WELCOME

David Sellers; Senior Engineer, Facility Dynamics Engineering

Commissioning Heat Pump Systems: Ventilation System Integration

May 13, 2024

PG&E

Facility Dynamics ENGINEERING

Please Visit These Links While We Are Waiting to Begin

https://tinyurl.com/HeatPumpD2Refresh

https://tinyurl.com/HeatPumpD2ExPref

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Safety

Earthquake:
Drop
Cover
Hold

Evacuation Plan

Review Emergency Plan
& Pack Go-Bag

Stretch,
Get Up & Move

Visit: www.pge.com/emergencypreparedness

Class Survey coming…

At the end of this class, we'll share a class survey. We'd love to hear your feedback and if the class met your expectations.

Your comments will help us improve future classes.

Class Survey

The survey should only take 2 minutes and your responses can be confidential.

Here's how to participate:

- Click the provided link: https://www.surveymonkey.com/r/EWB20240514CHP
- Scan the QR code with your phone's camera

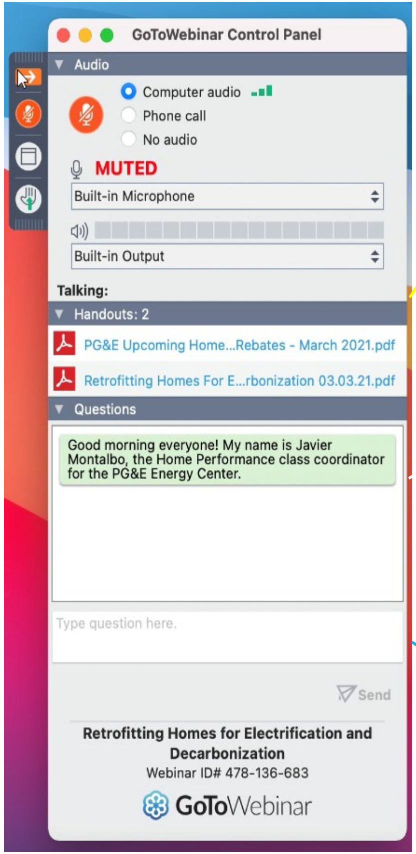
Using GoTo Webinar

- On the right-hand side of the GoTo panel you will find:

Handouts Tab

In-Class Resources

Questions Tab



Click the links to download today's course materials

Access links to in-class resources & the class survey in the 'Questions' pane

Let's engage! Type your questions in the text box.

Sign Up for Other Classes in this Series

Upcoming Classes for Commissioning Heat Pump Systems Series

(From 9:30am to 1:30pm Pacific)

Sign up for the whole series here

Or for individual classes:

- Commissioning Heat Pump Systems: New Construction- May 15
- Commissioning Heat Pump Systems: Existing Buildings- May 28
- Commissioning Heat Pump Systems: The Already All Electric Building - May 29

Introduction

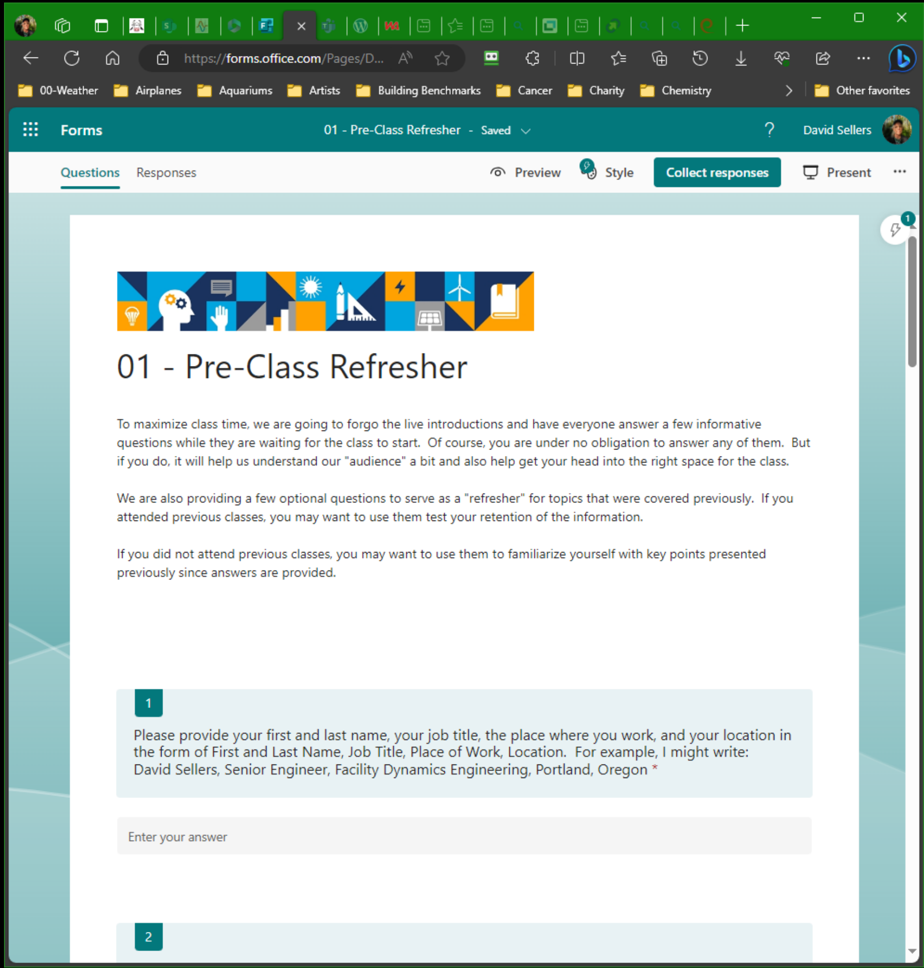
Today’s Agenda

1. Introduction
2. Ventilation System Approaches
3. Energy Recovery Strategies
4. Design and Operating Considerations
5. 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

Introductions

https://tinyurl.com/HeatPumpD2Refresh

https://tinyurl.com/HeatPumpD2ExPref



A Bit About Me

(See Module 1 and the Bio on the PG&E Training Site for Details)

A Senior Engineer for Facility Dynamics Engineering Focusing On:

- EBCx
- NCx Support
- Hands-on Technical Training
- System Analysis
- Control System Design

I Will Tend to Discuss Things in the RCx/Re-Cx/OCx Context (a.k.a Operating the Building Properly) https://www.av8rdas.com

HOME BLOG SKETCHUP MODELS TOOLS USEFUL FORMULAS WHAT'S THAT THING? RESOURCES VIDEOS TRAINING CONTACT LOG IN

Resources
(See Module 1 for Details)

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What's New?

Search

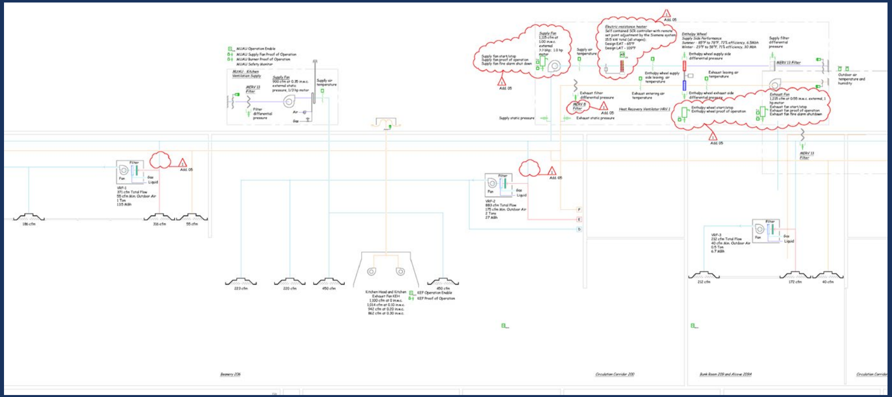
Buildings are Talking to Us

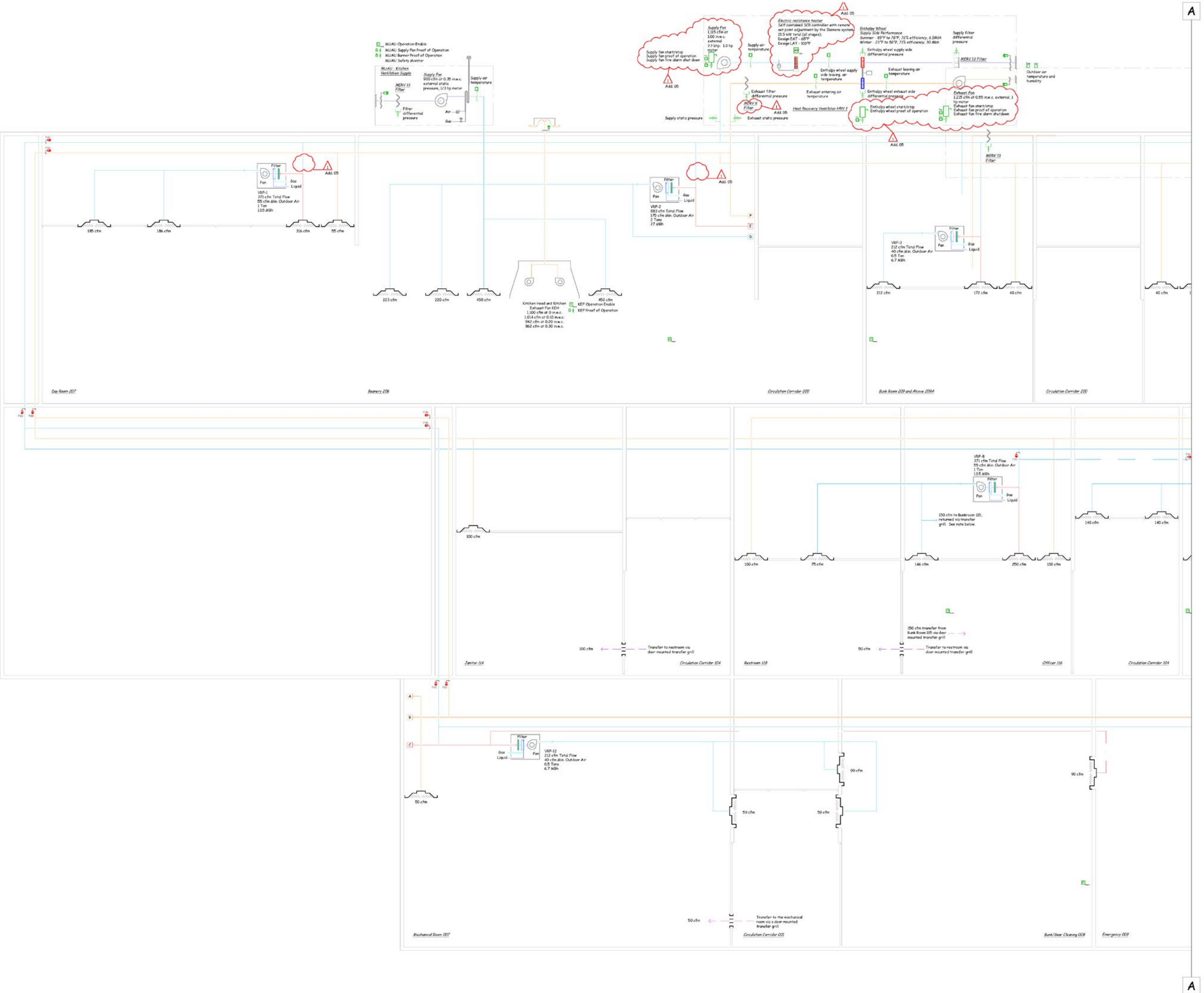
We Just Need to Learn How to Listen

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 - 68°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
Supply filter differential pressure
Enthalpy wheel supply side differential pressure
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Enthalpy wheel supply side leaving air temperature
Exhaust leaving air temperature
Outdoor air temperature and humidity
Exhaust filter differential pressure
Exhaust entering air temperature
Enthalpy wheel exhaust side differential pressure
MERV 8 Filter
Add. 05
Heat Recovery Ventilator HRV-1
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1,215 cfm at 0.55 in.w.c. external, 1 hp motor
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Liquid
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371 cfm Total Flow
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13.5 MBh
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316 cfm
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Filter
Fan
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VRF-2
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Beanery 206
Circulation Corridor 200
Bunk Room 209 and Alcove 209A
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Transfer to restroom via door mounted transfer grill
150 cfm transfer from Bunk Room 115 via door mounted transfer grill
50 cfm
Transfer to restroom via door mounted transfer grill
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Circulation Corridor 104
Restroom 118
Officer 116
Circulation Corridor 104
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212 cfm Total Flow
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Mechanical Room 007
Circulation Corridor 001
Bunk/Gear Cleaning 008
Emergency 009
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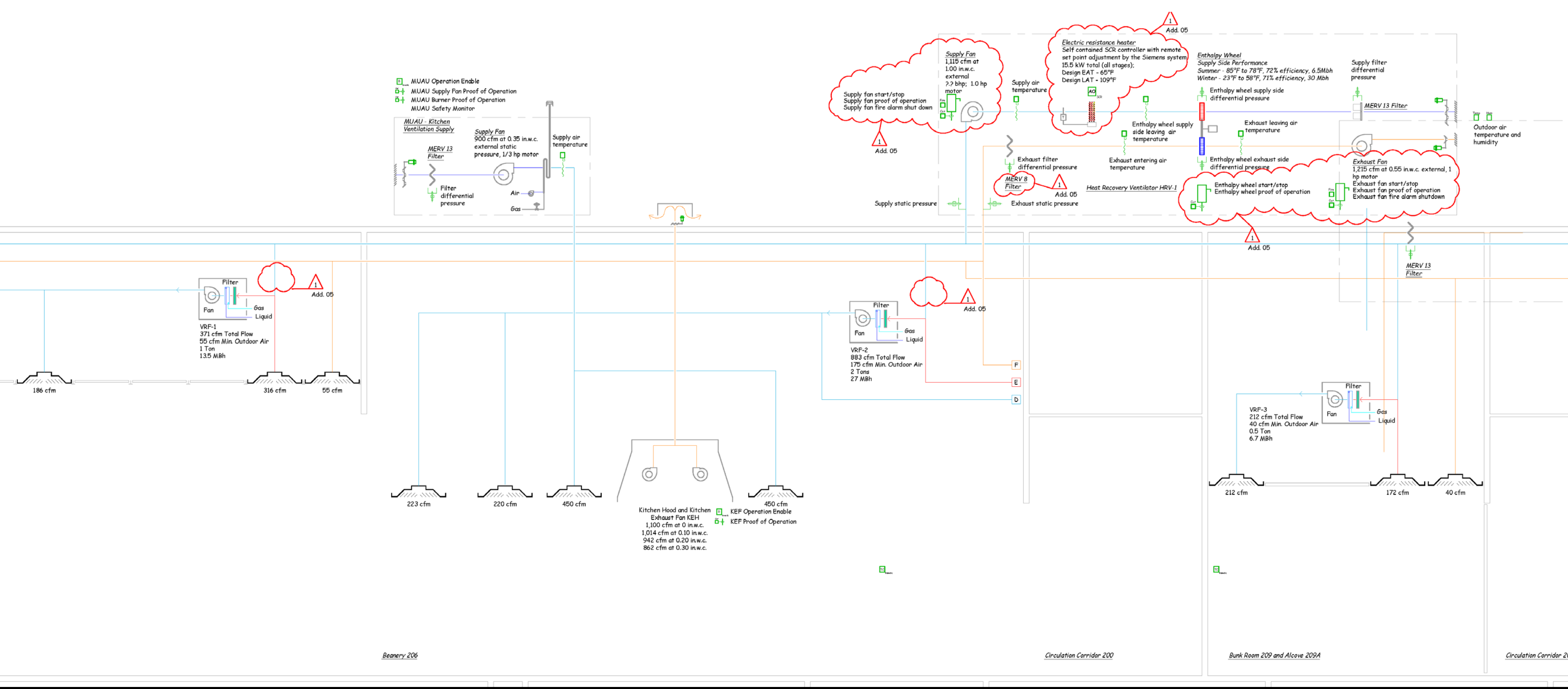

