HVAC Systems

Greg Drensky
Vice President

Agenda:

- Who Is Jacco?
- HVAC Systems
  - PTAC
  - Mini Splits
  - CAV
  - SZVAV
  - VVT
  - VAV
  - DOAS
  - Energy Recovery
  - Fan Coils
  - Heat Pumps
  - Chilled Beams
  - VRF
- HVAC Sequences

JACCO

Who is Jacco

- Established 1968
  - Hudson, Ohio
  - Columbus, Ohio
  - Toledo, Ohio

- Focused on the Engineered Environment

- Systems Knowledgeable
  - HVAC Systems
  - Service & Maintenance
  - Parts

JACCO

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

- Operations
  - –Brenda Homjak
  - –Mike Spangler
  - –Chad Russell
  - –Mike Mueller
- Contractor Owning Experience
  - –Dan Duignan
  - –Rick Baker
- Engineering Owning Experience
  - –Greg Drensky
  - –Jerry Cohen
- Owning Experience
  - –Beth Plazak
  - –Jeff Watson

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Who is Jacco

- 30 Minute Pledge
  - Design
  - Questions
  - Problems
  - Answers

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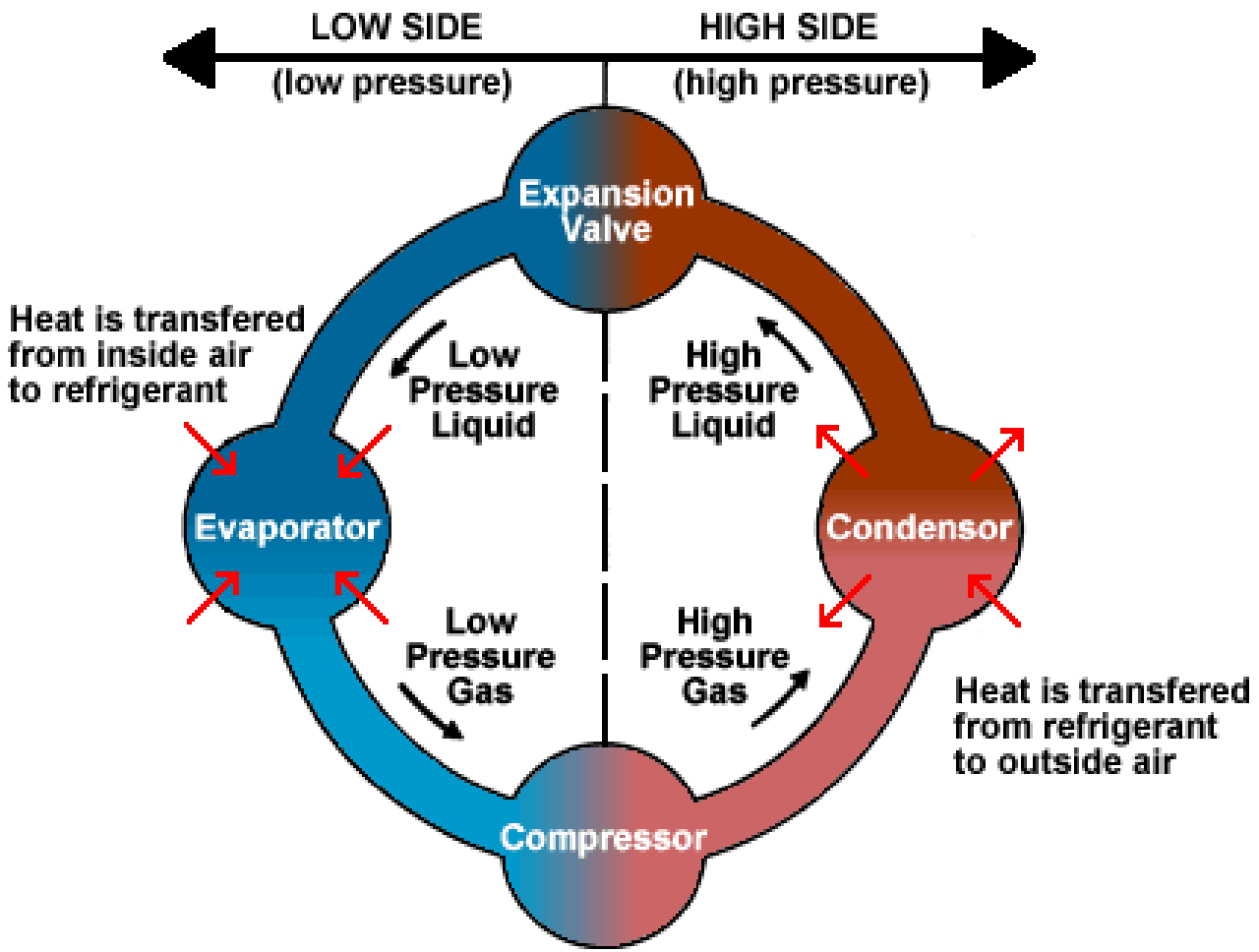
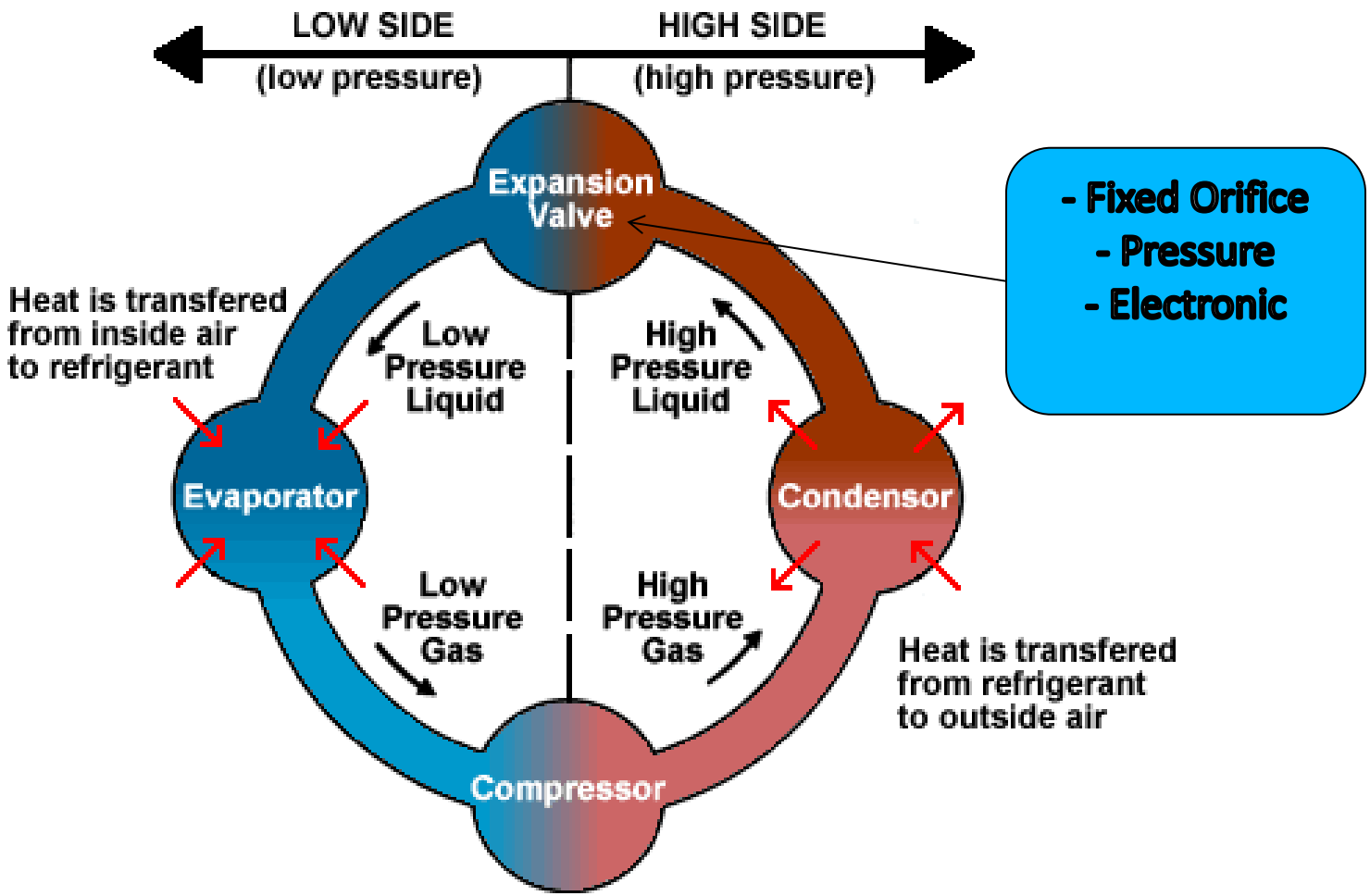
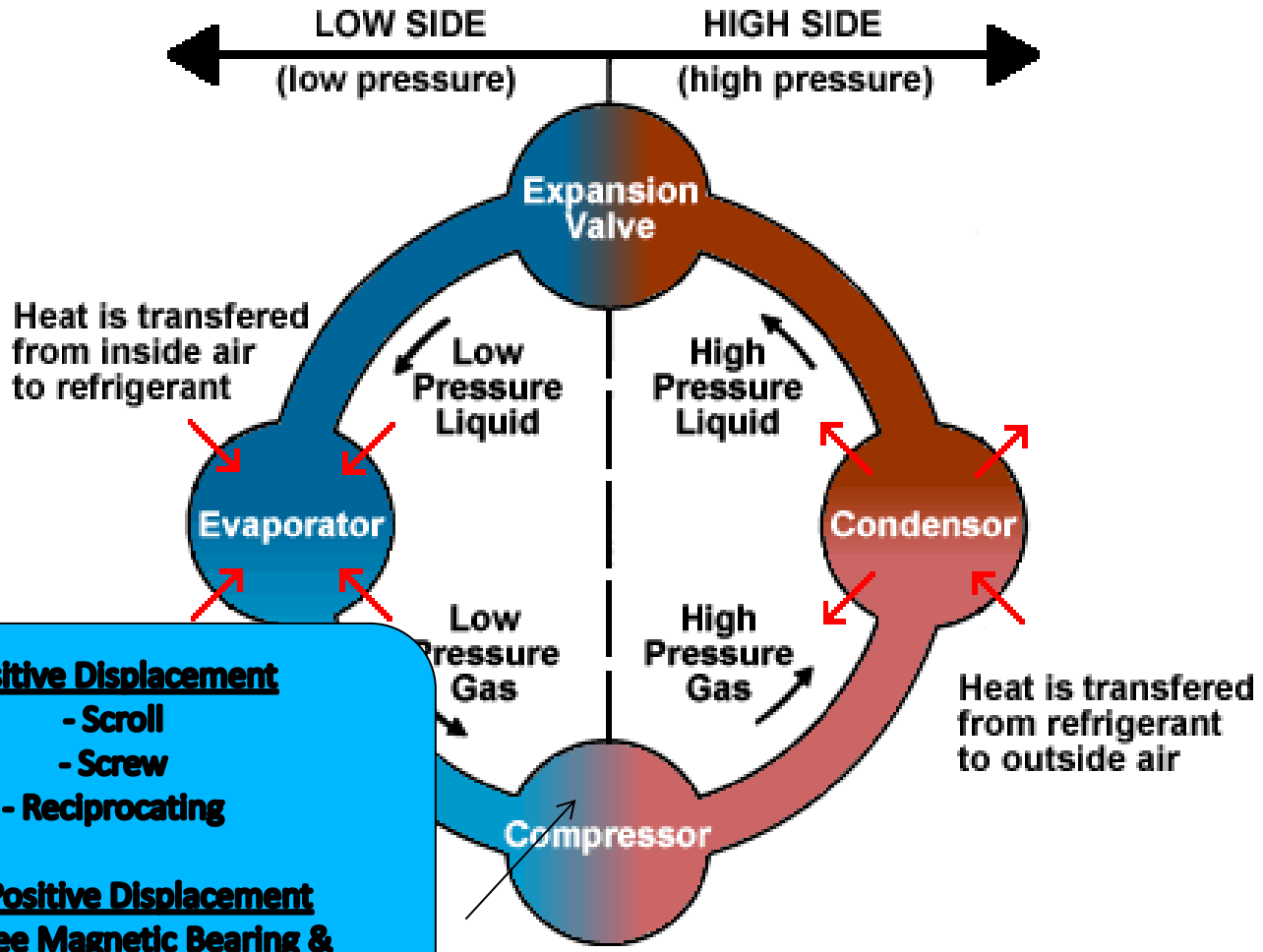
Upcoming Seminars:

