
Why Use Energy Recovery?

- Building codes require higher OA ventilation rates
- Controls indoor air pollution in crowded commercial building environments to assure proper occupant health and comfort.
- Outside air dilutes indoor pollutants including:
  - Human Generated ‘Bioeffluents’ (CO_2)
  - VOC’s
  - Airborne Virus
  - Odor
- Mitigates the ‘Sick Building Syndrome’

Why Use Energy Recovery?

- Reduced first time & installation costs
  - Smaller footprint
  - Lower gauge wiring
  - Less structural
- Reduced operational costs
- Reduce the load on the system by taking advantage of the work that has already been done to:
  - Heat
  - Cool
  - Humidify
  - Dehumidify

Why Use Energy Recovery?


STANDARD

ANSI/ASHRAE/IES Standard 90.1-2013

(Supersedes ANSI/ASHRAE/IES Standard 90.1-2010)

Includes ANSI/ASHRAE/IES Addenda listed in Appendix F

Energy Standard for Buildings Except Low-Rise Residential Buildings

(I-P Edition)


ANSI/ASHRAE/USGBC/IES Standard 189.1-2014

(Supersedes ANSI/ASHRAE/USGBC/IES Standard 189.1-2011)

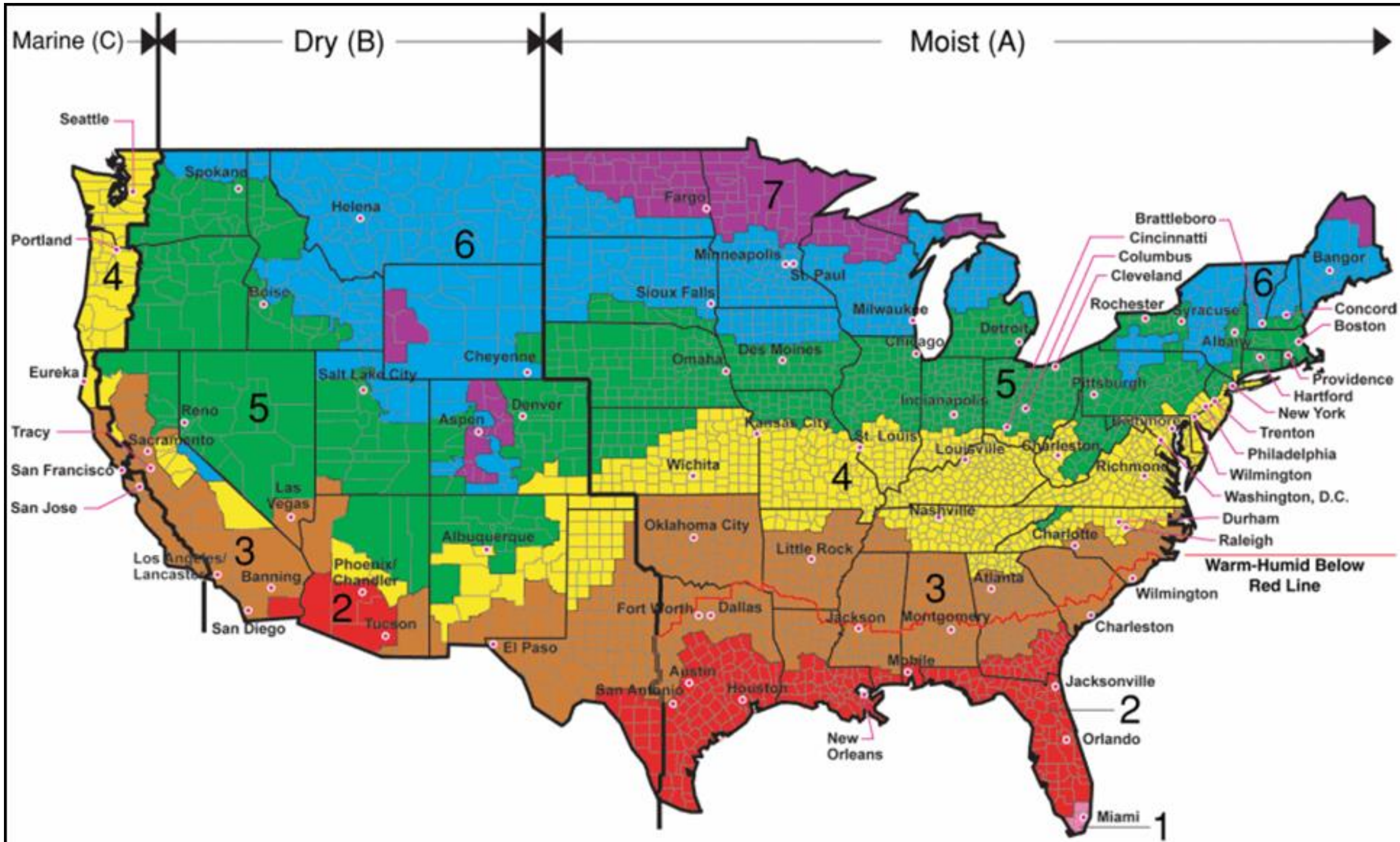
Standard for the Design of High-Performance Green Buildings

Except Low-Rise Residential Buildings

IgCC

A Compliance Option of the International Green Construction Code™

Why Use Energy Recovery?



All of Alaska in Zone 7 except for the following Boroughs in Zone 8: Bethel, Dellingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk

Zone 1 includes: Hawaii, Guam, Puerto Rico, and the Virgin Islands

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Why Use Energy Recovery?

TABLE 6.5.6.1 Exhaust Air Energy Recovery Requirements

Zone	% *Outdoor Air* at Full Design Airflow Rate					
	≥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

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Why Use Energy Recovery?

- 90.1-2010
  - Effectiveness Minimum of 50%
- 189.1-2014
  - Effectiveness Minimum of 60%

ARI Certification:

AHRI Standard 1060 (I-P)

2013 Standard for

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

AHRI
AIR-CONDITIONING, HEATING, & REFRIGERATION INSTITUTE
we make life better™

2111 Wilson Boulevard, Suite 500
Arlington, VA 22201, USA
www.ahrinet.org
PH 703.524.8800
FX 703.562.1942

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ARI Certification:

AIR-CONDITIONING & REFRIGERATION INSTITUTE

Representing Manufacturers of Heating, Ventilating, Air-Conditioning and Refrigeration Products

ARI 1060 Certification – Look for the Seal
No Seal, No Certification!

The ARI 1060 Certification Program for air-to-air heat exchangers for energy recovery ventilation equipment was released on 19 January 2001. It is the culmination of several years work by the ARI Air-to-Air Energy Recovery Ventilation Equipment Product Section.

The ARI 1060 Certification Program is, to date, the **only** independent certification program for commercial energy recovery ventilation equipment in North America*. It certifies thermal and leakage performance of heat pipe, plate, and rotary wheel heat exchanger components rated at or above 50 scfm used in energy recovery ventilation equipment. A certified piece of equipment can be identified by the distinctive ARI Certification Seal affixed to the equipment, or affixed to the packaged equipment containing a certified heat exchanger and by its listing in the Certified Directory on the ARI website. The Seal can also be seen on the literature of certified manufacturers where certified ratings are shown.

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ARI 1060 Rating:

1. Airflow, scfm
2. Pressure Drop, in H_2O
3. Sensible Effectiveness (at 100% and 75% rated airflow for heating and cooling conditions)
4. Latent Effectiveness (at 100% and 75% rated airflow for heating and cooling conditions)
5. Total Effectiveness (at 100% and 75% rated airflow for heating and cooling conditions)
6. Exhaust Air Transfer Ratio, Outdoor Air Correction Factor, and Purge Angle or Setting (if applicable) at 0.00 in H_2O and two or more pressure differentials
7. Tilt Angle, °, (at heating and cooling conditions, if applicable)

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Heat Wheel:

ARI STANDARD 1060-2005

- The purpose of this standard is to establish for Air-to-Air Heat Exchangers intended for use in Air-to-Air Energy Recovery Ventilation Equipment: definitions; test requirements; rating requirements; minimum data requirements for Published Ratings; marking and nameplate data; and conformance conditions.

Why Use Energy Recovery?

3.5 *Effectiveness.* A ratio of the actual energy transfer (sensible, latent, or total) to the product of the minimum energy capacity rate and the maximum difference in temperature, humidity ratio, or enthalpy. The equation for determining Effectiveness is Equation C1 in Appendix C.

Effectiveness is not adjusted to account for that portion of the psychrometric change in the Leaving Supply Airflow that is the result of leakage of Entering Exhaust Airflow rather than exchange of heat or moisture between the airstreams.

3.5.1 *Sensible Effectiveness.* The Effectiveness determined in Section 3.5 using only measured dry bulb temperature differences, specific heat capacities and mass airflow rates.

3.5.2 *Latent Effectiveness.* The Effectiveness determined in Section 3.5 using only measured humidity ratios, heat of vaporization values, and mass airflow rates.

3.5.3 *Total Effectiveness.* The Effectiveness determined in Section 3.5 using only measured enthalpies and mass airflow rates.

3.5.4 *Net Effectiveness.* The Effectiveness adjusted to account for that portion of the psychrometric change in the Leaving Supply Airflow that is the result of leakage of Entering Exhaust Airflow rather than exchange of heat or moisture between the airstreams. The derivation of Net Effectiveness is given in Appendix C.

Why Use Energy Recovery?

APPENDIX C. CALCULATION OF EFFECTIVENESS – NORMATIVE

C1 *Effectiveness.* The sensible, latent or total Effectiveness of an Exchanger for use in Air-to-Air Energy Recovery Ventilation Equipment is described by Equation C1.

$$\varepsilon = \frac{C_2(X_1 - X_2)}{C_{min}(X_1 - X_3)} \qquad \text{C1}$$

Where:

ε = Sensible, latent, or total effectiveness
X = Dry-bulb temperature, T, humidity ratio, W, or total enthalpy, h, respectively, at the station locations indicated in Figure 1
C = Capacity Rate for each airstream
= $\dot{m}c_p$ for sensible effectiveness
= $\dot{m}h_{fg}$ for latent effectiveness
= $\dot{m}$ for total effectiveness
C_{min} = Minimum (C_2 or C_3)
$\dot{m}$ = Mass flow rate of dry air. lb/min
c_p = Specific heat of dry air, Btu/lb°F
h_{fg} = Heat of vaporization of water, Btu/lb

X1 = Entering Air Supply
X2 = Leaving Air Supply
X3 = Entering Air Return

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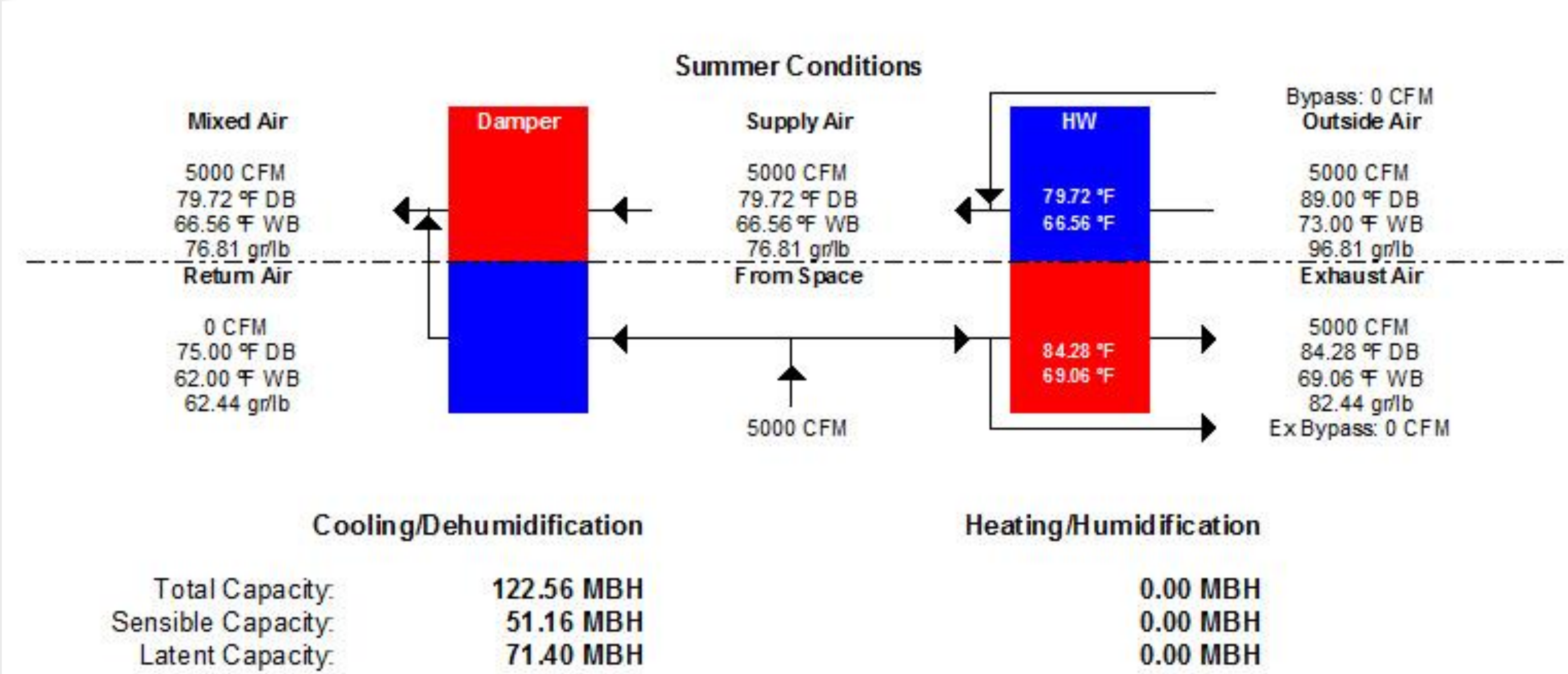
Why Use Energy Recovery?



