Commissioning Heat Pump Systems: Ventilation System Integration

Please Visit These Links While We Are Waiting to Begin

https://tinyurl.com/HeatPumpD2Refresh

https://tinyurl.com/HeatPumpD2ExPref

Presented By:
David Sellers
Senior Engineer, Facility Dynamics Engineering

Disclaimer

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Learning Objectives – Class Series

1. Attendees will be able to discuss some of the issues and opportunities associated with applying heat pumps as a source of heat for buildings as we move towards electrification

Learning Objectives – Class Series

2. Attendees will be able to name the common heat pump types and describe their general characteristics (ground source, air source, water source, variable flow refrigeration, etc.)

Learning Objectives – Class Series

3. Attendees will be able to discuss ventilation strategies that can be applied in conjunction with heat pump systems and how they can be integrated with the heat pumps and the zones they serve

Learning Objectives – Class Series

4. Attendees will be able to discuss the design and commissioning issues associated with applying heat pumps to new construction and retrofit projects

Learning Objectives – Class Series

5. Attendees will be able to identify existing building commissioning issues and opportunities associated with heat pumps and heat pump systems

Learning Objectives – Today's Session

Attendees will be able to:

1. Discuss ventilation strategies that can be applied in conjunction with heat pump systems

Learning Objectives – Today's Session

Attendees will be able to:

2. Describe how ventilation air is provided to zones served by heat pumps

Learning Objectives – Today's Session

Attendees will be able to:

3. Recognize the difference between energy recovery system effectiveness and energy recovery system efficiency

Learning Objectives – Today’s Session

Attendees will be able to:

4. Identify ventilation system heat recovery strategies and their characteristics (wheels, plates, run-around coils, heat pipes, etc.)

Today's Agenda

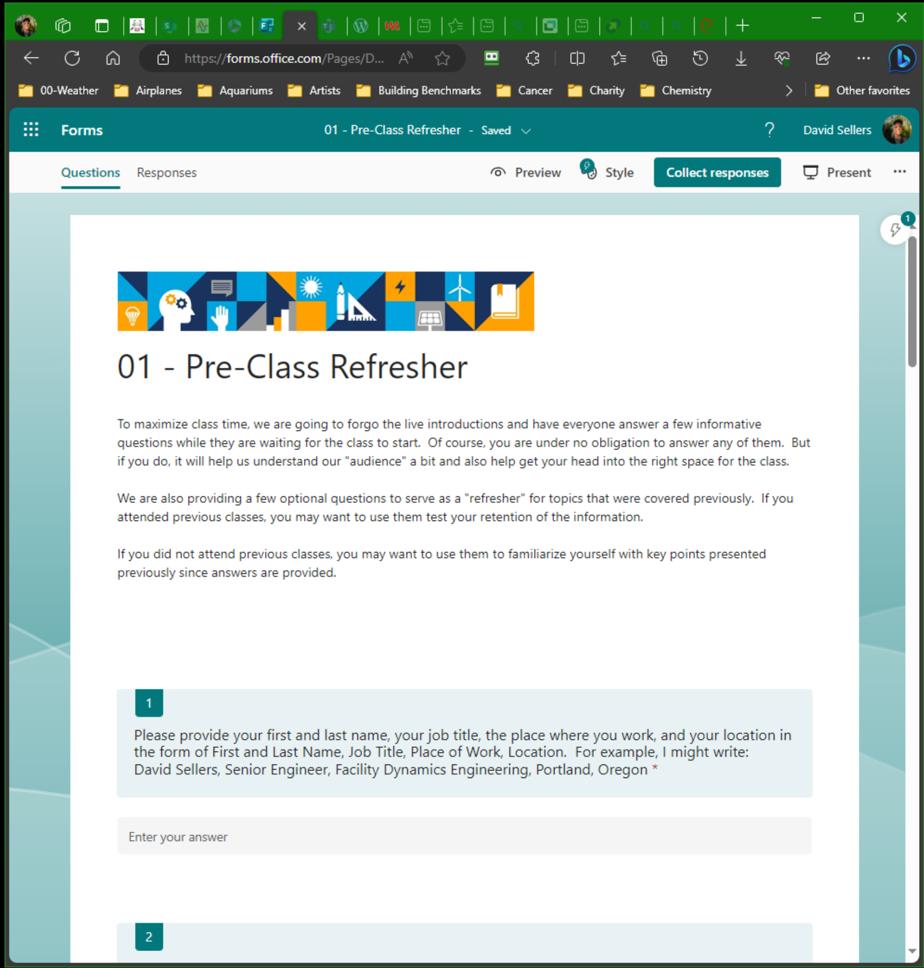
1. Introduction
2. Ventilation System Approaches and Associated Energy Recovery Strategies
3. Introducing Ventilation Air
4. Exercises (Time permitting; priority set by attendee vote)
   a. Assessing the Flow Path and Savings Opportunity for a Make Up Air System
   b. Exploring a Heat Recovery Unit and Building a Monitoring Plan
   c. Using Field Data to Assess Heat Recovery Ventilator Effectiveness
   d. Estimating the Maximum Possible Savings that Can Be Achieved from a DOAS System and its Cost/Benefit

Introduction

Introductions

https://tinyurl.com/HeatPumpD2Refresh

https://tinyurl.com/HeatPumpD2ExPref



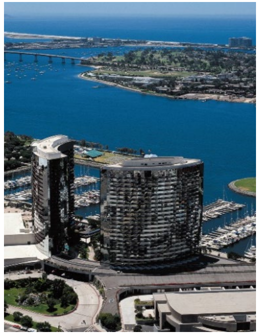
A Bit About Me

I intended to be an aircraft maintenance engineer

- I'm doing something *totally* different

A Bit About Me

- HVAC field technician
- Control system designer
- HVAC designer
- MCC Powers system engineer
- Murphy Company controls and start-up engineer
- Project engineer
- Wafer fab facilities engineer and system owner
- A happily married PECI technical support engineer and trainer
- FDE Senior Engineer



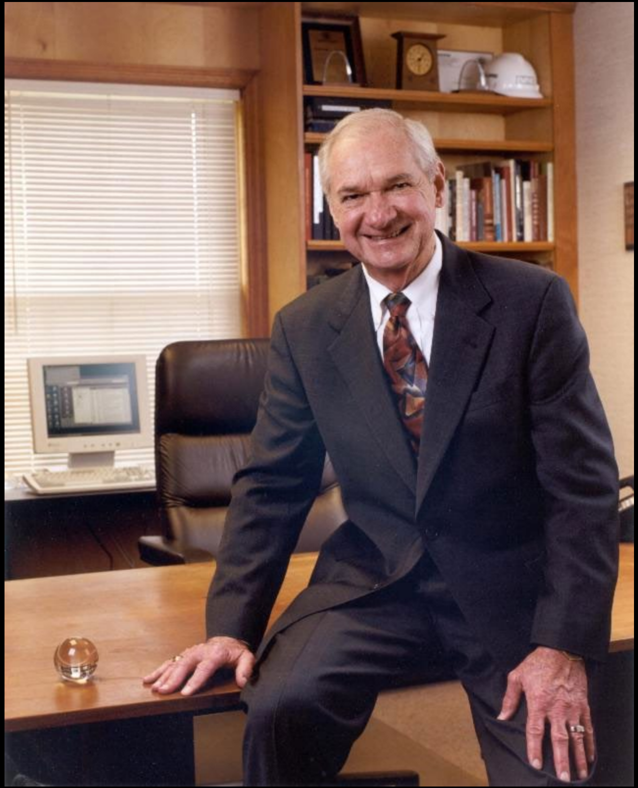
I’ve Had Great Mentors Along the Way

Bill Coad’s Thoughts on Energy Conservation

“… that is to practice our profession with an emphasis upon our responsibility to protect the long-range interests of the society we serve and, specifically, to incorporate the ethics of energy conservation and environmental preservation in everything we do.”

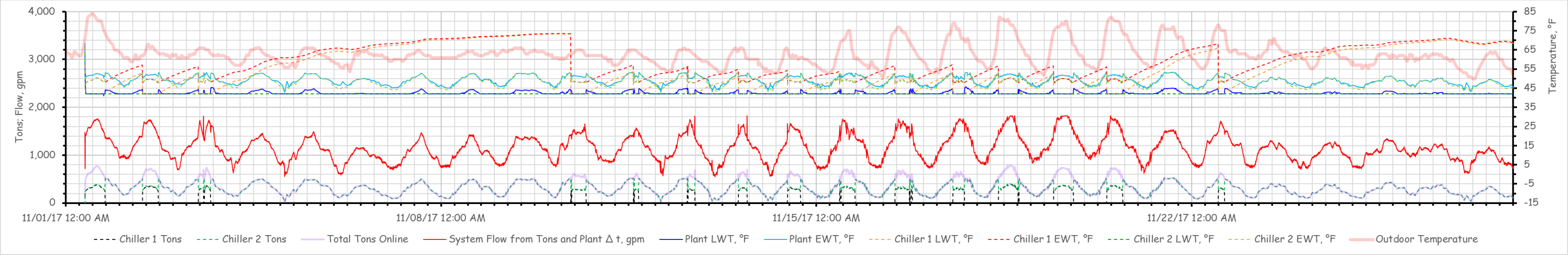
Energy Conservation is an Ethic
ASHRAE Journal, vol. 42, no. 7, p. 16-21

PDF available at
https://tinyurl.com/EnergyConservationEthic



My Most Important Lesson

It’s all about the load profile



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What's New?

Search

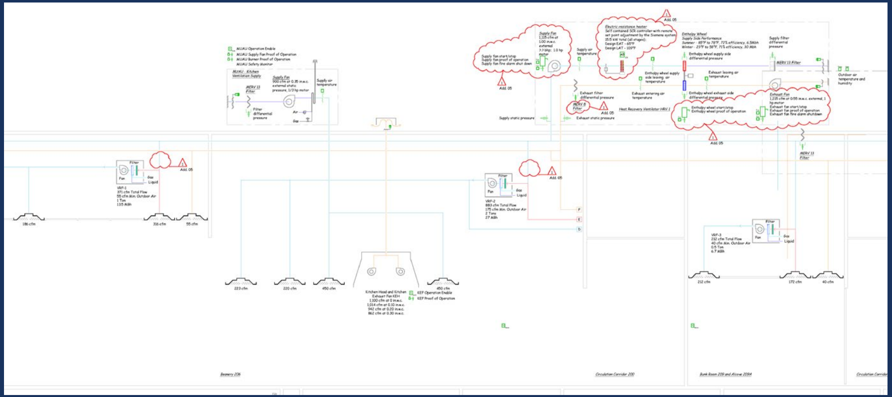
Buildings are Talking to Us

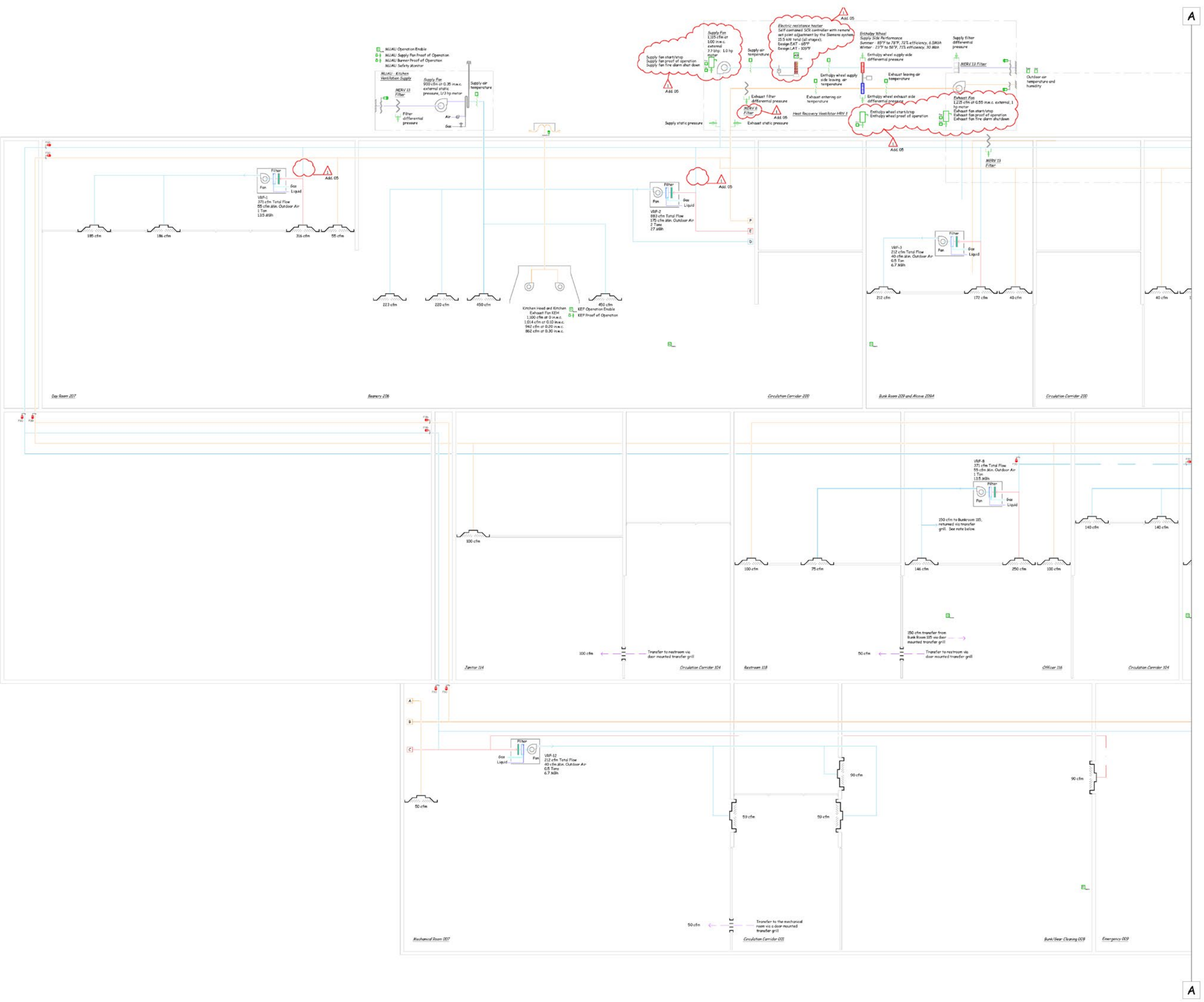
We Just Need to Learn How to Listen

My Goal

Ventilation

Today’s Focus




A
MUAU Operation Enable
MUAU Supply Fan Proof of Operation
MUAU Burner Proof of Operation
MUAU Safety Monitor
MUAU - Kitchen Ventilation Supply
MERV 13 Filter
Supply Fan
900 cfm at 0.35 in.w.c. external static pressure, 1/3 hp motor
Supply air temperature
Filter differential pressure
Air
Gas
Supply fan start/stop
Supply fan proof of operation
Supply fan fire alarm shut down
Add. 05
Supply Fan
1,115 cfm at 1.00 in.w.c. external
7.7 bhp: 1.0 hp motor
Supply air temperature
Electric resistance heater
Self contained SCR controller with remote set point adjustment by the Siemens system.
15.5 kW total (all stages);
Design EAT - 65°F
Design LAT - 109°F
Add. 05
Enthalpy Wheel
Supply Side Performance
Summer - 85°F to 78°F, 72% efficiency, 6.5Mbh
Winter - 23°F to 58°F, 71% efficiency, 30 Mbh
Enthalpy wheel supply side differential pressure
Supply filter differential pressure
MERV 13 Filter
Outdoor air temperature and humidity
Enthalpy wheel supply side leaving air temperature
Exhaust leaving air temperature
Exhaust filter differential pressure
Exhaust entering air temperature
Enthalpy wheel exhaust side differential pressure
MERV 8 Filter
Add. 05
Heat Recovery Ventilator HRV-1
Enthalpy wheel start/stop
Enthalpy wheel proof of operation
Exhaust Fan
1,215 cfm at 0.55 in.w.c. external, 1 hp motor
Exhaust fan start/stop
Exhaust fan proof of operation
Exhaust fan fire alarm shutdown
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Exhaust static pressure
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Filter
Fan
Gas
Liquid
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VRF-1
371 cfm Total Flow
55 cfm Min. Outdoor Air
1 Ton
13.5 MBh
185 cfm
186 cfm
316 cfm
55 cfm
VRF-2
883 cfm Total Flow
175 cfm Min. Outdoor Air
2 Tons
27 MBh
Add. 05
F
E
D
223 cfm
220 cfm
450 cfm
Kitchen Hood and Kitchen Exhaust Fan KEH
1,100 cfm at 0 in.w.c.
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KEF Operation Enable
KEF Proof of Operation
VRF-3
212 cfm Total Flow
40 cfm Min. Outdoor Air
0.5 Ton
6.7 MBh
212 cfm
172 cfm
40 cfm
40 cfm
Day Room 207
Beanery 206
Circulation Corridor 200
Bunk Room 209 and Alcove 209A
Circulation Corridor 200
100 cfm
VRF-8
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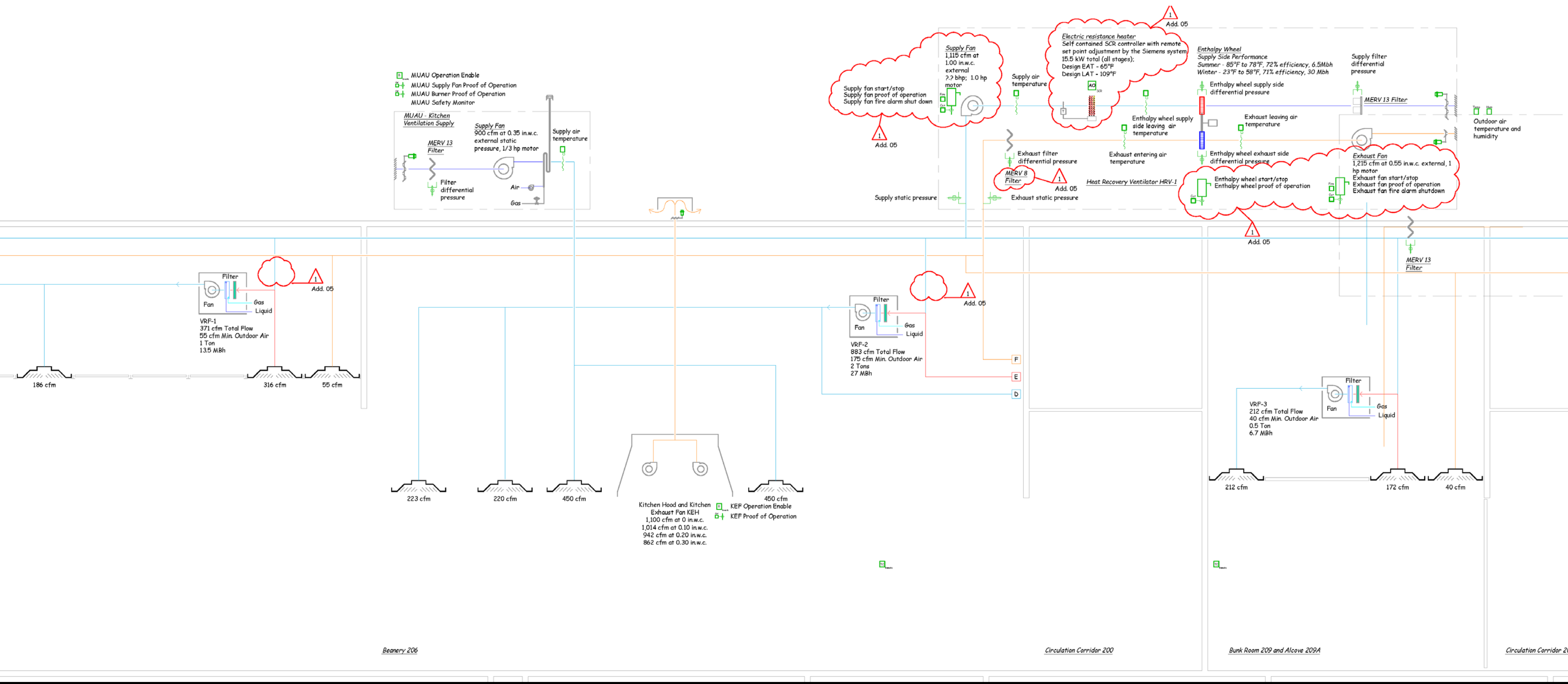
100 cfm
75 cfm
146 cfm
250 cfm
100 cfm
140 cfm
140 cfm
150 cfm transfer from Bunk Room 115 via door mounted transfer grill
100 cfm
Transfer to restroom via door mounted transfer grill
50 cfm
Transfer to restroom via door mounted transfer grill
Janitor 114
Circulation Corridor 104
Restroom 118
Officer 116
Circulation Corridor 104
A
B
C
VRF-12
212 cfm Total Flow
40 cfm Min. Outdoor Air
0.5 Tons
6.7 MBh
90 cfm
59 cfm
59 cfm
90 cfm
50 cfm
50 cfm
Transfer to the mechanical room via a door mounted transfer grill
Mechanical Room 007
Circulation Corridor 001
Bunk/Gear Cleaning 008
Emergency 009
A