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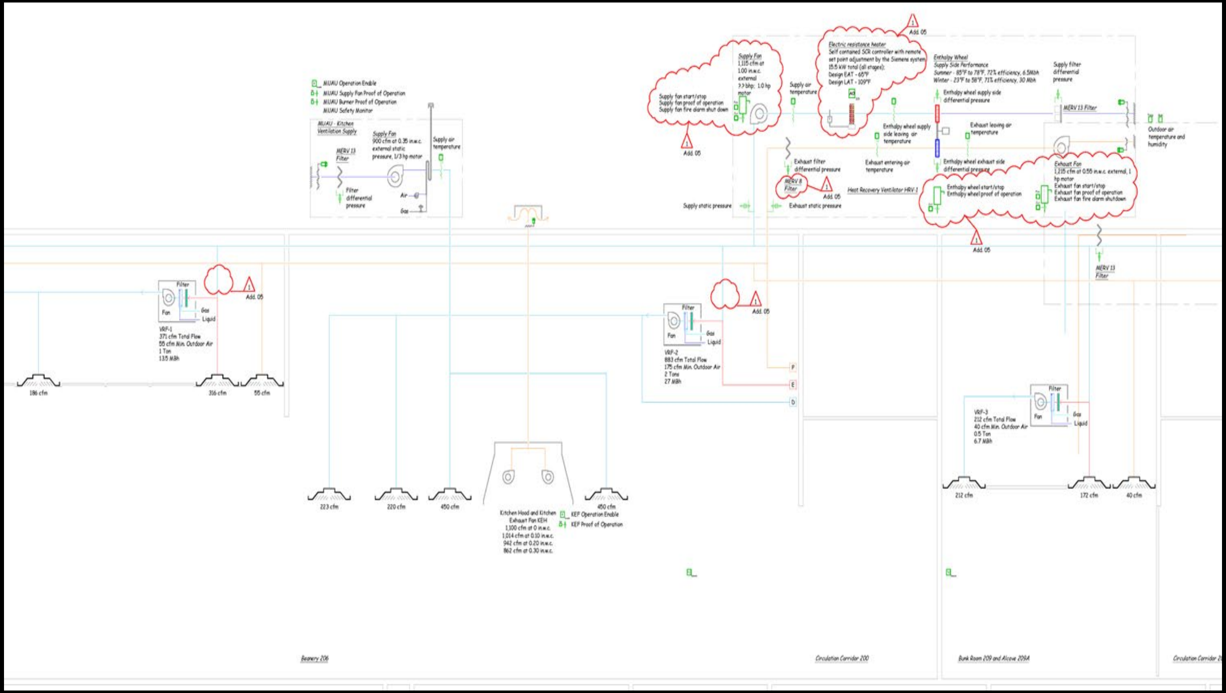
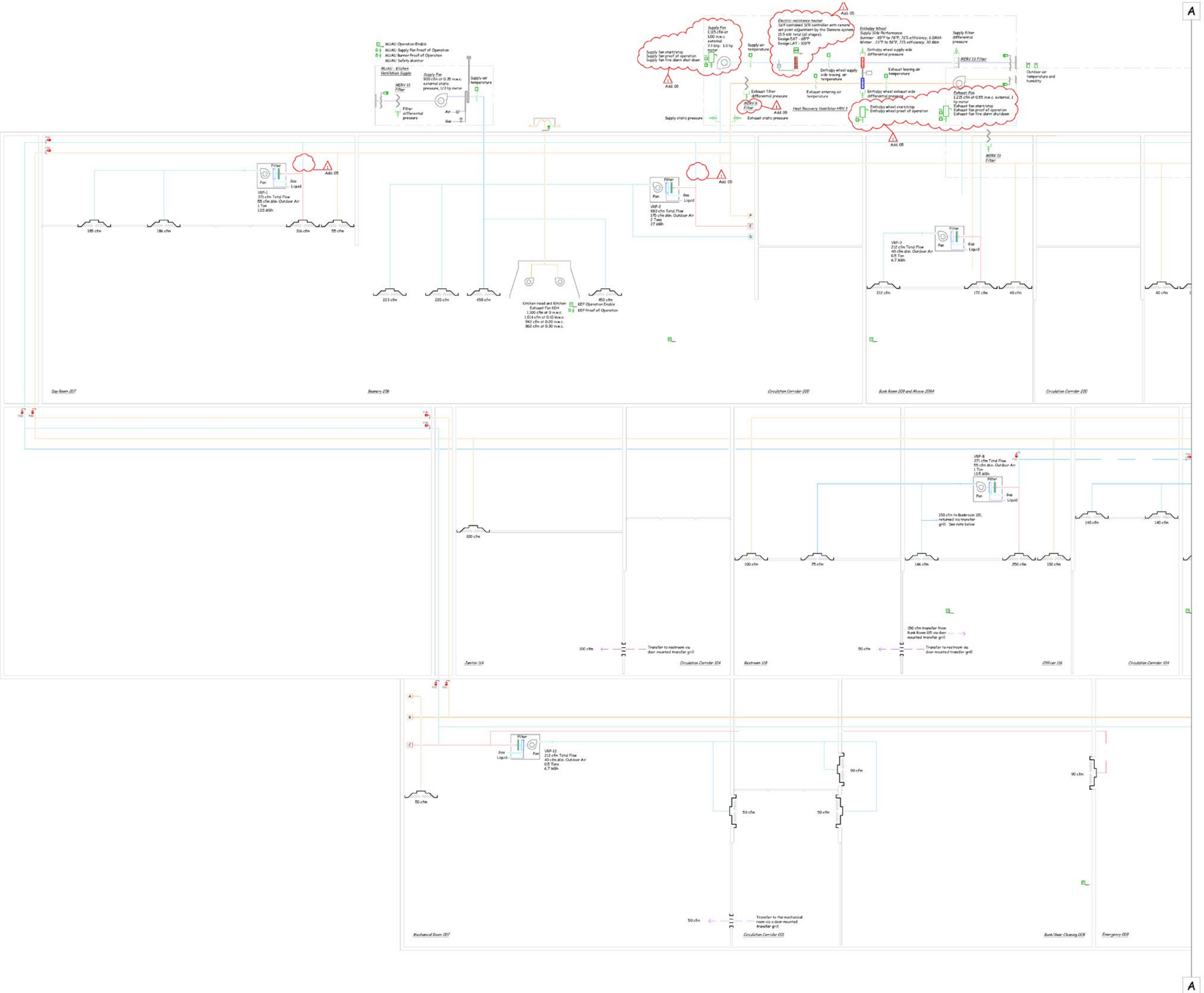
Circulation Corridor 2

A Question For You

https://tinyurl.com/HeatPumpD2Q1Vent

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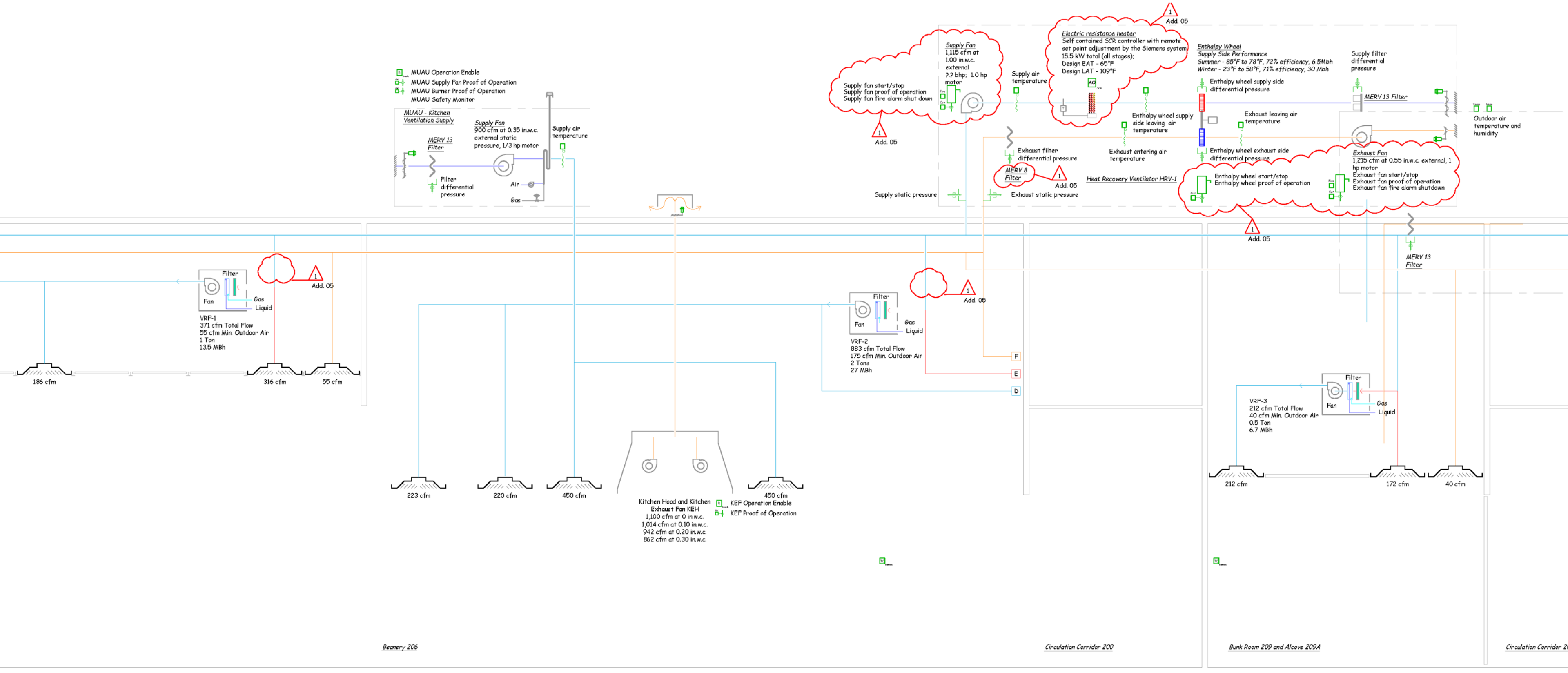

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A Few More Definitions

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

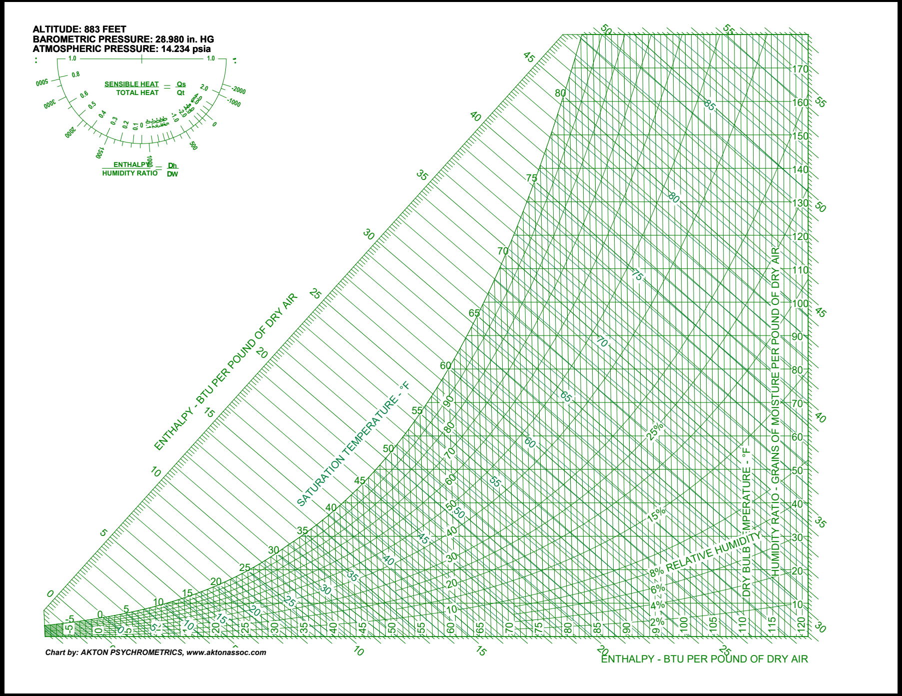
- The heating and cooling energy required to condition the ventilation air that is brought into a facility
  - With a positively pressurized space, it occurs at the central station AHU or in the system supplying outdoor air to the zone, not in the zone
  - It is often framed up in the context of delivering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

A Few More Definitions

Neutral Air

– Air that has been conditioned to match the targeted space condition

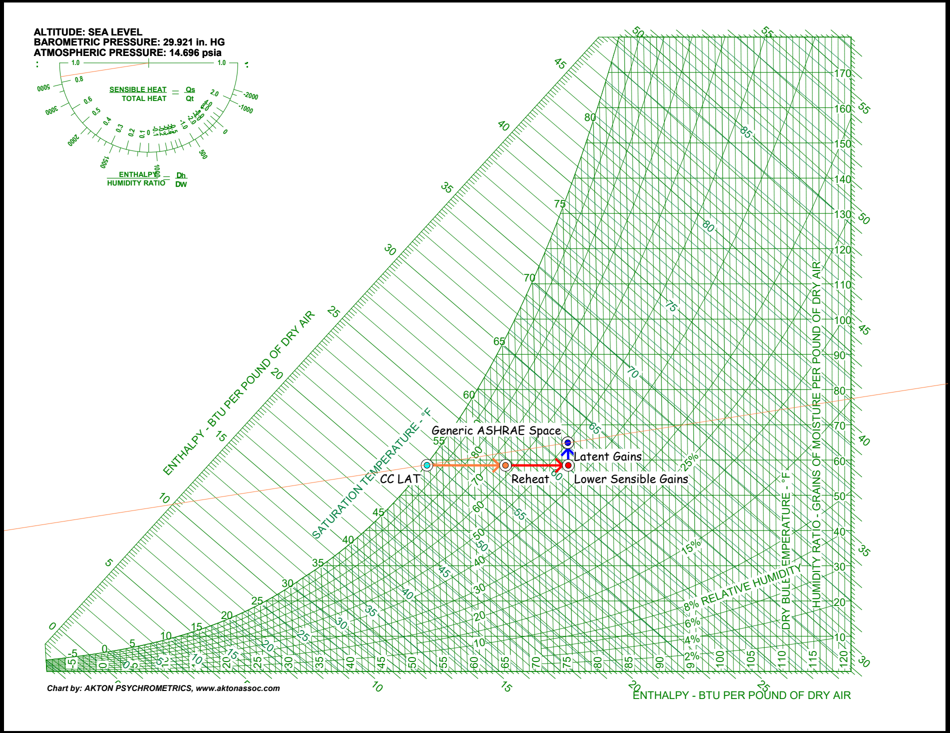
  – Since this air is at the targeted space condition, it can be introduced directly into the space and will not impact the space load



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

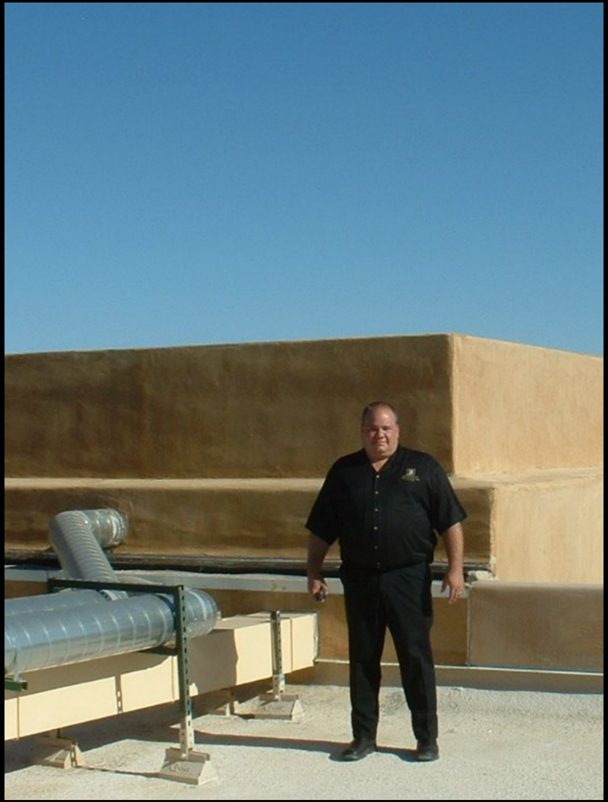
  MAU Air Mauritius (ICAO code)

A Few More Definitions

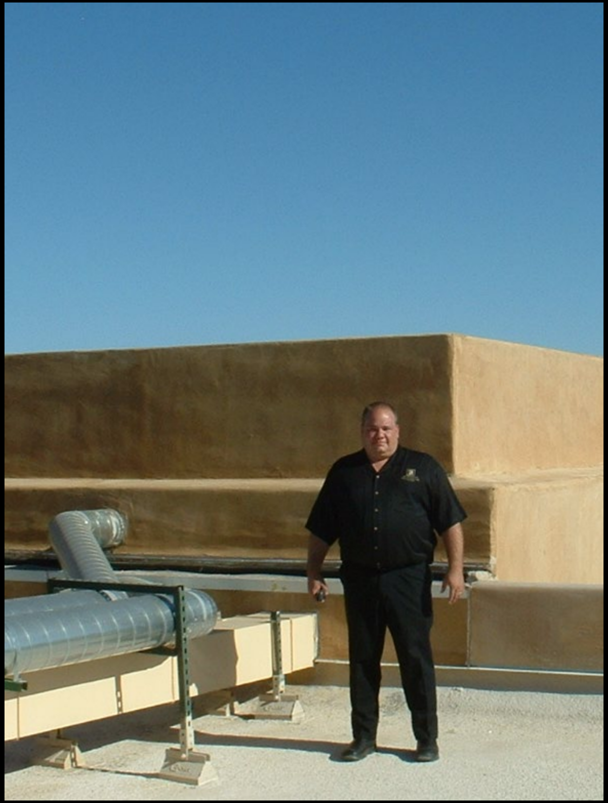
MAU

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


AHU-03



Ambient Condition
(shirt sleeves)



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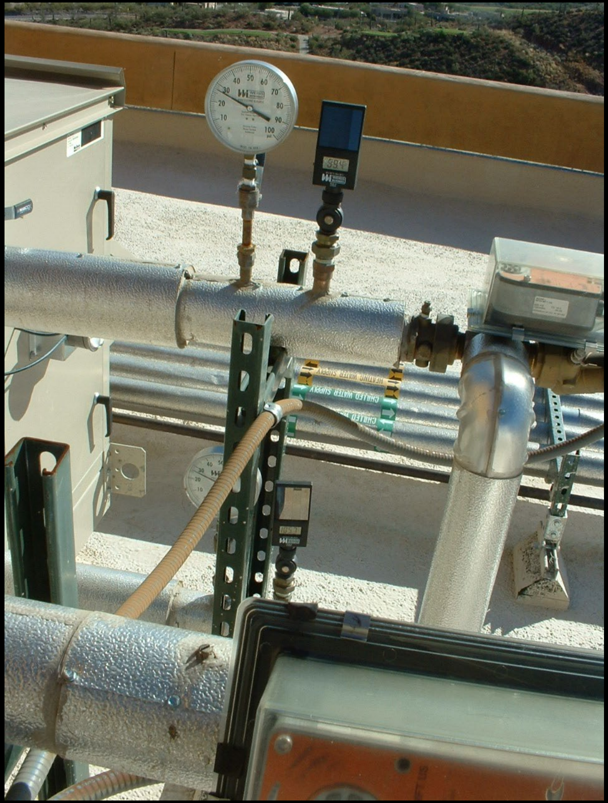
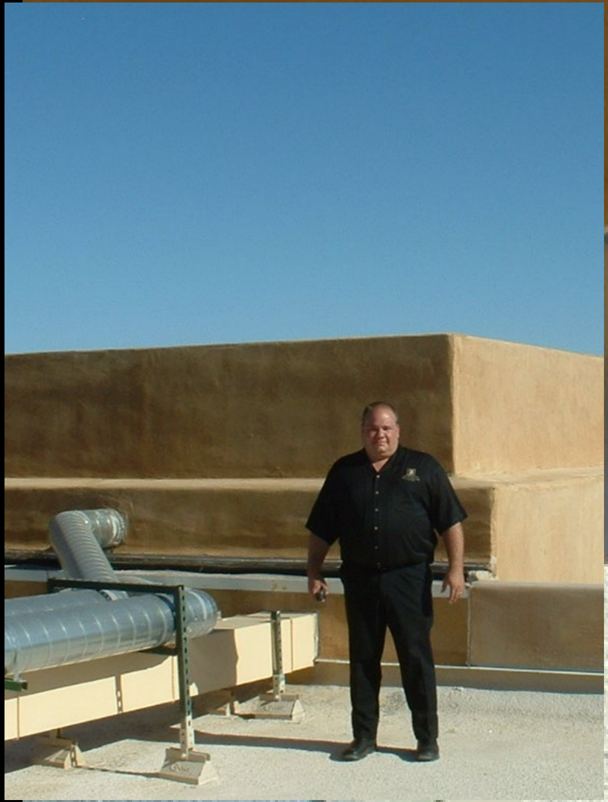
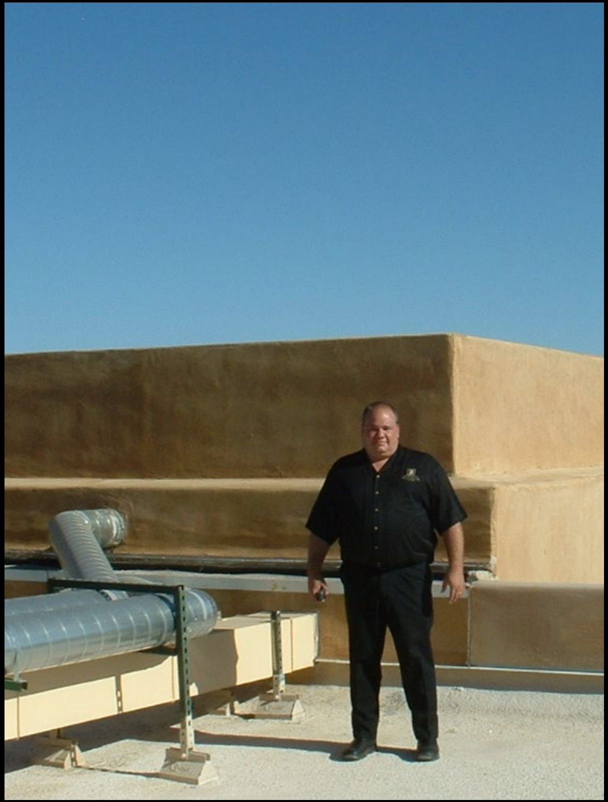