Effectiveness = 5000*(89-79.72)/5000*(89-75)
Effectiveness = 66%

ASHRAE OA Classification

- Class 1 Air:
  - Air with low contaminant intensity
  - Re-circulation is ok to any space
  - Examples: Offices, classrooms, churches, corridors
- Class 2 Air:
  - Moderate contaminant concentration & odors
  - Can be recirculated to any similar purpose & use spaces with Class 2 or Class 3 air similar in pollutant sources
  - Examples: Rest rooms, swimming pools, dining rooms, locker rooms, warehouses

ASHRAE OA Classification

- Class 3 Air:
  - Significant contaminant concentration or odors
  - Not suitable for recirculation
  - Examples: Kitchens, dry cleaners, beauty salons, labs, pet shops
- Class 4 Air:
  - Highly objectionable fumes or gases with potentially dangerous particles
  - Not suitable for recirculation
  - Examples: Paint spray booth, lab fume exhaust, kitchen grease exhaust

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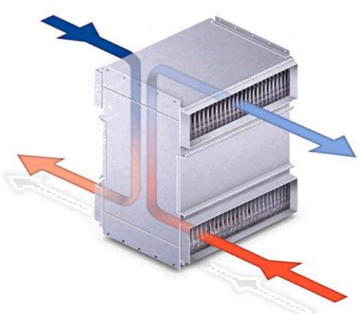
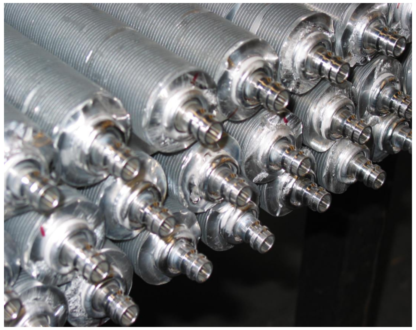
ASHRAE OA Classification

- Energy Recovery Re-Designation:
  - Class 2 air may be re-designated as Class 1 air in the process of recovering energy when it is diluted with outdoor air such that no more than 10% of the resulting airstream is Class 2 air. Class 3 air may be re-designated as Class 1 air in the process of recovering energy when it is diluted with outdoor air such that no more than 5% of the resulting airstream is Class 3 air."

Types of Energy Recovery:

- Rotary Wheel
- Fixed Plate
- Heat Pipe
- Runaround Coil





Heat Wheels:

- Total or sensible energy recovery
- Compact design
- Low frost threshold
- Moving parts involved
- Some maintenance required
- Potential cross-contamination
- 75-80% effectiveness
- 15 year lifetime

Heat Wheels:

- Spiral wound polymer film (sometimes AL)
- Wheel thickness between 1” to 3”, some can go 12”
- Single piece or pie-shaped segments
  - Segments are sized for ease of handling during installation, removal and cleaning.
- Silica gel desiccant is used for moisture handling scenarios
- ARI Certification

Heat Wheels:

- Total Or Enthalpy Wheel
  - Includes Silica Gel
  - Transfers Latent Energy/Enthalpy Between Airstreams
- Sensible Wheel
  - Transfers Only Sensible Heat
  - Obviously Use Where You Don’t Want Moisture Transfer

Heat Wheels:

- Polymer Wheel
  - Lightweight
  - Can Handle Corrosive Environments (salt)
  - Desiccant Permanently Imbedded
  - Lower Cost
- Aluminum Wheel
  - Higher Cost
  - Desiccant Degrades Over Time / Maintenance

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Heat Wheels:

- Type A Silica Gel
  - Used In Enthalpy Wheels
  - Extremely Porous
  - Can Adsorb More Than 40% Of Own Weight In Water
  - 22 Angstroms In Diameter
  - 1 Gram = 800m2 Surface Area
  - 1 Teaspoonful = Entire Football Field

Heat Wheels:

- Type A Silica Gel
  - Vapor Pressure
    - Silica Gel Adsorption Has Greater Capacity At Higher Relative Pressures
    - Water Is One Of The Highest Pressure Components
  - Competition With Other Components
    - Based On Vapor Pressure
  - Molecule’s Polarity
    - Water Has High Polarity Creating Greater Attraction

Heat Wheels:

Table 1: Calculation of Relative Vapor Pressures for Various Components

Component	Concentration[1] (ppm)	Relative Vapor Pressure (P/Ps)	Multiple of Water Pressure Versus Component[2]
Water	14,900	0.5	1
Isopropyl Alcohol	400	0.0069	72
Ammonia	50	0.000006	87,639
Carbon Dioxide	5,000	0.00009	5,646
Formaldehyde	.75	0.0000001	3,406,109

[1] Concentrations are OSHA limits for 8 hour exposure. Typical buildings should be well below these levels. Water concentration is 75°F, 50% rh
[2] Ratio of water to component relative vapor pressure

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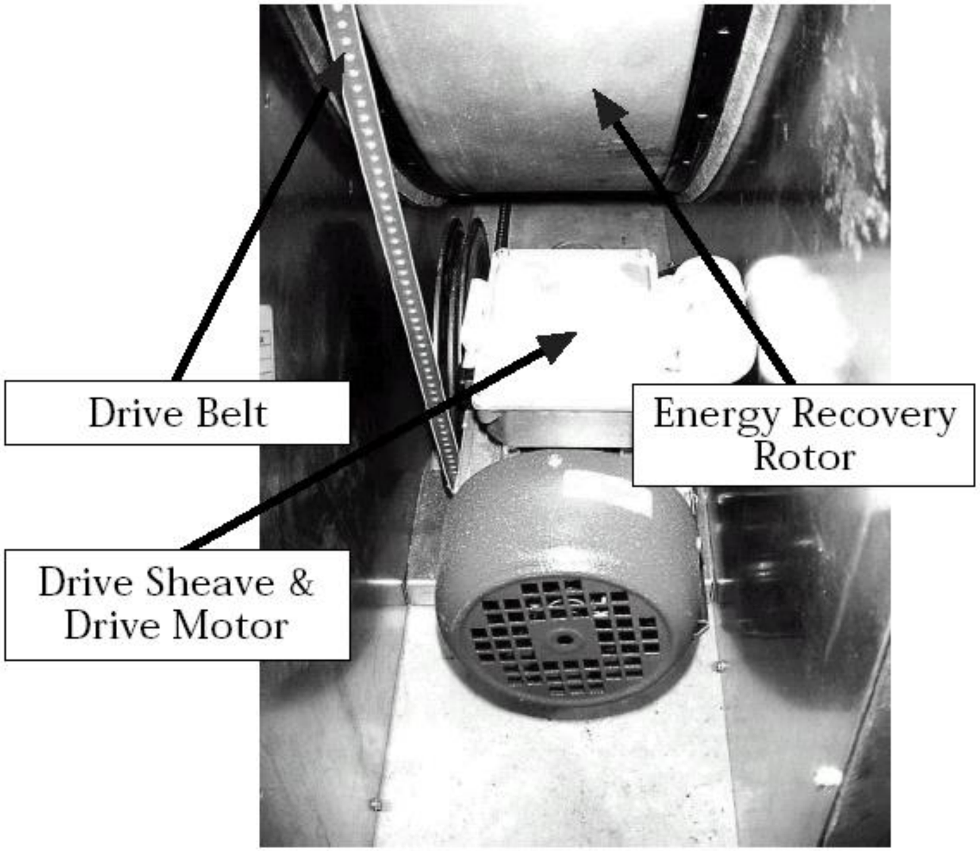
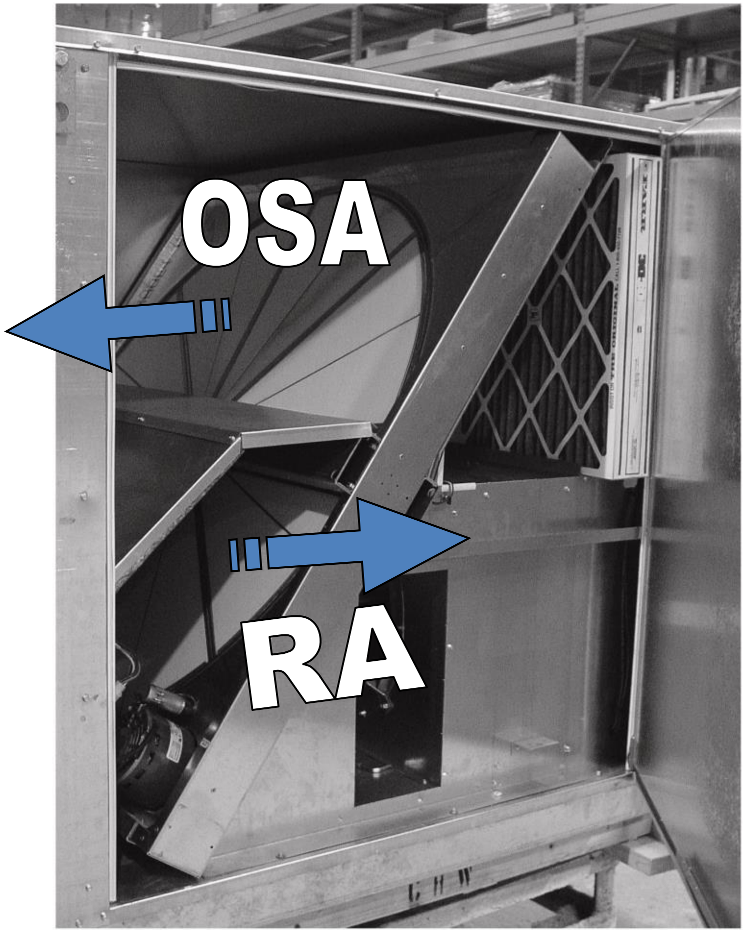
Heat Wheel:



Heat Wheel:



Heat Wheel:

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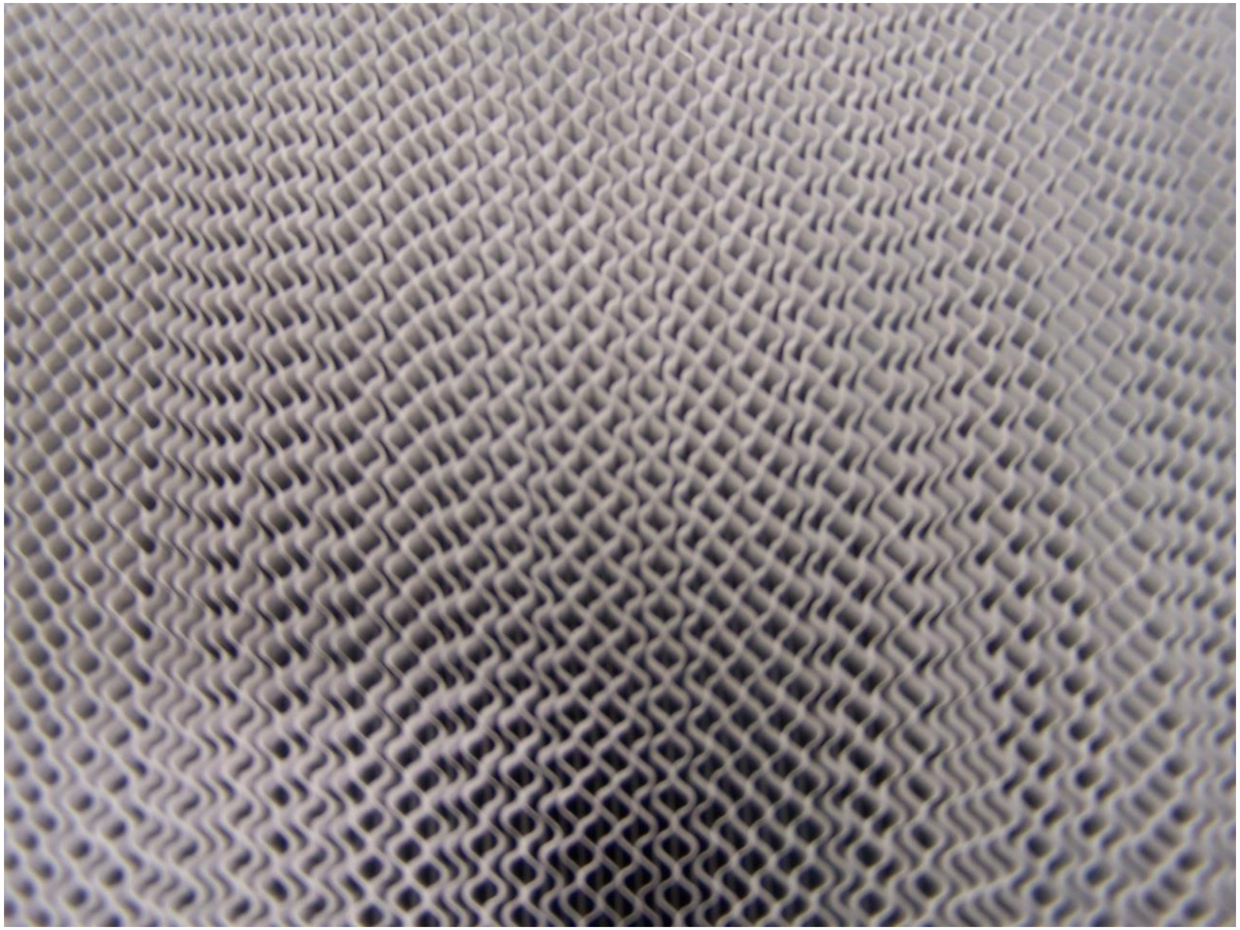
Heat Wheel:



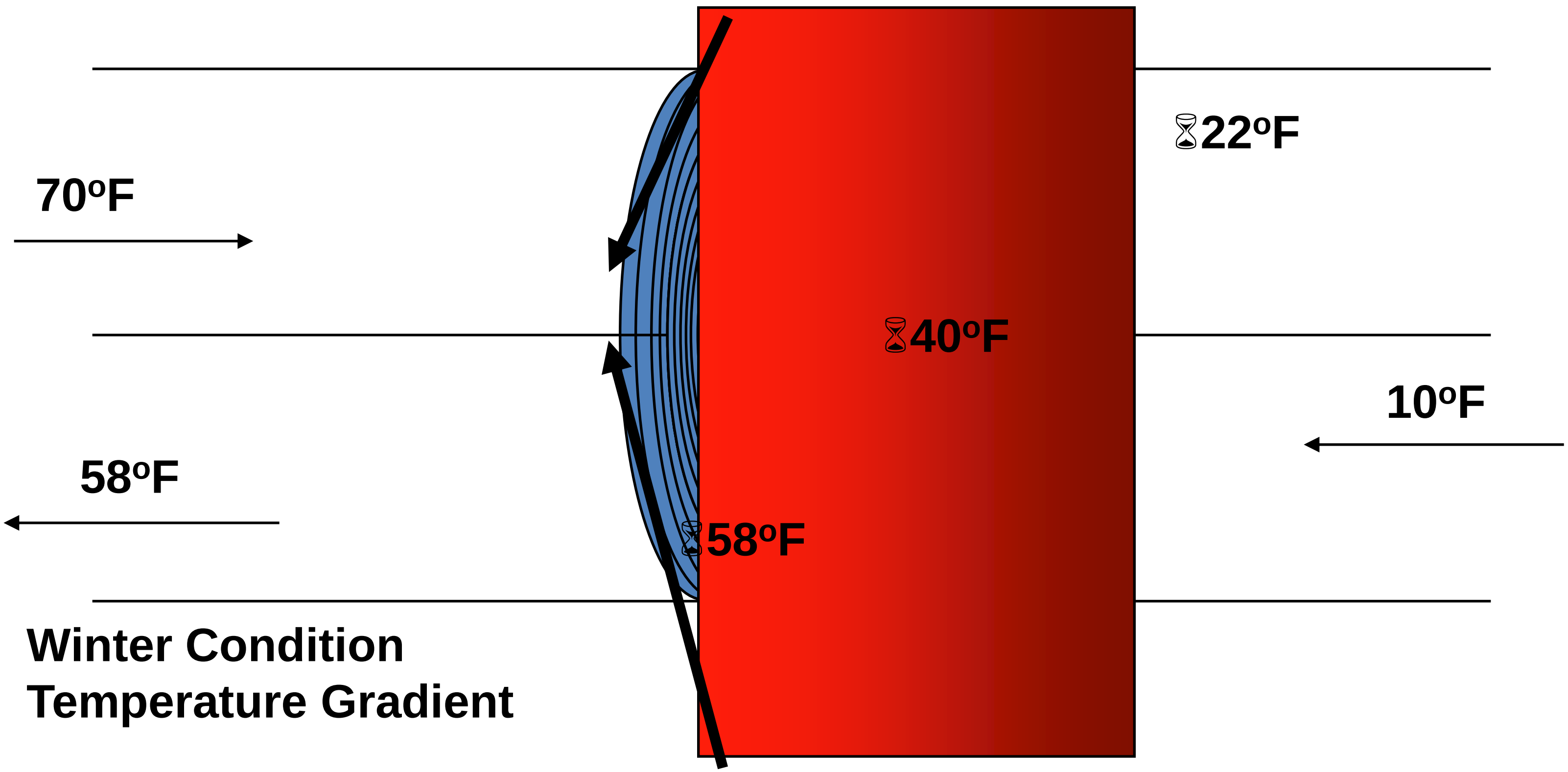
Heat Wheel:

Bypass Dampers

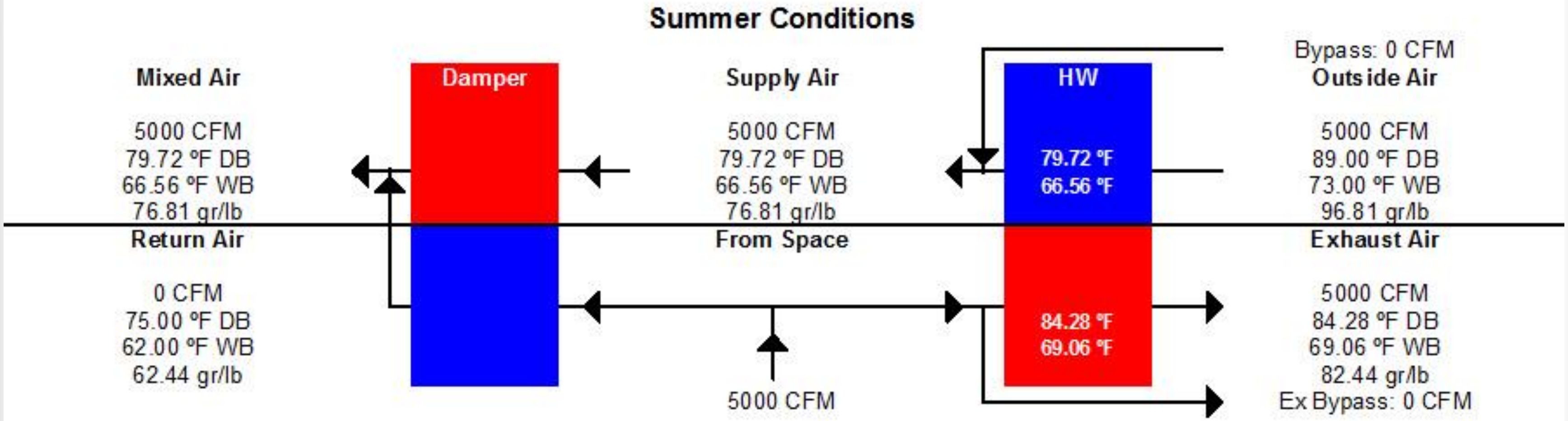
- Excess Air
- Economizer Operation

Heat Wheel Theory:

Rotary Air-to-Air Heat Exchange: 80%



Heat Wheel Performances:



	Cooling/Dehumidification	Heating/Humidification
Total Capacity:	**122.56 MBH**	**0.00 MBH**
Sensible Capacity:	**51.16 MBH**	**0.00 MBH**
Latent Capacity:	**71.40 MBH**	**0.00 MBH**

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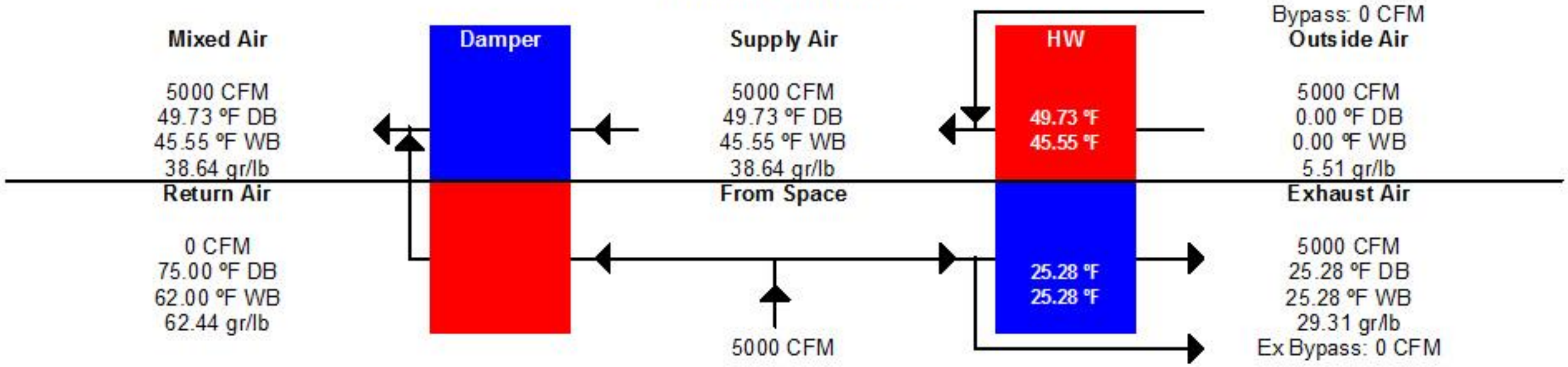
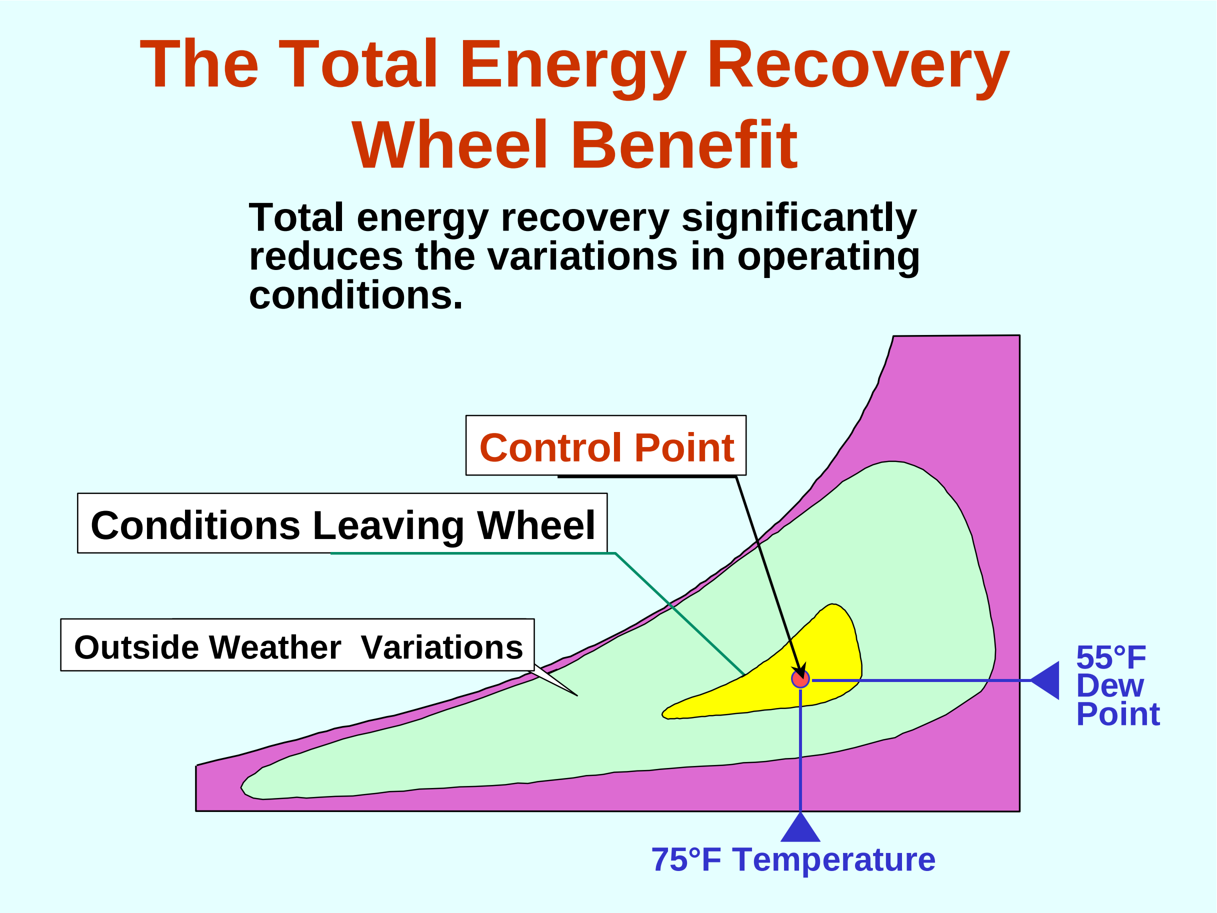
Heat Wheel Performances:

Winter Conditions



	Cooling/Dehumidification	Heating/Humidification
Total Capacity:	**0.00 MBH**	**383.28 MBH**
Sensible Capacity:	**0.00 MBH**	**269.51 MBH**
Latent Capacity:	**0.00 MBH**	**113.77 MBH**

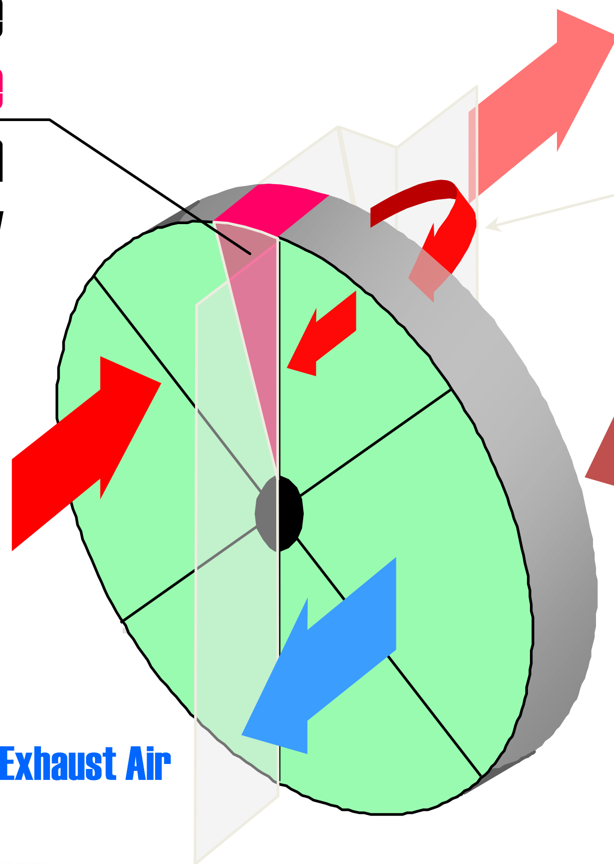
Heat Wheel Benefit:



Purge System:

Purge Removes air internal to rotor during rotation

Field adjustable purge angle is dependent on face velocity



A portion of the outside air stream is used to flush out the contaminated return air still contained in the flutes of the wheel.

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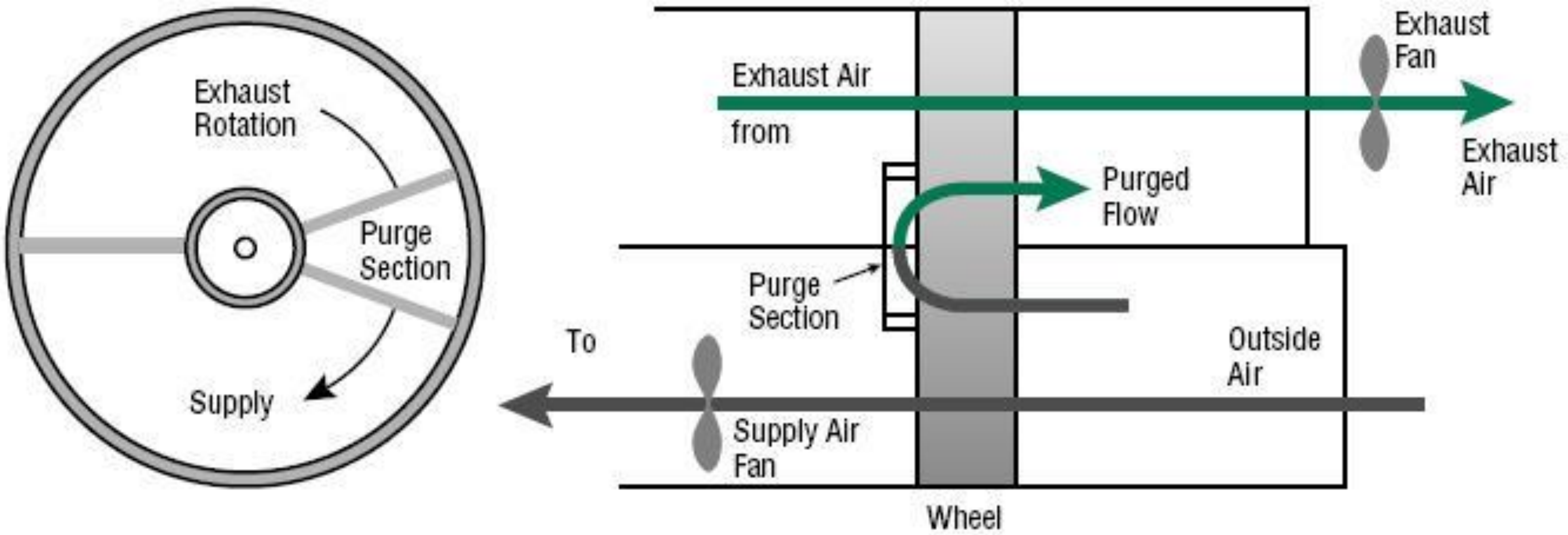
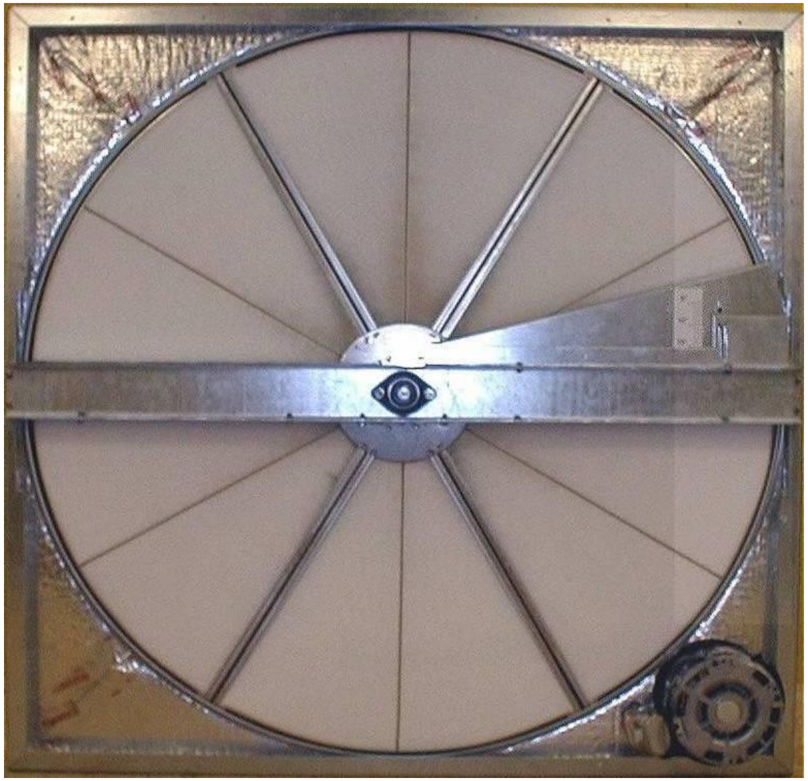
Purge System:

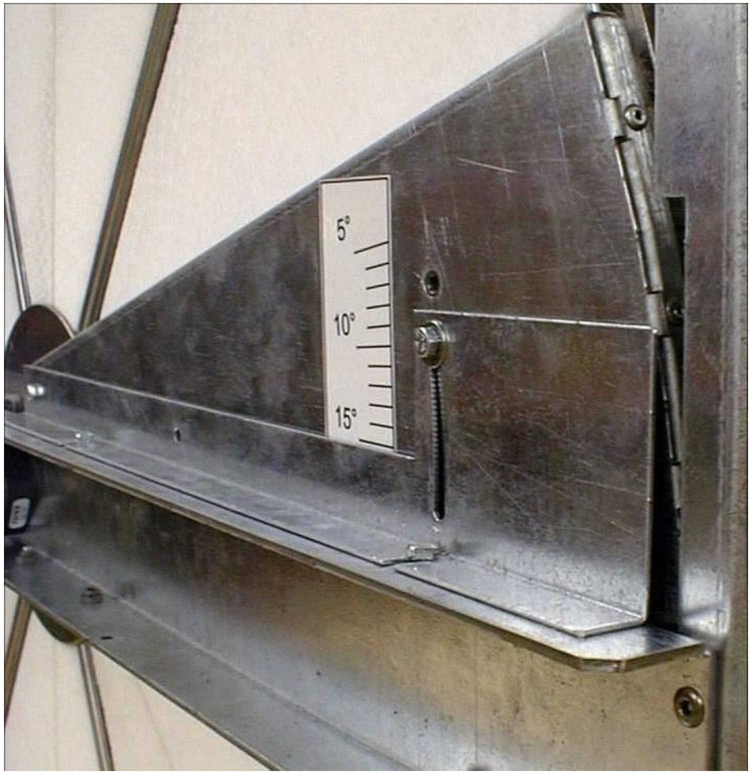


Front Cross Section with Upstream Exhaust

Side Cross Section with Purge Section

Heat Wheel With Purge:





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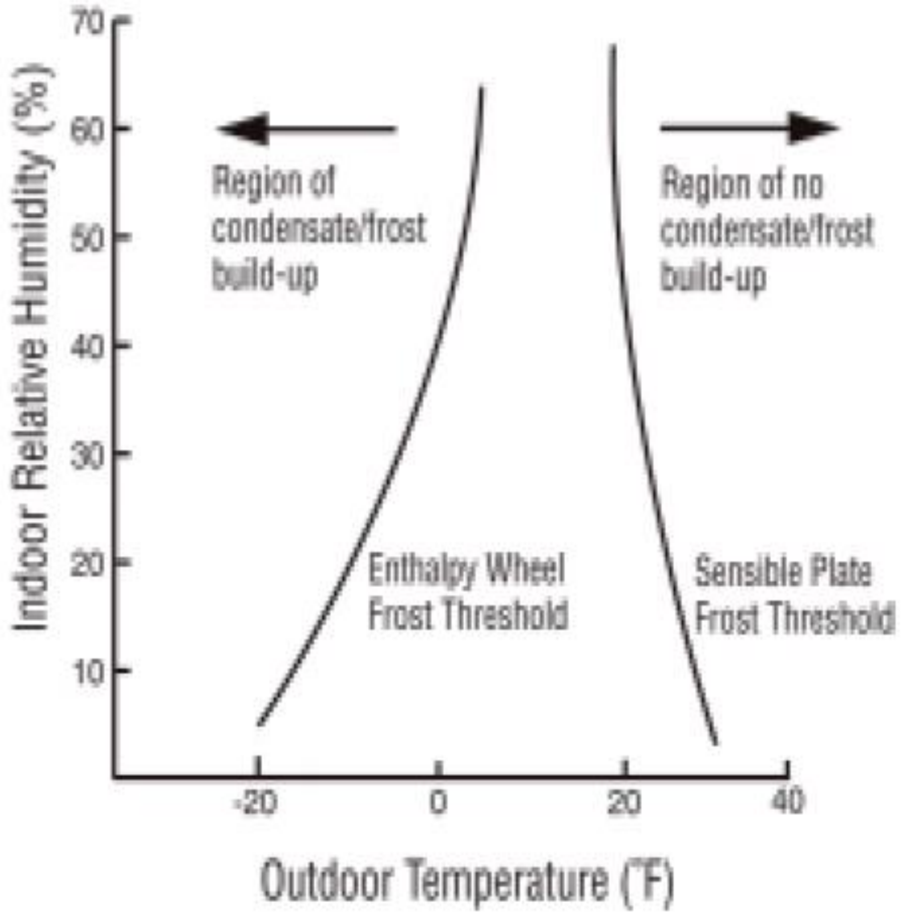
Heat Wheel Frost Control:



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Heat Wheel Frost Control:

- Frost Threshold Temperature (FTT)
  - Temperature Below Which Frost Accumulates
  - Function of OAT and Indoor RH
- Wheel FTT: -20 to 5F
- Remove Water From EA, Lowering DP Of Exhaust, Water Then Picked Up By Entering OA

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Heat Wheel Frost Control:

Frost Threshold Temperature (°F)				
Indoor Air RH (%)	Indoor Air Dry Bulb Temperature			
	70° F	72° F	75° F	80° F
20	-14	-13	-11	-8
30	-3	-2	-1	3
40	5	7	9	11
50	12	13	15	18
60	18	19	21	26

Heat Wheel Frost Control:

- VFD
  - Slow Down Wheel To Gain More Exposure To EA
  - Reduces Effectiveness
- Preheat
  - Lowers OAT RH, Lowers FTT
- Bypass Dampers
  - Bypass Supply Air
- On/Off Wheel
  - Expose Wheel To More EA

Heat Wheel Frost Control:

Outdoor Winter Design Temp.	Indoor Air (Return) Conditions					
	70°F and 20%RH (Frost Threshold -14°F)		70°F and 30%RH (Frost Threshold -3°F)		70°F and 40%RH (Frost Threshold 5°F)	
	Preheat Temperature At Design	Required Capacity ΔT	Preheat Temperature At Design	Required Capacity ΔT	Preheat Temperature At Design	Required Capacity ΔT
5	-	-	-	-	-	-
0	-	-	-	-	2.5	2.5
-5	-	-	-4.3	0.7	0.8	5.8
-10	-	-	-6.3	3.7	-0.6	9.4
-15	-14.7	0.3	-7.9	7.1	-1.7	13.3
-20	-16.7	4.3	-9.1	10.9	-2.5	17.5
-25	-18.3	6.7	-10	15	-3.1	21.9
-30	-19.4	10.6	-10.7	19.3	-3.6	26.4
-35	-20.3	14.7	-11.3	23.7	-3.9	31.1
-40	-21	19	-11.7	28.3	-4.2	35.8

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Fungal Growth:

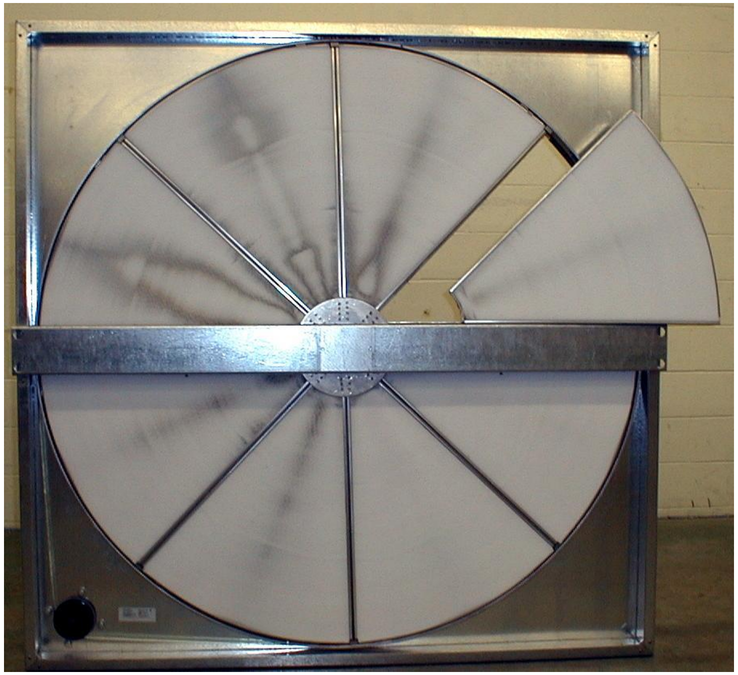
- Silica Gel Based Desiccant Wheels Transfer Water Molecules By Sorption
- Sorption – Physical & Chemical Process Where One Substance Becomes Attached To Another
- Condensation Does Not Occur
- Transfer Of Water Occurs In Vapor Or Gas Phase
- Frosting Does Not Support Fungal Growth

Odors:

- Forms From Dirt, Tar Or Grease Accumulation
- Remove With Frequent Cleaning
- Similar Issues If Don't Maintain Filters

Heat Wheel Maintenance:

- Wheels need to be ‘deep' cleaned just like evap coils to maintain latent recovery performance.
- It is easier and less risky to clean a wheel outside of the HVAC unit than within.
- Follow manufacturers instructions.



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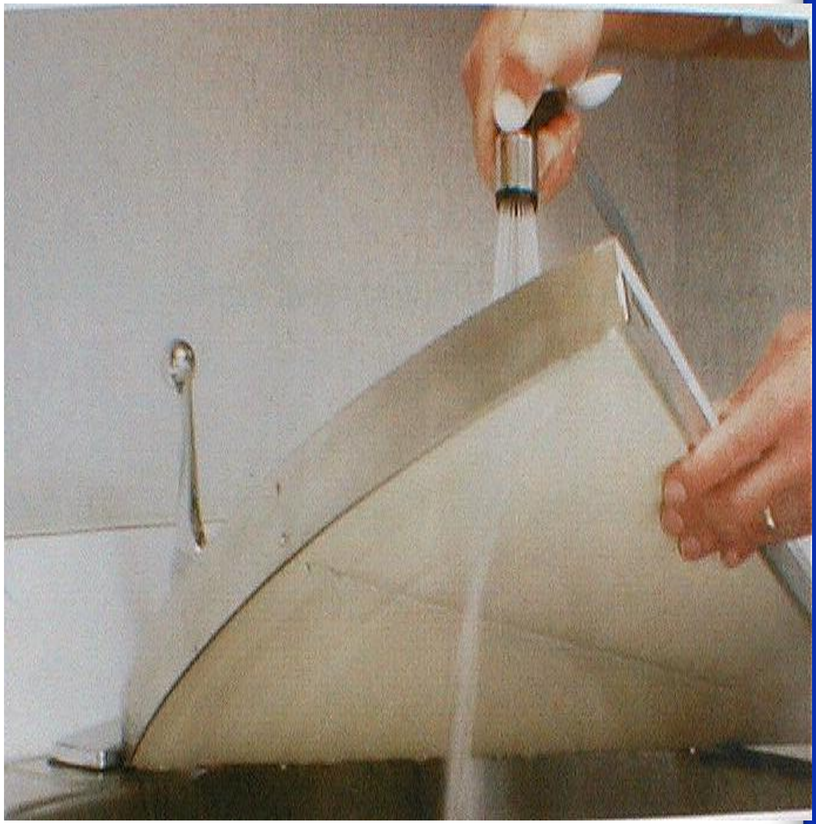
Heat Wheel Maintenance:

- Wheel is accessed and segment is removed.
- Segment is soaked in alkaline cleaner.
- Segment is rinsed and drained.
- Segment is dried and ready for use.