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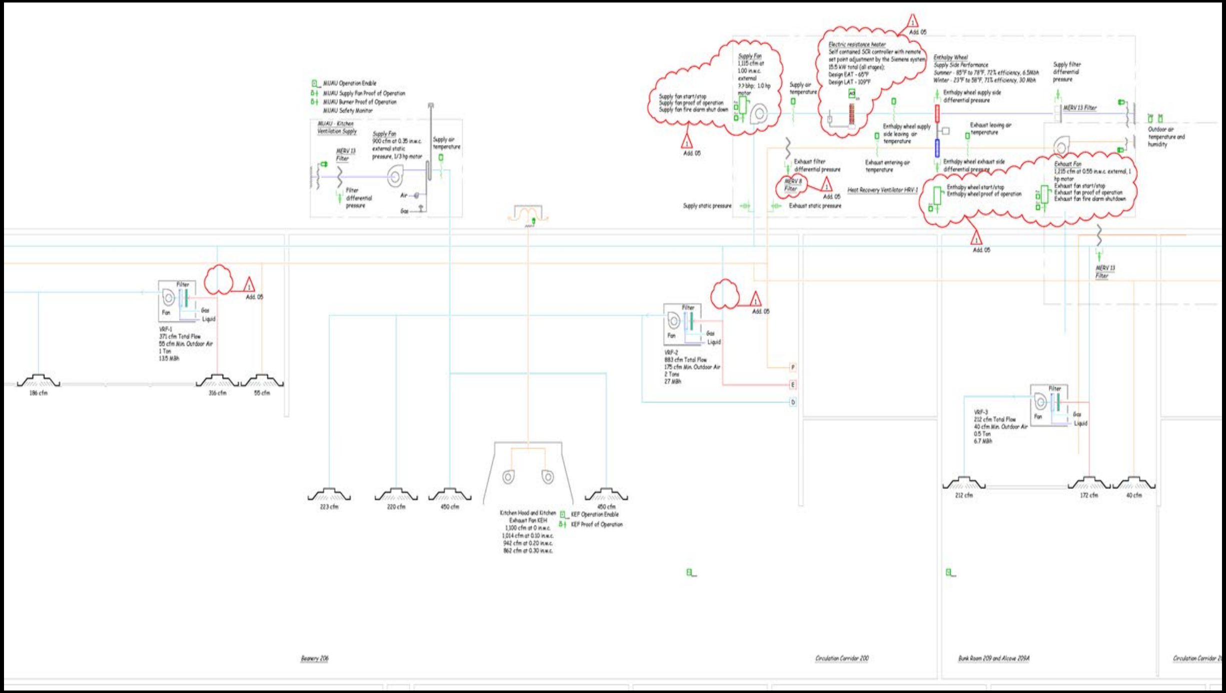
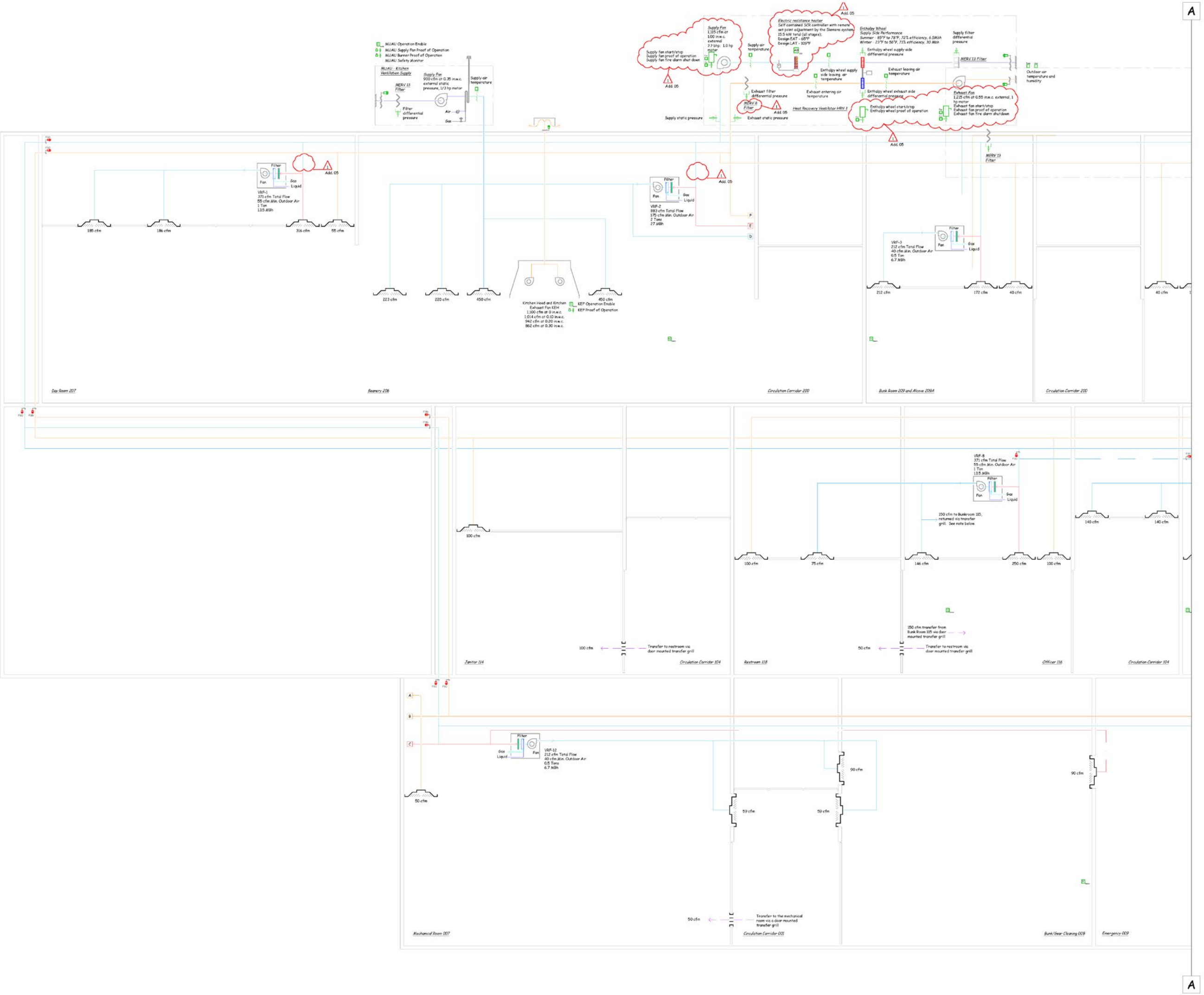
Bunk Room 209 and Alcove 209A
Circulation Corridor 2

A Question For You

https://tinyurl.com/HeatPumpD2Q1Vent

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Mechanical Room 007
Circulation Corridor 001
Bunk/Gear Cleaning 008
Emergency 009
A

A Few More Definitions

Ventilation

- Outdoor air that is brought into the building to manage contaminates, generally by dilution
- The outdoor air volume is dictated by:
  - Type of contaminant
  - Capture velocity
  - Occupant count
  - Code requirements
- ASHRAE Standard 62.1 is usually the basis for design
- Ventilation air typically is removed by exhaust systems

A Few More Definitions

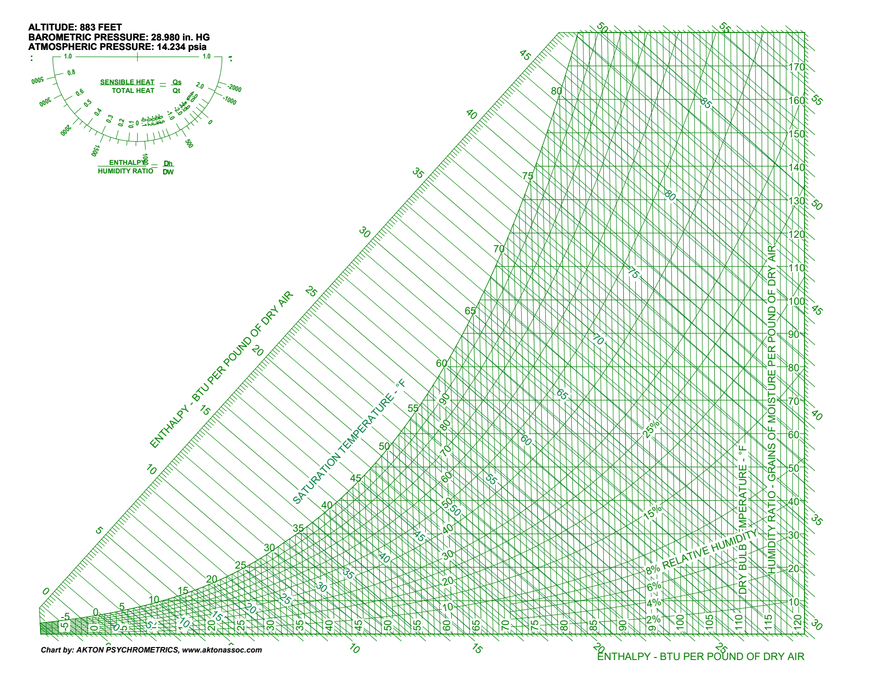
Ventilation Load

- The heating and cooling energy required to condition the ventilation air that is brought into a facility
  - With a positively pressurized space, it occurs at the central station AHU or in the system supplying outdoor air to the zone, not in the zone
  - It is often framed up in the context of delivering neutral air

A Few More Definitions

Neutral Air

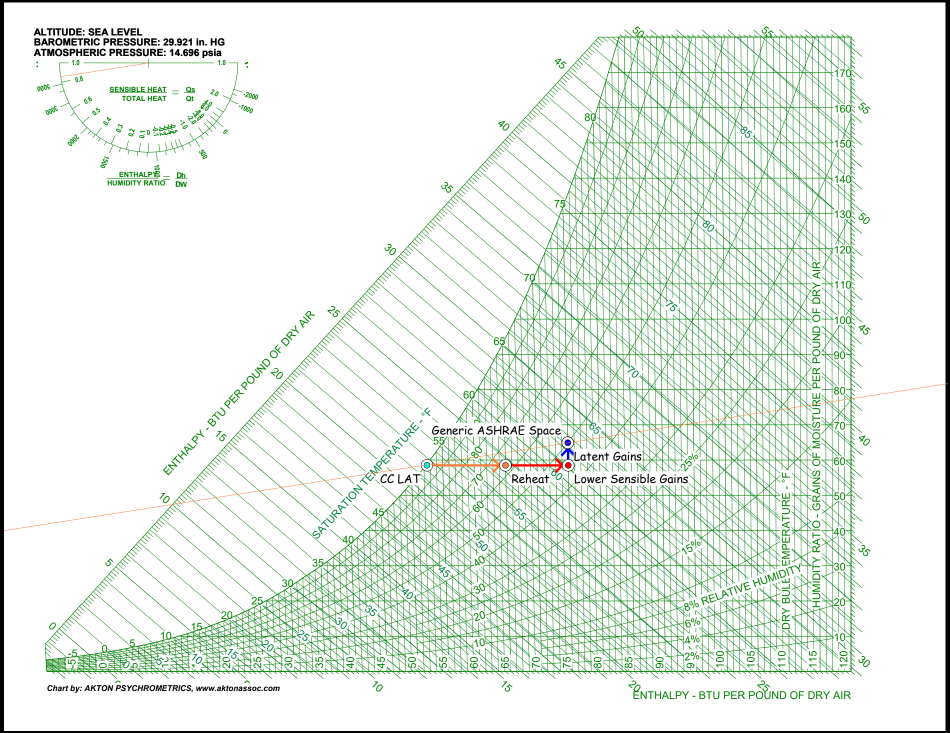
- Air that has been conditioned to match the targeted space condition
  - Since this air is at the targeted space condition, it can be introduced directly into the space and will not impact the space load



A Few More Definitions

Neutral Air

- Delivering neutral air may require that you do reheat
- Neutral air may work against you in some applications



A Few More Definitions

MAU

- https://tinyurl.com/HeatPumpD2Q2MAU

A Few More Definitions

MAU

- Do You Know what "MAU" stands for?
- Make Up Air Unit

  Along with about 28 other things

  MAU Monthly Active Users

  MAU Multistation Access Unit

  MAU Multiple Access Unit

  MAU Multistation Access Unit (token ring)

  MAU Medium Attachment Unit

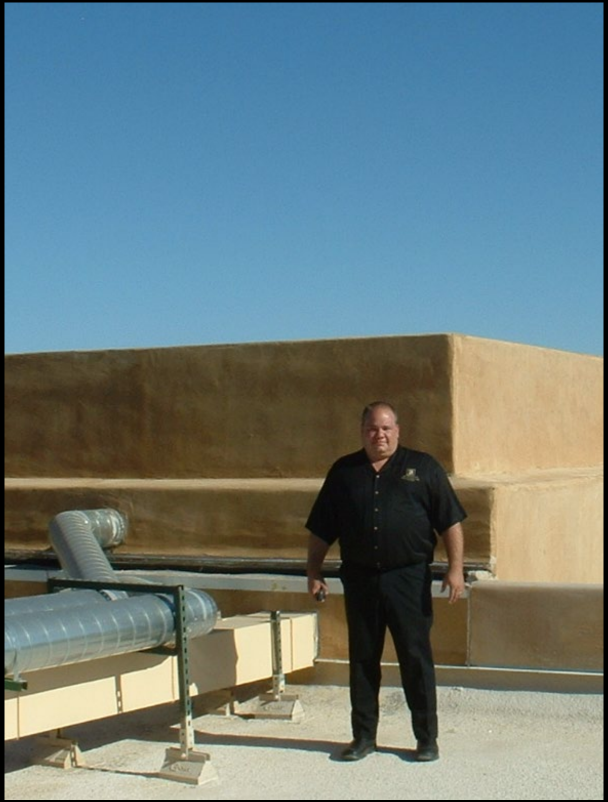
  MAU Air Mauritius (ICAO code)

A Few More Definitions

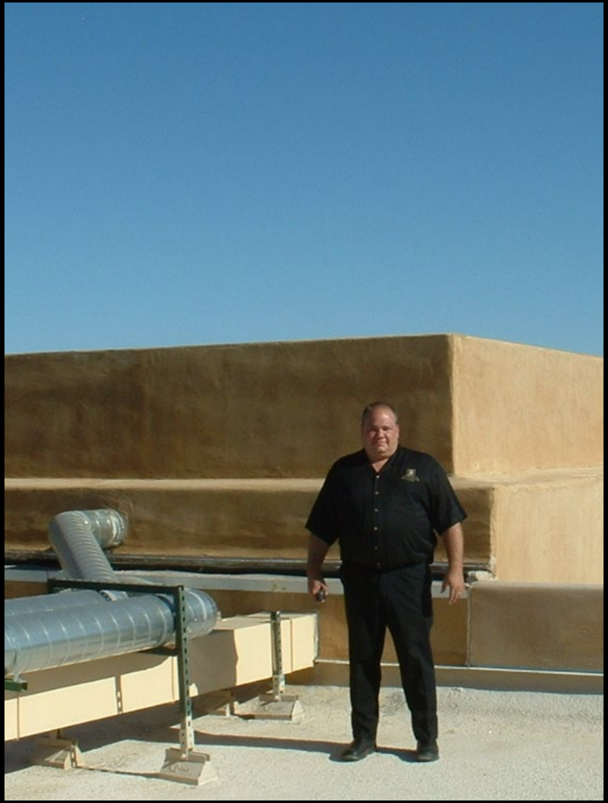
MAU

- Do You Know what “MAU” stands for?
- Make Up Air Unit
- Typically
  - 100% outdoor air
  - Includes filtration, a preheat process, a cooling process, and a reheat process
  - May include a humidification process


AHU-03



Ambient Condition
(shirt sleeves)



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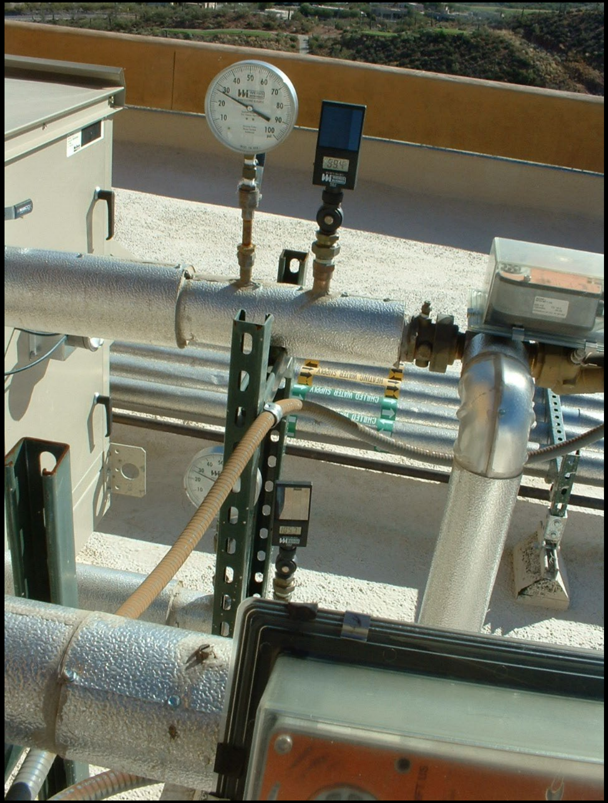
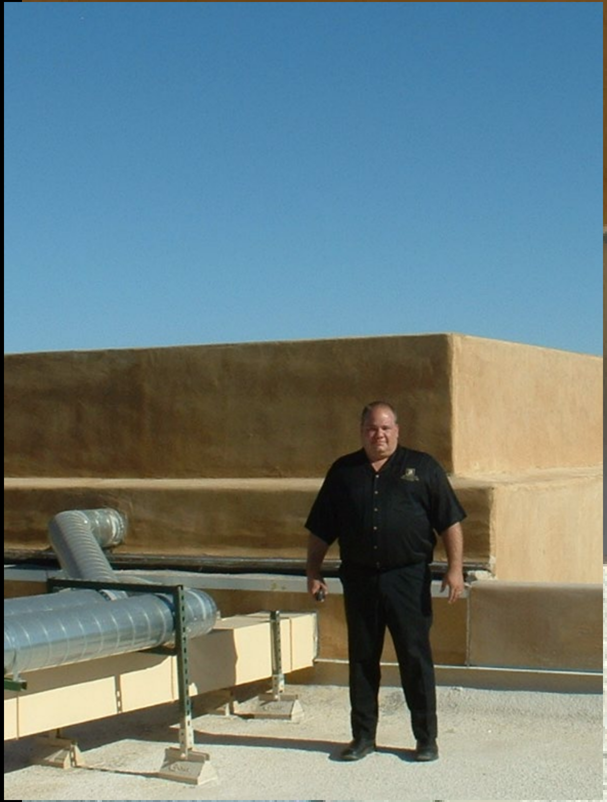