Active Preheat




Ambient Condition
(shirt sleeves)
Active Preheat



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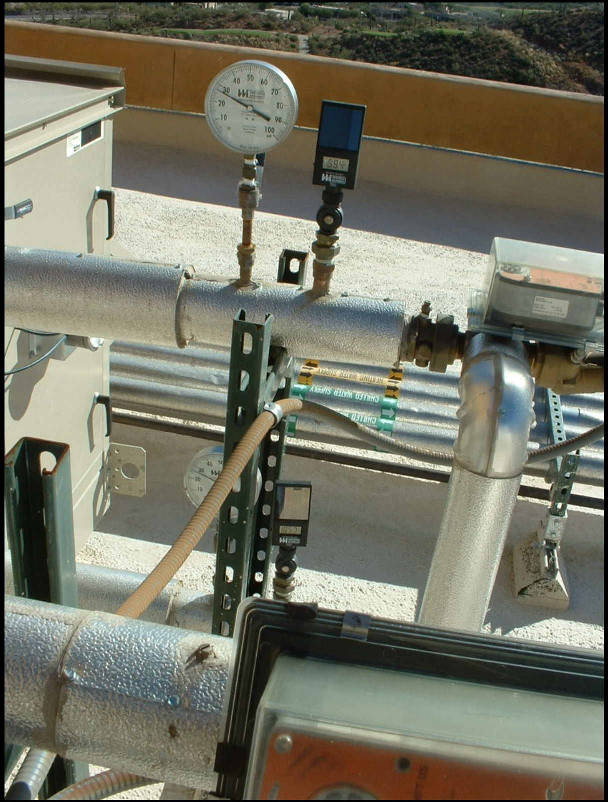
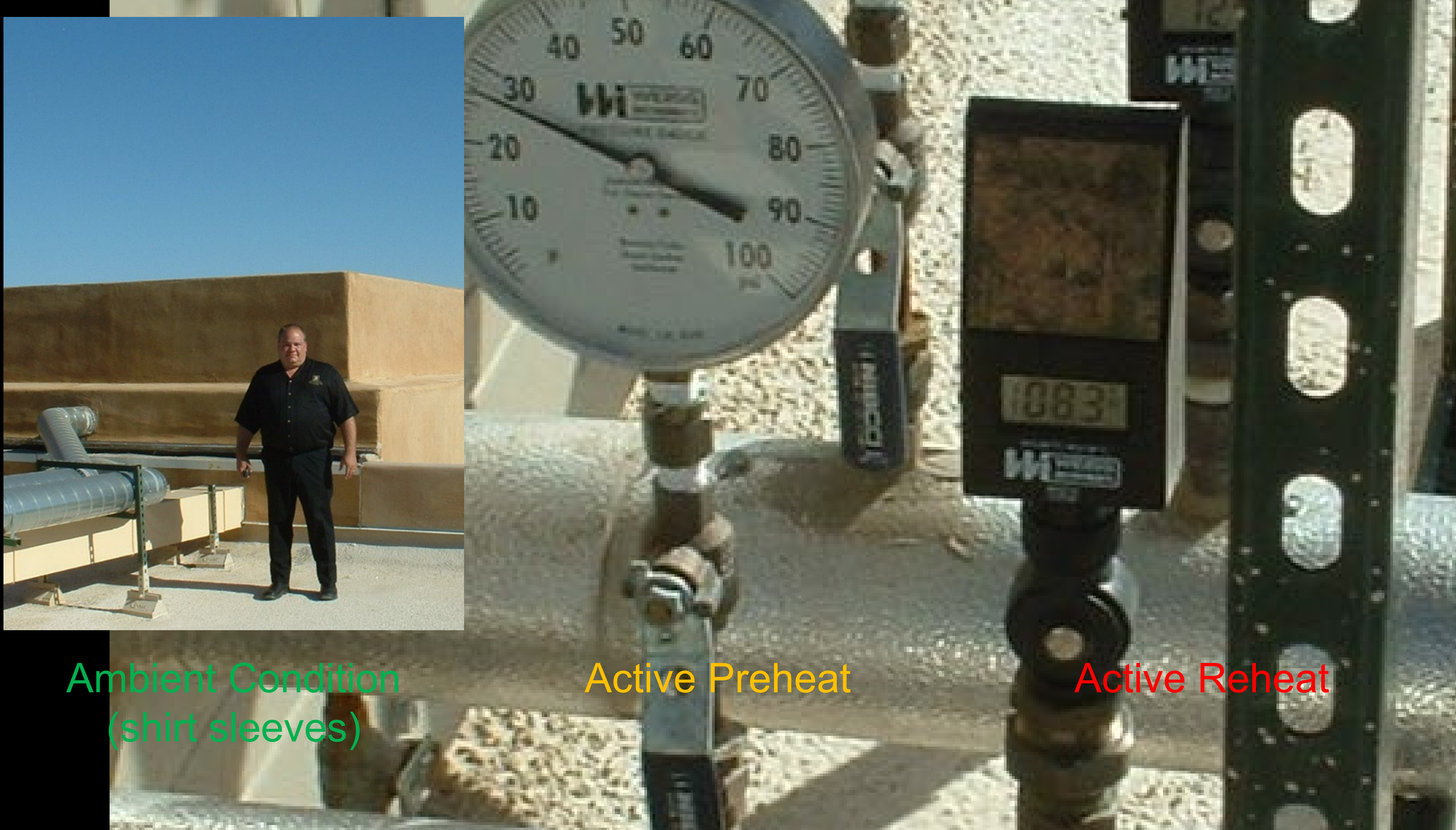


Active Preheat

Active Reheat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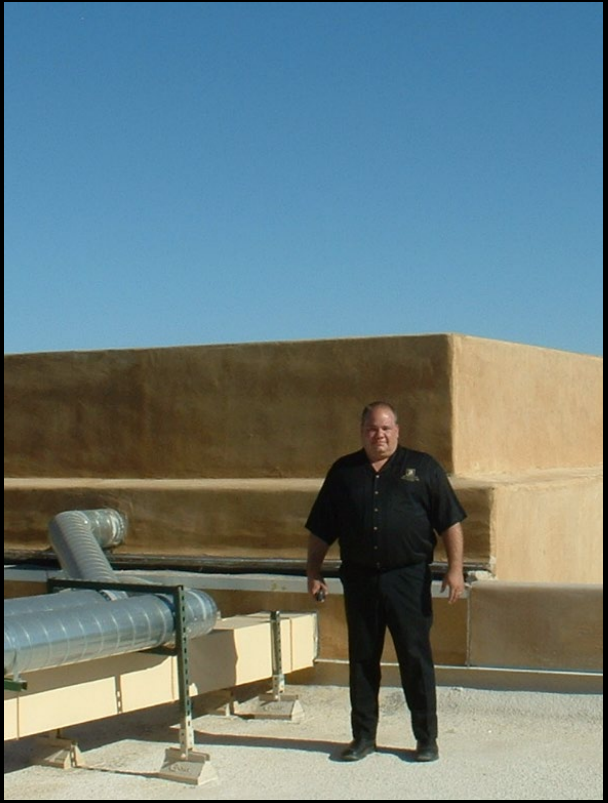

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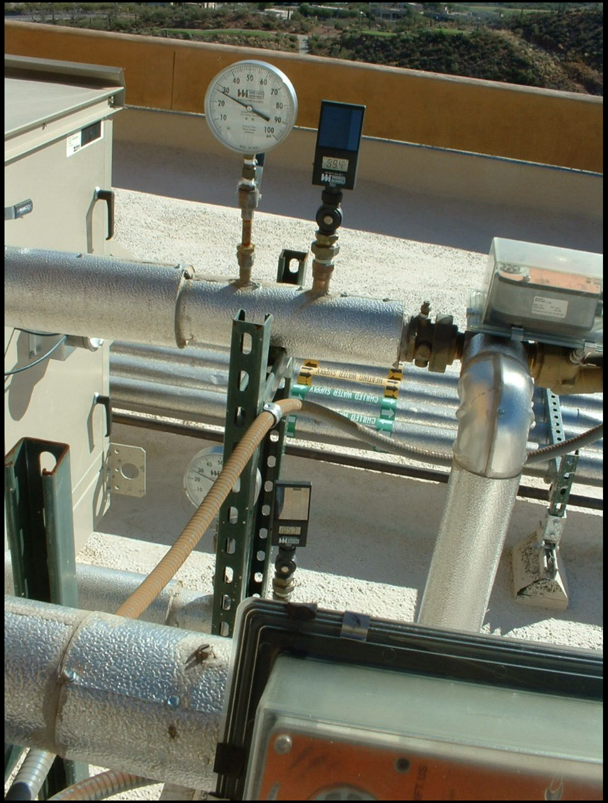


Active Preheat

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

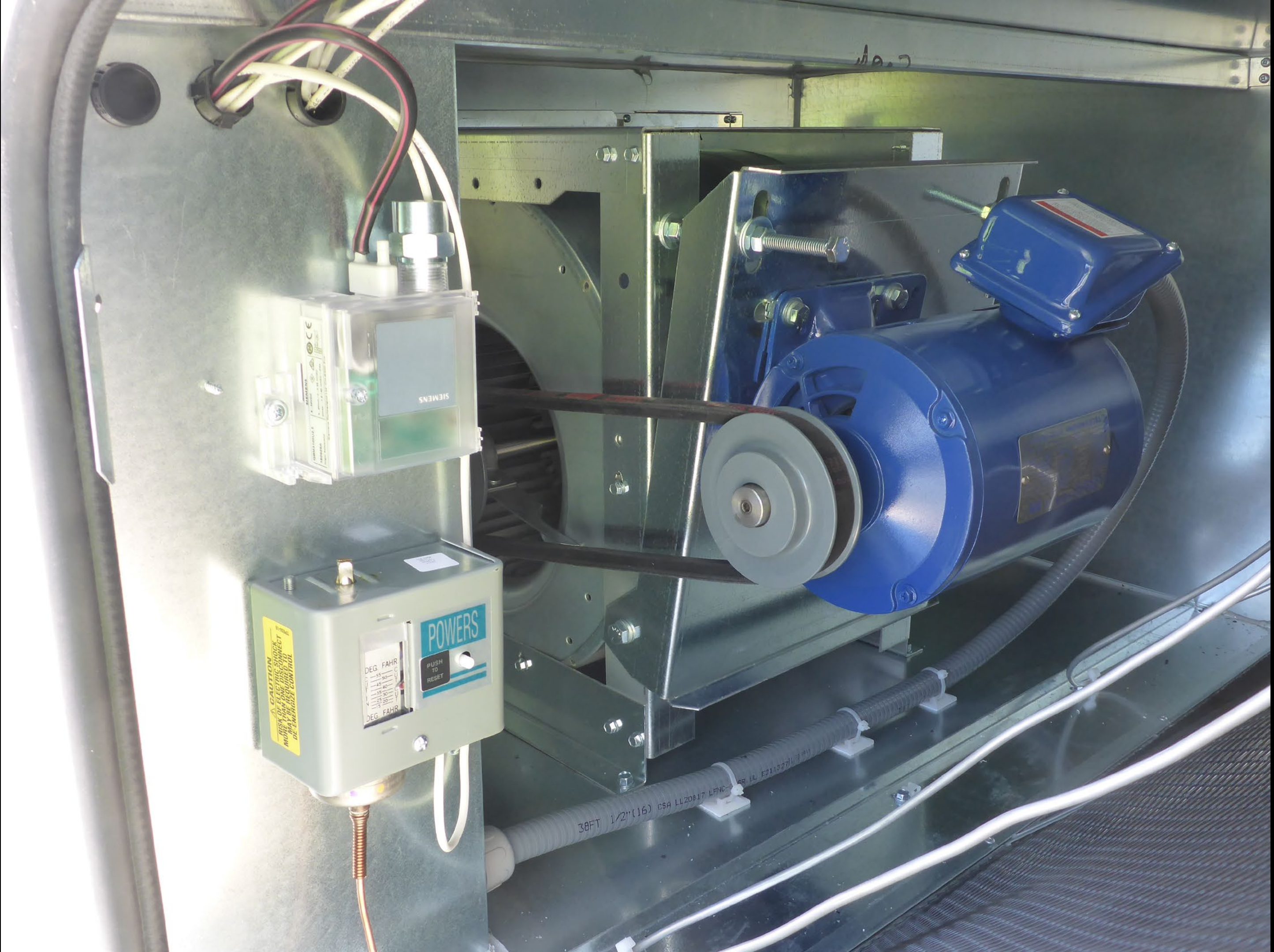
- Energy Recovery Ventilator
- Typically
  - 100% outdoor air
  - Includes filtration, some sort of energy recovery device, and fans for the supply and exhaust air stream


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

Another Question For You

https://tinyurl.com/HeatPumpD2Q4RTEquip


Fabriqué au Canada
Made in Canada
SERPENTIN ÉLECTRIQUE SUR MESURE
CUSTOM ELECTRIC DUCT HEATER
SDHI10X30-15K208V3P-CIR011-GHLOPDD-OEMF
DATE
16-03-17-40
15KW | 208V | 3PH | 41.6AMPS. | 60HZ | Dim. 10" X 30"
100 mA
40 VA
2
N/A
24
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
CAUTION