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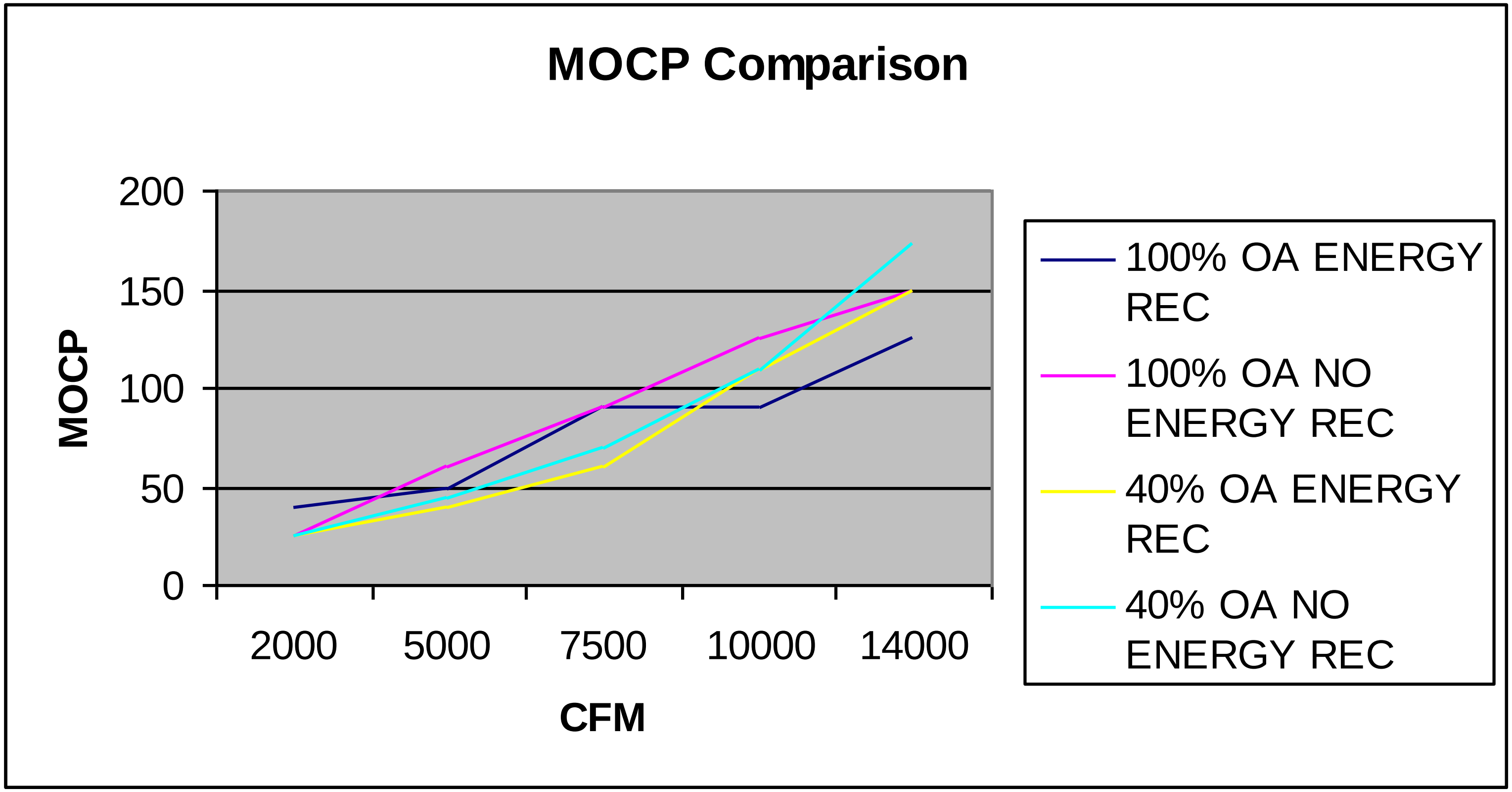
MOCP Comparison:



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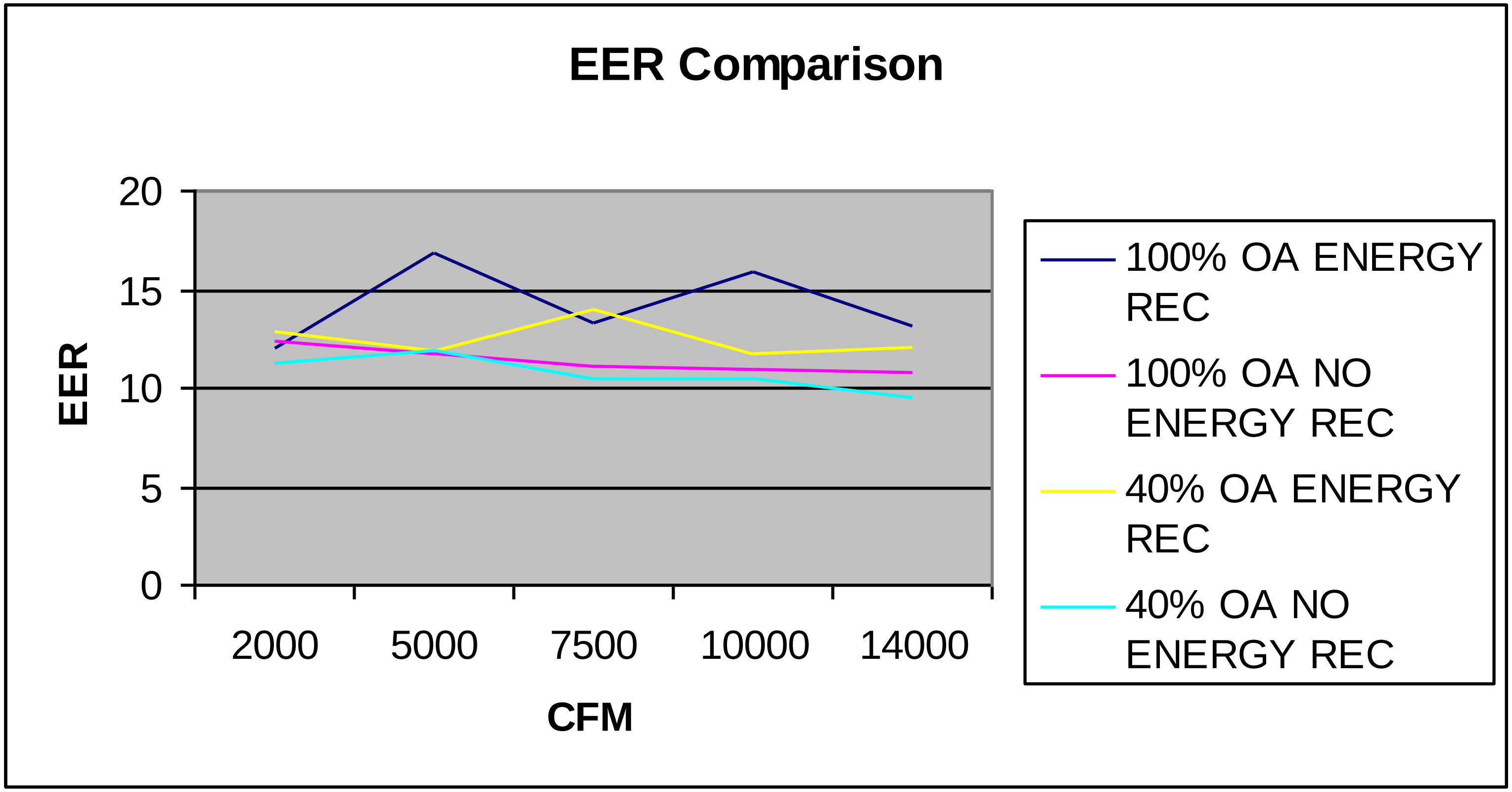
EER Comparison:



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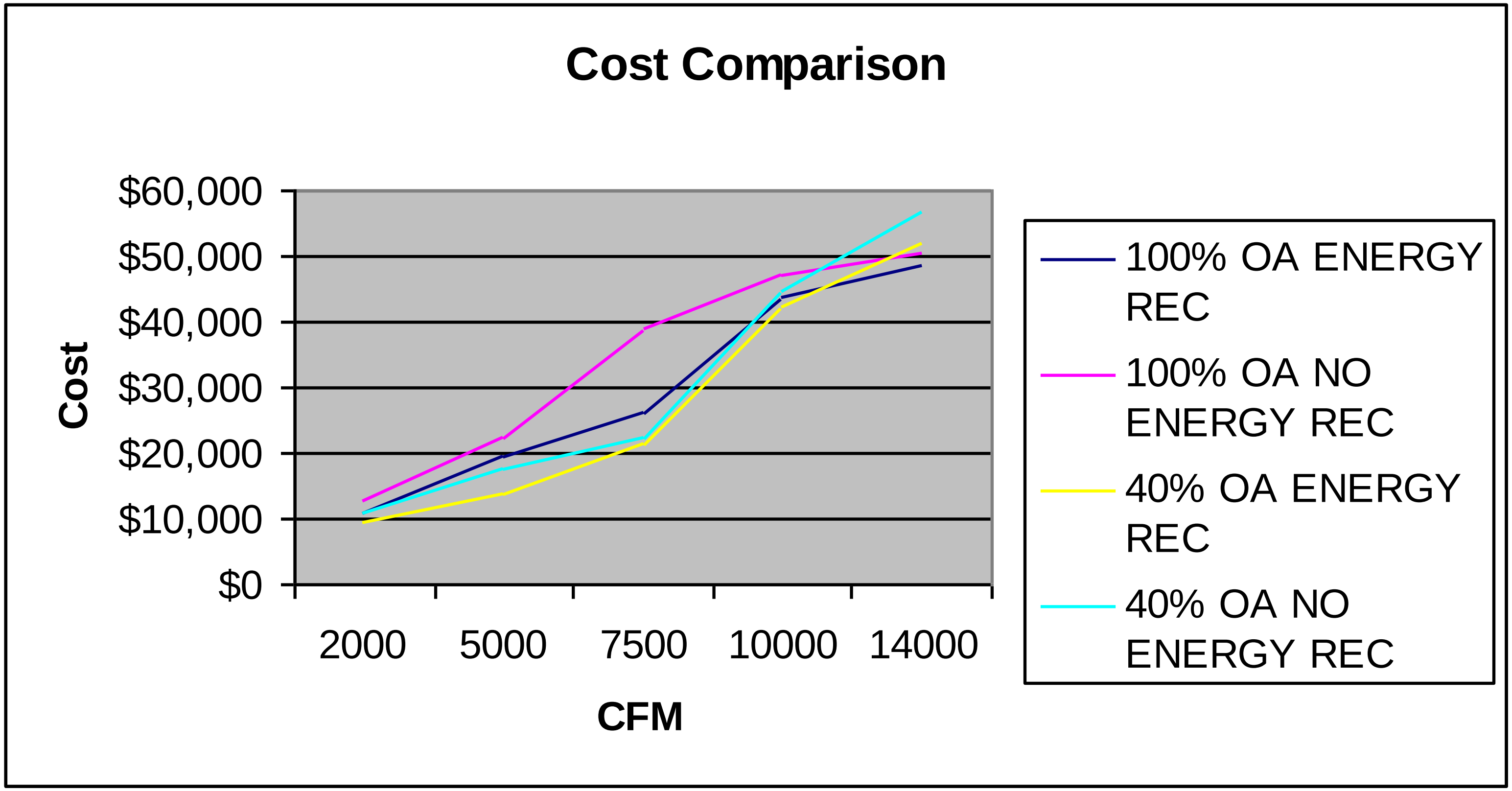
Cost Comparison:



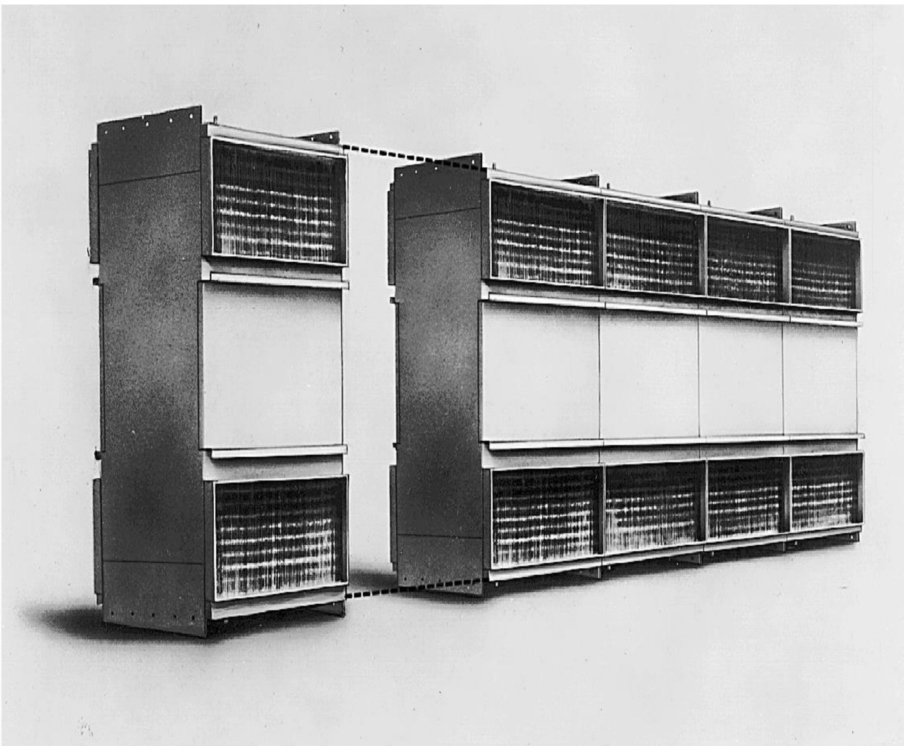
Heat Wheel Applications:

- Over 40% OA
- Schools
- Hospitals
- Churches
- Gymnasiums
- Nursing Homes
- Hotels/Motels
- Recreation Centers
- Offices
- Dedicated Outdoor Air Systems
- Dorms
- Terminal Unit Projects:
  - Heat pumps
  - Ptacs
  - Fan coils
  - Chilled Beams
  - VRF
- LEED Projects

Plate Heat Exchanger:

- Sensible energy recovery only
- Large face area design
- Higher frost threshold
- No moving parts involved
- Minimal maintenance required
- No potential cross-contamination
- 65-70% effectiveness
- 25 year + lifetime

Plate Heat Exchanger:



- Incorporated in Packaged Heat Recovery & Dehumidification Equipment
- Available with aluminum or stainless steel construction
- 450 Deg. Maximum operating temperature
- Nominal 68% Efficiency
- Modular Design
- Variable Plate Spacing

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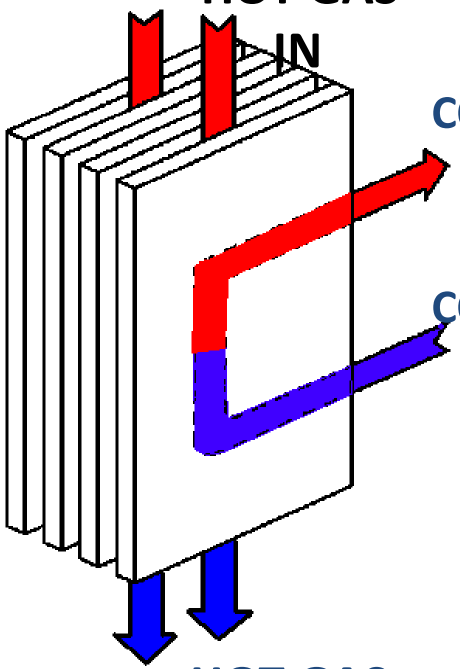
Counter Flow Plate Heat Exchanger:



- Two streams flow counter current
- Max potential for plate HX
- Longer the flow length, the more effective the heat exchanger
- Up to 85% effectiveness