Active Preheat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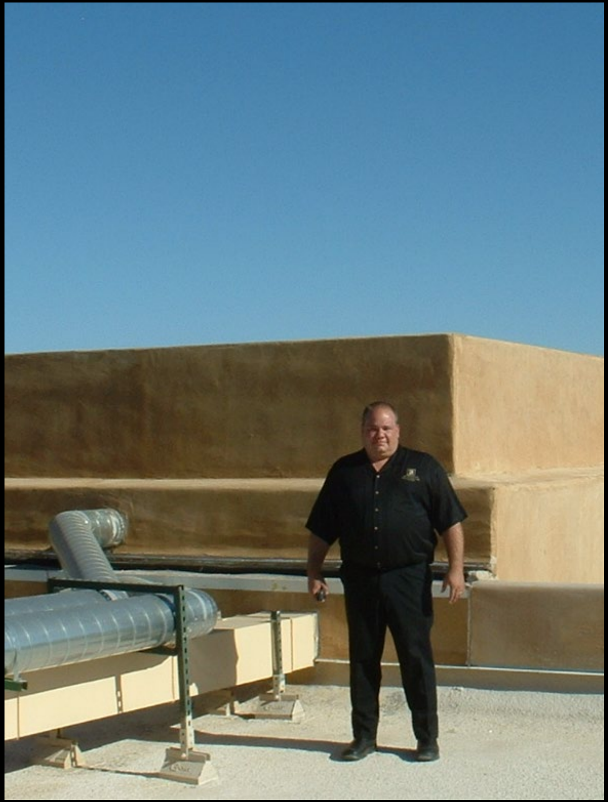
Active Preheat



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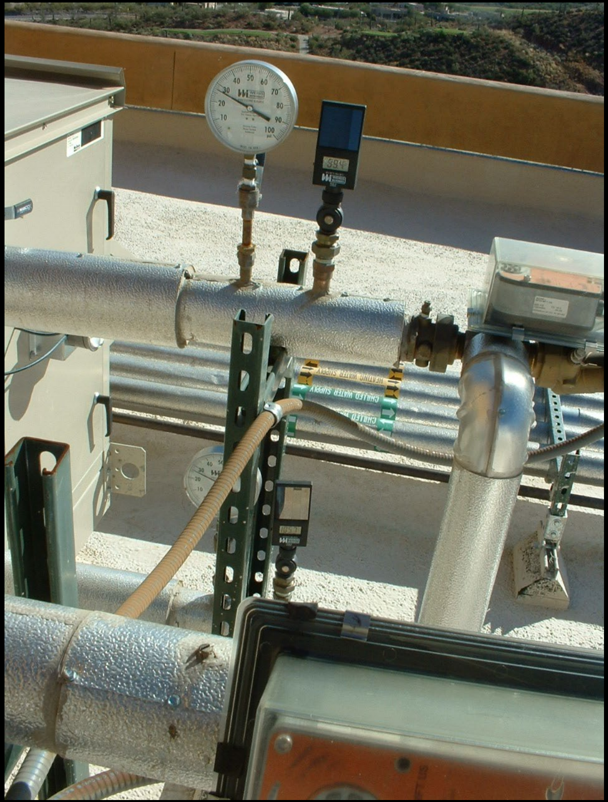
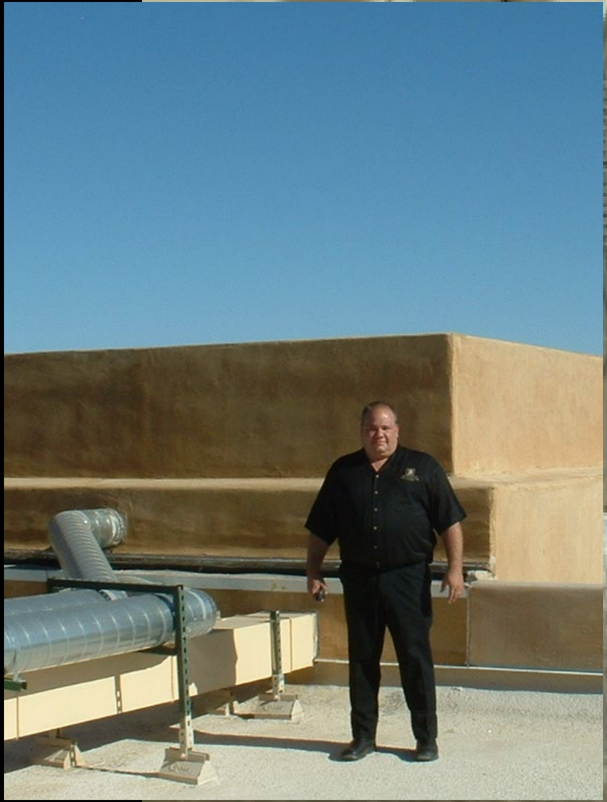
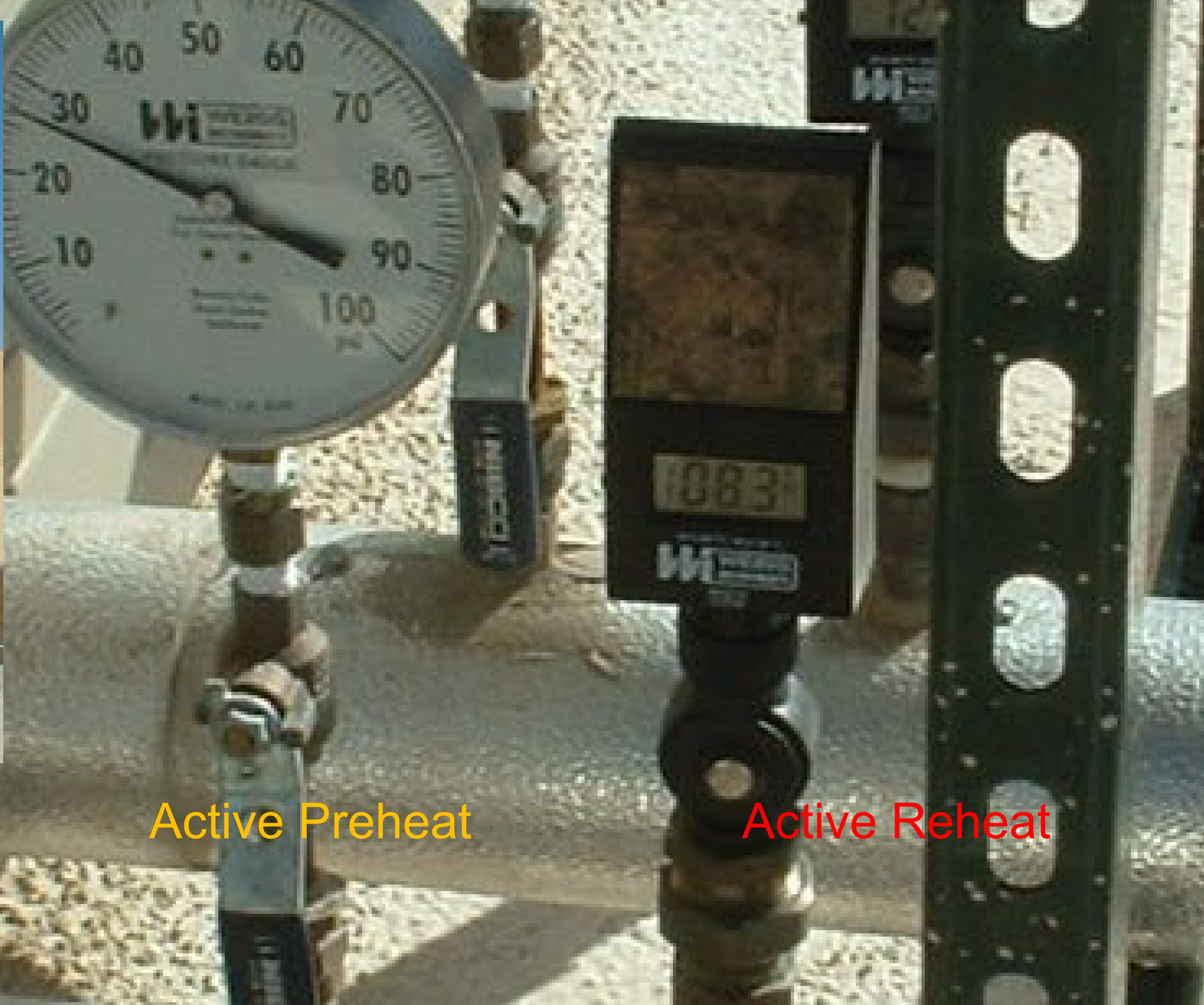


Active Preheat

Active Reheat





Ambient Condition
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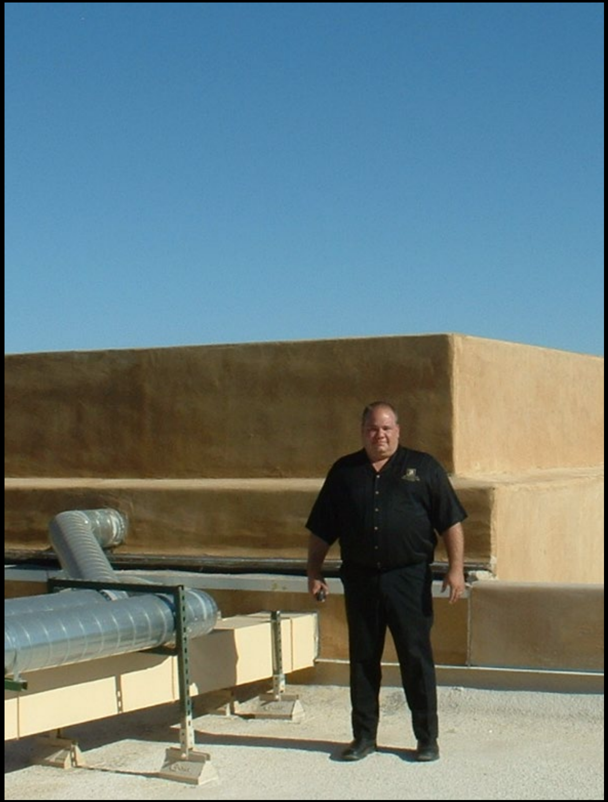
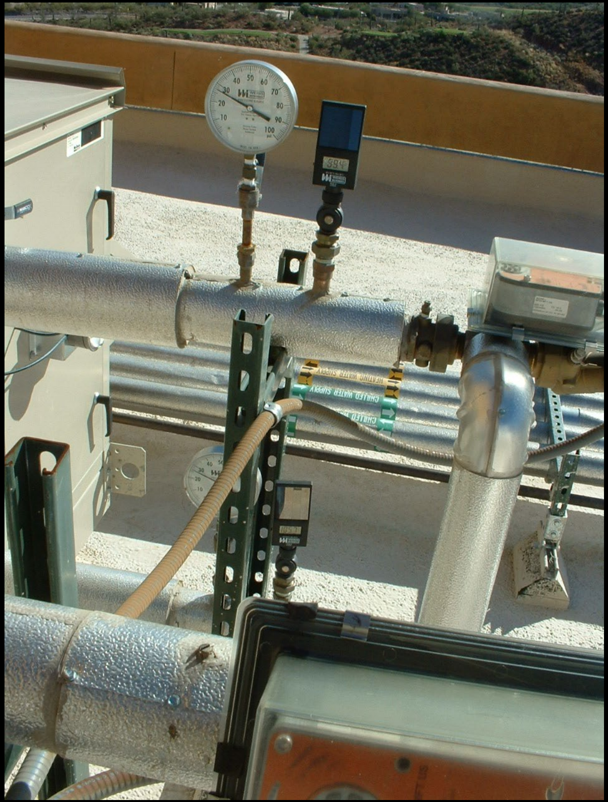
Active Preheat

Active Reheat



Ambient Condition
(shirt sleeves)



Active Preheat

Active Reheat

Cooling was also active

The Tall Things are Cactus

Can you “connect the dots”?

https://tinyurl.com/HeatPumpD2Q3MAU

A Few More Definitions

ERV

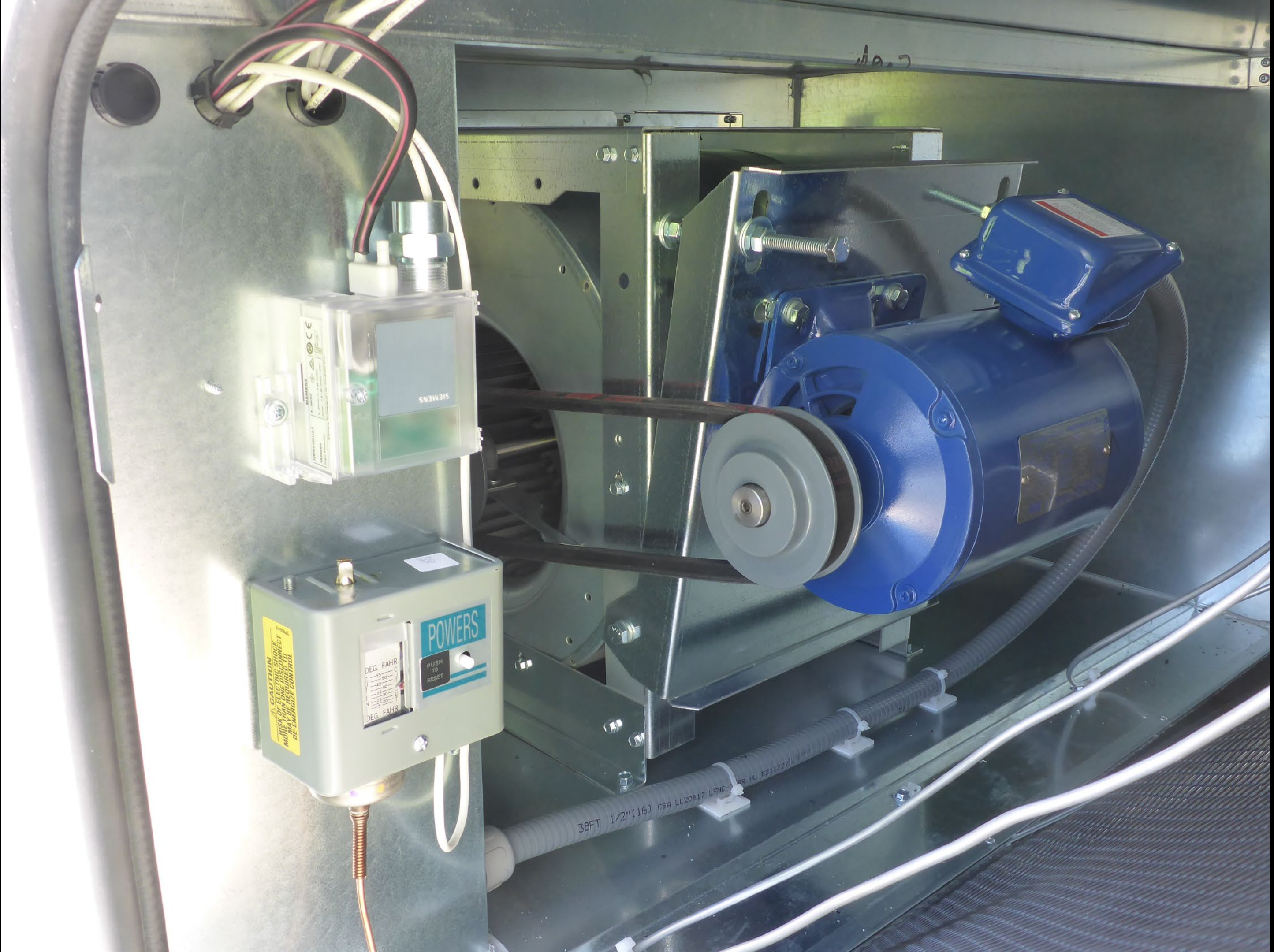
- Energy Recovery Ventilator
- Typically
  - 100% outdoor air
  - Includes filtration, some sort of energy recovery device, and fans for the supply and exhaust air stream


E
D
C
B
A
22
aldes
aldes
aldes
aldes
208 V

Another Question For You

https://tinyurl.com/HeatPumpD2Q4RTEquip


Fabriqué au Canada
Made in Canada
SERPENTIN ÉLECTRIQUE SUR MESURE
CUSTOM ELECTRIC DUCT HEATER
DATE
SDHI10X30-15K208V3P-CIR011-GHLOPDD-OEMF
16-03-17-40
15KW | 208V | 3PH | 41.6AMPS. | 60HZ | Dim. 10" X 30"
100 mA
40 VA
2
N/A
24
0
HORIZONTAL
300
AVERTISSEMENT
RISQUE DE CHOC ÉLECTRIQUE.
PEUT CAUSER DES BLESSURES GRAVES
OU LA MORT. DÉCONNECTER TOUTES
LES SOURCES D'ALIMENTATION
AVANT L'ENTRETIEN DE L'APPAREIL.
WARNING
RISK OF ELECTRIC SHOCK.
CAN CAUSE INJURY OR DEATH.
DISCONNECT ALL REMOTE
ELECTRIC POWER SUPPLIES
BEFORE SERVICING.
DIRECTION DU DÉBIT D'AIR / AIRFLOW DIRECTION


SIEMENS
POWERS
PUSH TO RESET
DEG. FAHR
DEG. FAHR


SIEMENS


RV-1
208V

208V
Lenze
AC Tech
Lenze
AC Tech


MC1
MC2
MC3
RS1
RS2
ECB-253
BACnet
R5
R6
ATTENTION
TOUJOURS COUPER LE CIRCUIT D'ALIMENTATION AVANT TOUTE RÉPARATION.
CAUTION
ALWAYS CUT OFF ELECTRICAL SUPPLY BEFORE DOING ANY REPAIR.
SAFETY
RIBU1C
RIBU1C


RV-1
208V


208V
Lenze
AC Tech
Lenze
AC Tech


RV-1
208V


208V
Lenze
AC Tech
Lenze
AC Tech


R1
R2
R3
R4
R5
INPUT1
INPUT2
DRV1
DRV2
SMVector
Lenze
AC Tech
WARNING
ATTENTION
CAUTION
RIBU1C
BACnet


RV-1
208V

208V
Lenze
AC Tech
Lenze
AC Tech

A Few More Definitions

DOAS

- Dedicated Outdoor Air System
- A complete package for handling and conditioning outdoor air
- Typically
  - 100% outdoor air
  - Includes filtration, some sort of energy recovery device, and fans for the supply and exhaust air stream
  - May include some form of supplemental heating or cooling or humidification or all three