SIEMENS


RV-1
208V


208V
Lenze
AC Tech


MC1
MC2
MC3
RS1
RS2
ATTENTION
CAUTION
RIBU1C
RIBU1C


RV-1
208V

208V
Lenze
AC Tech
Lenze
AC Tech


208V
ATTENTION
CAUTION

208V
ATTENTION
CAUTION
Lenze
AC Tech
Lenze
AC Tech


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

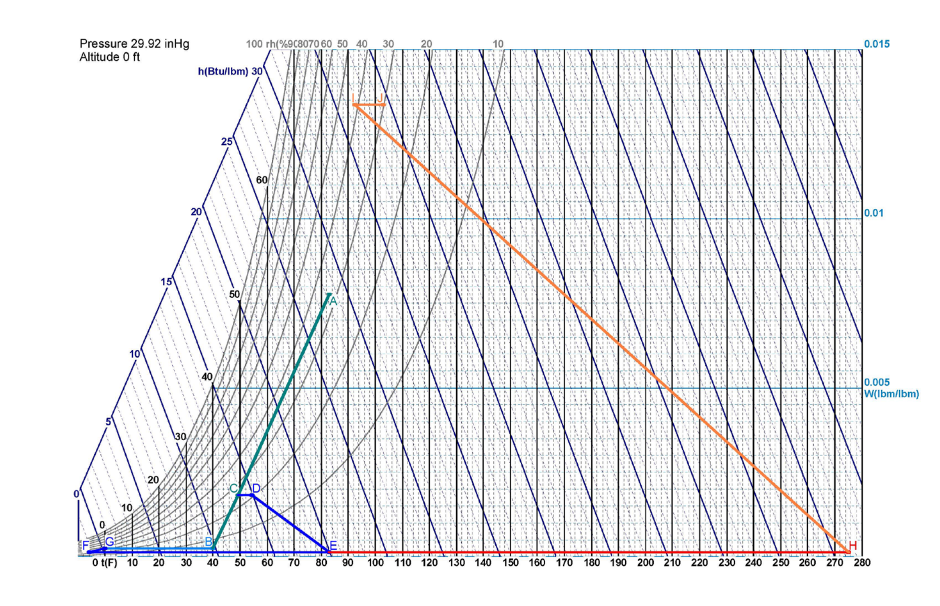

HEATING WATER SUPPLY
190
CHILLED WATER SUPPLY
CHILLED WATER RETURN

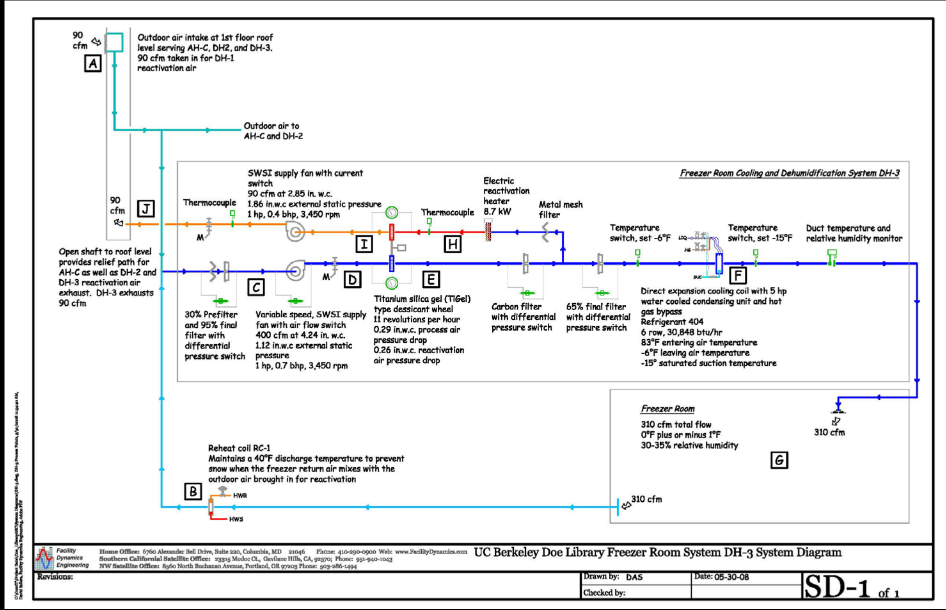
HEATING WATER SUPPLY

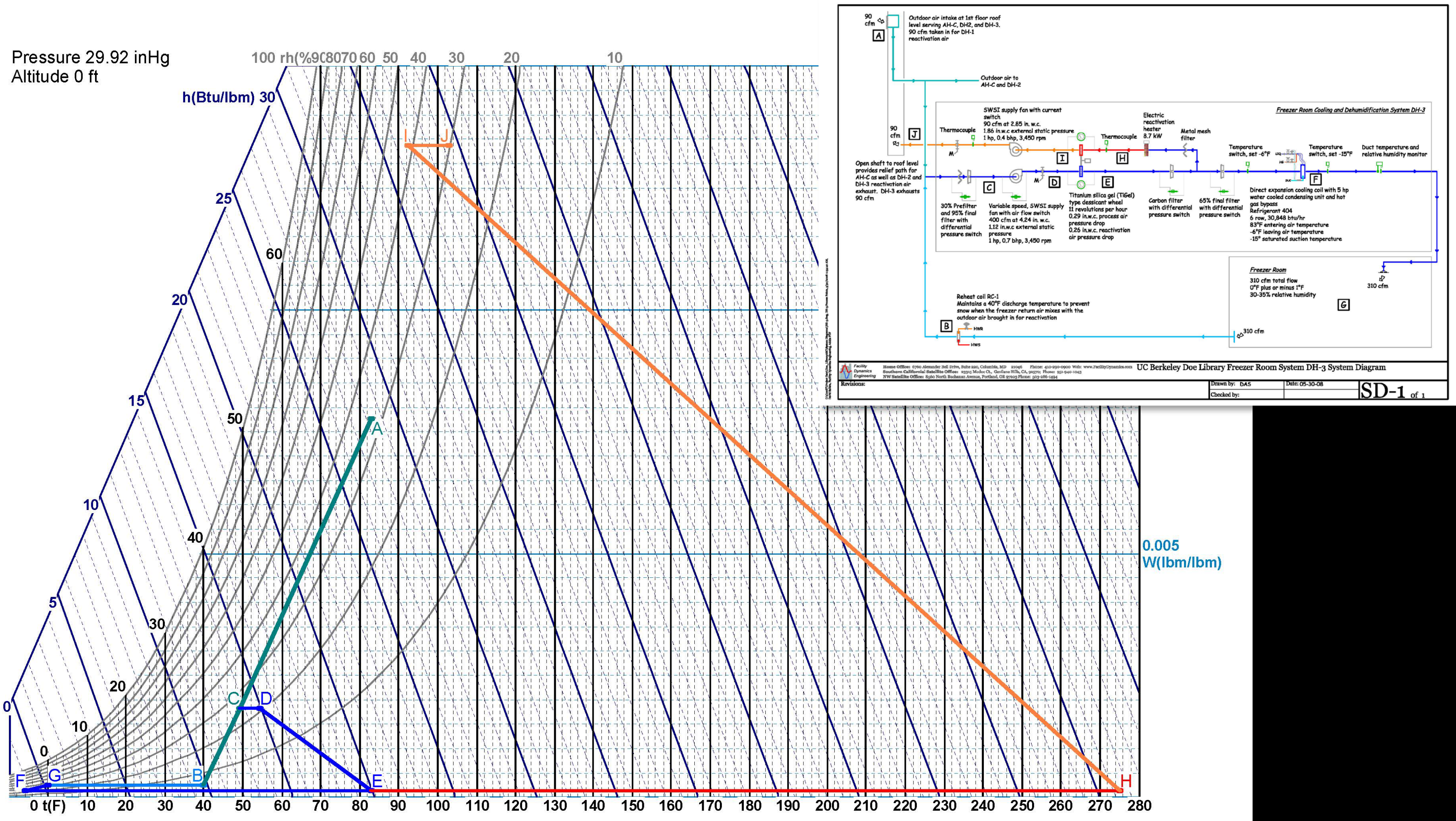

A Few More Definitions

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)
t(F)
A
B
C
D
E
F
G
H
I
J


90 cfm
Outdoor air intake at 1st floor roof level serving AH-C, DH2, and DH-3. 90 cfm taken in for DH-1 reactivation air
A
Outdoor air to AH-C and DH-2
Freezer Room Cooling and Dehumidification System DH-3
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
Electric reactivation heater 8.7 kW
Metal mesh filter
Thermocouple
Thermocouple
90 cfm
J
I
H
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
Temperature switch, set -6°F
Temperature switch, set -15°F
Duct temperature and relative humidity monitor
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
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
UC Berkeley Doe Library Freezer Room System DH-3 System Diagram
Revisions:
Drawn by: DAS
Checked by:
Date: 05-30-08
SD-1 of 1



Pressure 29.92 inHg
Altitude 0 ft
h(Btu/lbm) 30
25
20
15
10
5
0
100 rh(%) 90 80 70 60 50 40 30 20 10
60
50
40
30
20
10
0
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
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
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8.7 kW
Metal mesh filter
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
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310 cfm
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HWR
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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

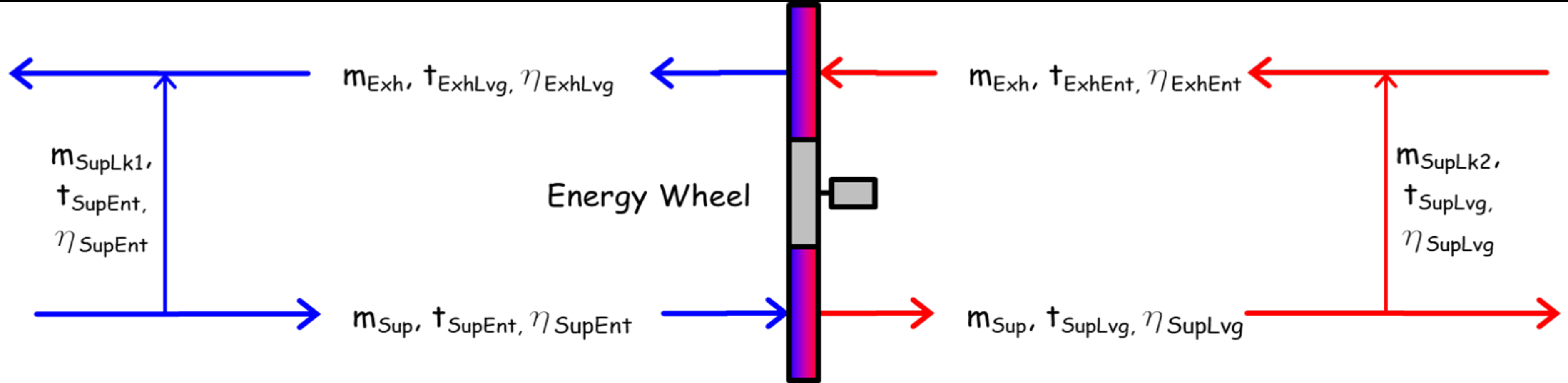
$\eta_{Sup_{Ent}}$ = Supply air entering enthalpy

$\eta_{Sup_{Lvg}}$ = 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

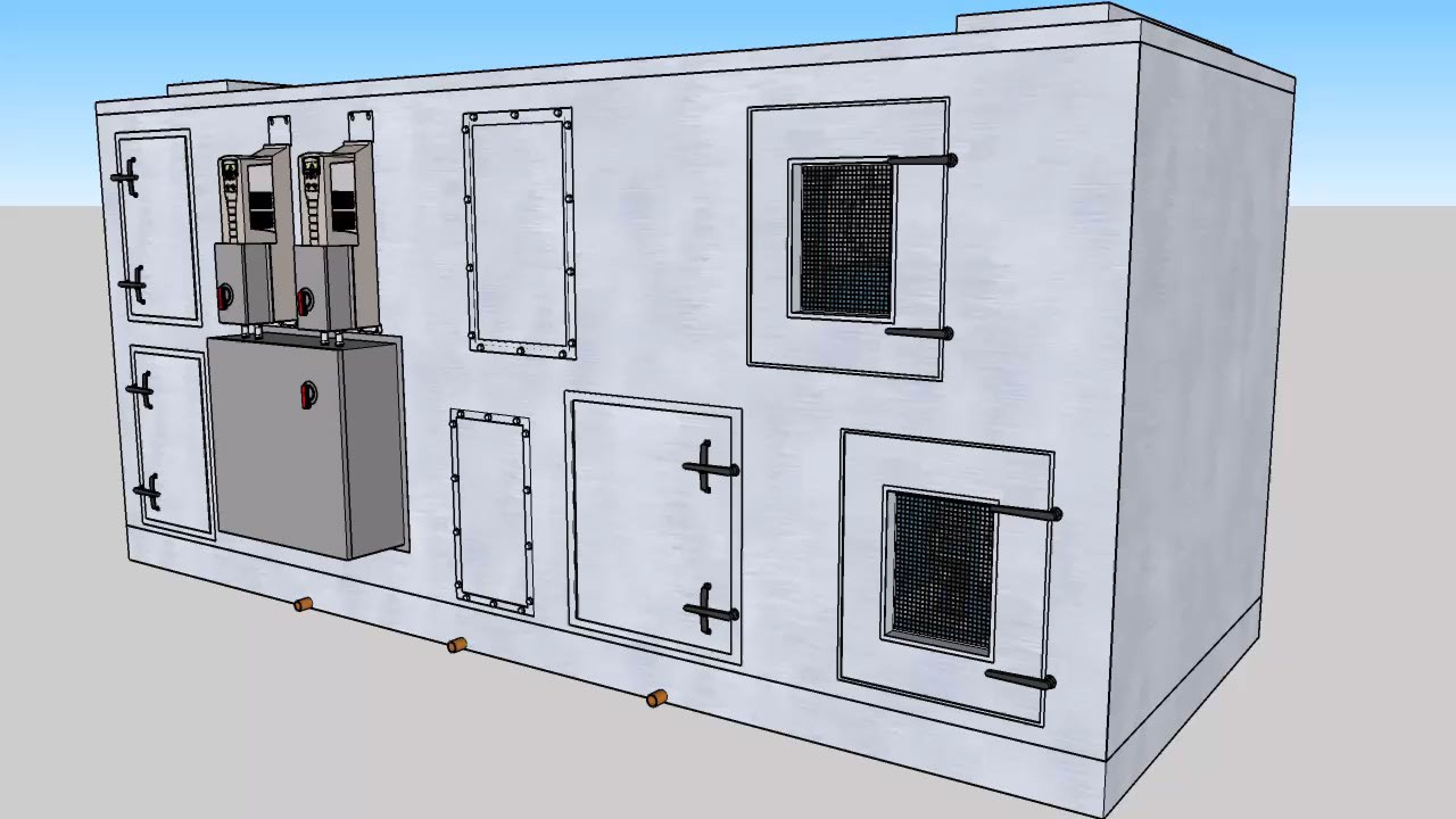
ASHRAE Systems and Equipment Handbook
Chapter 26 is a good reference

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

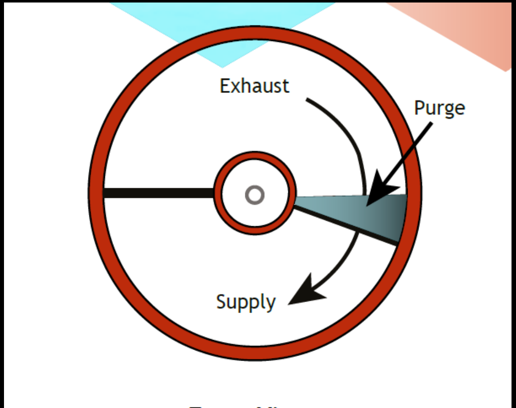


AX-48

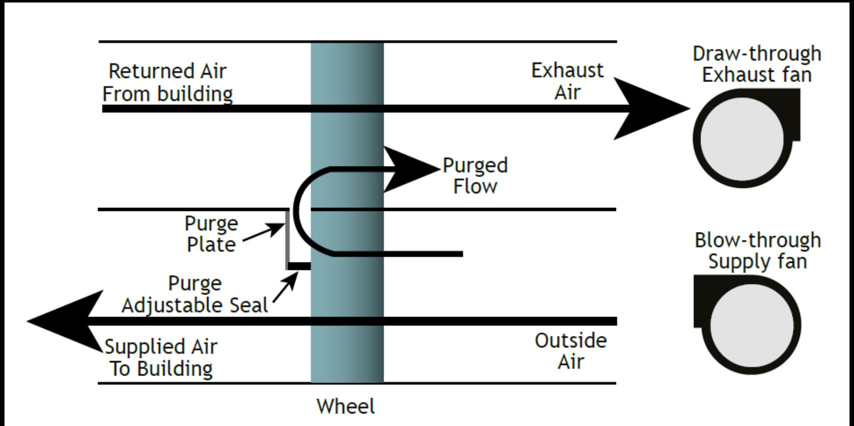
Heat and Energy Wheel Purge

- By their nature, wheels will move a bit of exhaust air to the supply air stream and vice versa
- Purge hardware reverses the flow through a sector of the wheel as it enters the supply air stream
- This reduces cross-contamination but reduces effectiveness and increases fan power

Images courtesy innergytech.com



Front View
With Upstream Exhaust



Side Cross Section
with Purge Section

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?

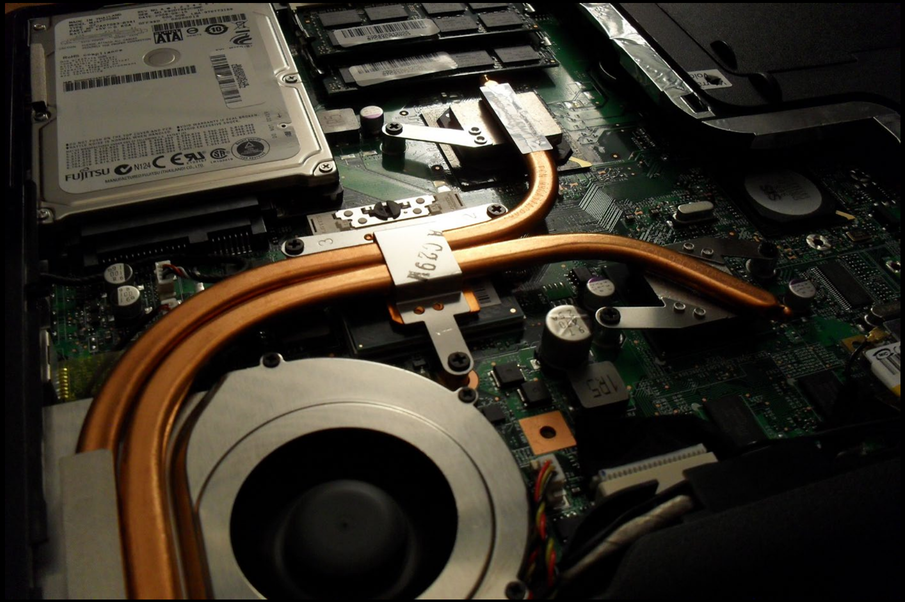


Image courtesy Kristoferb, Creative Commons Attribution-Share Alike 3.0 Unported

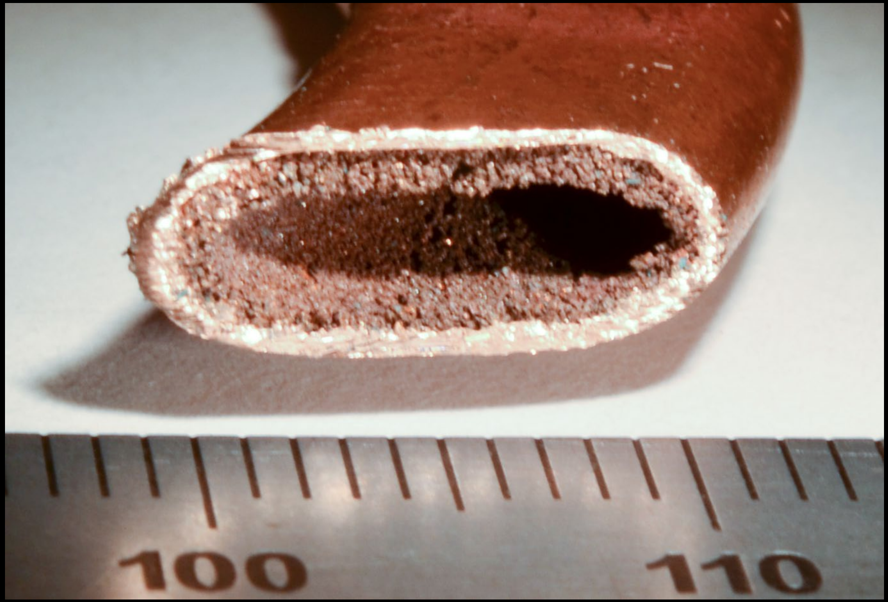


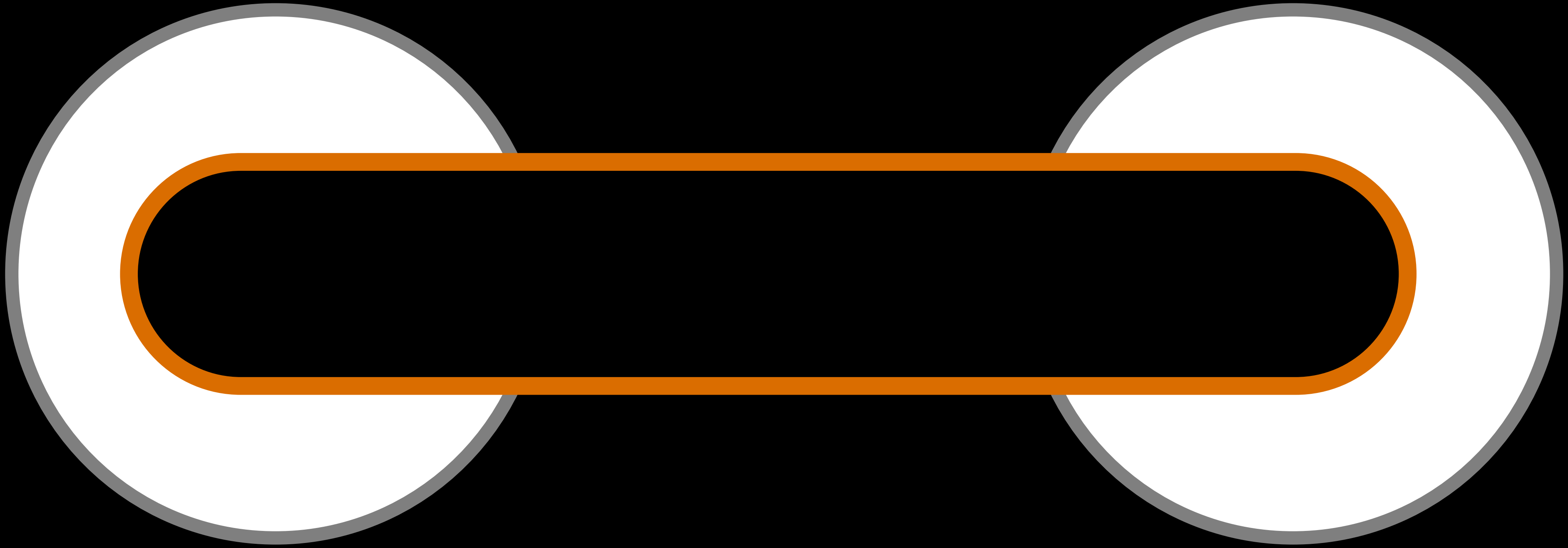
Image courtesy Epbernard, Creative Commons CC0 1.0 Universal Public Domain Dedication