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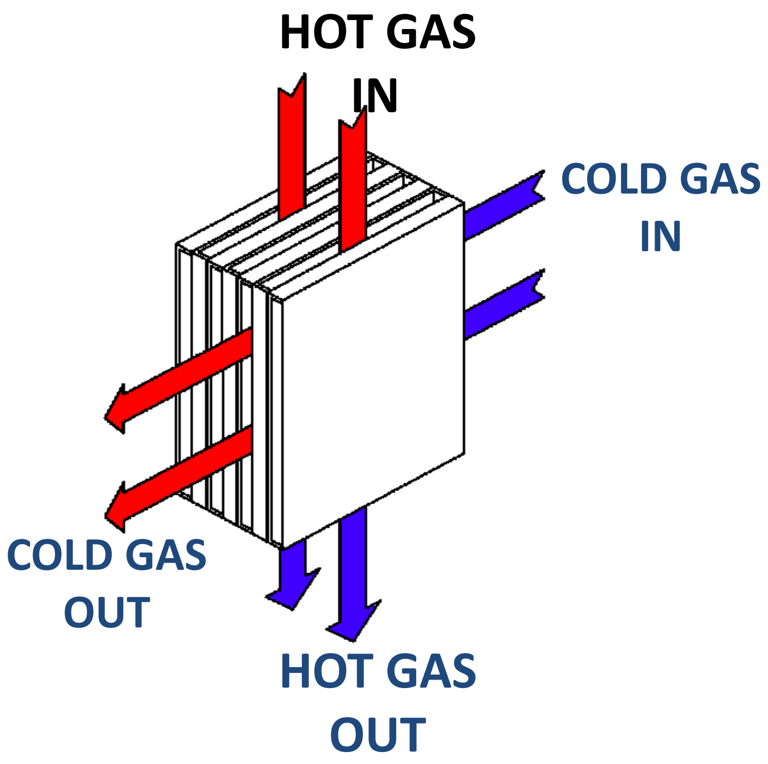
Cross Flow Plate Heat Exchanger:



- Two air streams are 90° from each other

Plate Heat Exchanger:

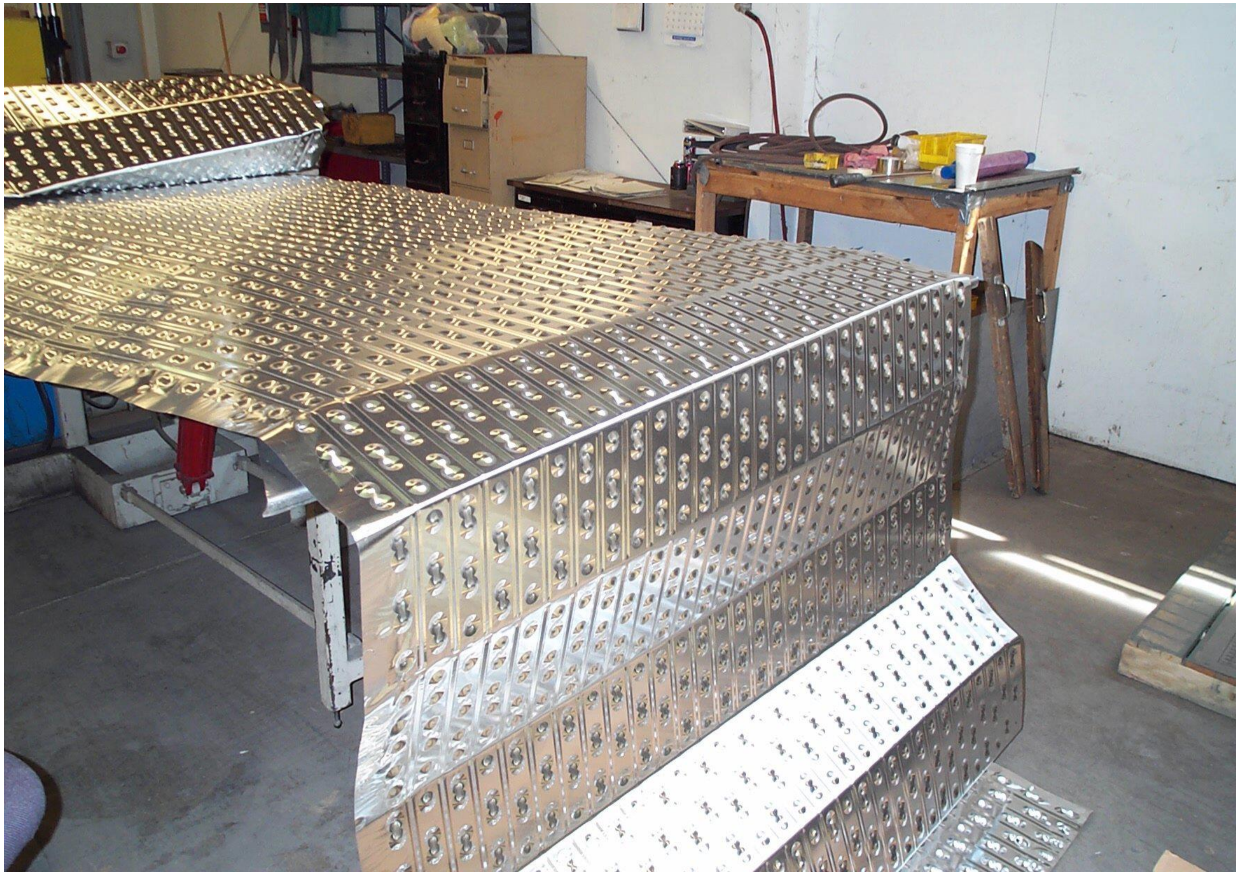
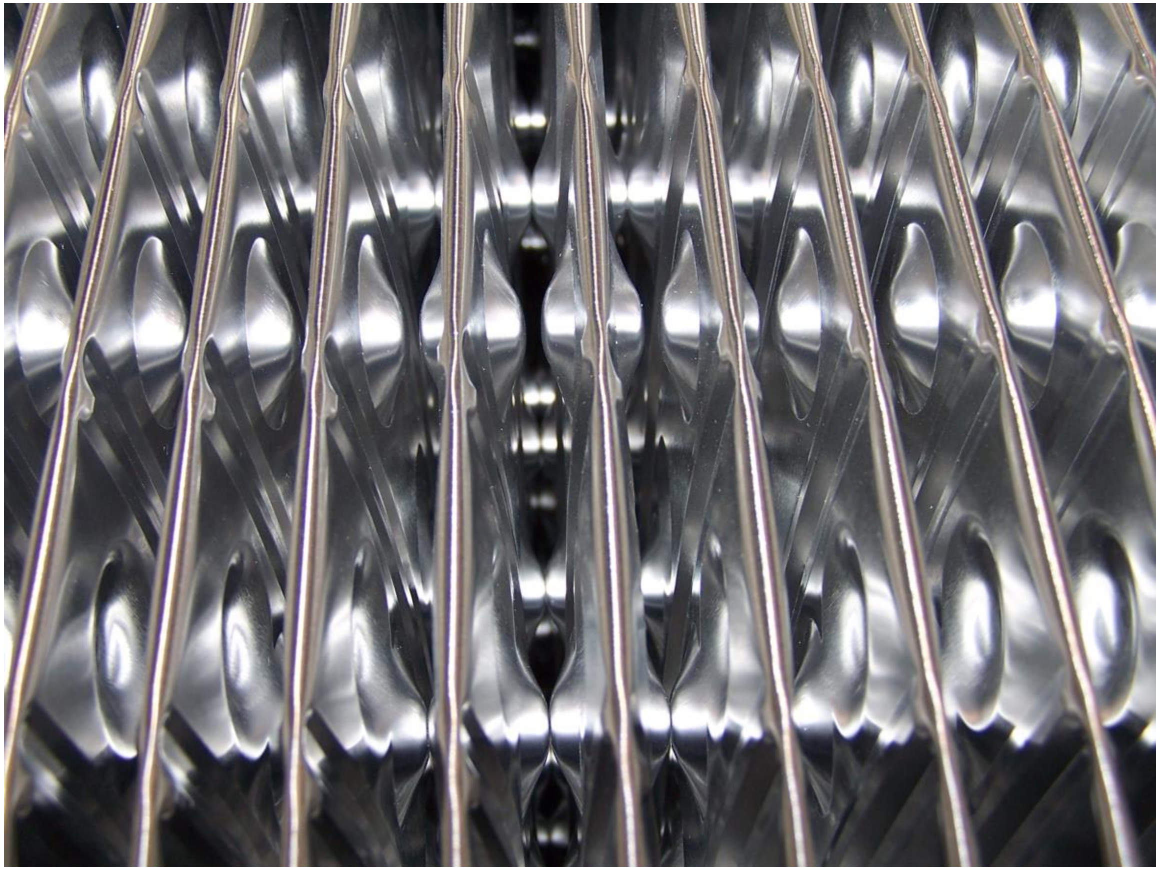


Plate Heat Exchanger:



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Cross Flow Plate Heat Exchanger:

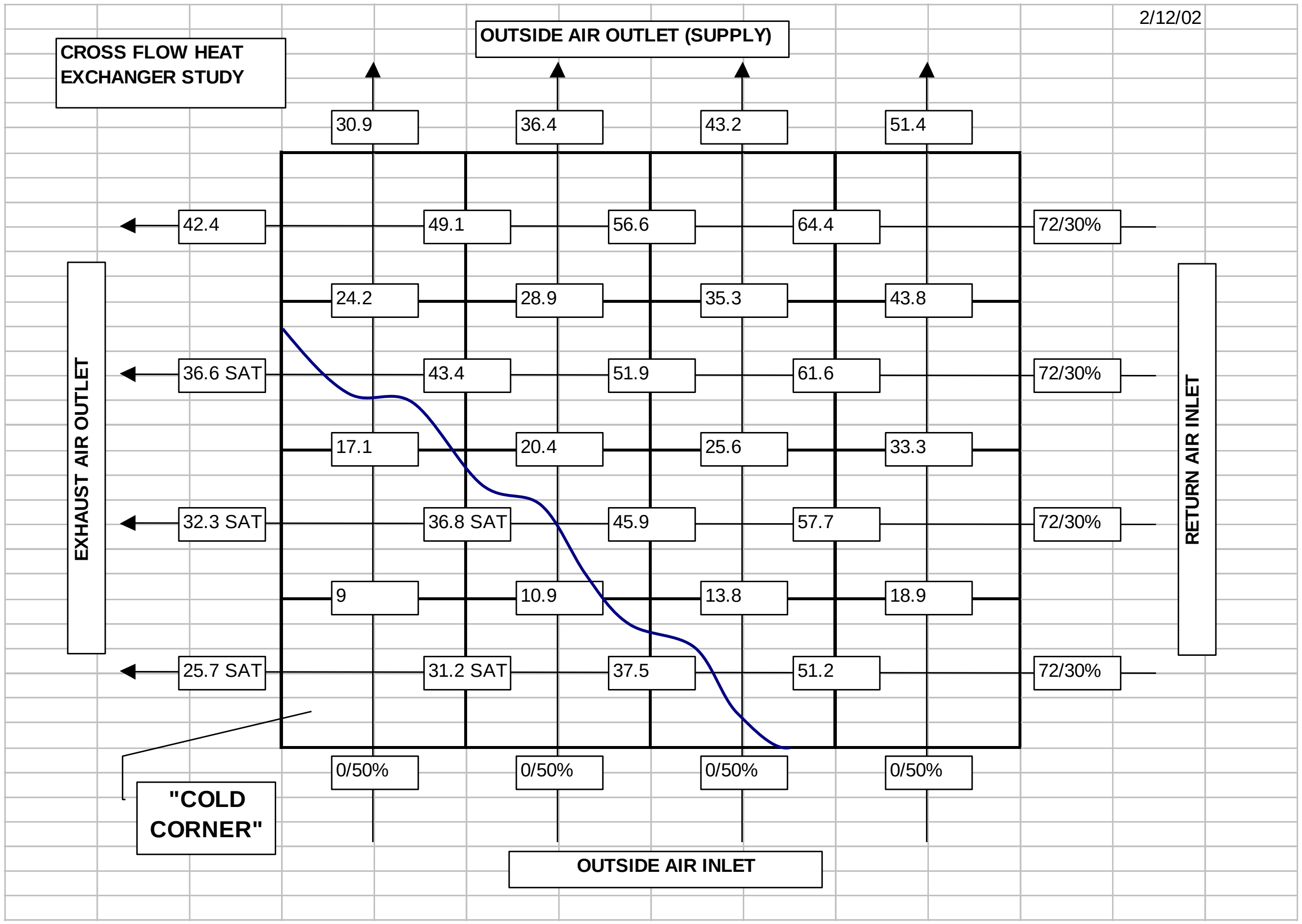

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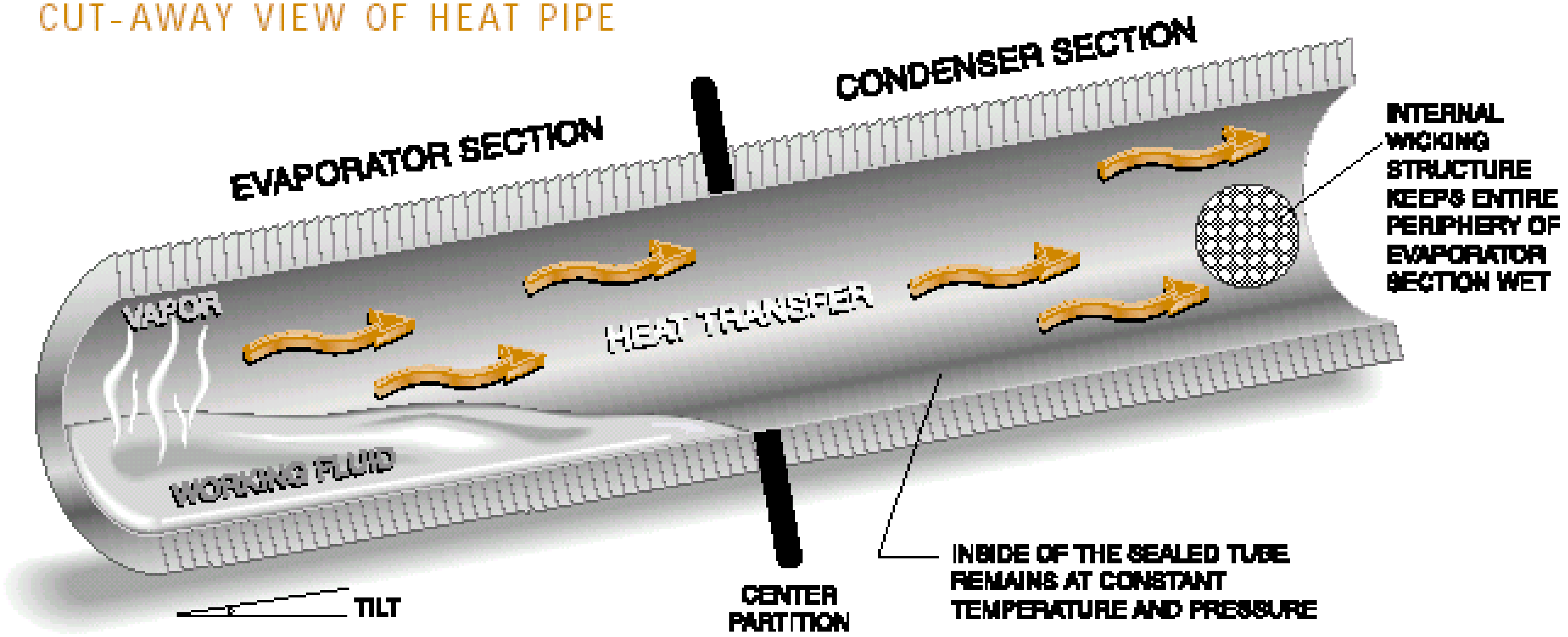
Plate Heat Exchanger Applications:

- Hospitals
- Clean rooms
- Pool units
- LEED Projects
- Projects with Class 4 air

Heat Pipe:

- Sensible energy recovery only
- Compact face area design
- No moving parts involved
- Minimal maintenance required
- No potential cross-contamination
- 55-60% effectiveness
- 25 year + lifetime
- Potential charge leak

Heat Pipe:



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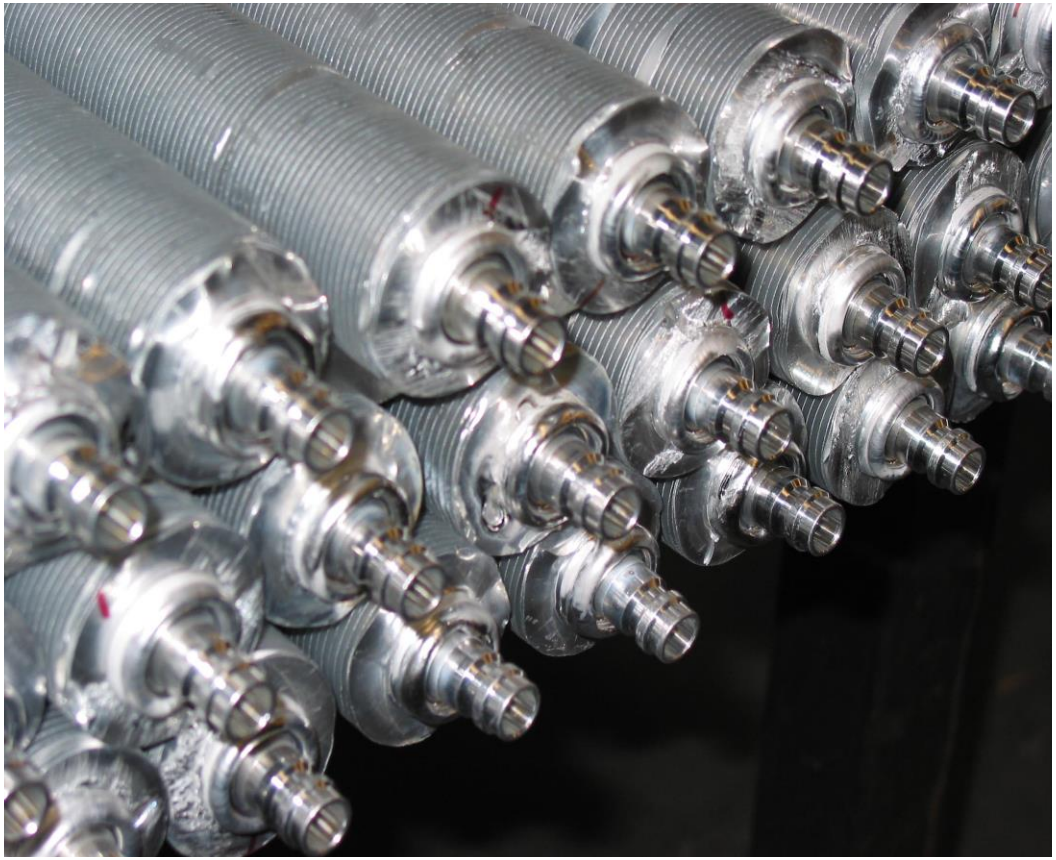
Heat Pipe:



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Heat Pipe:

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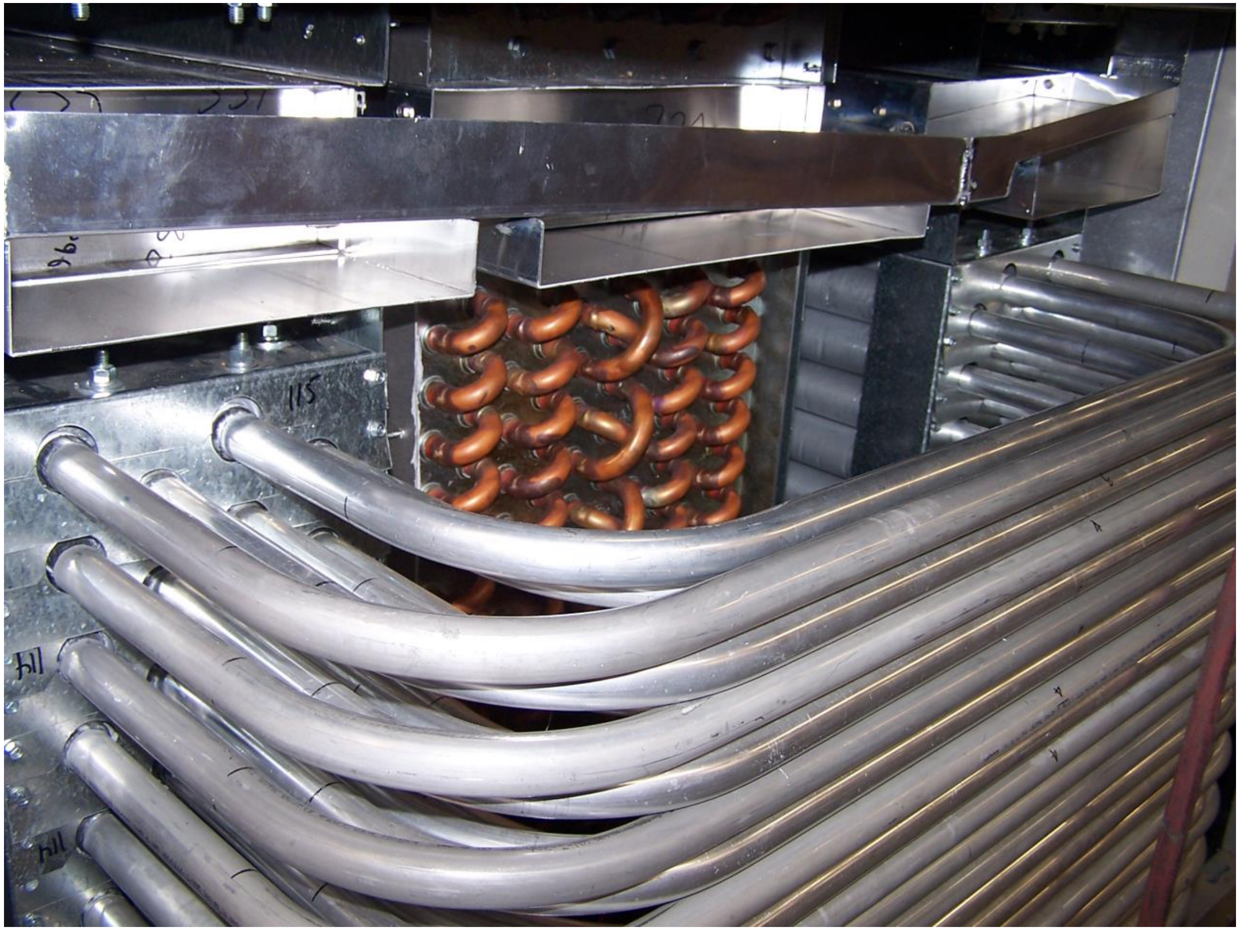
Wrap Around Heat Pipe:



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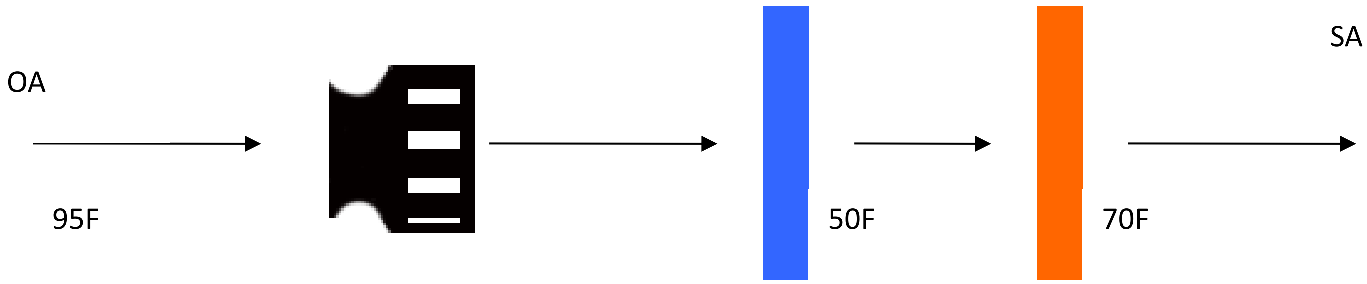
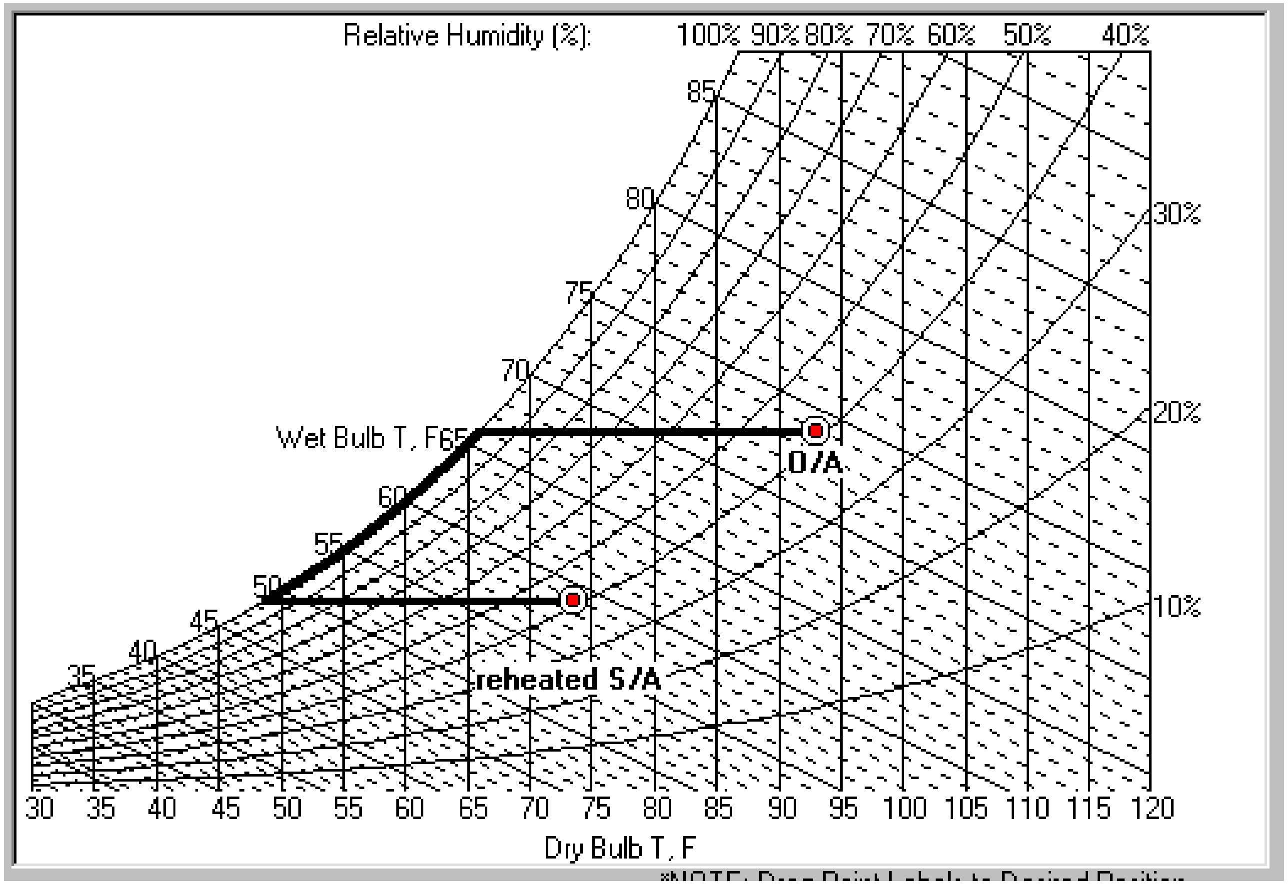
Heat Pipe Applications:

- Hospitals
- Clean rooms
- Pool units
- LEED projects
- Projects with Class 4 air

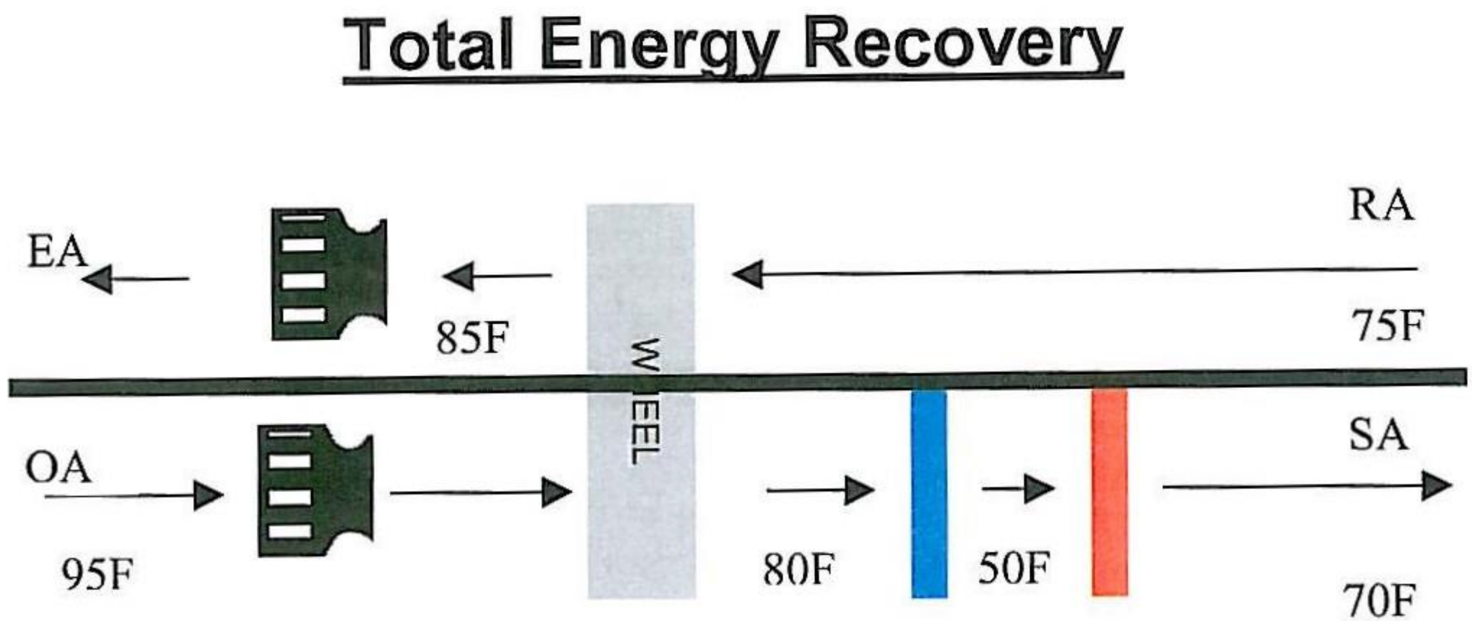
Brute Force:



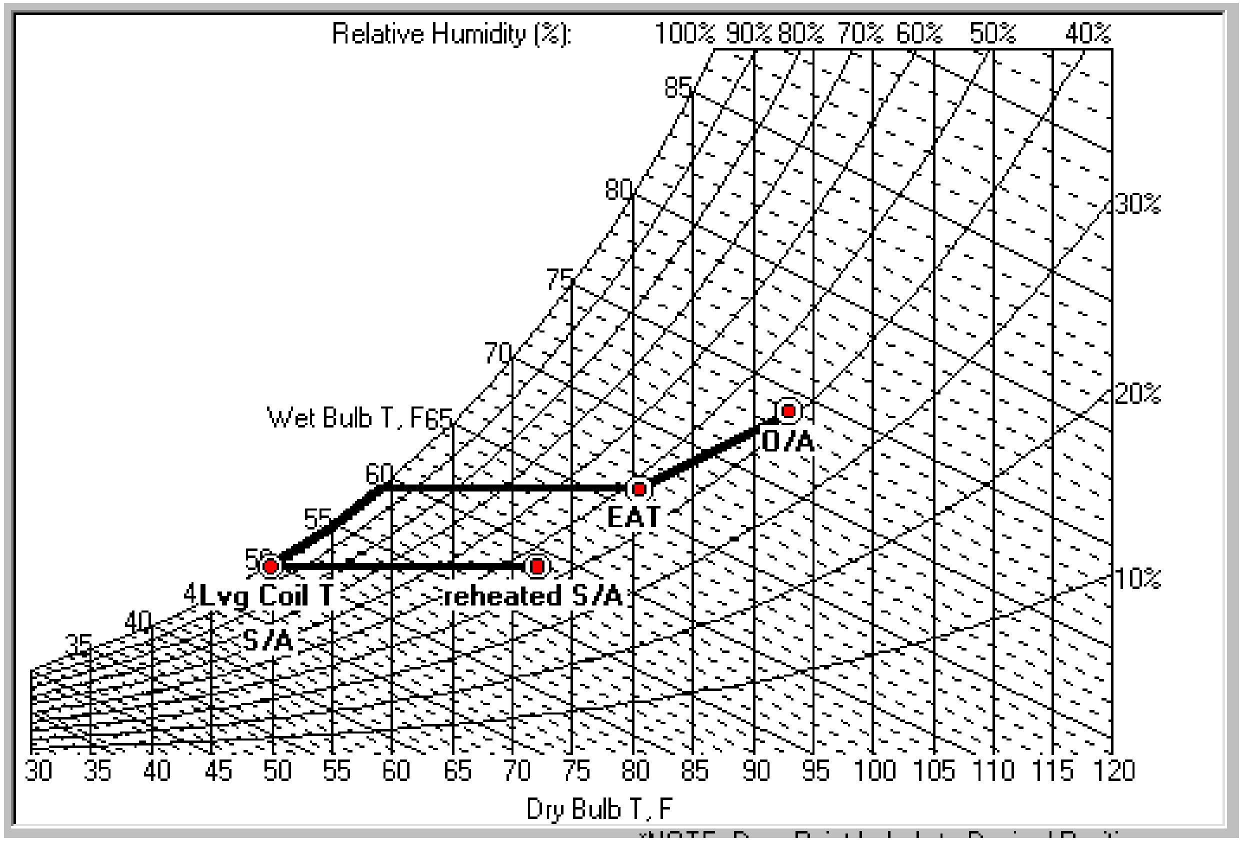
Brute Force:


Relative Humidity (%):
100% 90% 80% 70% 60% 50% 40%
30%
20%
10%
85
80
75
70
Wet Bulb T, F65
60
55
50
45
40
35
O/A
reheated S/A
30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
Dry Bulb T, F

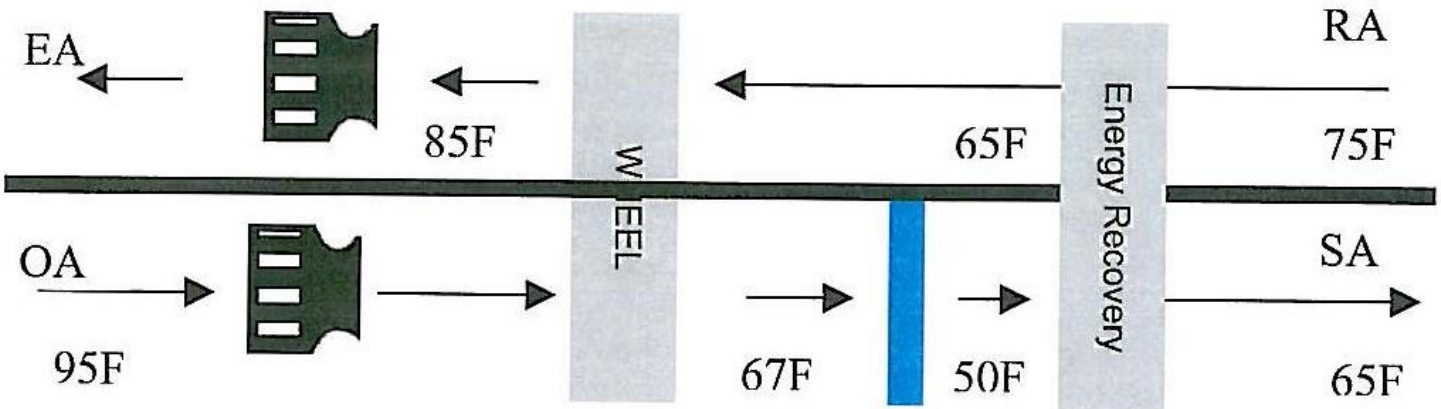
Total Energy Recovery:



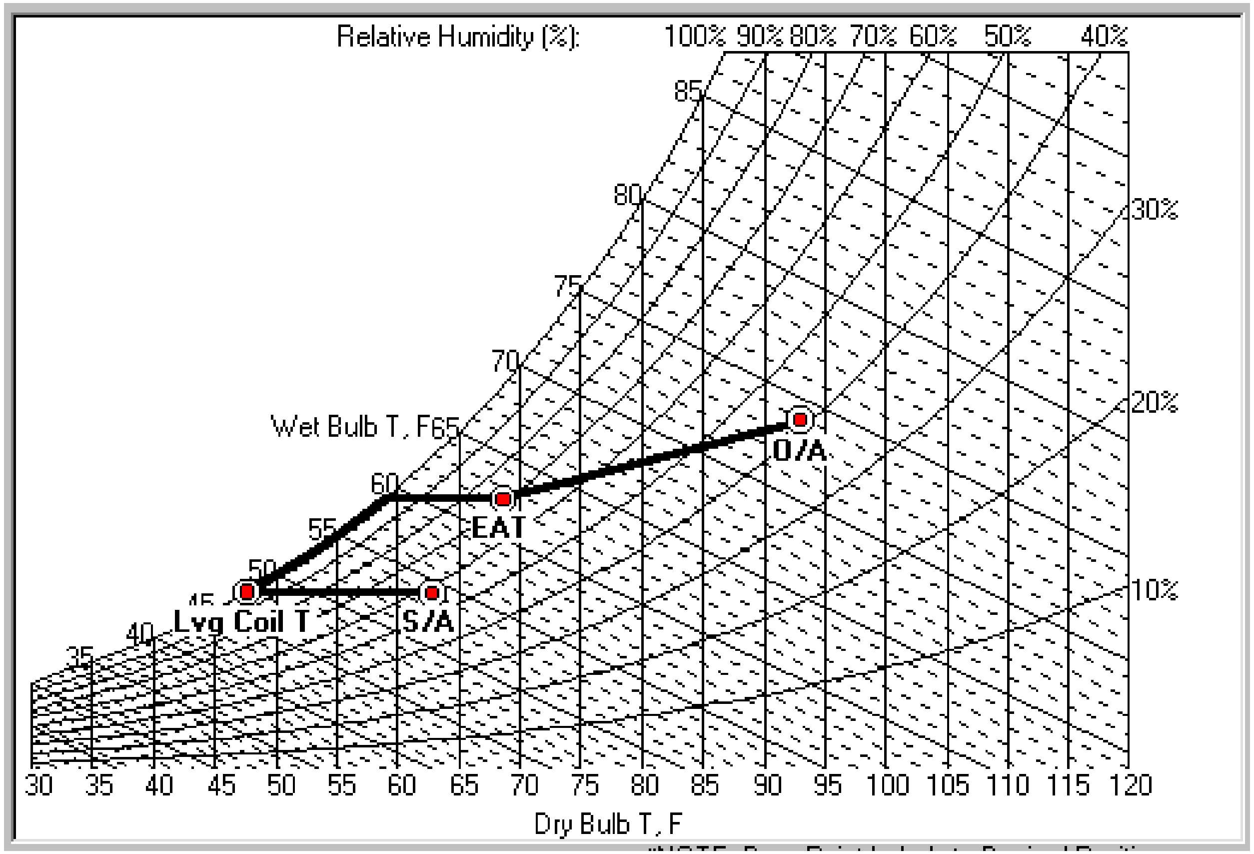
Total Energy Recovery:



Dual Energy Recovery System:



Dual Energy Recovery System:



Cost Comparison:

$0.10/Kwh, $10/Million BTUH, 20,000 CFM, 50% Time Operation

Akron, OH

SUMMARY

TEMPERATURES DRY BULB	MCWB	TOTAL HOURS AT CONDITION	TOTAL HOURS OF OPERATION	B F	Sens	Total	ERC No Exh	S&S	T&S
102	74	0	0.00	$0.00	$0.0	$0.0	$0.0	$0.00	$0.00
97	72	2	1.00	$16.81	$13.8	$11.9	$8.1	$8.26	$5.87
92	72	22	11.00	$185.31	$159.9	$131.5	$89.7	$98.78	$64.70
87	71	106	53.00	$853.82	$767.5	$624.9	$427.1	$472.82	$303.12
82	69	270	135.00	$1,977.13	$1,848.9	$1,548.1	$1,098.9	$1,098.23	$728.61
77	66	439	219.50	$2,754.82	$2,695.3	$2,416.0	$1,666.4	$1,474.67	$1,083.50
72	64	669	334.50	$4,894.07	$4,894.1	$3,585.3	$2,618.4	$2,035.92	$1,554.76
67	61	832	416.00	$5,305.34	$5,305.3	$5,305.3	$3,118.4	$3,048.49	$2,777.28
62	57	773	386.50	$4,027.19	$4,027.2	$4,027.2	$2,592.9	$2,192.51	$2,381.91
57	52	697	348.50	$1,701.55	$794.1	$595.5	$1,701.6	$581.36	$522.94
52	48	643	321.50	$2,005.76	$889.5	$645.3	$2,005.8	$627.89	$567.19
47	43	617	308.50	$2,343.06	$1,004.2	$711.3	$2,343.1	$690.37	$617.56
42	39	625	312.50	$2,797.27	$1,169.8	$813.7	$2,797.3	$788.32	$699.83
37	35	665	332.50	$3,427.24	$1,407.0	$965.0	$3,427.2	$933.47	$823.62
32	30	825	412.50	$4,811.30	$1,946.9	$1,320.3	$4,811.3	$1,275.55	$1,119.80
27	26	641	320.50	$4,172.91	$1,669.2	$1,121.5	$4,172.9	$1,082.35	$946.21
22	21	431	215.50	$3,098.08	$1,227.5	$818.4	$3,098.1	$789.13	$687.42
17	16	236	118.00	$1,856.44	$729.8	$483.3	$1,856.4	$465.71	$404.45
12	11	160	80.00	$1,367.10	$533.8	$351.5	$1,367.1	$338.52	$293.21
7	7	67	33.50	$617.91	$239.9	$157.2	$617.9	$151.30	$130.74
2	1	29	14.50	$287.12	$110.9	$72.4	$287.1	$69.62	$60.04
-3	-3	12	6.00	$126.95	$48.8	$31.7	$126.9	$30.52	$26.27
			TOTAL	**$48,627.16**	**$31,483.45**	**$25,737.48**	**$40,232.64**	**$18,253.79**	**$15,799.05**
			FAN HP COSTS	**$0.00**	**$3,420.05**	**$3,420.05**	**$2,470.03**	**$5,320.07**	**$6,080.08**
			ANNUAL TOTAL	**$48,627.2**	**$34,903.5**	**$29,157.5**	**$42,702.7**	**$23,573.9**	**$21,879.1**

Heat Exchanger Comparison:

	PLATE	HEAT PIPE	WHEEL
NOMINAL SENSIBLE EFFECTIVENESS	68%	58%	75%
NOMINAL LATENT EFFECTIVENESS	0%	0%	75%
MOVING PARTS	NO	NO	YES
MAINTENANCE REQUIREMENTS	MINIMAL	MINIMAL	HIGH
PARTICULATE PASSAGE	EXCELLENT	GOOD	NOT GOOD
LEAKAGE	NONE	NONE	5% - 20%
CLEANABILITY	EXCELLENT	GOOD	NOT GOOD
SIZE	LARGE	COMPACT	VERY COMPACT
LIFE EXPECTANCY	25 YRS +	25 YRS +	10 YRS +
COST	$1/CFM	$1/CFM	$1/CFM
MARKET VARIANCE	COUNTER-FLOW VS. CROSS FLOW	ONE-PIECE INDIVIDUALLY CHARGED VS. TWO PIECE MULTIPLE TUBE CHARGE	VOLLUTED VS. RIBBON. SYNTHETIC VS. ALUMINUM. 4A VS. 3A

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Manufacturers:

SAMSUNG

Energy Labs, Inc.

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SEASONS 4™

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Thank You!