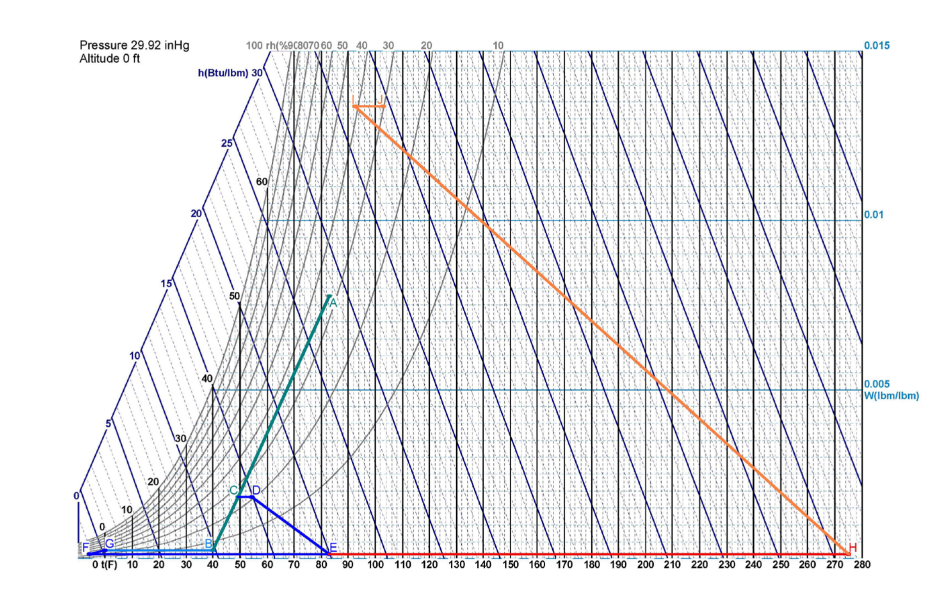

HEATING WATER SUPPLY
CHILLED WATER SUPPLY
CHILLED WATER RETURN
190

HEATING WATER SUPPLY

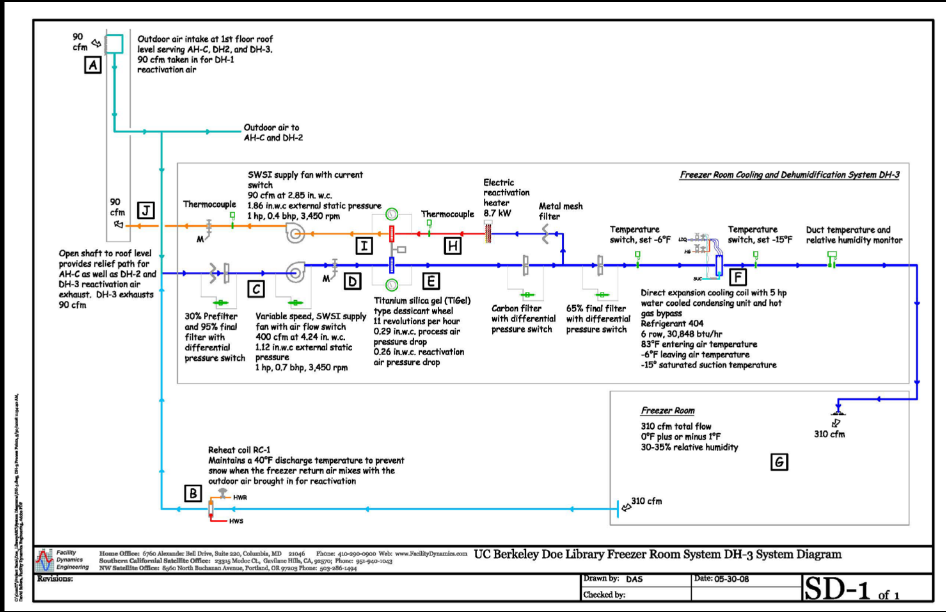
A Few More Definitions

Desiccant Dehumidification

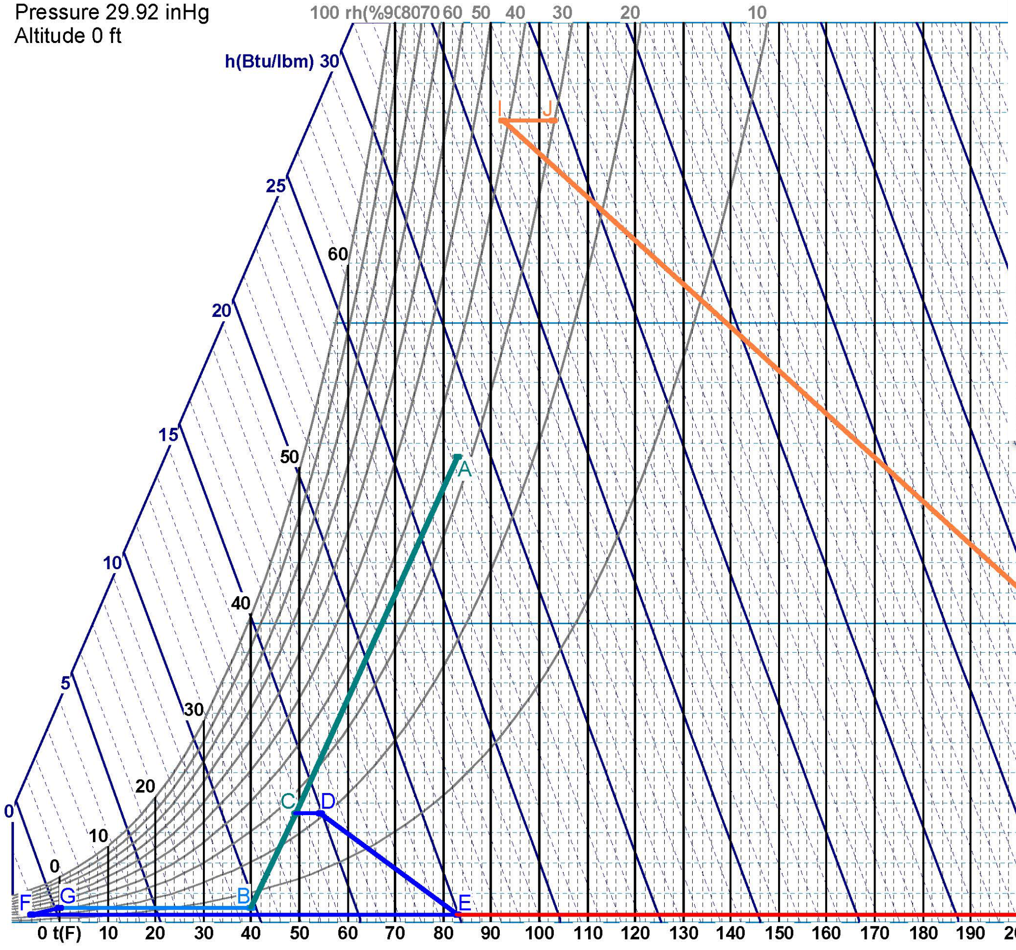
- Similar in concept to heat and energy wheels
  - Actively dehumidify vs. transfer latent energy
  - Require regeneration
  - May be an option in humid climates
  - More often used for special applications



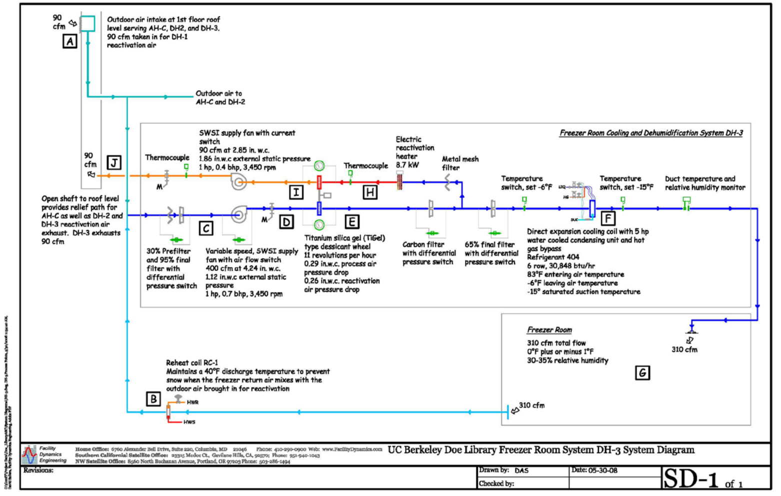
Pressure 29.92 inHg
Altitude 0 ft
h(Btu/lbm)
100 rh(%)
W(lbm/lbm)
0.015
0.01
0.005
t(F)
A
B
C
D
E
F
G
H
I
J



90 cfm
A
Outdoor air intake at 1st floor roof level serving AH-C, DH2, and DH-3. 90 cfm taken in for DH-1 reactivation air
Outdoor air to AH-C and DH-2
Freezer Room Cooling and Dehumidification System DH-3
90 cfm
J
Thermocouple
SWSI supply fan with current switch
90 cfm at 2.85 in. w.c.
1.86 in.w.c external static pressure
1 hp, 0.4 bhp, 3,450 rpm
Thermocouple
Electric reactivation heater
8.7 kW
Metal mesh filter
I
H
Temperature switch, set -6°F
Temperature switch, set -15°F
Duct temperature and relative humidity monitor
Open shaft to roof level provides relief path for AH-C as well as DH-2 and DH-3 reactivation air exhaust. DH-3 exhausts 90 cfm
C
D
E
F
30% Prefilter and 95% final filter with differential pressure switch
Variable speed, SWSI supply fan with air flow switch
400 cfm at 4.24 in. w.c.
1.12 in.w.c external static pressure
1 hp, 0.7 bhp, 3,450 rpm
Titanium silica gel (TiGel) type dessicant wheel
11 revolutions per hour
0.29 in.w.c. process air pressure drop
0.26 in.w.c. reactivation air pressure drop
Carbon filter with differential pressure switch
65% final filter with differential pressure switch
Direct expansion cooling coil with 5 hp water cooled condensing unit and hot gas bypass
Refrigerant 404
6 row, 30,848 btu/hr
83°F entering air temperature
-6°F leaving air temperature
-15° saturated suction temperature
Freezer Room
310 cfm total flow
0°F plus or minus 1°F
30-35% relative humidity
310 cfm
G
Reheat coil RC-1
Maintains a 40°F discharge temperature to prevent snow when the freezer return air mixes with the outdoor air brought in for reactivation
B
HWR
HWS
310 cfm
Facility Dynamics Engineering
UC Berkeley Doe Library Freezer Room System DH-3 System Diagram
Revisions:
Drawn by: DAS
Date: 05-30-08
Checked by:
SD-1 of 1



Pressure 29.92 inHg
Altitude 0 ft
100 rh(%90 80 70 60 50 40 30 20 10
h(Btu/lbm) 30
25
20
15
10
5
0
60
50
40
30
20
10
0
I
J
A
C
D
B
E
F
G
H
0.005
W(lbm/lbm)
0 t(F) 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280



90 cfm
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Outdoor air to AH-C and DH-2
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30-35% relative humidity
G
310 cfm
Reheat coil RC-1
Maintains a 40°F discharge temperature to prevent snow when the freezer return air mixes with the outdoor air brought in for reactivation
B
HWR
HWS
310 cfm
Facility Dynamics Engineering
Home Office: 6760 Alexander Bell Drive, Suite 220, Columbia, MD 21046 Phone: 410-290-0900 Web: www.FacilityDynamics.com
Southern California Satellite Office: 23315 Medoc Ct., Gavilane Hills, CA, 92570; Phone: 951-940-1043
NW Satellite Office: 8560 North Buchanan Avenue, Portland, OR 97203 Phone: 503-286-1494
UC Berkeley Doe Library Freezer Room System DH-3 System Diagram
Revisions:
Drawn by: DAS
Date: 05-30-08
Checked by:
SD-1 of 1

A Few More Definitions

Effectiveness

- Can be defined in terms of:
  - Total energy (enthalpy)
  - Sensible energy
  - Latent energy

$$\varepsilon = \left(\frac{\text{Actual transfer of energy}}{\text{Maximum transfer of energy possible}} \right)$$

Therefore, we can say ...

$$\varepsilon = \left(\frac{m_{Exh} \times \left(\eta_{Exh_{Lvg}} - \eta_{Exh_{Ent}} \right)}{m_{Min} \times \left(\eta_{Sup_{Ent}} - \eta_{Exh_{Ent}} \right)} \right). \text{ and } .\varepsilon = \left(\frac{m_{Sup} \times \left(\eta_{Sup_{Ent}} - \eta_{Sup_{Lvg}} \right)}{m_{Min} \times \left(\eta_{Sup_{Ent}} - \eta_{Exh_{Ent}} \right)} \right)$$

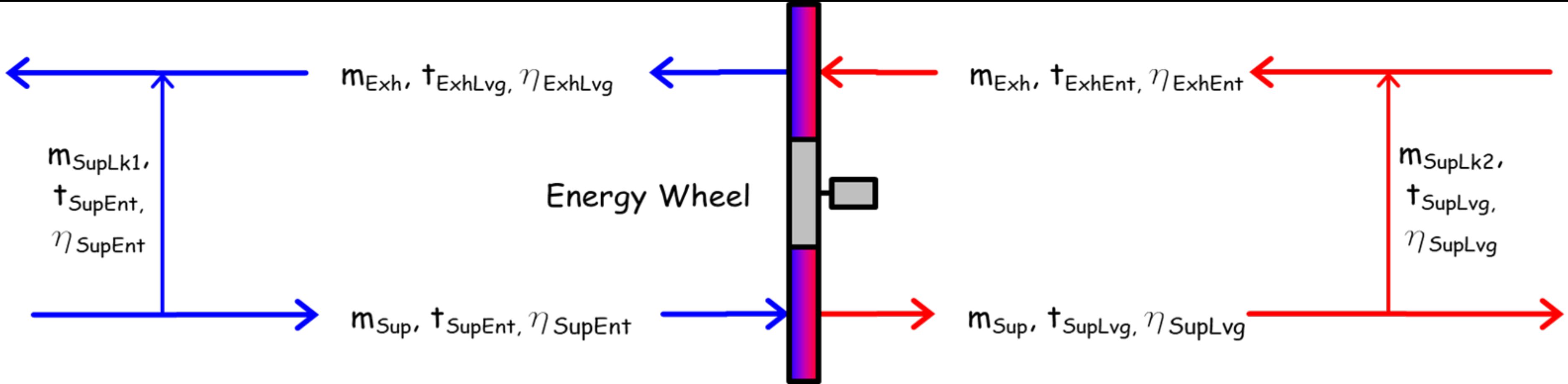
Where:

ε = Wheel effectiveness
m_{Exh} = Exhaust mass flow rate
m_{Sup} = Supply mass flow rate
m_{Min} = Minimum of the two mass flow rates
$\eta_{Exh_{Lvg}}$ = Exhaust air leaving enthalpy
$\eta_{Exh_{Ent}}$ = Exhaust air entering enthalpy
$\eta_{Sup_{Ent}}$ = Supply air entering enthalpy
$\eta_{Sup_{Lvg}}$ = Supply air leaving enthalpy

A Few More Definitions

Effectiveness

- From the perspective of the exhaust air stream
  - Cooling supply air is numerically positive
  - Heating supply air is numerically negative



A Few More Definitions

Recovery Efficiency Ratio

- Considers the energy it takes to recover energy
  - Extra fans
  - Additional filter static losses
  - Energy recovery device static losses
  - Run around coil pumps

$$RER_{Total} = \frac{Q_{Recovered}}{Q_{Input}}$$

$$= \frac{Q_{Recovered}}{\left(W_{SupplyFan} + W_{ExhaustFan} + W_{WheelMotor}\right)}$$

$$= \frac{\varepsilon \times m_{Min} \times \left(\eta_{Sup_{Ent}} - \eta_{Exh_{Ent}}\right)}{\left(+W_{SupplyFan} + W_{ExhaustFan} + W_{WheelMotor}\right)}$$

Where:

RER_{Total}	=	Recovery efficiency ratio, total energy basis, Btu per watt hour
ε	=	Recovery device effectiveness
$\eta_{Sup_{Ent}}$	=	Supply air entering enthalpy, Btu/lb
$\eta_{Exh_{Ent}}$	=	Exhaust air entering enthalpy, Btu/lb
m_{Min}	=	Minimum of the two mass flow rates associated with the wheel (m_{Sup} and m_{Exh})
m_{Sup}	=	Supply mass flow rate, lb/hr
m_{Exh}	=	Exhaust mass flow rate, lb/hr
$W_{SupplyFan}$	=	Supply fan energy, watts
$W_{ExhaustFan}$	=	Exhaust fan energy, watts
$W_{WheelMotor}$	=	Wheel (or other power consuming recovery device) motor energy, watts

Energy Recovery Strategies

Options

- Plate Heat Exchangers
- Wheels
- Heat Pipes
- Run Around Coils
- Thermosiphons
- Liquid Desiccant Recovery
- Fixed Bed Regenerator

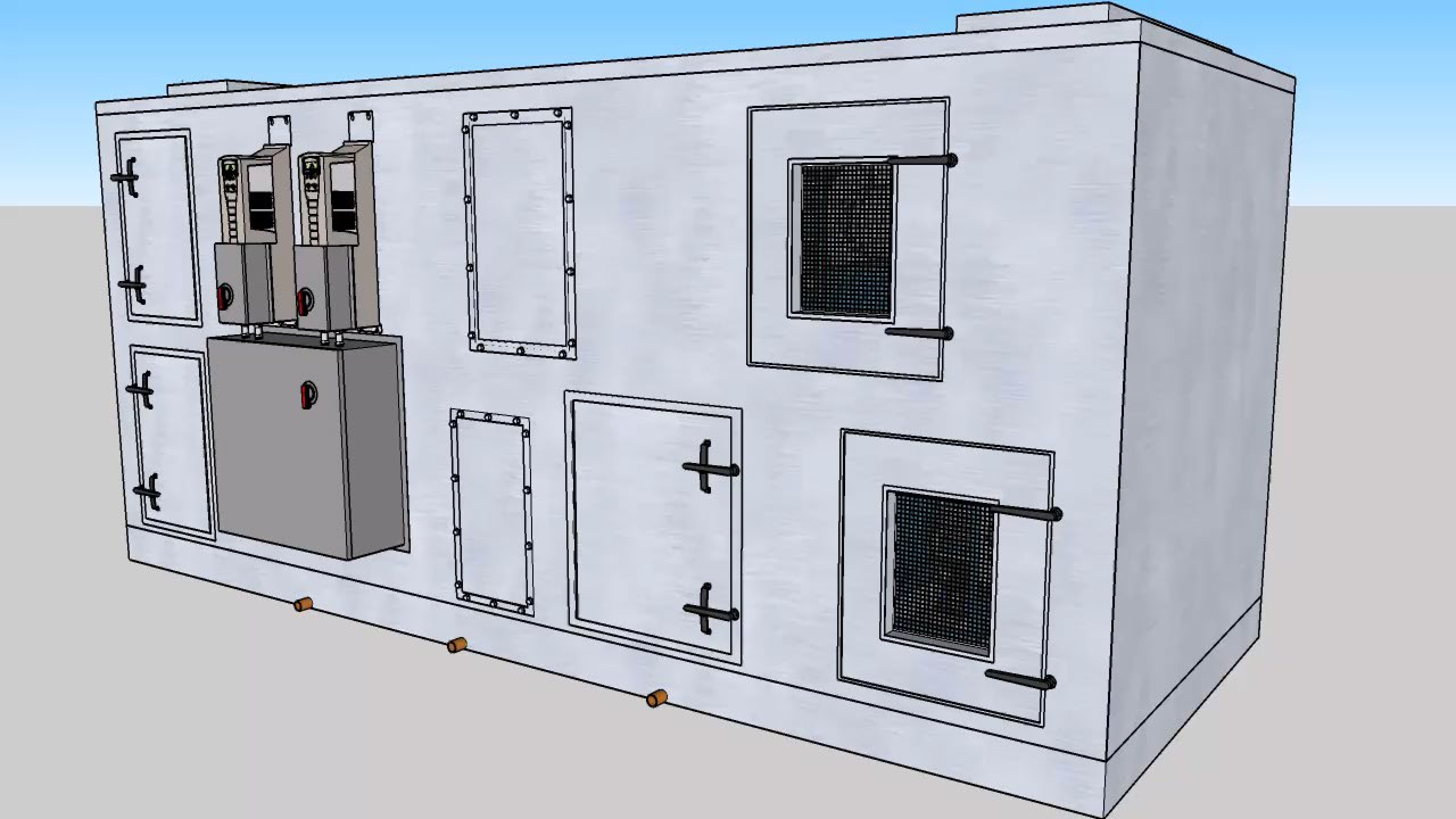
ASHRAE Systems and Equipment Handbook
Chapter 26 is a good reference

Energy Recovery Strategies

Plate Heat Exchangers

- Non-permeable (sensible only) and permeable (sensible and latent) option
- Typical effectiveness range
  - Sensible – 50-75
  - Latent – 25-60
  - Total – 35 – 70
- Pressure drop range – 0.4 – 4.0 in.w.c. at up to 1,000 fpm
- Control methods
  - Bypass dampers

UP
EA



Energy Recovery Strategies

Wheels

- Sensible only and total energy options
- Typical effectiveness range
  - Sensible – 65 - 80
  - Latent – 50 - 80
  - Total – 25 - 60
- Pressure drop range – 0.4 – 1.2 in.w.c. at up to 800 fpm
- Control methods
  - Bypass dampers
  - Wheel speed control


SIEMENS


AX-48

Energy Recovery Strategies

Heat Pipes

- Sensible only
- Typical effectiveness range – 40 - 60
- Pressure drop range – 0.6 – 2.0 in.w.c. at up to 800 fpm
- Controlled by tilting the coil

How Many of You Are Familiar With Heat Pipes?