Heat Pipe Operation

https://tinyurl.com/HeatPipeDetails

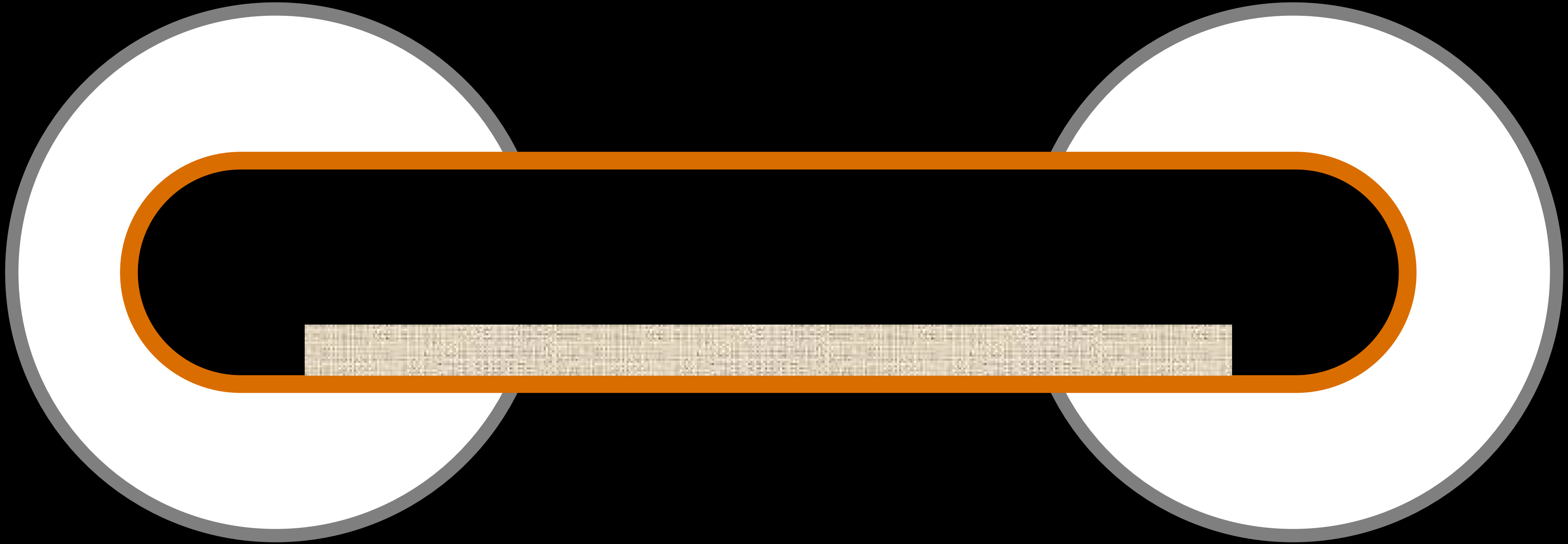
Heat Pipe Operation

Start with a sealed conductive metal tube between two ducts



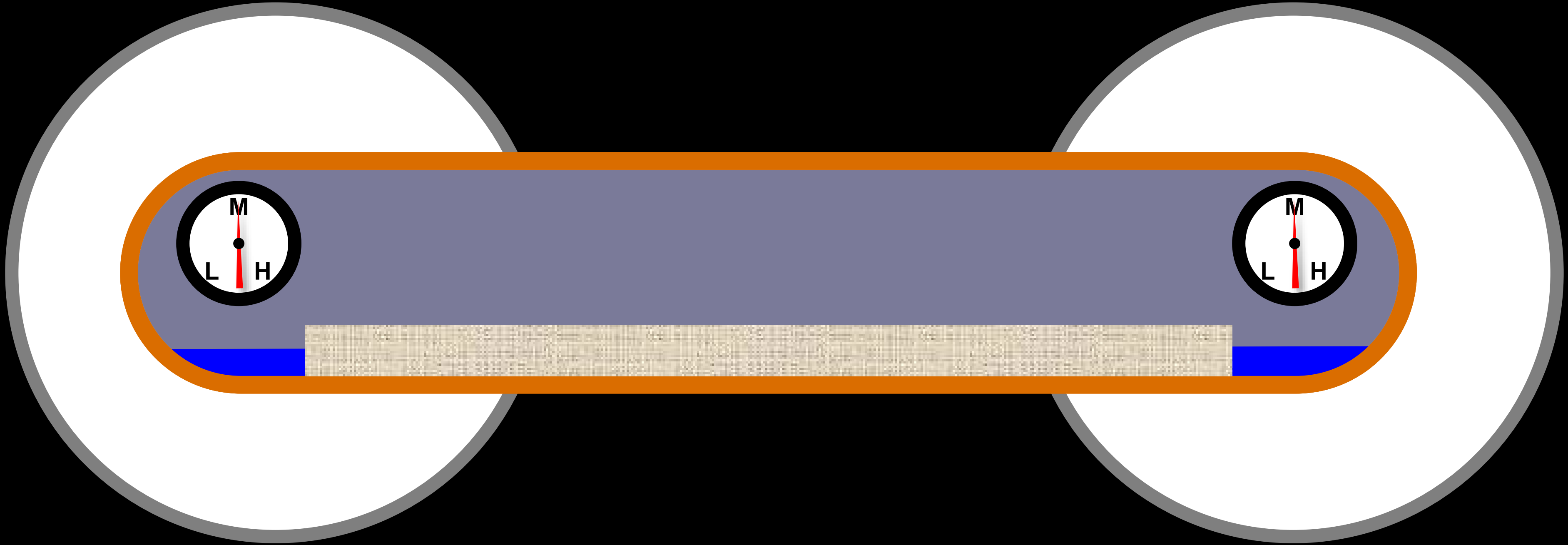
Heat Pipe Operation

Add a wick



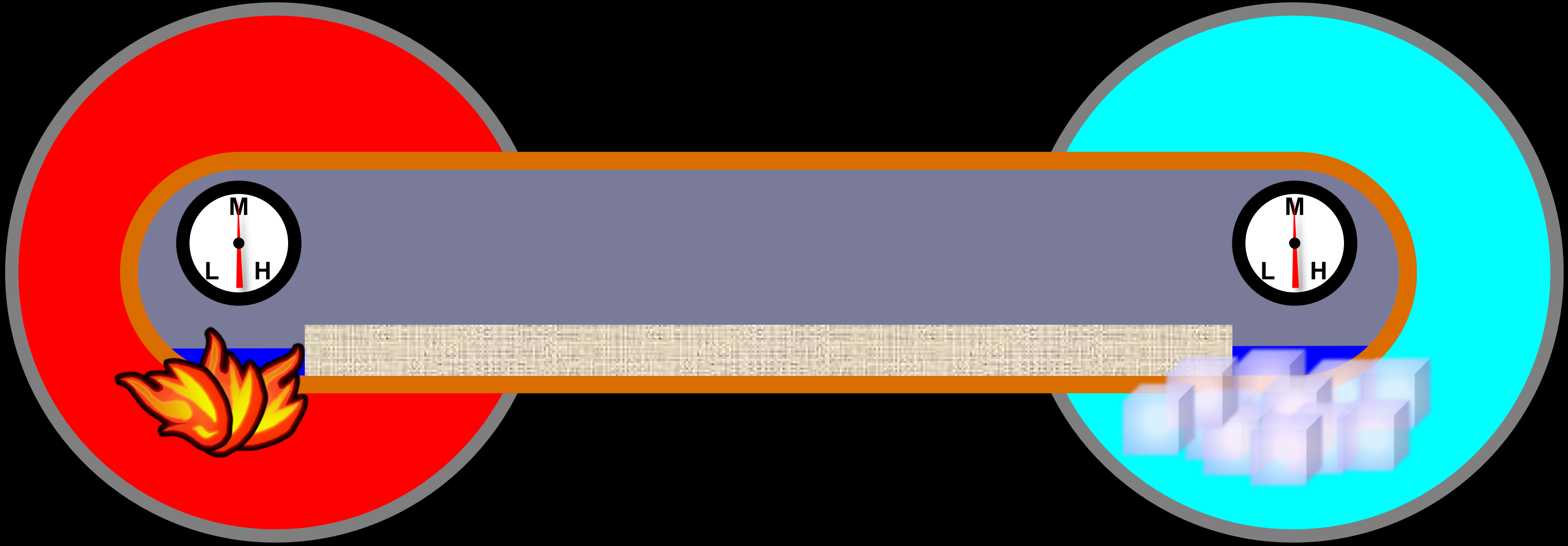
Heat Pipe Operation

Charge it with refrigerant in a saturated state



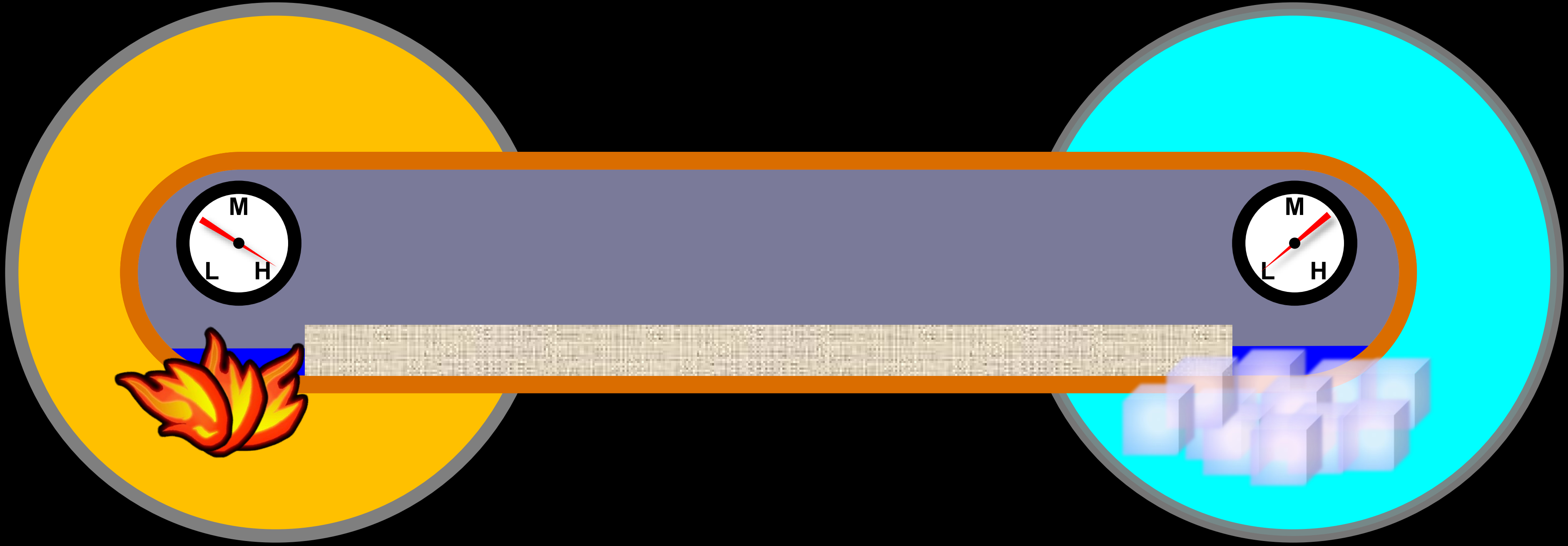
Heat Pipe Operation

Create a thermal gradient along its length



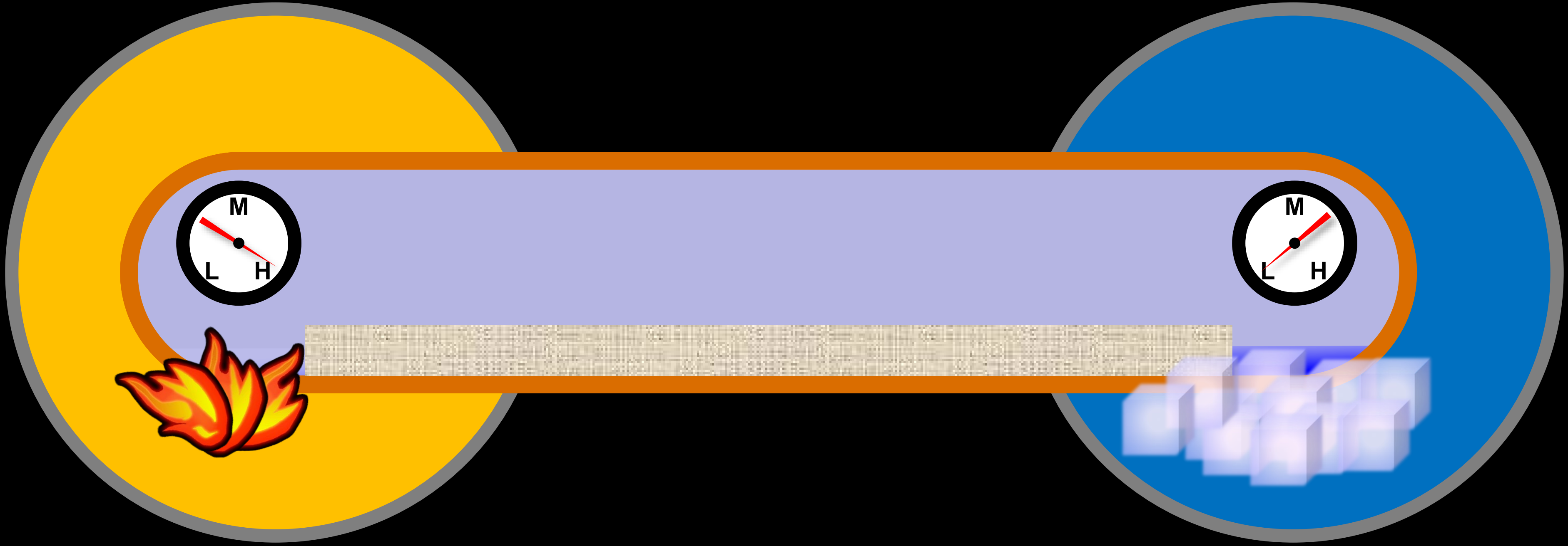
Heat Pipe Operation

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



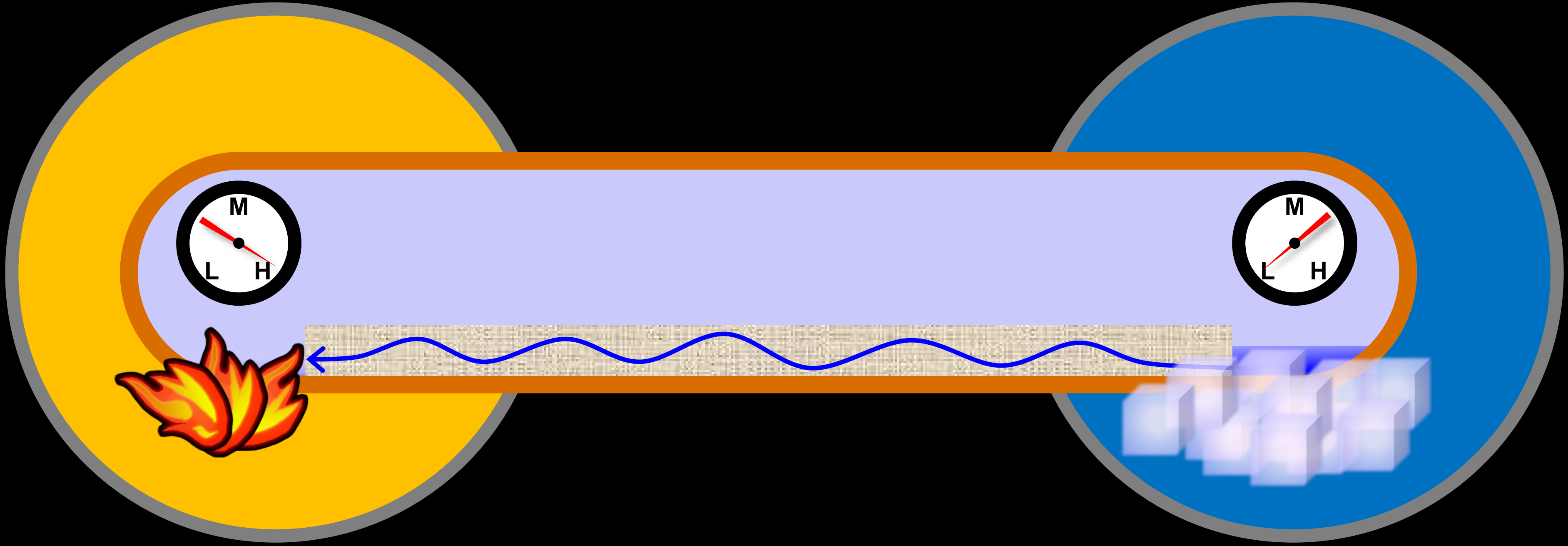
Heat Pipe Operation

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



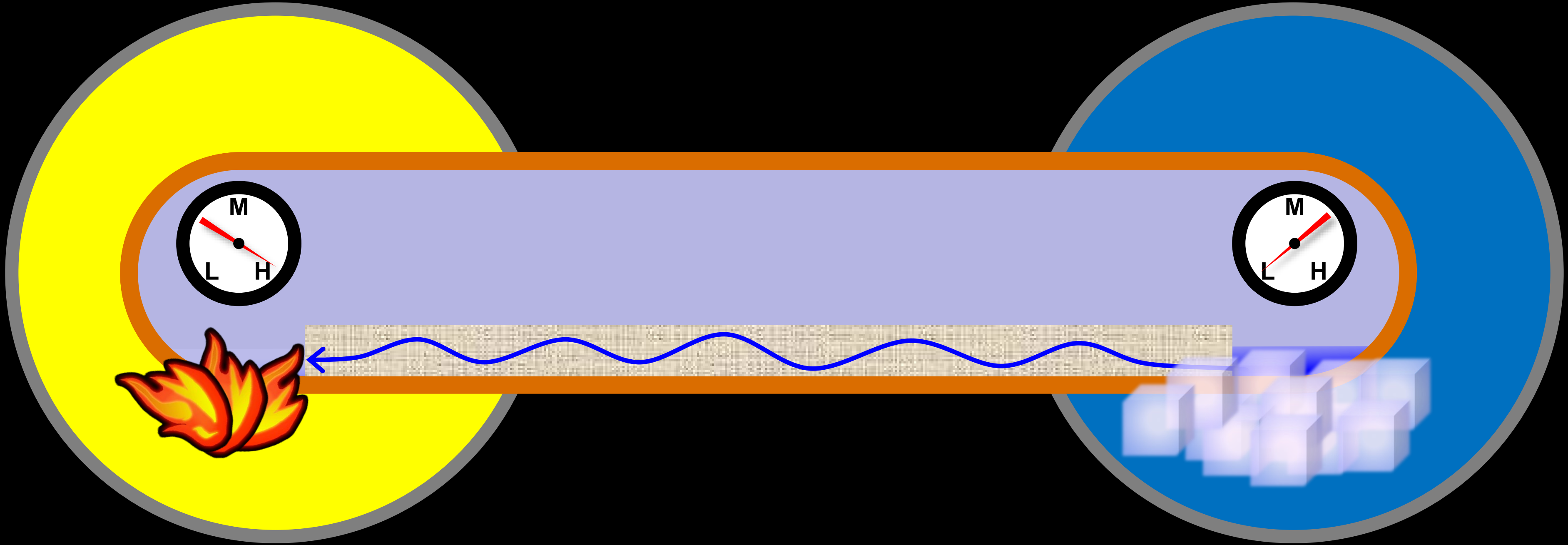
Heat Pipe Operation

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



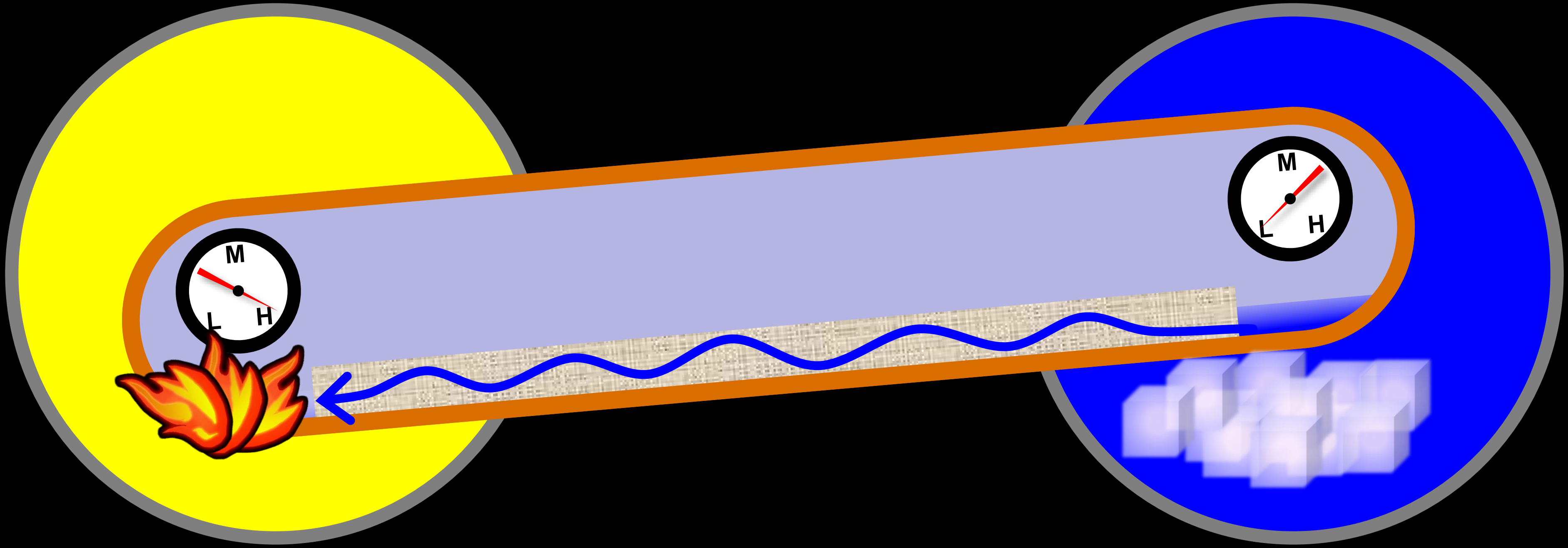