- March 14th: Applying Natural Gas, Water Cooled & Air Cooled Modular Chillers
- June 13th: Best Practices For DX Piping
- September 12th: Applying Adiabatic and Steam Humidification Systems
- December 12th: Applying Low Dewpoint OA Systems Using DX and Desiccant Technology

Quick Review!


LOW SIDE
(low pressure)
HIGH SIDE
(high pressure)
Expansion Valve
Heat is transfered from inside air to refrigerant
Low Pressure Liquid
High Pressure Liquid
Evaporator
Condensor
Low Pressure Gas
High Pressure Gas
Heat is transfered from refrigerant to outside air
Compressor


LOW SIDE
(low pressure)
HIGH SIDE
(high pressure)
Expansion Valve
- Fixed Orifice
- Pressure
- Electronic
Heat is transfered from inside air to refrigerant
Low Pressure Liquid
High Pressure Liquid
Evaporator
Condensor
Low Pressure Gas
High Pressure Gas
Heat is transfered from refrigerant to outside air
Compressor



Positive Displacement
- Scroll
- Screw
- Reciprocating

Non Positive Displacement
- Oil Free Magnetic Bearing & Centrifugal

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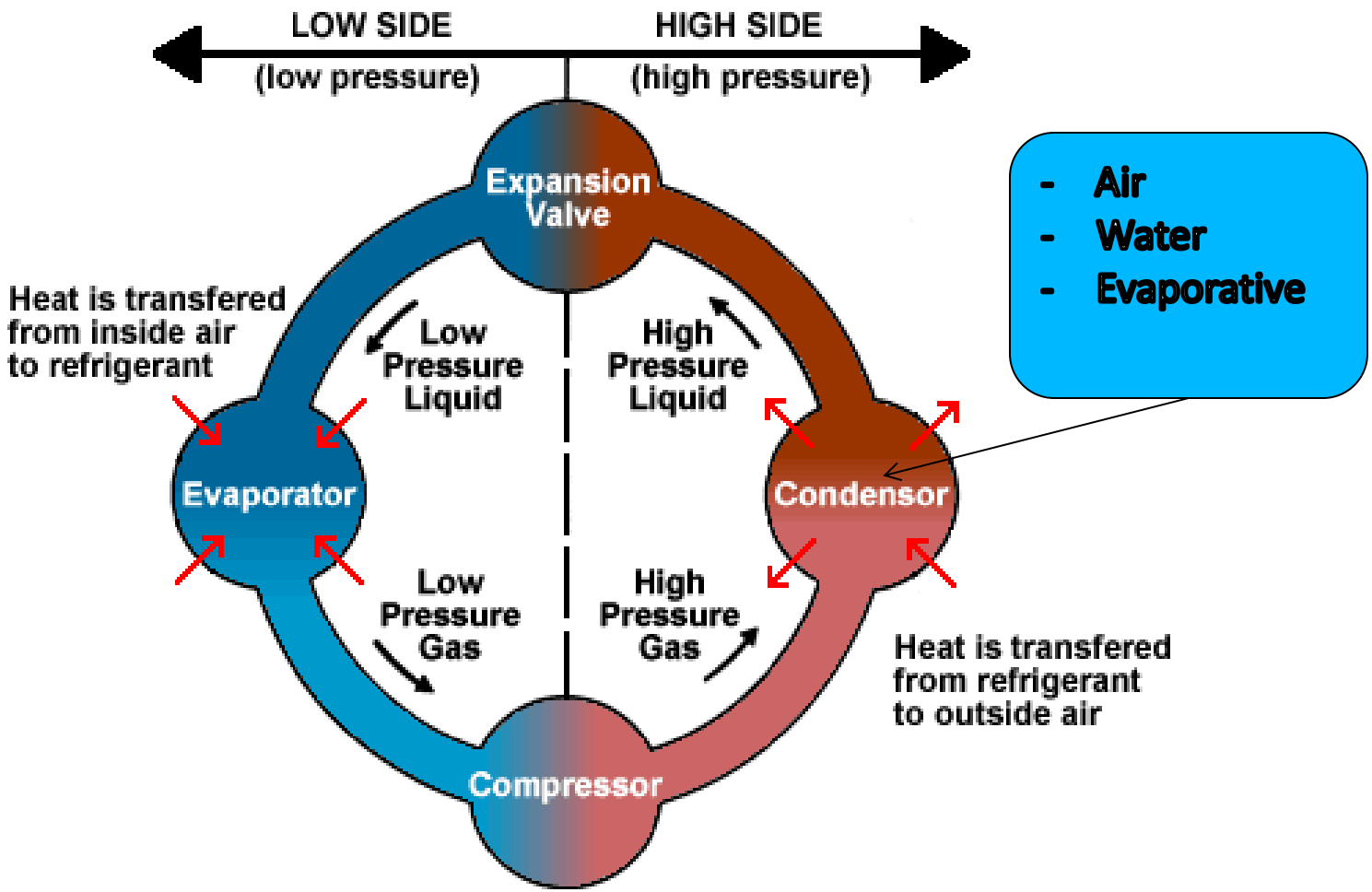
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Low Pressure Liquid
High Pressure Liquid
Evaporator
Condensor
Low Pressure Gas
High Pressure Gas
Compressor
Heat is transfered from refrigerant to outside air
- Air
- Water
- Evaporative