How Many of You Are Familiar With Heat Pipes?

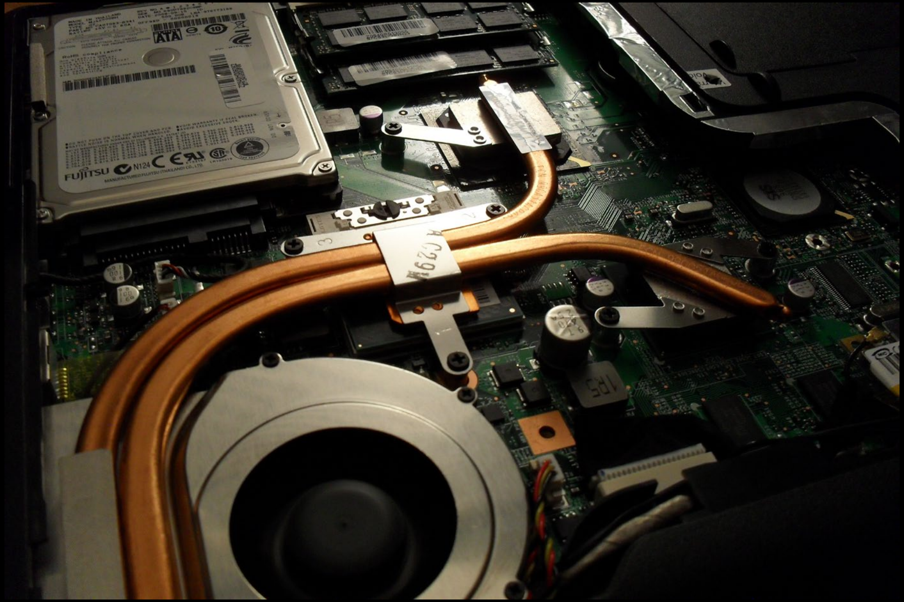


Image courtesy Kristoferb, Creative Commons Attribution-Share Alike 3.0 Unported

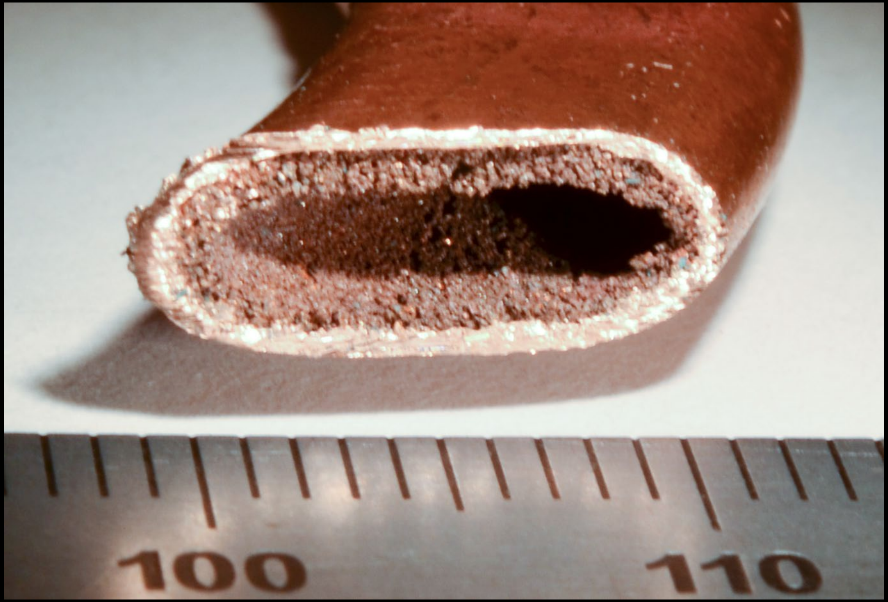


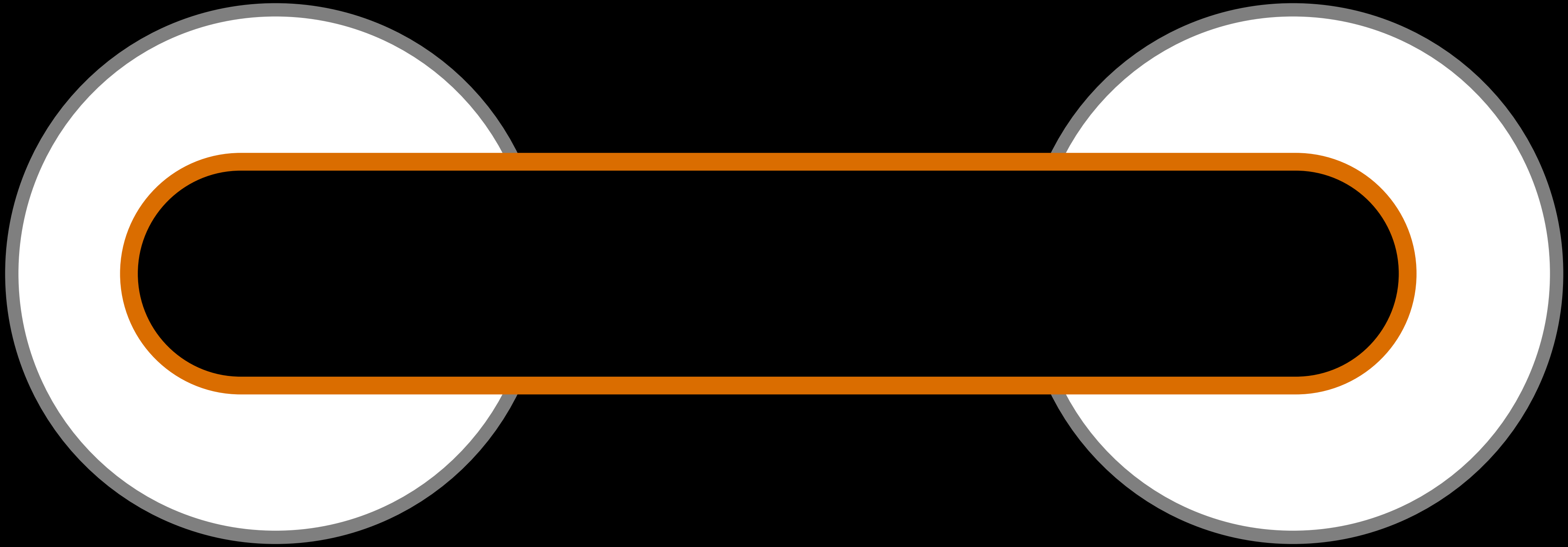
Image courtesy Epbernard, Creative Commons CC0 1.0 Universal Public Domain Dedication