Heat Pipe Operation

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

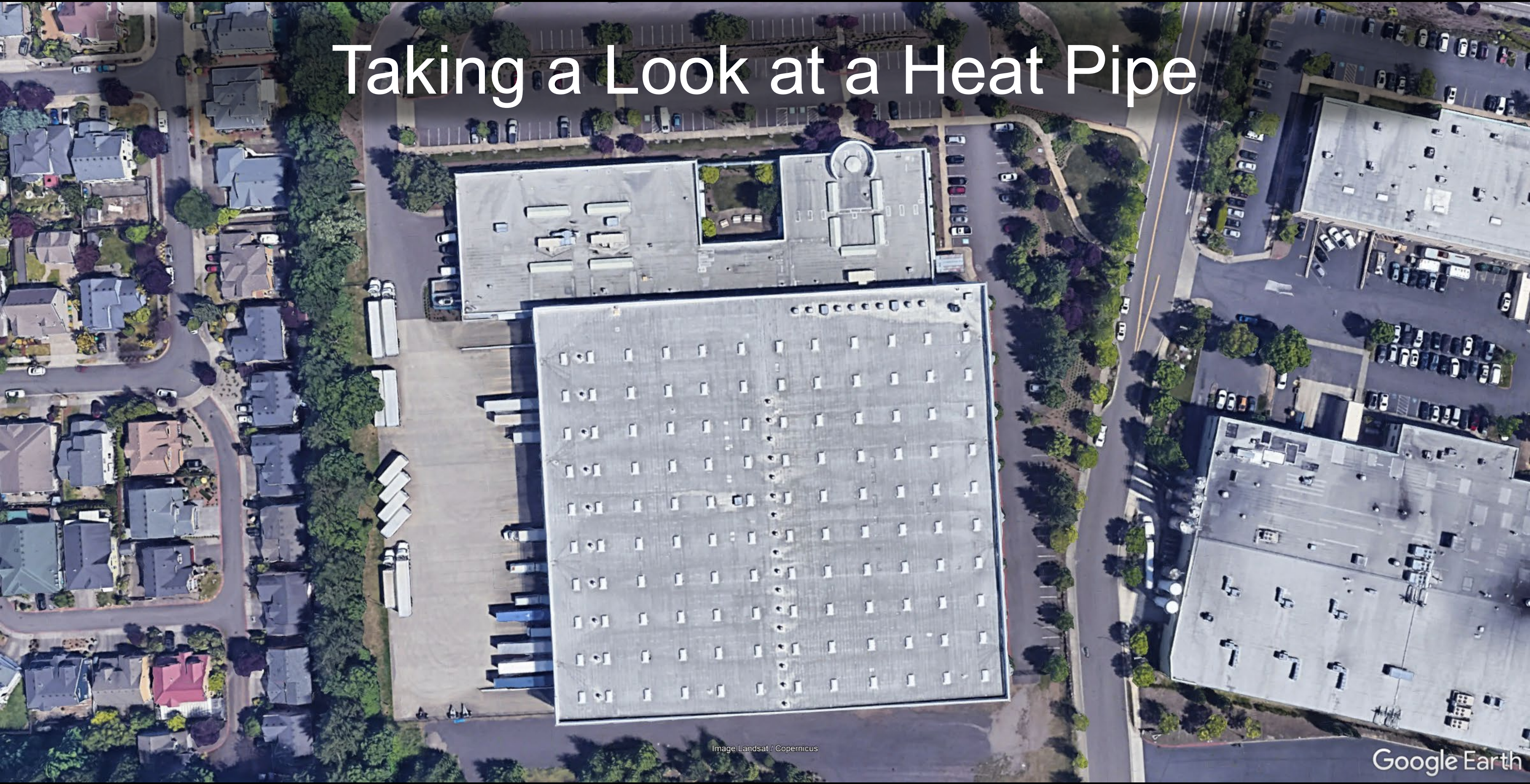


Heat Pipe Operation

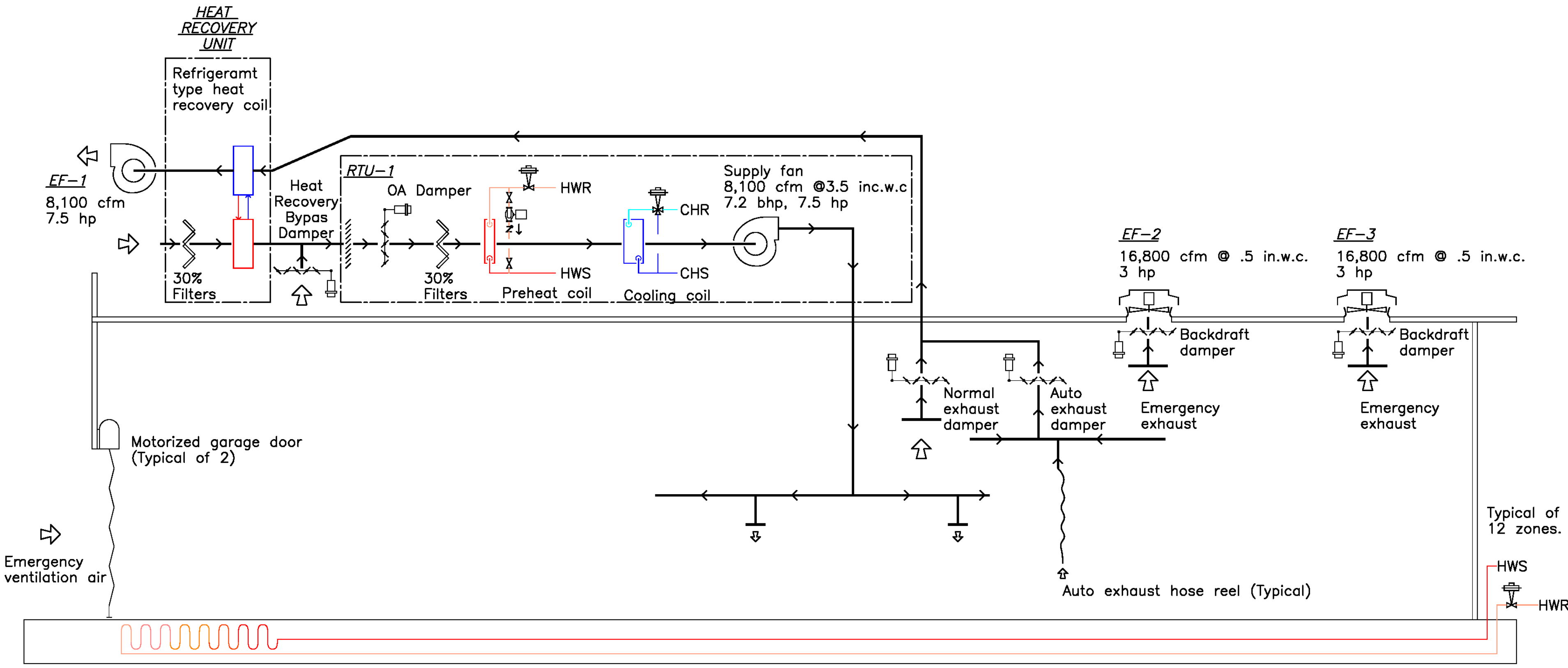
Tilting the tube impacts the capillary action and can modulate energy transfer



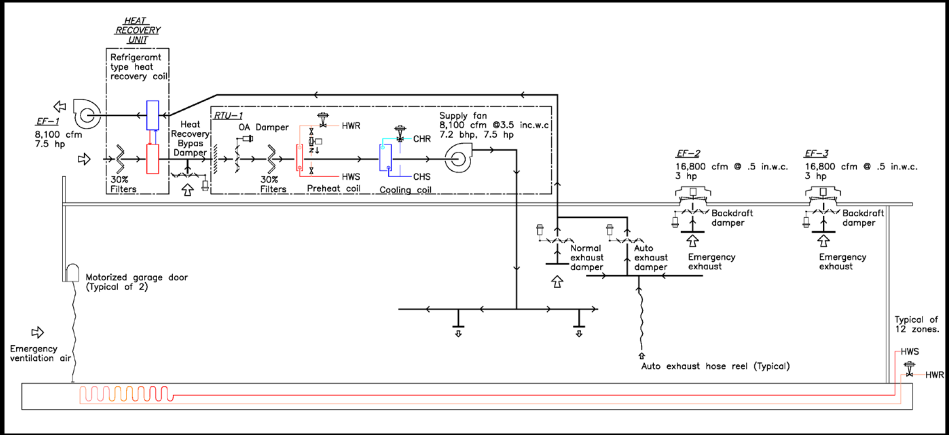
Taking a Look at a Heat Pipe




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
Backdraft damper
Emergency exhaust
EF-3
16,800 cfm @ .5 in.w.c.
3 hp
Backdraft damper
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


7/16/2001 4:54pm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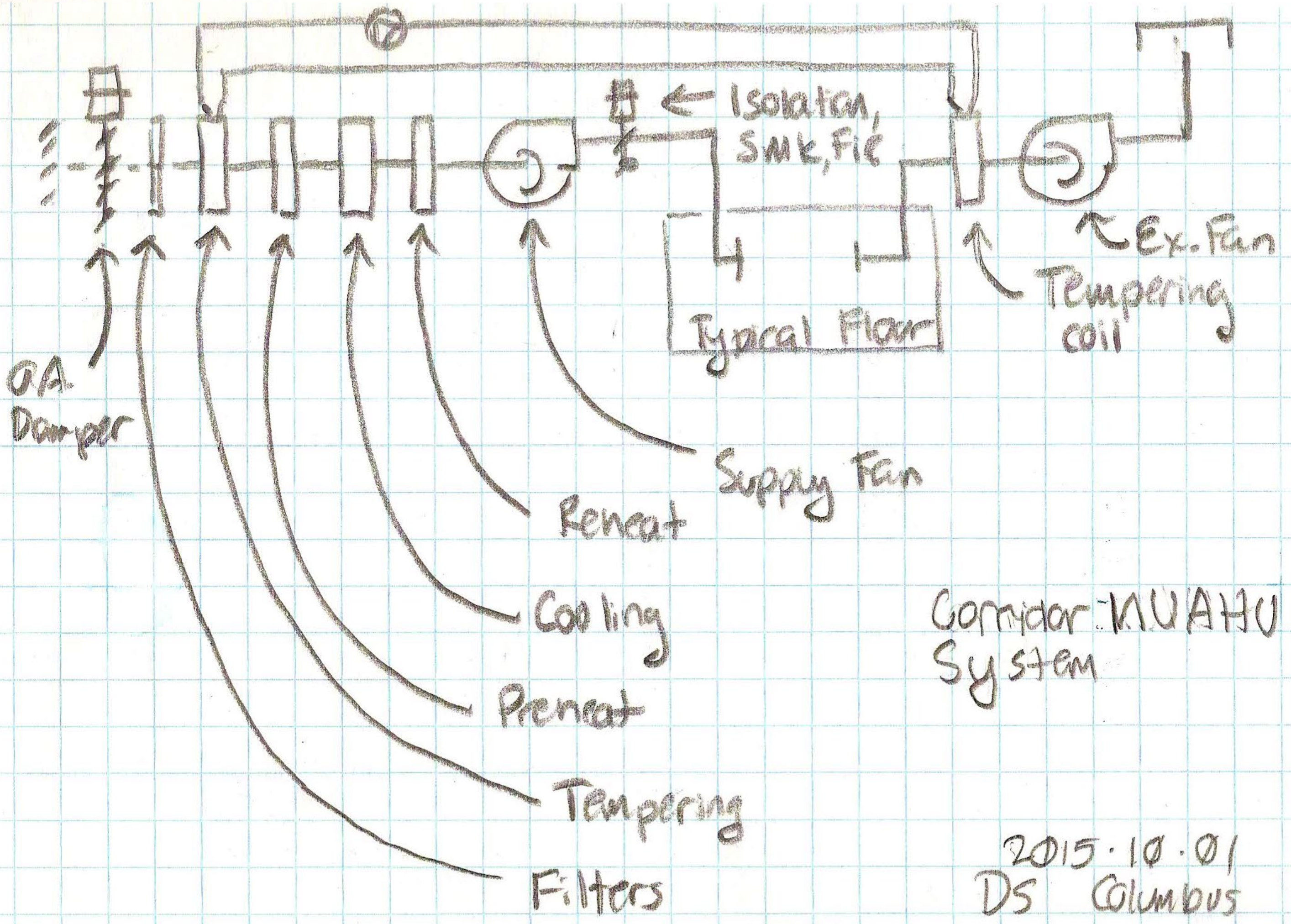
Backdraft damper
Emergency exhaust
Normal exhaust damper
Auto exhaust damper
Motorized garage door
(Typical of 2)
Emergency ventilation air
Auto exhaust hose reel (Typical)
Typical of 12 zones.
HWS
HWR

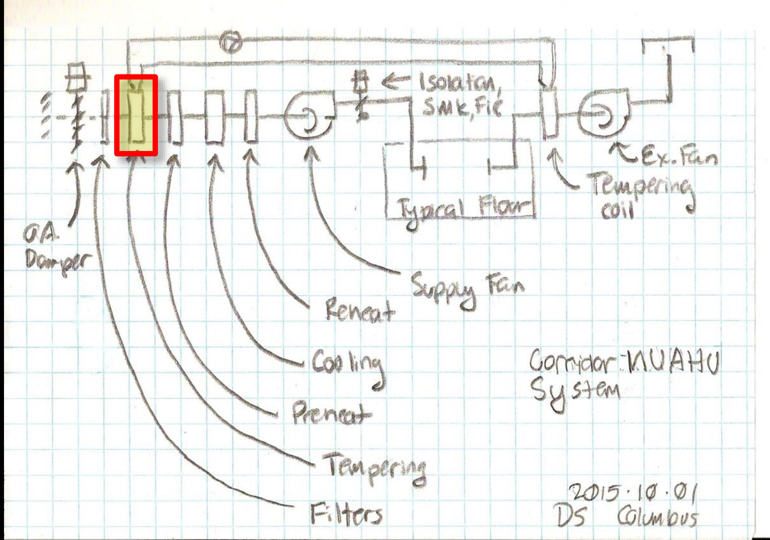
Energy Recovery Strategies

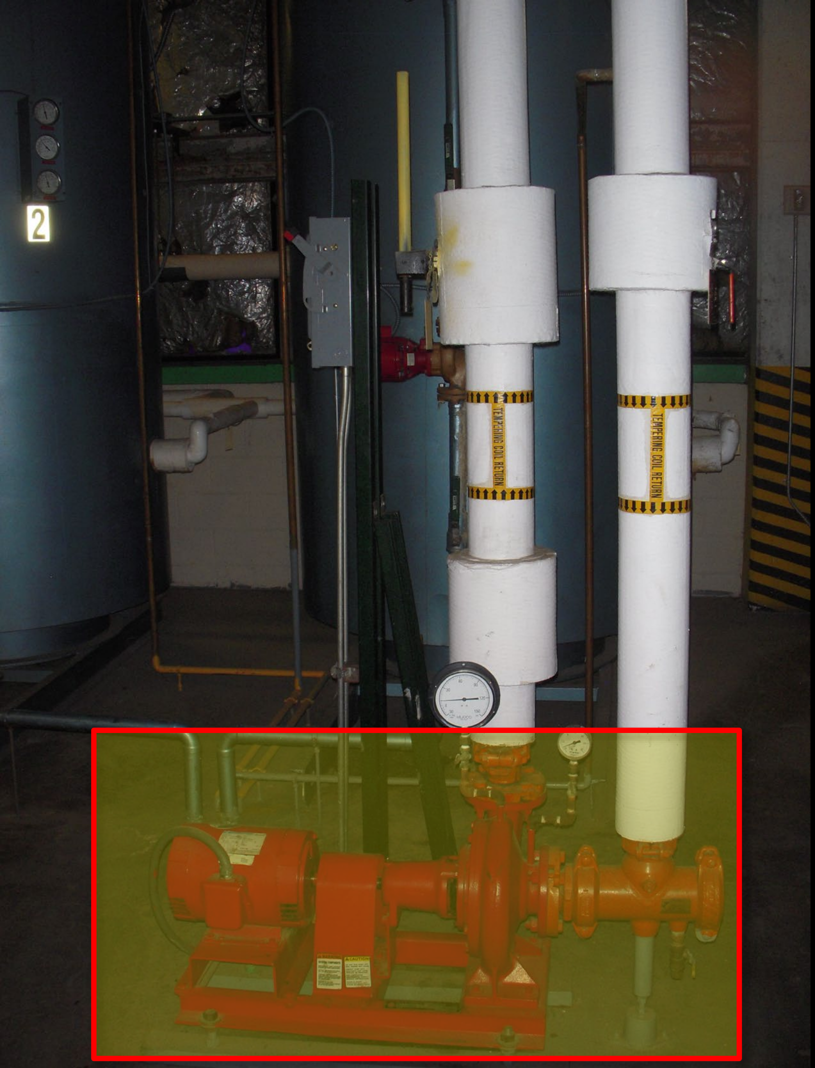
Run Around Coils

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


AIR


Isolation, Smk, Fire
O.A. Damper
Filters
Tempering
Preheat
Cooling
Reheat
Supply Fan
Typical Floor
Tempering coil
Ex. Fan
Corridor M.U. AHU System
2015.10.01
DS Columbus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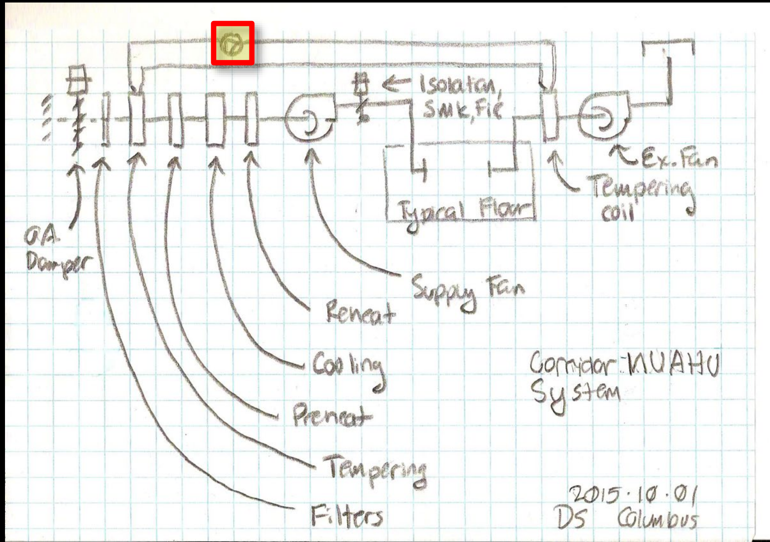
TEMPERING COIL RETURN
TEMPERING COIL RETURN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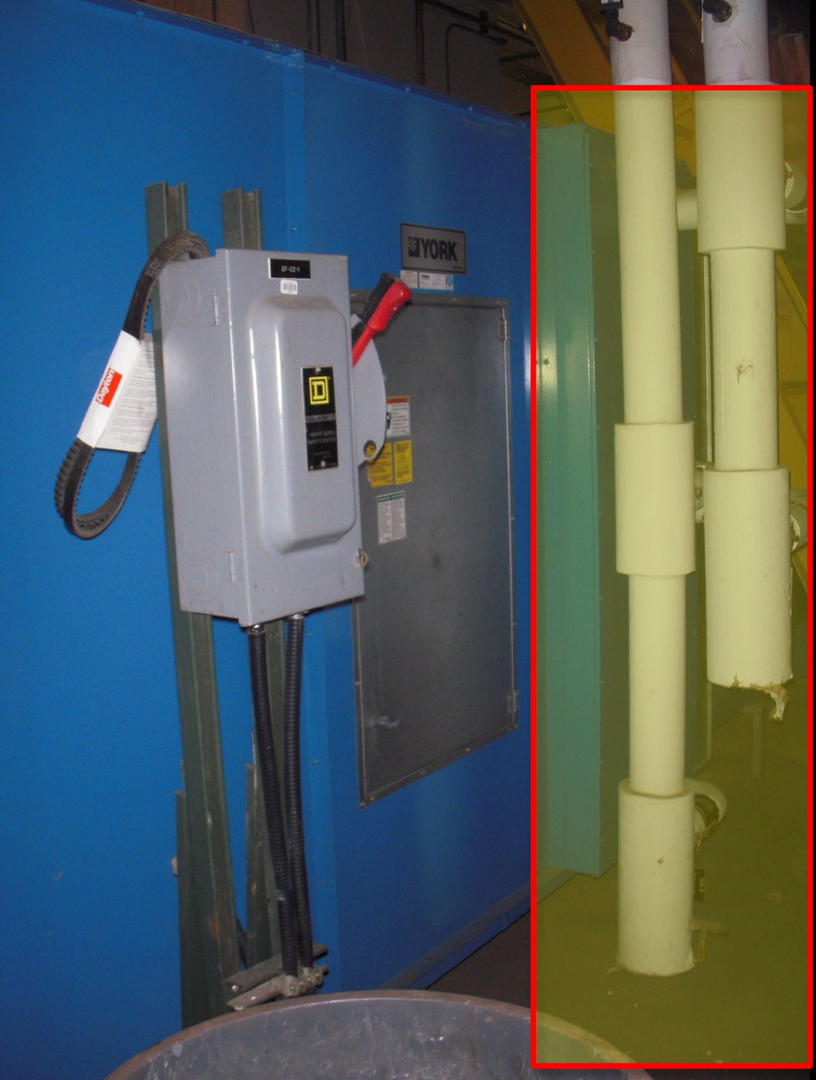
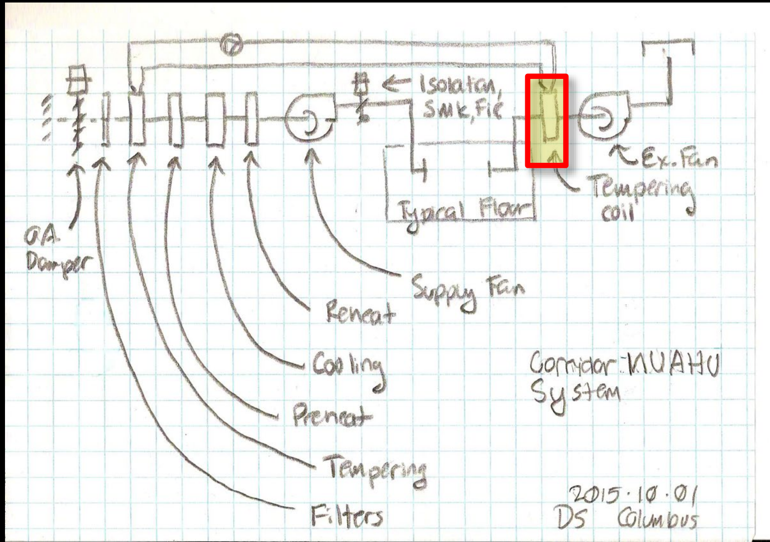
2015.10.01
DS Columbus


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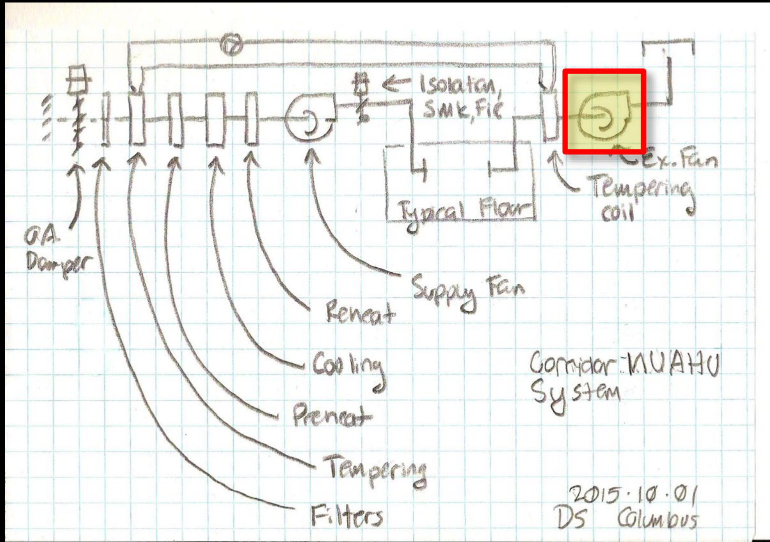
Ex. Fan
Tempering coil
Typical Floor
O.A. Damper
Supply Fan
Reheat
Cooling
Preheat
Tempering
Filters
Corridor MUAHU System
2015.10.01
DS Columbus


YORK
Dayton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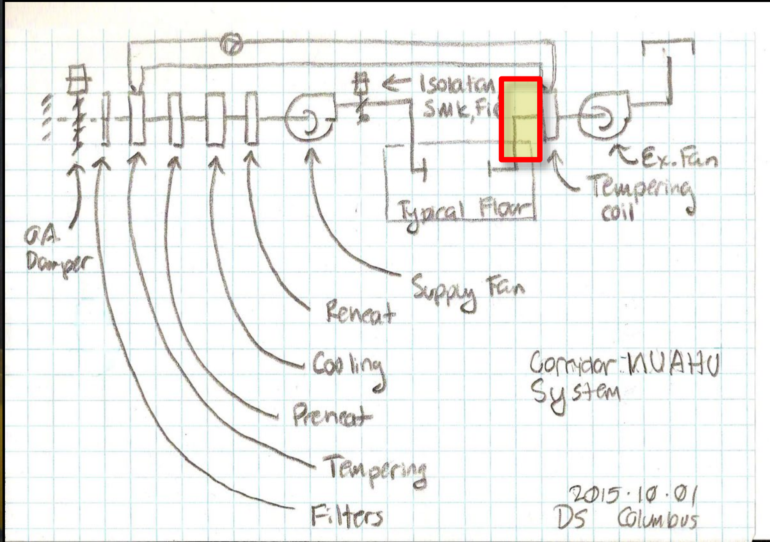
Corridor MUAHU System
2015.10.01
DS Columbus


AIR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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

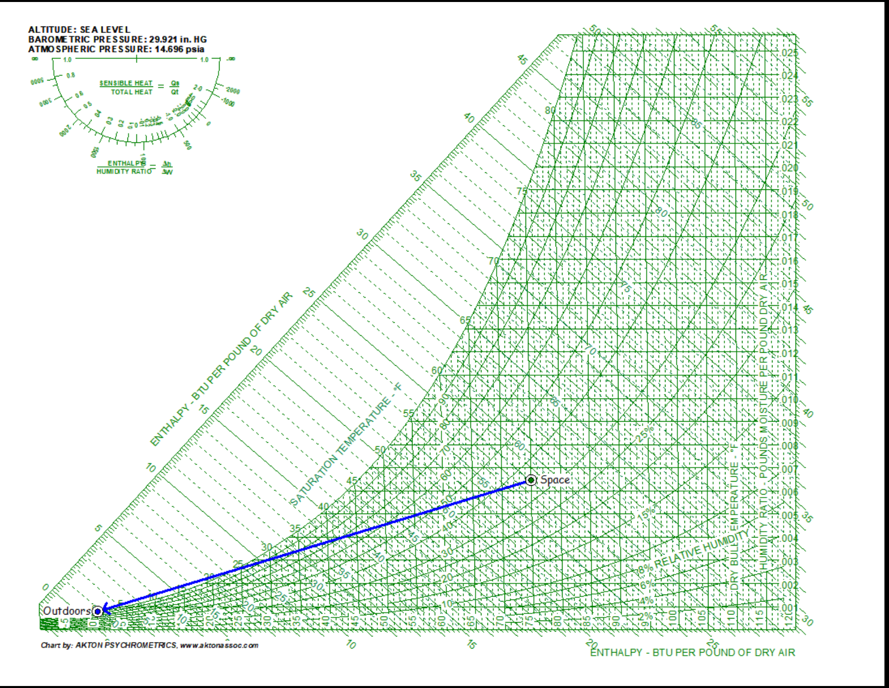
Energy Recovery Technology Contrast

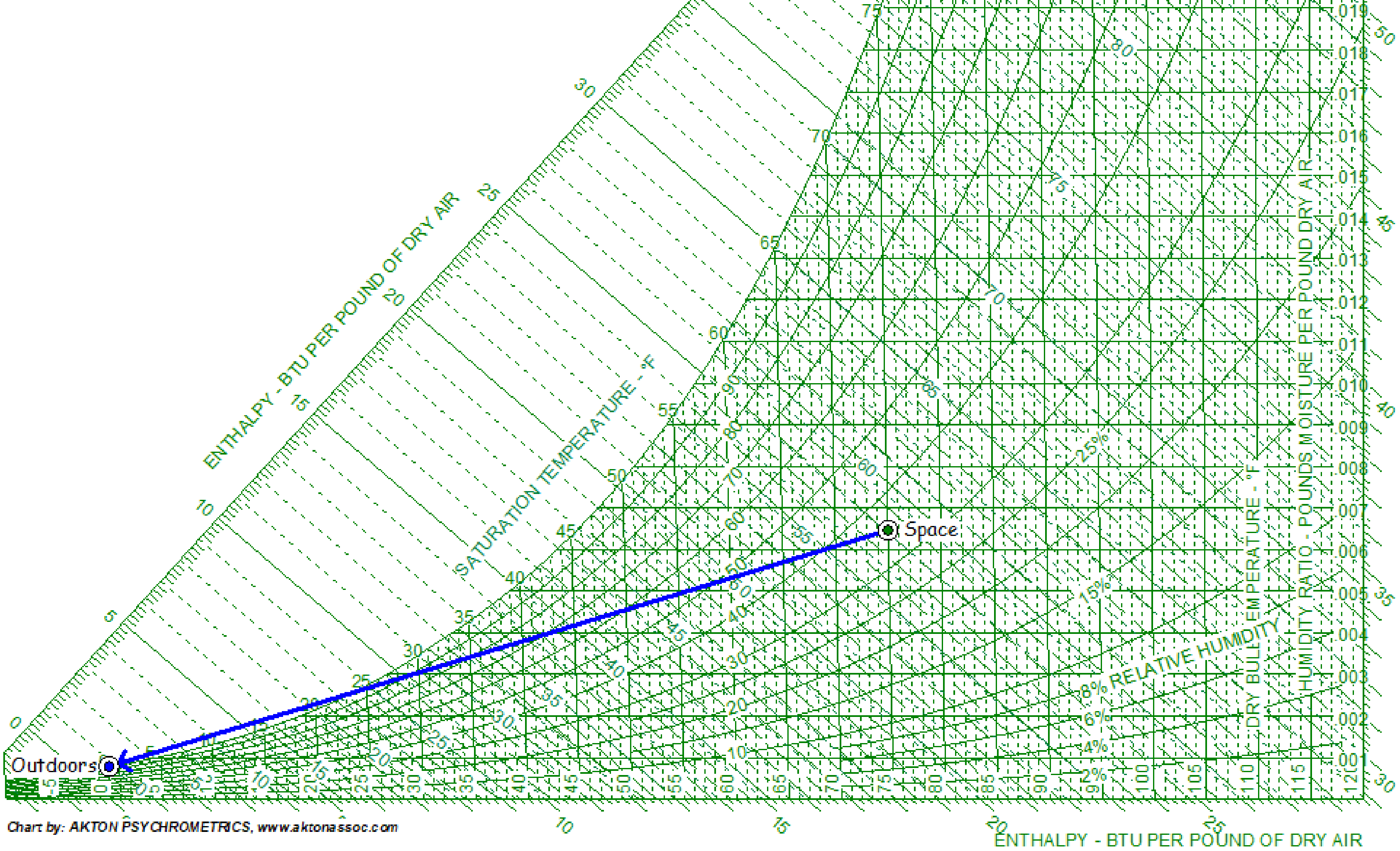
Technology	Heat Transfer		Effectiveness Range						Pressure Drop Range			Control Methods			
	Sensible	Total	Sensible		Latent		Total		Min. in.w.c.	Max. in.w.c.	Velocity fpm	Bypass Damper	Speed Control	Tilt	Bypass Valve
			Min.	Max.	Min.	Max.	Min.	Max.							
Plate Heat Exchangers	✓	✓	50%	75%	25%	60%	35%	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				✓