Heat Pipe Operation

https://tinyurl.com/HeatPipeDetails

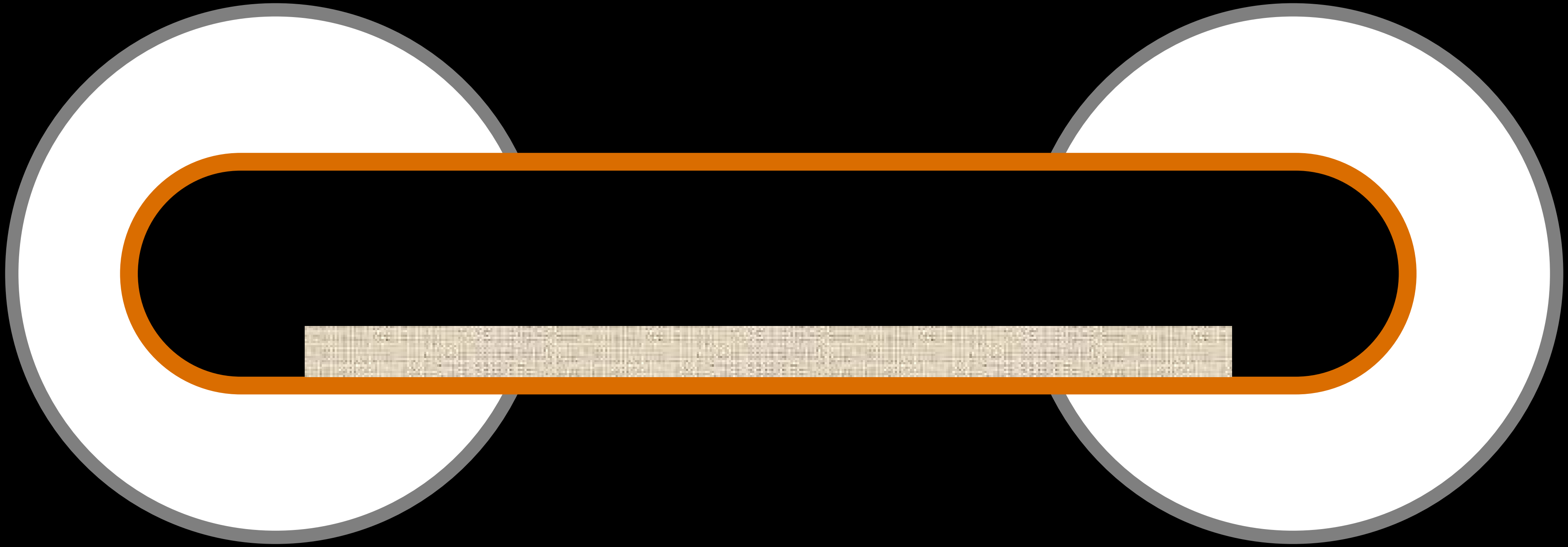
Heat Pipe Operation

Start with a sealed conductive metal tube between two ducts



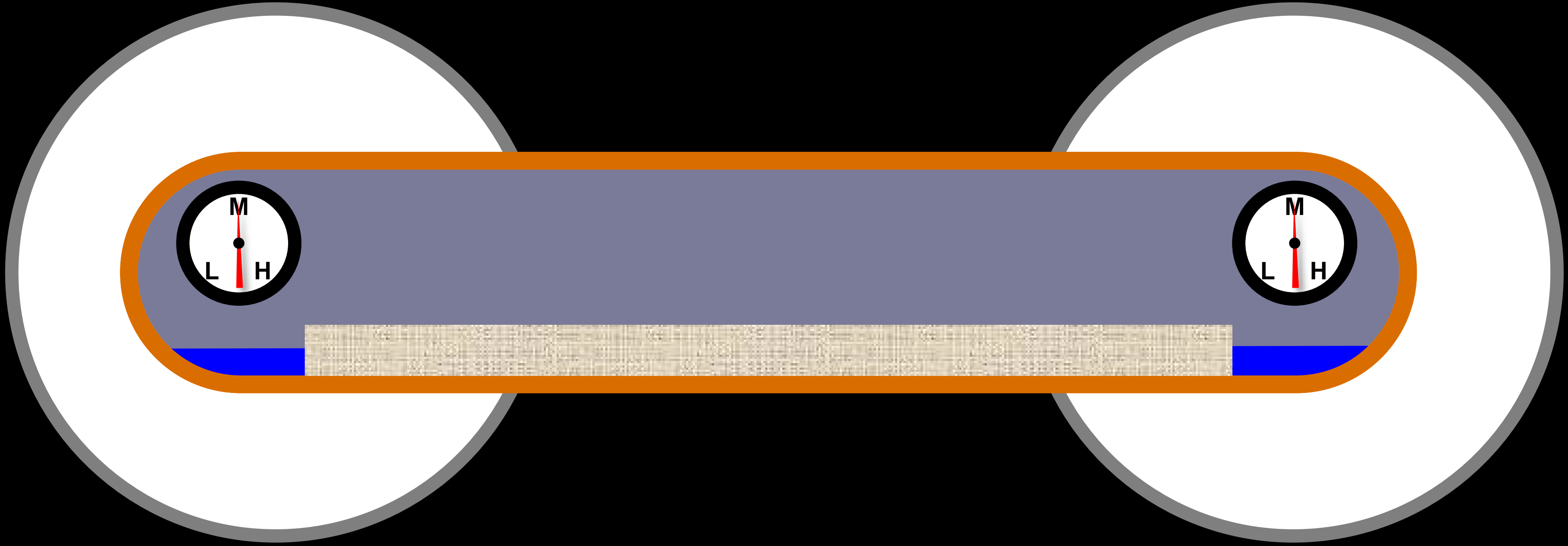
Heat Pipe Operation

Add a wick



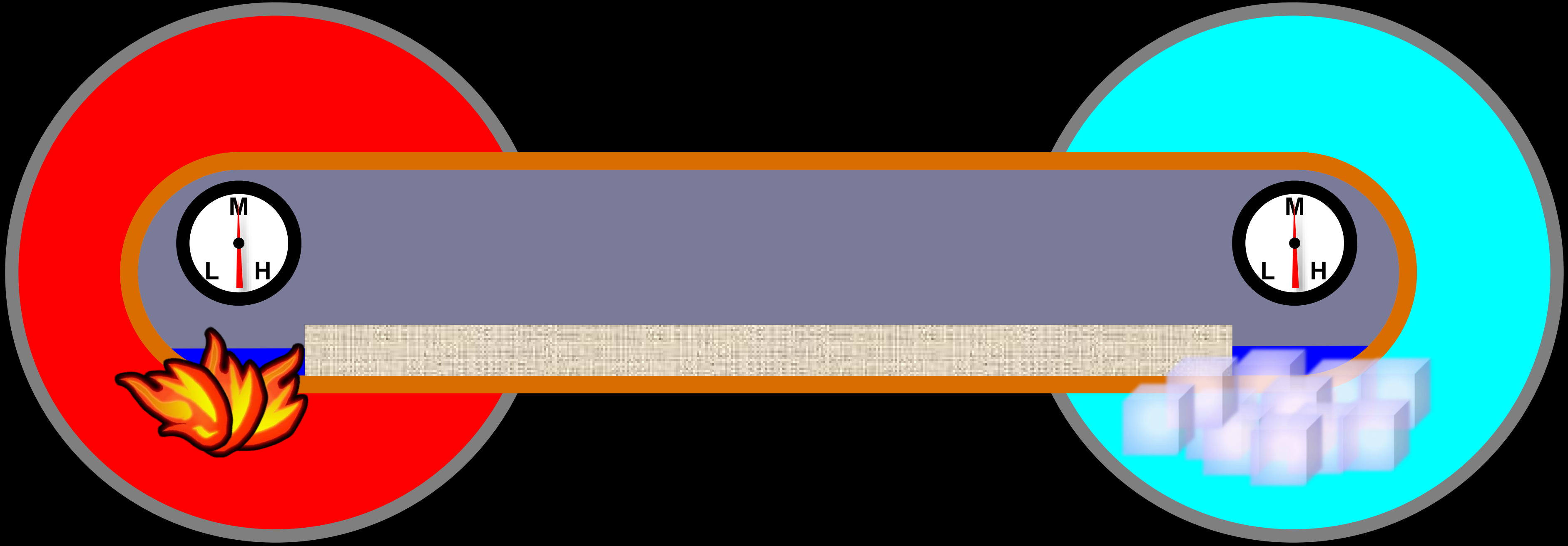
Heat Pipe Operation

Charge it with refrigerant in a saturated state



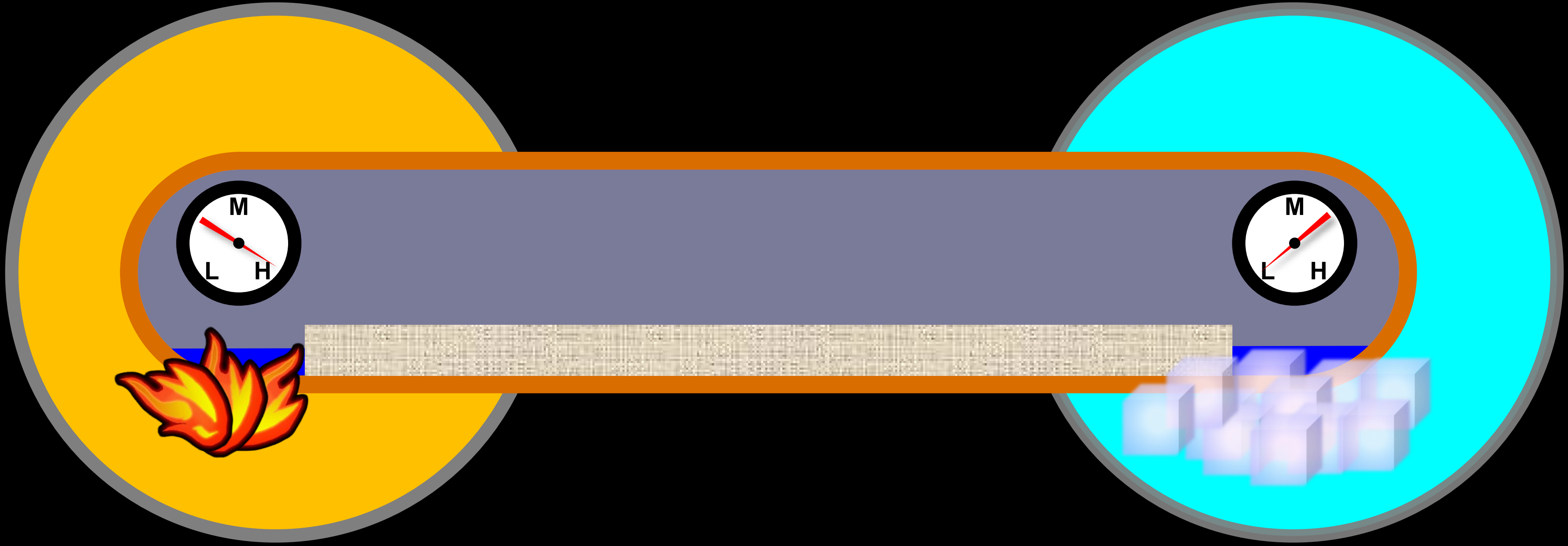
Heat Pipe Operation

Create a thermal gradient along its length



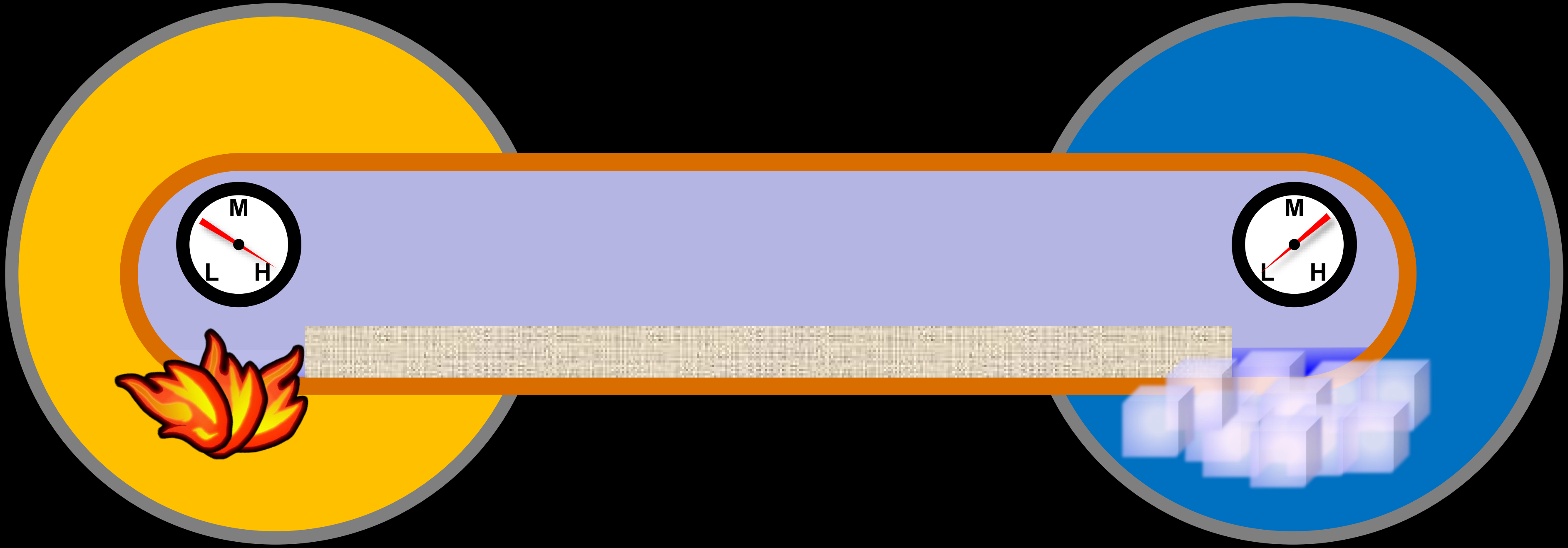
Heat Pipe Operation

Evaporating refrigerant at the hot end removes energy from the vicinity of the hot end and creates a pressure gradient in the tube



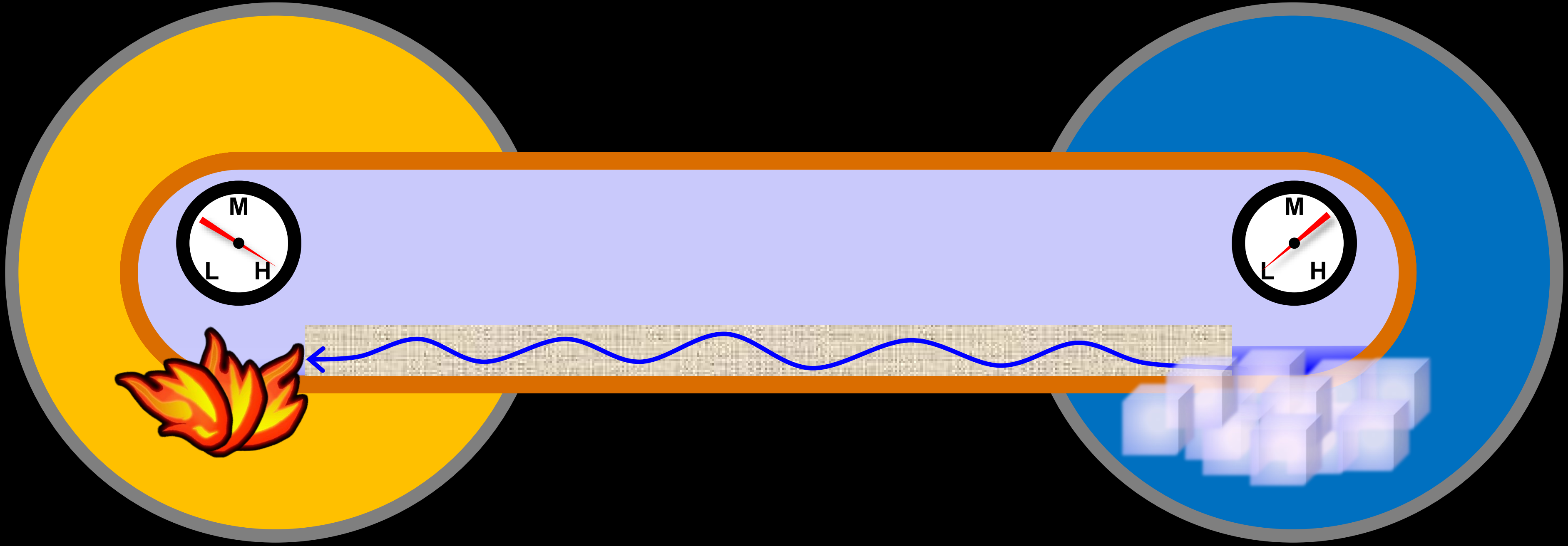
Heat Pipe Operation

The pressure gradient causes vapor to flow to the cold end where it condenses and releases the energy in the vicinity of the cold end



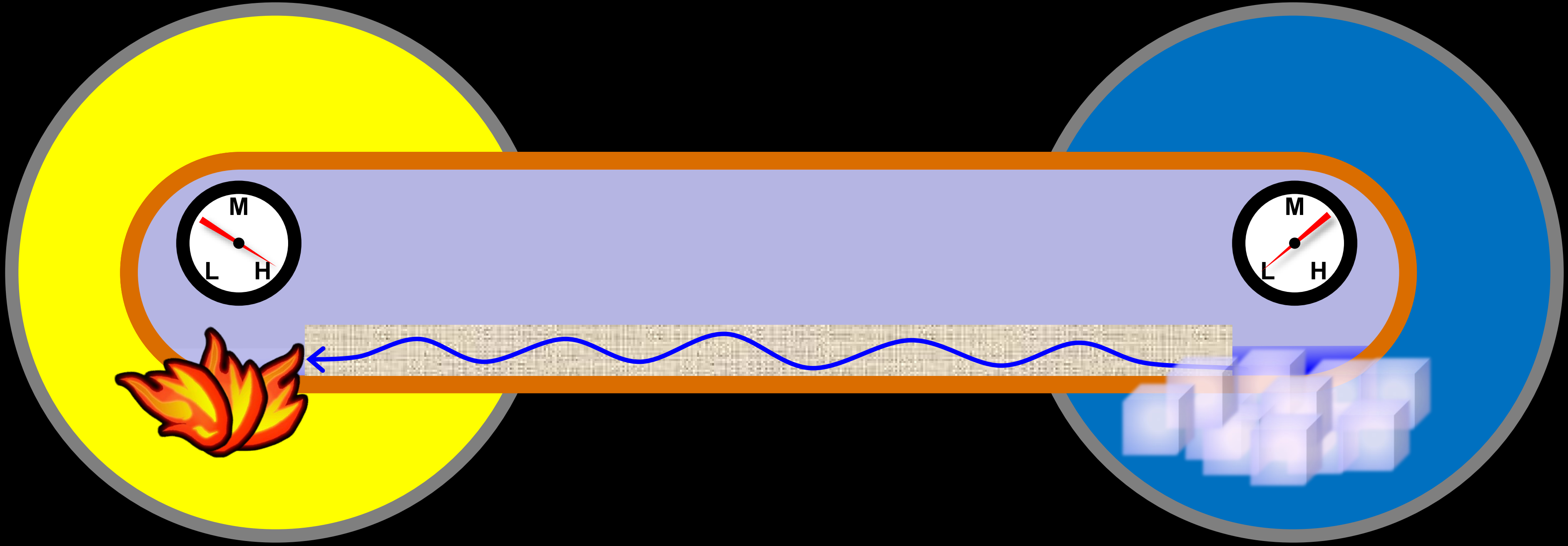
Heat Pipe Operation

Capillary action in the wick moves the liquid refrigerant back to the hot end to repeat the cycle



Heat Pipe Operation

Tilting the tube impacts the capillary action and can modulate energy transfer



Heat Pipe Operation

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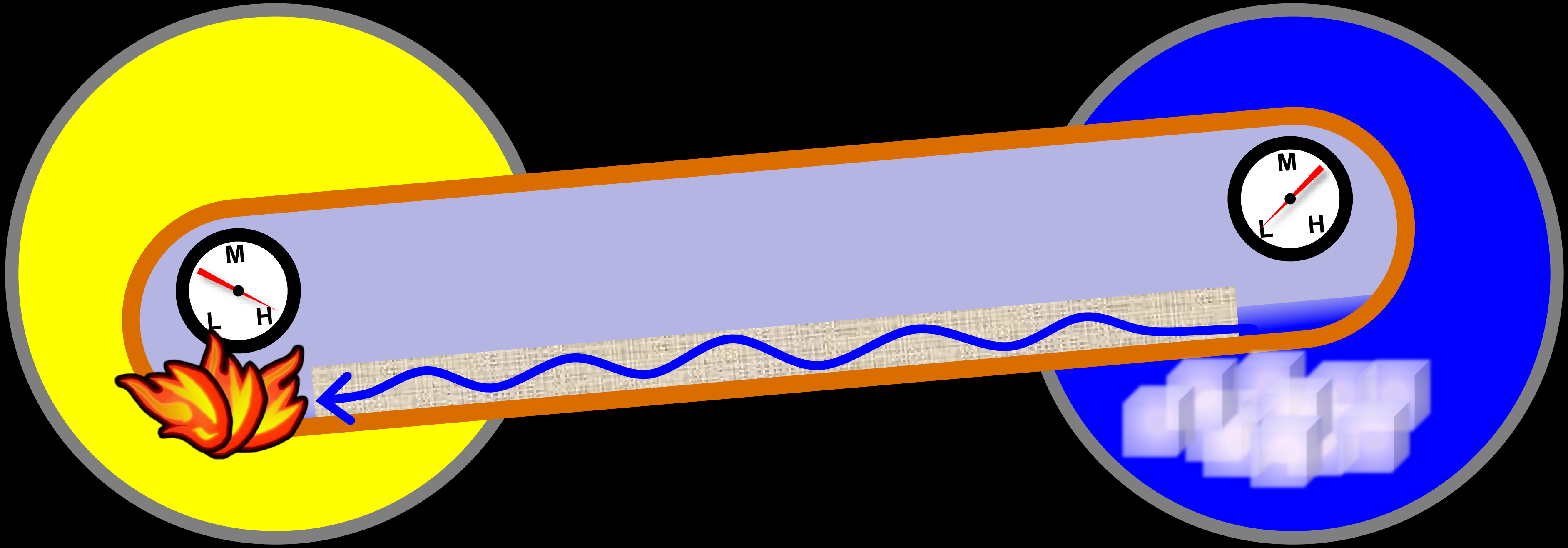
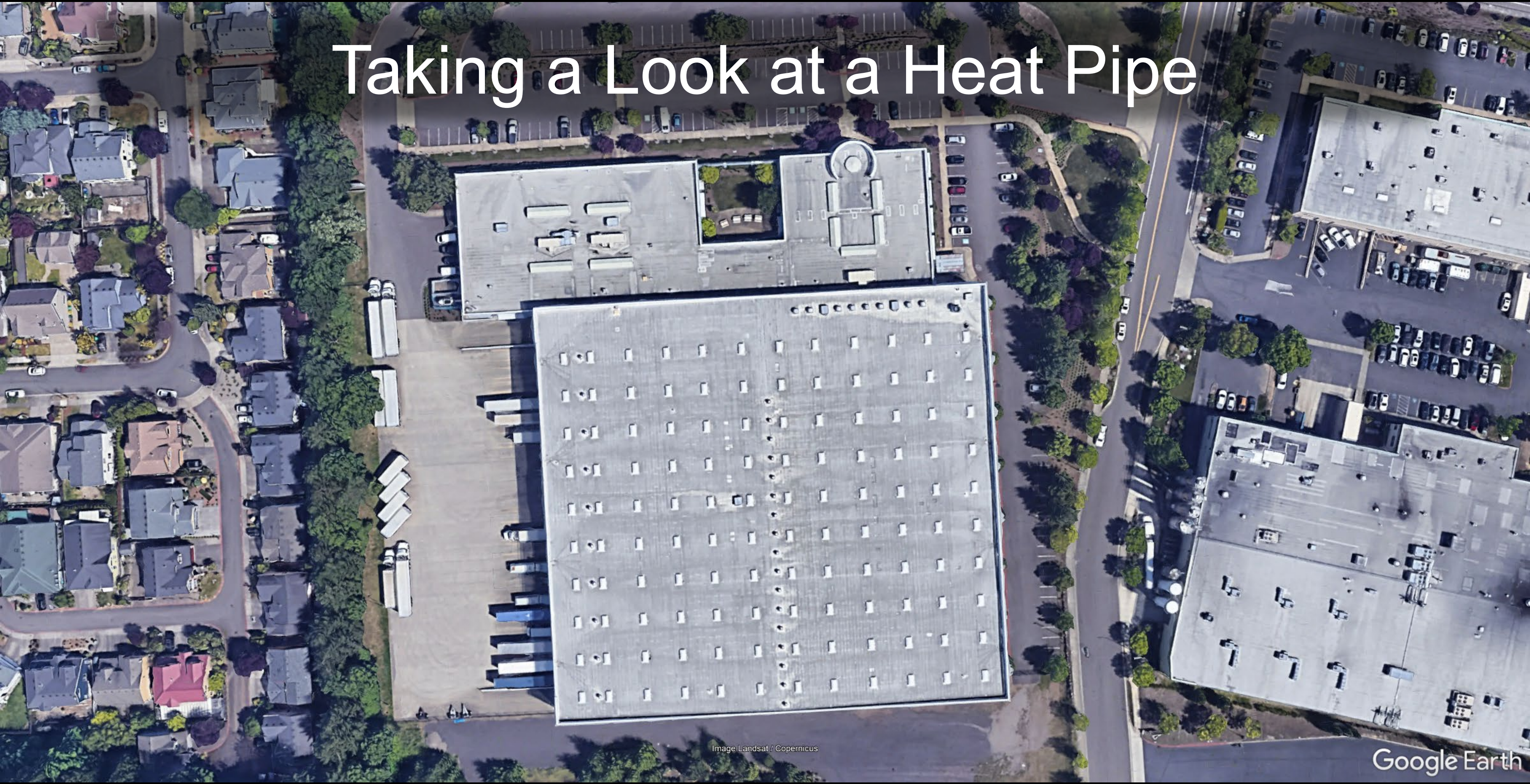
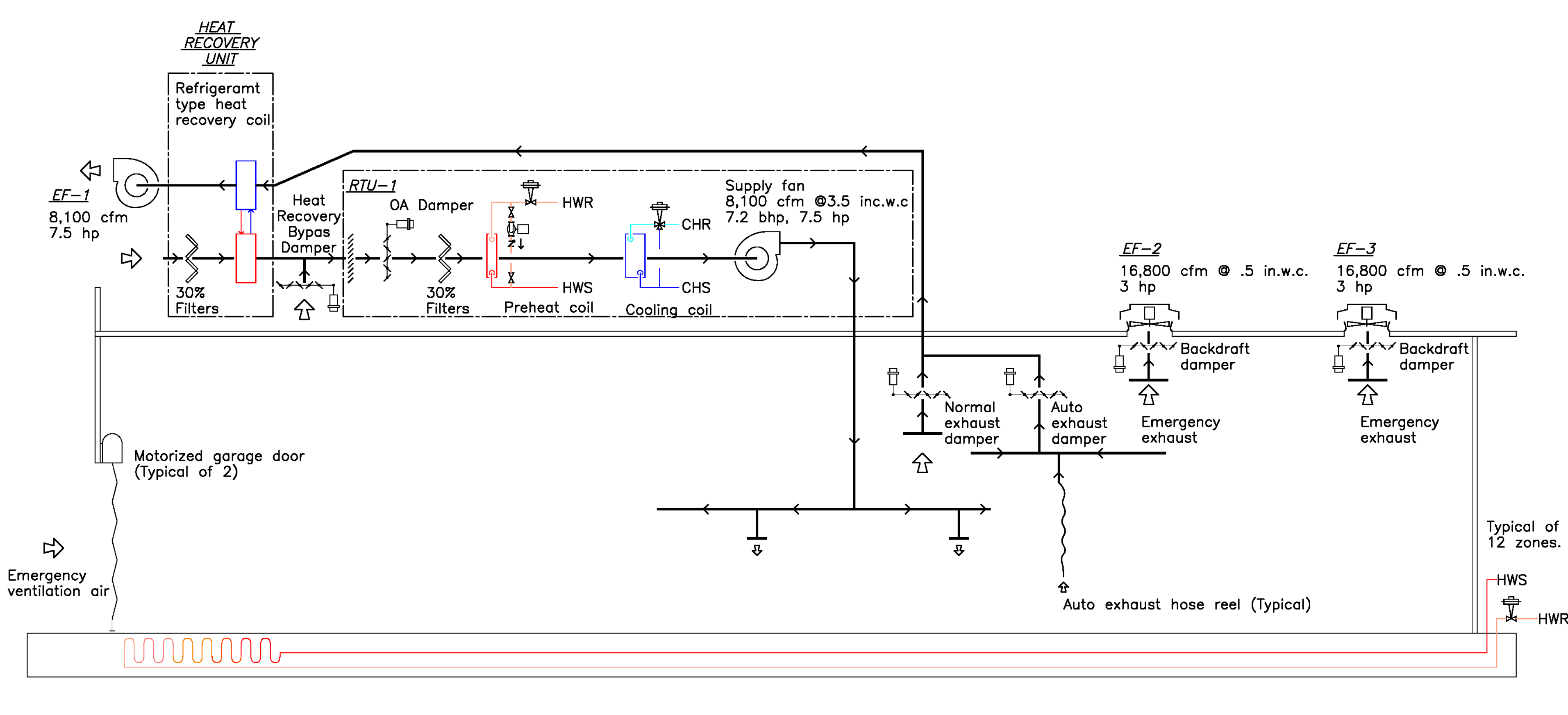


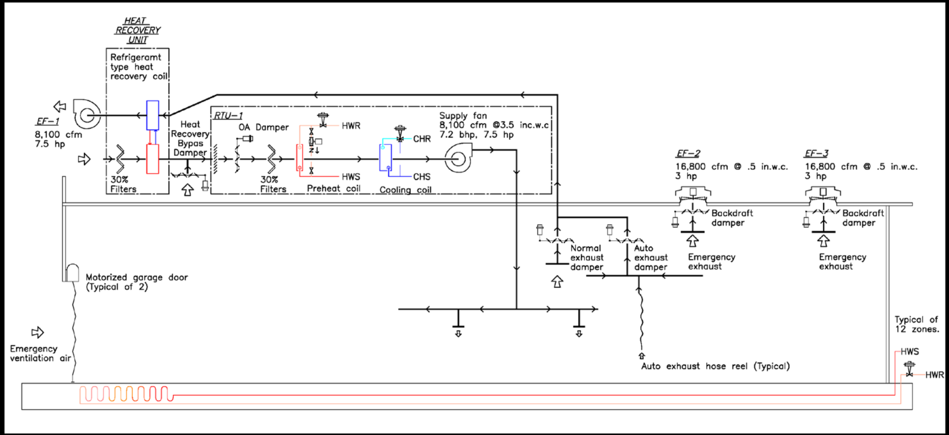
Taking a Look at a Heat Pipe




7/16/2001 4:54pm


HEAT RECOVERY UNIT
Refrigeramt type heat recovery coil
EF-1
8,100 cfm
7.5 hp
30% Filters
Heat Recovery Bypas Damper
RTU-1
OA Damper
30% Filters
HWR
HWS
Preheat coil
CHR
CHS
Cooling coil
Supply fan
8,100 cfm @3.5 inc.w.c
7.2 bhp, 7.5 hp
EF-2
16,800 cfm @ .5 in.w.c.
3 hp
EF-3
16,800 cfm @ .5 in.w.c.
3 hp
Backdraft damper
Backdraft damper
Normal exhaust damper
Auto exhaust damper
Emergency exhaust
Emergency exhaust
Motorized garage door (Typical of 2)
Emergency ventilation air
Auto exhaust hose reel (Typical)
Typical of 12 zones.
HWS
HWR


7/16/2001 4:54pm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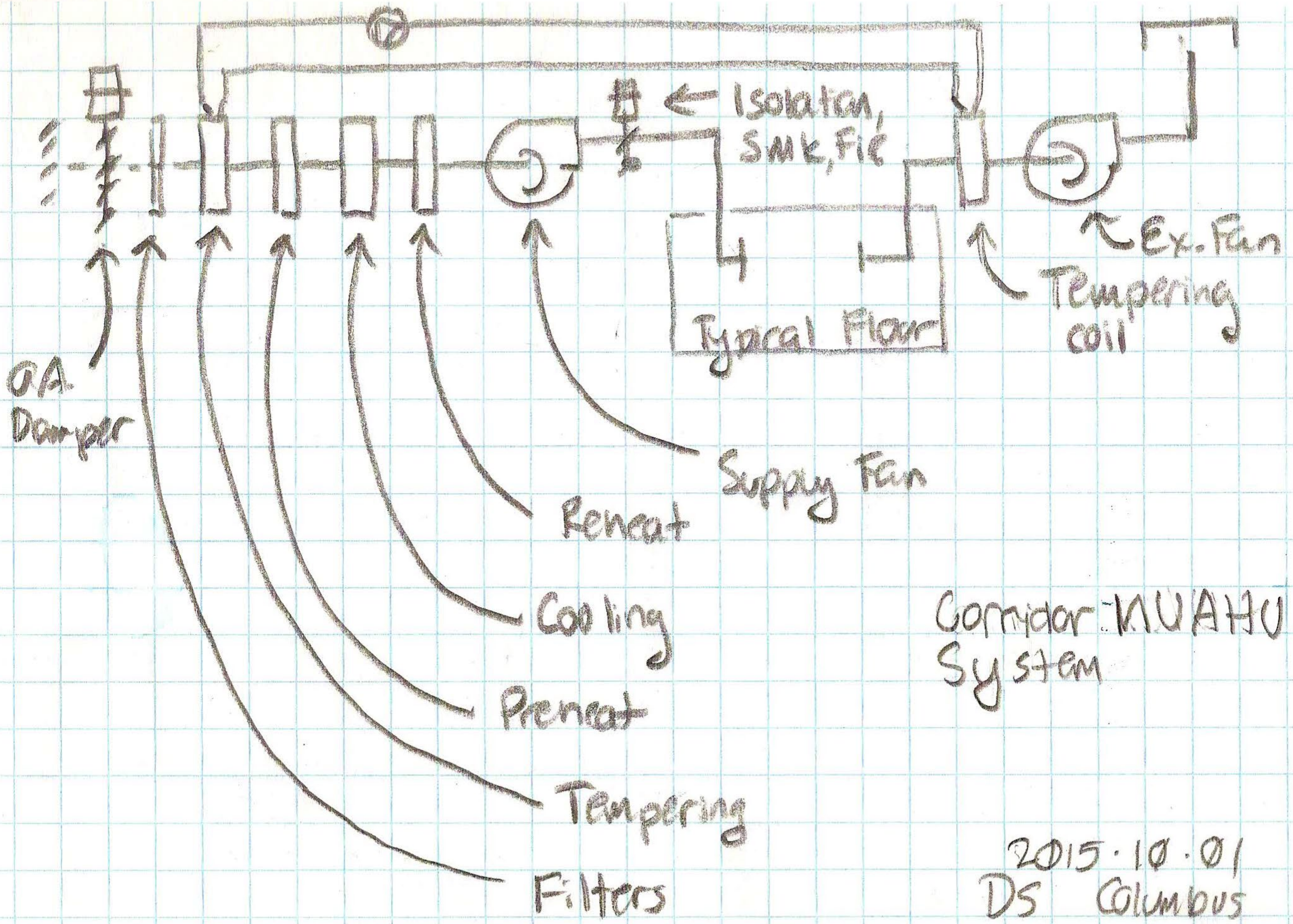
CHR
CHS
Cooling coil
Supply fan
8,100 cfm @3.5 inc.w.c
7.2 bhp, 7.5 hp
EF-2
16,800 cfm @ .5 in.w.c.
3 hp
EF-3
16,800 cfm @ .5 in.w.c.
3 hp
Backdraft damper
Backdraft damper
Emergency exhaust
Emergency exhaust
Normal exhaust damper
Auto exhaust damper
Motorized garage door
(Typical of 2)
Emergency ventilation air
Auto exhaust hose reel (Typical)
Typical of 12 zones.
HWS
HWR

Energy Recovery Strategies

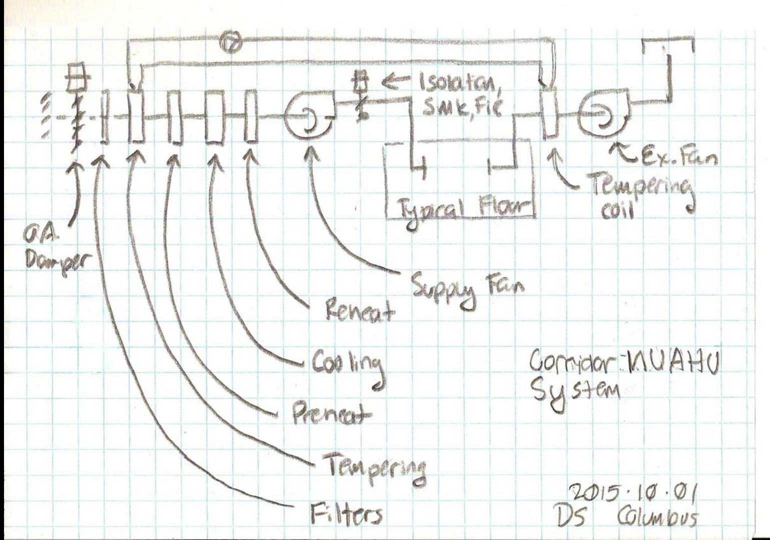
Run Around Coils

- Sensible only
- Typical effectiveness range – 45 - 65
- Pressure drop range – 0.6 – 2.0 in.w.c. at up to 600 fpm
- Controlled by a valve that bypasses flow around the coil

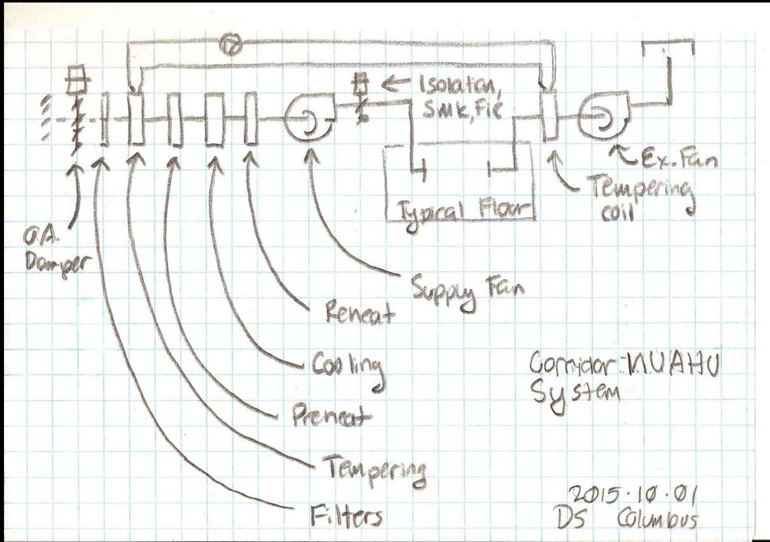


Isolation, Smk, Fire
O.A. Damper
Filters
Tempering
Preheat
Cooling
Reheat
Suppy Fan
Typical Floor
Tempering coil
Ex. Fan
Corridor MUAHU System
2015.10.01
DS Columbus

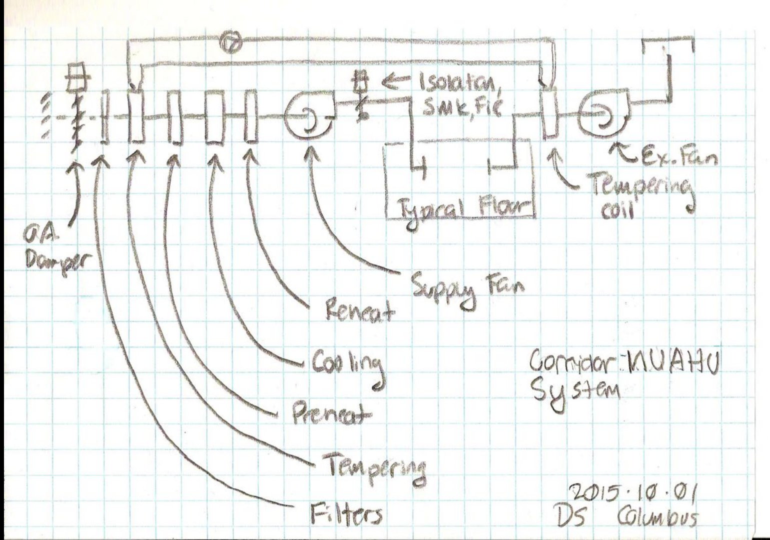

AIR


Isolation,
Smk, Fire
Ex. Fan
Tempering
coil
Typical Floor
O.A.
Damper
Supply Fan
Reheat
Cooling
Preheat
Tempering
Filters
Corridor MUAHU
System
2015.10.01
DS Columbus


2
TEMPERING COIL RETURN
TEMPERING COIL RETURN


Isolation, SMK, Fire
Ex. Fan
Tempering coil
Typical Floor
O.A. Damper
Supply Fan
Reheat
Cooling
Preheat
Tempering
Filters
Corridor MUAHU System
2015.10.01
DS Columbus


EF-22-1
YORK
Dayton


Isolation, SMK, Fire
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DS Columbus


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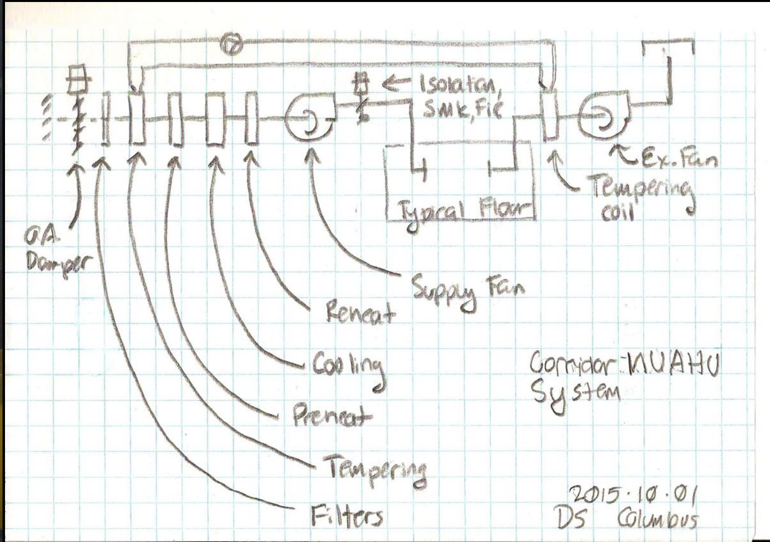

Isolation, Smk, Fire
Ex. Fan
Tempering coil
Typical Floor
O.A. Damper
Supply Fan
Reheat
Cooling
Preheat
Tempering
Filters
Corridor MUAHU System
2015.10.01
DS Columbus

Summary

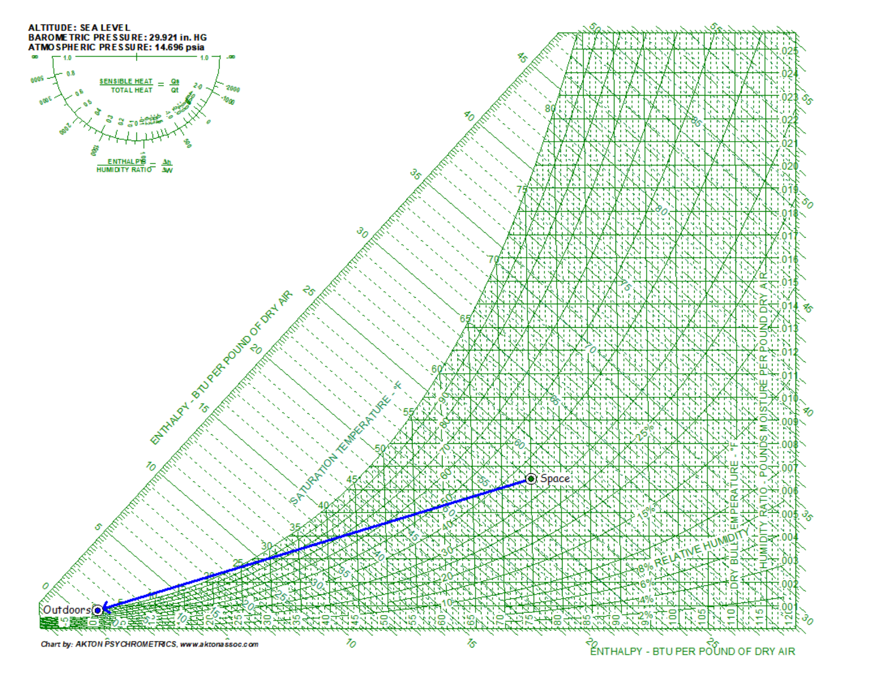
Energy Recovery Technology Contrast

Technology	Heat Transfer		Effectiveness Range						Pressure Drop Range			Control Methods			
	Sensible	Total	Sensible		Latent		Total		Min. in.w.c.	Max. in.w.c.	Velocity fpm	Bypass Damper	Speed Control	Tilt	Bypass Valve
			Min.	Max.	Min.	Max.	Min.	Max.							
Plate Heat Exchangers	✓	✓	50%	75%	25%	60%	35%	70%	0.40	4.00	1,000	✓	✓		
Wheels	✓	✓	65%	80%	50%	80%	25%	60%	0.40	1.20	800		✓		
Heat Pipes	✓		40%	60%	N/A	N/A	N/A	N/A	0.60	2.00	800			✓	
Run Around Coils	✓		45%	65%	N/A	N/A	N/A	N/A	0.60	2.00	600				✓

Frosting

A Concern in Cold Environments

- Occurs when:
  - The dew point of the return air is high enough to result in condensation on the recovery device
  - Outdoor temperatures are below 32°F