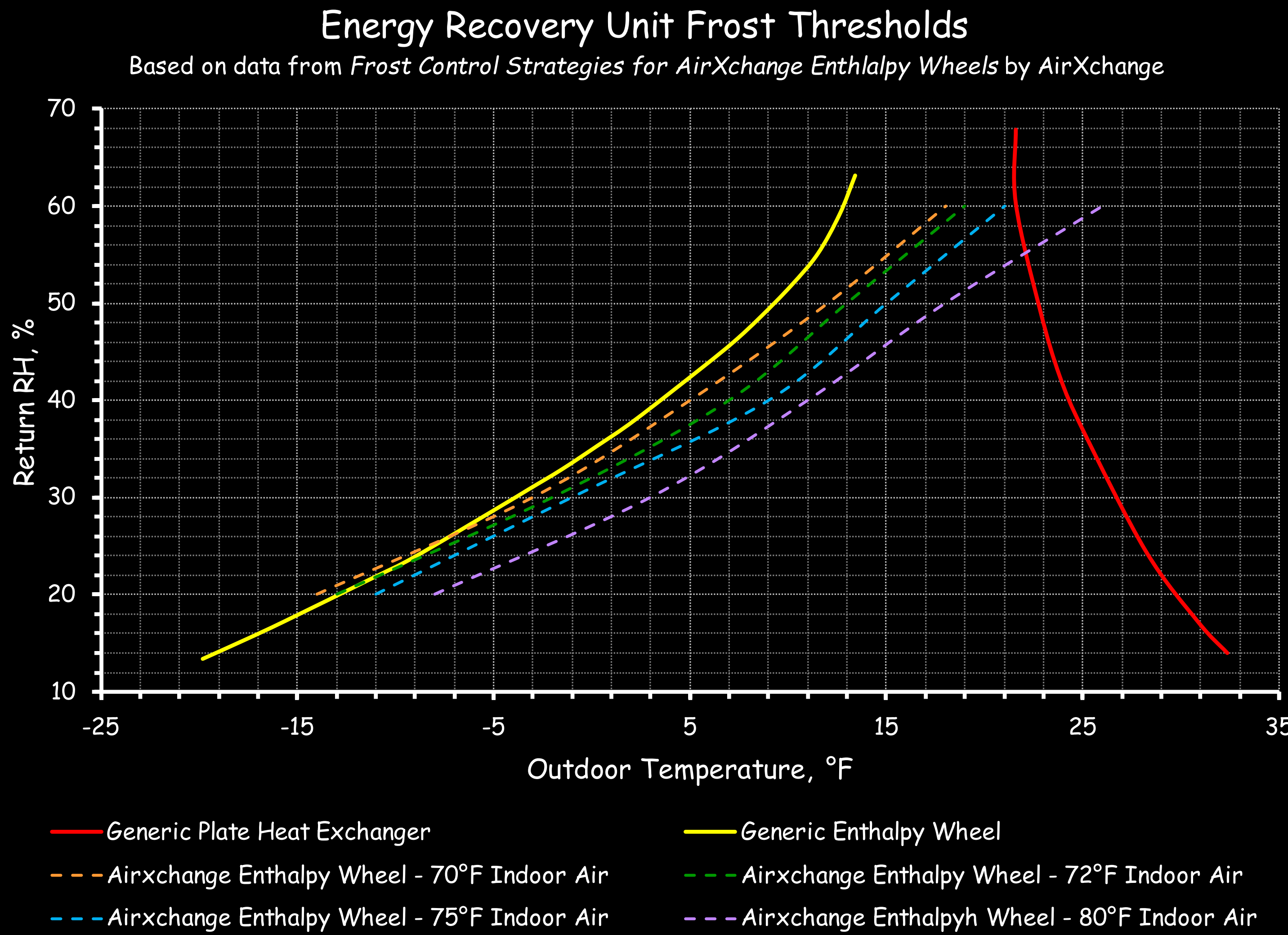
Frosting

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




ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
8% RELATIVE HUMIDITY
Space
Outdoors
Chart by: AKTON PSYCHROMETRICS, www.aktonassoc.com
ENTHALPY - BTU PER POUND OF DRY AIR


Energy Recovery Unit Frost Thresholds
Based on data from Frost Control Strategies for AirXchange Enthlalpy Wheels by AirXchange
70
60
50
40
30
20
10
Return RH, %
-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	2023 cost based on the Bureau of Labor Statistics Inflation Calculator
Greenheck	Application Guide	$3.60	Copyright 1997	$6.95
Loren-Cook	ERV Catalog	$3.00	Mar-16	$3.90

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

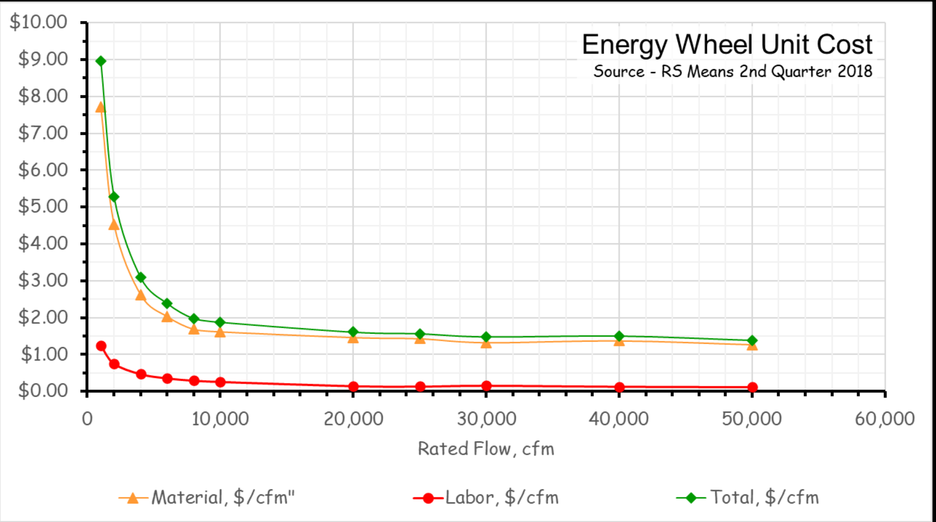
COOLING:
Chilled Water - 1 Coil - Model: 5WQ1206C - 51 x 24 - Conn. Size- 2 - 29.1 GPM $9,561

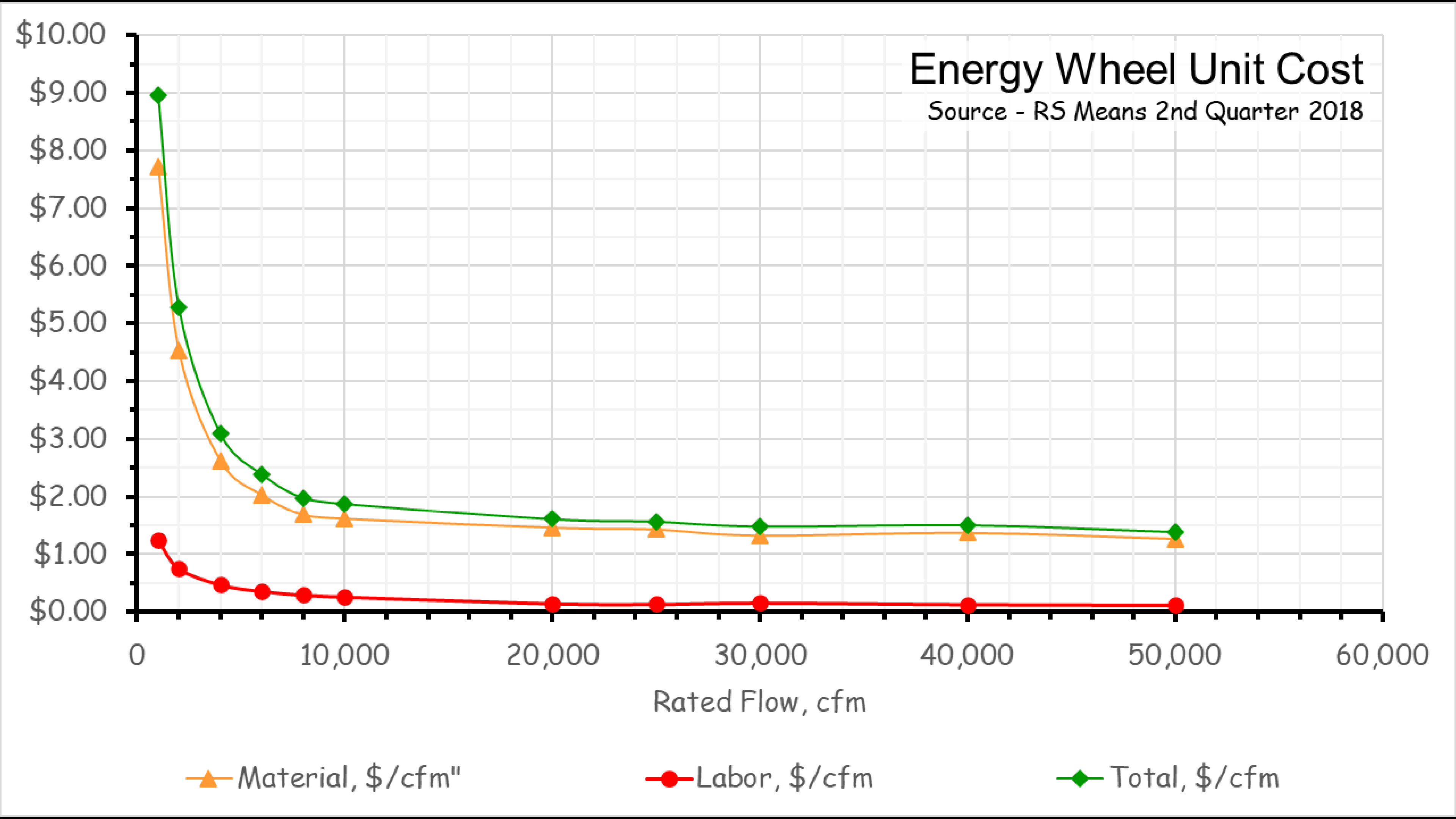
ACCESSORIES:	
Outdoor Air Intake Damper, Motorized, Low Leakage VCD-23	$1,515
Exhaust Air Intake Damper, Motorized, Low Leakage VCD-23	$1,226
Duct Flange	$236
Outdoor Air Filter, 2" pleated (30% efficient)	$711
Exhaust Air Filters, 2" pleated (30% efficient)	$711
Listed to UL-1995	$31
Water Coil(s) piped 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

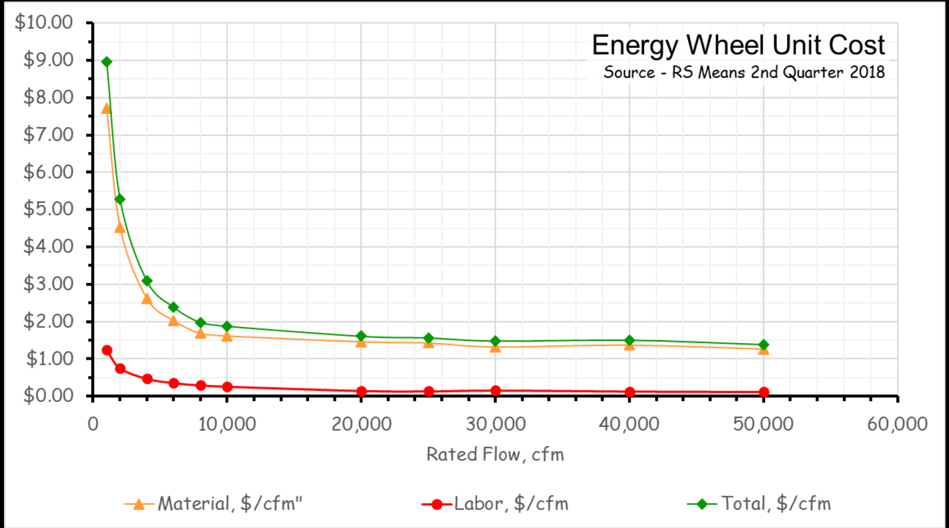
Industry Metrics Could Be Misleading

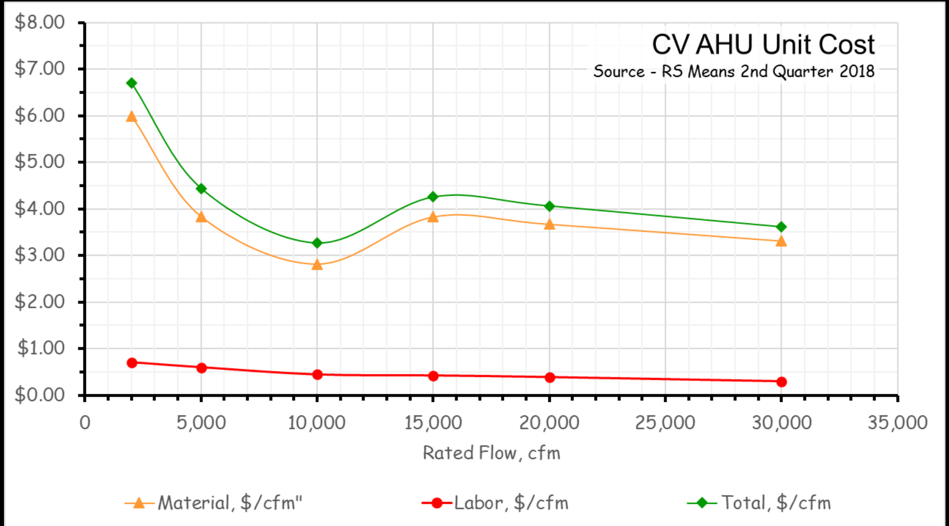
- They could be dated
- They may not consider all of the desired features
- Size has a significant impact

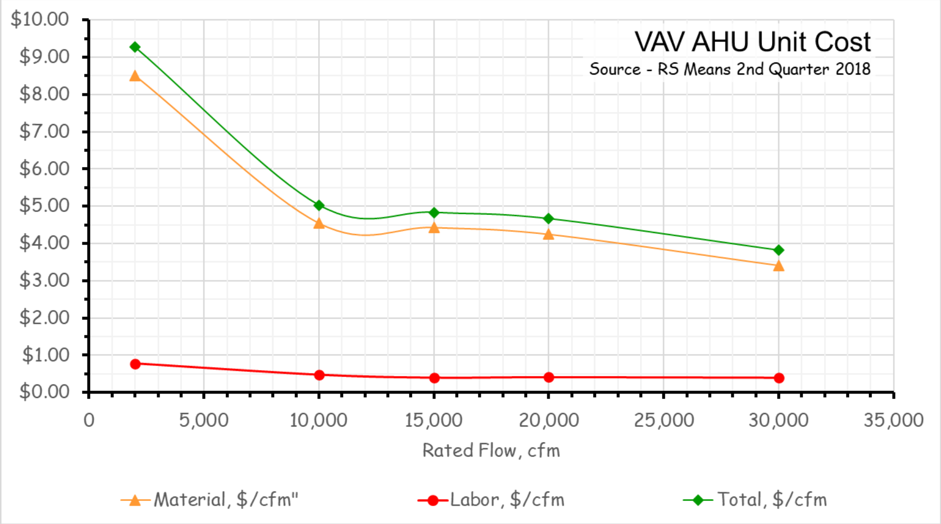




Energy Wheel Unit Cost
Source - RS Means 2nd Quarter 2018
$10.00
$9.00
$8.00
$7.00
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
0
10,000
20,000
30,000
40,000
50,000
60,000
Rated Flow, cfm
Material, $/cfm"
Labor, $/cfm
Total, $/cfm


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
20,000
30,000
40,000
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?

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THANK YOU

Please fill out the class survey here,
we appreciate your feedback!

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