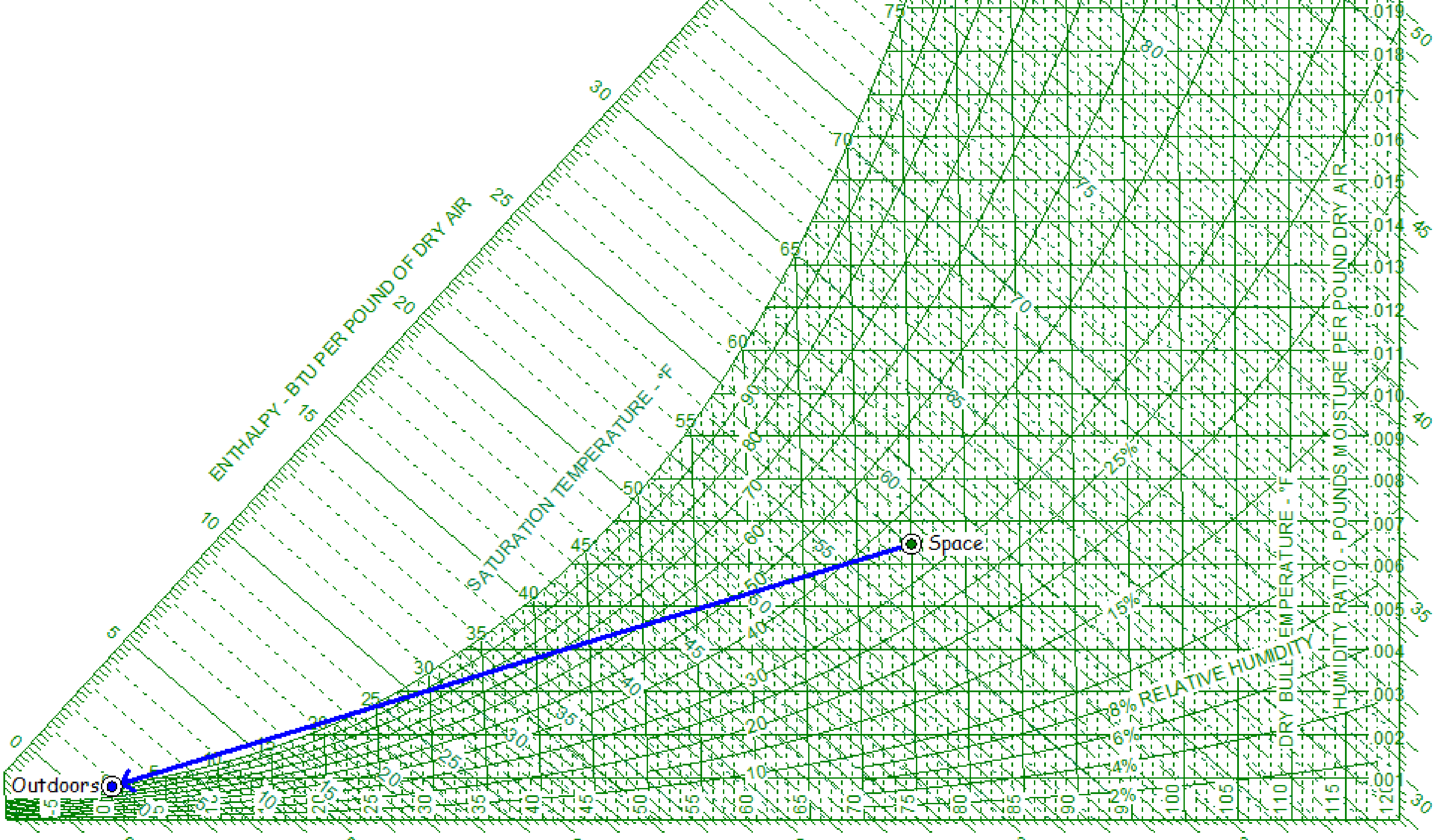
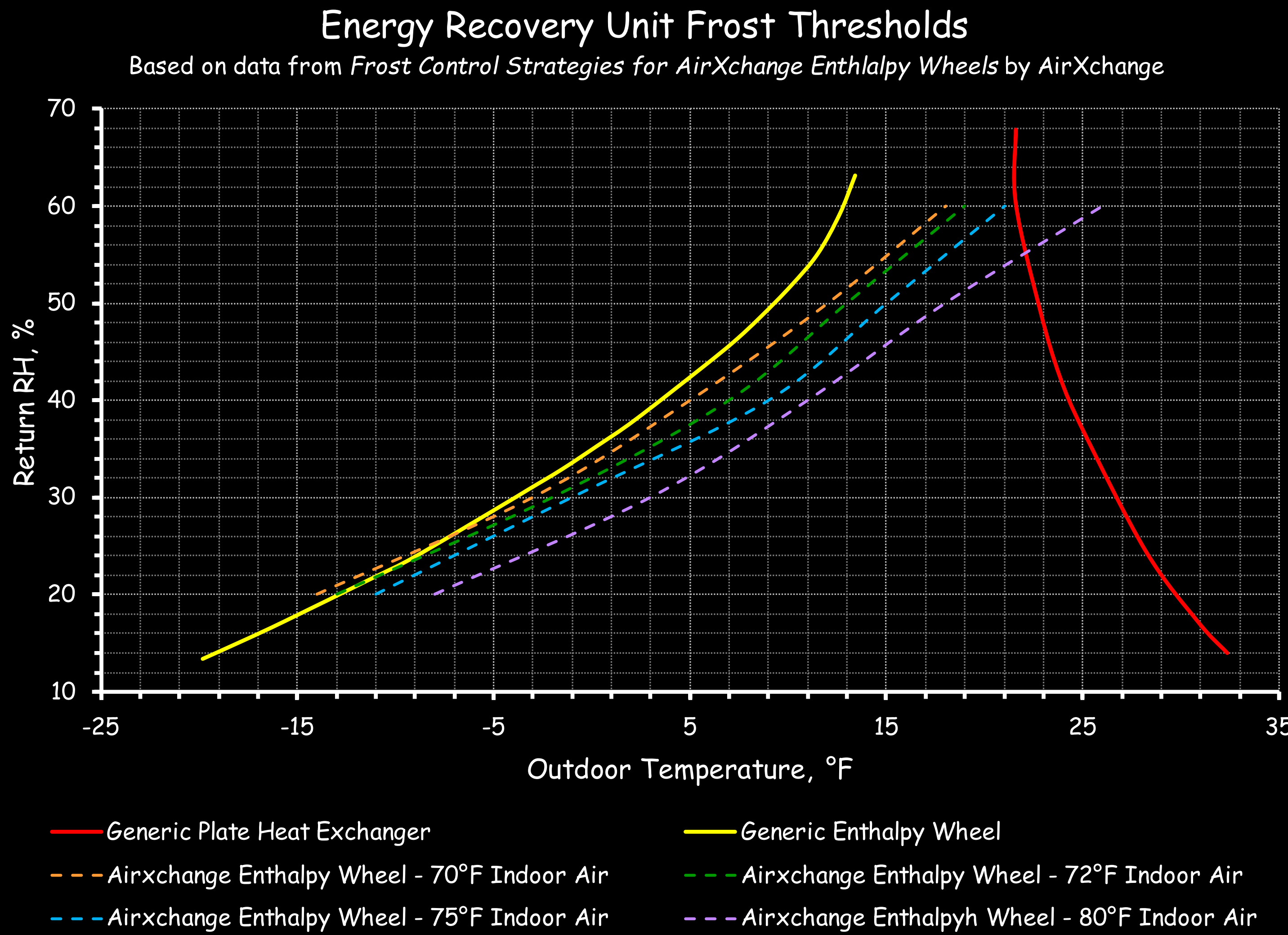


Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com



Energy Recovery Unit Frost Thresholds
Based on data from Frost Control Strategies for AirXchange Enthlalpy Wheels by AirXchange
Return RH, %
70
60
50
40
30
20
10
-25
-15
-5
5
15
25
35
Outdoor Temperature, °F
Generic Plate Heat Exchanger
Generic Enthalpy Wheel
Airxchange Enthalpy Wheel - 70°F Indoor Air
Airxchange Enthalpy Wheel - 72°F Indoor Air
Airxchange Enthalpy Wheel - 75°F Indoor Air
Airxchange Enthalpyh Wheel - 80°F Indoor Air

Costs

There Are Many Things to Consider

- Is supplemental capacity required?
- Is redundancy required?
- Is the goal:
  - Saving energy
  - Avoiding demand
  - Reducing first cost
  - Any or all
- Size

Costs

Industry Metrics Could Be Misleading

- They could be dated

Vendor	Source	per cfm cost	Date	2018 cost based on the Bureau of Labor Statistics Inflation Calculator
Greenheck	Application Guide	$3.60	Copyright 1997	$5.69
Loren-Cook	ERV Catalog	$3.00	Mar-16	$3.18

Costs

Industry Metrics Could Be Misleading

- They could be dated
- They may not consider all of the desired features

Maximum flow rate -	3,500 cfm
Basic ERU cost -	$47,841
	13.67 $/cfm
As furnished ERU cost -	$71,450
	20.41 $/cfm

Mark: HRU-1 Model: ERCH-45H-15 Product Family: Energy Recovery

Qty	Supply FRPM	Outdoor Volume (CFM)	Supply SP (in wg)	Exhaust FRPM	Exhaust Volume (CFM)	External SP (in wg)	List
1	1,658	3,500	1.75	905	2,250	0.75	$47,841

ID: 4
Tag HRU-1
TAGS

SELECTION		CONFIGURATION		MOTOR SPECS	
Elevation (ft):	800	OA Intake Position:	Top	Outdoor Size (hp):	5
Weatherhood:	No	OA Discharge Position:	Top	Exhaust Size (hp):	1 1/2
Frost Controls:	Timed Exhaust	EA Intake Position:	Top	UL:	UL/cUL-1995
Night Setback:	No	EA Discharge Position:	Top	Enclosure:	ODP
Outdoor Damper:	Yes			Power:	60 Cycle
Outdoor Filters:	Pleated			Phase:	3
Exhaust Damper:	Yes			Voltage (V):	208
Exhaust Filters:	Pleated			RPM:	1725
				Efficiency Selected:	SE
				MCA (A):	29.2
				MOCP (A):	45.0

HEATING:
Hot Water - 1 Coil - Model: 5WQ0802B - 51 x 24 - Conn. Size- 2.5 - 12.5 GPM $4,226

COOLING:
Chilled Water - 1 Coil - Model: 5WQ1206C - 51 x 24 - Conn. Size- 2 - 29.1 GPM $9,561

ACCESSORIES:	
Outdoor Air Intake Damper, Motorized, Low Leakage VCD-23	$1,515
Exhaust Air Intake Damper, Motorized, Low Leakage VCD-23	$1,226
Duct Flange	$236
Outdoor Air Filter, 2" pleated (30% efficient)	$711
Exhaust Air Filters, 2" pleated (30% efficient)	$711
Listed to UL-1995	$31
Water Coil(s) piped external to unit	Incl.
Temp Control by Others	Incl.
Timed Exhaust Frost Control	$562
Variable Air Volume - Modulating	$4,830

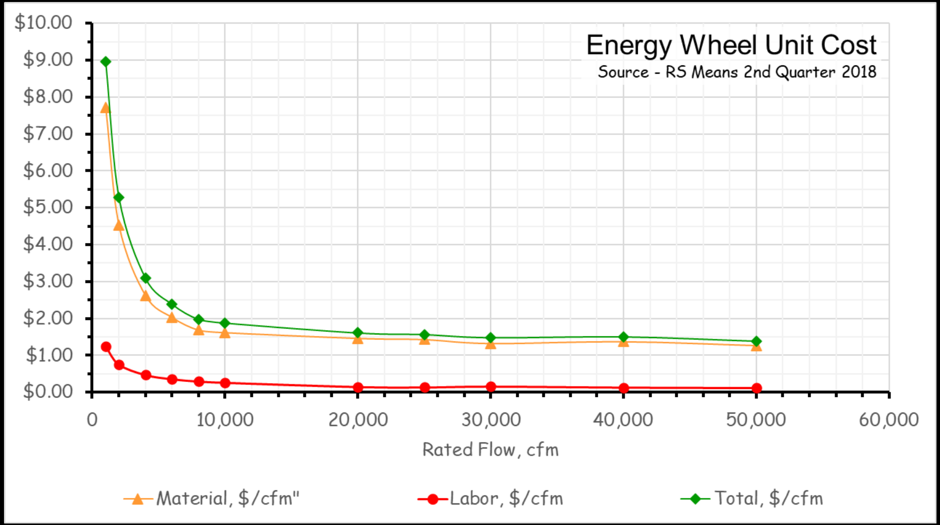
Extended Subtotal ($) $71,450

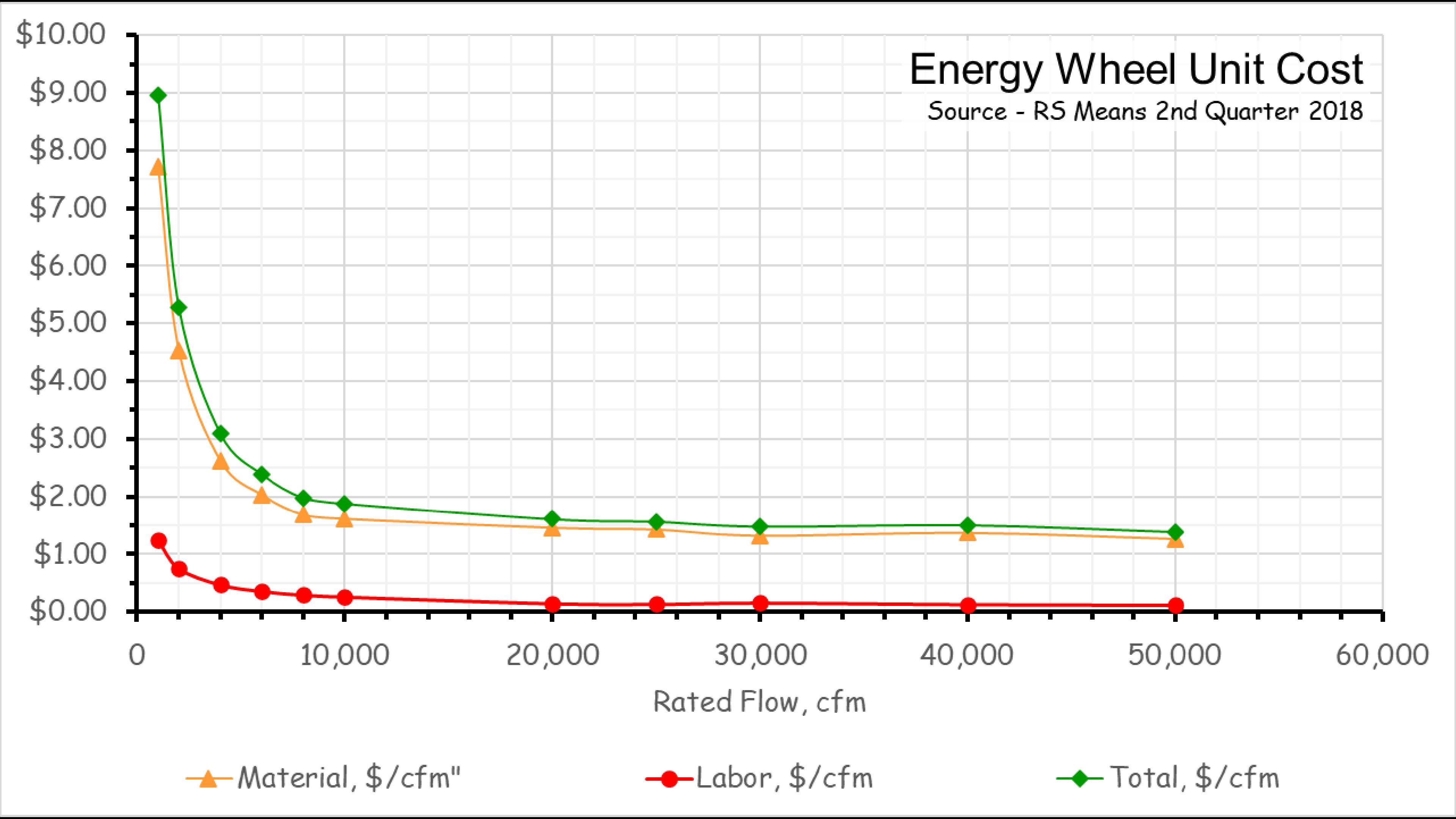
ER1 0.2440 17,433.80

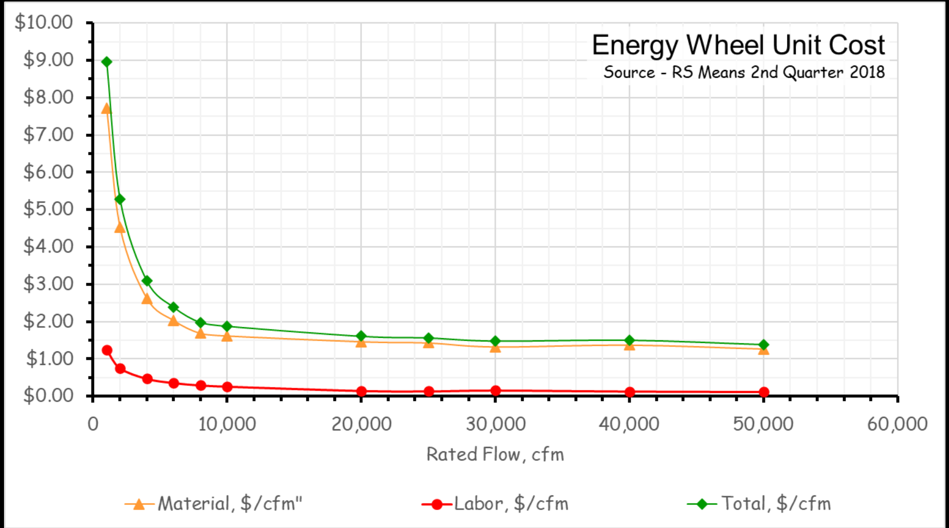
Costs

Industry Metrics Could Be Misleading

- They could be dated
- They may not consider all of the desired features
- Size has a significant impact




Energy Wheel Unit Cost
Source - RS Means 2nd Quarter 2018
$10.00
$9.00
$8.00
$7.00
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
0
10,000
20,000
30,000
40,000
50,000
60,000
Rated Flow, cfm
Material, $/cfm"
Labor, $/cfm
Total, $/cfm


Energy Wheel Unit Cost
Source - RS Means 2nd Quarter 2018
$10.00
$9.00
$8.00
$7.00
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
0
10,000
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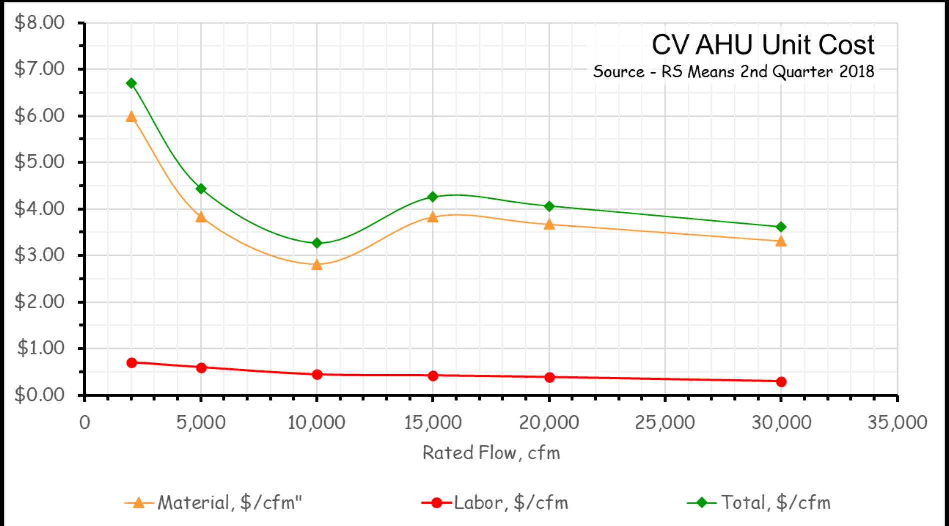
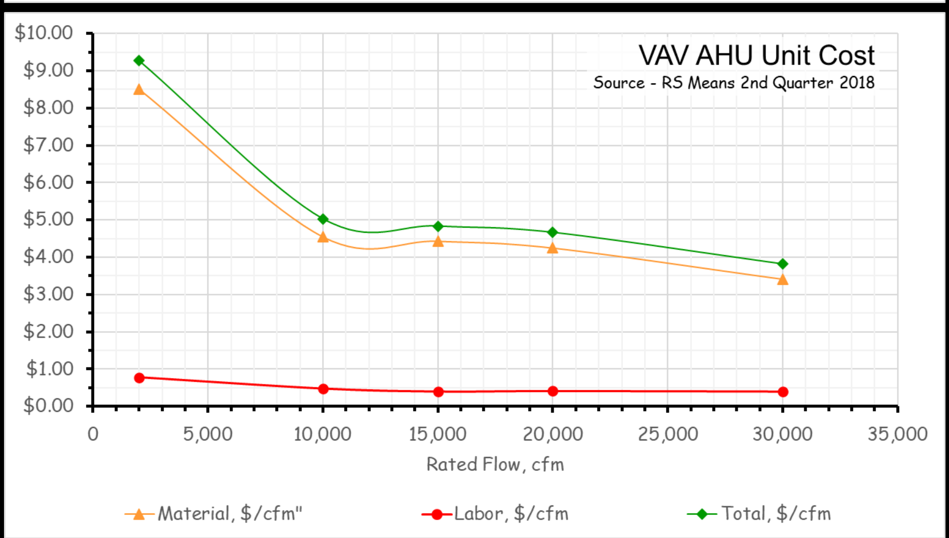
50,000
60,000
Rated Flow, cfm
Material, $/cfm"
Labor, $/cfm
Total, $/cfm


CV AHU Unit Cost
Source - RS Means 2nd Quarter 2018
$8.00
$7.00
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
Rated Flow, cfm
Material, $/cfm"
Labor, $/cfm
Total, $/cfm


VAV AHU Unit Cost
Source - RS Means 2nd Quarter 2018
$10.00
$9.00
$8.00
$7.00
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
Rated Flow, cfm
Material, $/cfm"
Labor, $/cfm
Total, $/cfm

Questions?

Together, Building
a Better California