Refrigerant Pressure/Temperature Chart

HFC-134a

105 Condensing Temperature = 134.9 PSIG

HFC-410a

105 Condensing Temperature = 339.9 PSIG

HFC-134a

125 Condensing Temperature = 184.5 PSIG

HFC-410a

125 Condensing Temperature = 444.5 PSIG

Refrigerant Pressure Temperature Chart

Temperature		Refrigerant				
°F	°C	R-22	R-410a	R-407c	R-134a	R-404a
-60	-51.1	*11.9*	*0.9*	*16.0*	*21.6*	-
-55	-48.3	*9.2*	1.8	*13.7*	*20.2*	-
-50	-45.6	*6.1*	4.3	*11.1*	*18.6*	-
-45	-42.8	*2.7*	7.0	*8.1*	*16.7*	-
-40	-40.0	0.6	10.1	*4.8*	*14.7*	4.9
-35	-37.2	2.6	13.5	*1.1*	*12.3*	7.5
-30	-34.4	4.9	17.2	1.5	*9.7*	10.3
-25	-31.7	7.5	21.4	3.7	*6.8*	13.5
-20	-28.9	10.2	25.9	6.2	*3.6*	16.8
-18	-27.8	11.4	27.8	7.2	*2.2*	18.3
-16	-26.7	12.6	29.7	8.4	*0.7*	19.8
-14	-25.6	13.9	31.8	9.5	0.4	21.3
-12	-24.4	15.2	33.9	10.7	1.2	22.9
-10	-23.3	16.5	36.1	11.9	2.0	24.6
-8	-22.2	17.9	38.4	13.2	2.8	26.3
-6	-21.1	19.4	40.7	14.6	3.7	28.0
-4	-20.0	20.9	43.1	15.9	4.6	29.8
-2	-18.9	22.4	45.6	17.4	5.5	31.7
0	-17.8	24.0	48.2	18.9	6.5	33.7
1	-17.2	24.8	49.5	19.6	7.0	34.7
2	-16.7	25.7	50.9	20.4	7.5	35.7
3	-16.1	26.5	52.2	21.2	8.0	36.7
4	-15.6	27.4	53.6	22.0	8.6	37.7
5	-15.0	28.3	55.0	22.8	9.1	38.8
6	-14.4	29.1	56.4	23.7	9.7	39.8
7	-13.9	30.0	57.9	24.5	10.2	40.9
8	-13.3	31.0	59.3	25.4	10.8	42.0
9	-12.8	31.9	60.8	26.2	11.4	43.1
10	-12.2	32.8	62.3	27.1	12.0	44.3
11	-11.7	33.8	63.9	28.0	12.6	45.4
12	-11.1	34.8	65.4	29.0	13.2	46.6
13	-10.6	35.8	67.0	29.9	13.8	47.8
14	-10.0	36.8	68.6	30.9	14.4	49.0
15	-9.4	37.8	70.2	31.8	15.1	50.2
16	-8.9	38.8	71.9	32.8	15.7	51.5
17	-8.3	39.9	73.5	33.8	16.4	52.7
18	-7.8	40.9	75.2	34.8	17.1	54.0
19	-7.2	42.0	77.0	35.9	17.7	55.3
20	-6.7	43.1	78.7	36.9	18.4	56.6
21	-6.1	44.2	80.5	38.0	19.2	57.9
22	-5.6	45.3	82.3	39.1	19.9	59.3
23	-5.0	46.5	84.1	40.2	20.6	60.6
24	-4.4	47.6	85.9	41.3	21.4	62.0
25	-3.9	48.8	87.8	42.4	22.1	63.4
26	-3.3	50.0	89.7	43.6	22.9	64.8
27	-2.8	51.2	91.6	44.7	23.7	66.2
28	-2.2	52.4	93.5	45.9	24.5	67.7
29	-1.7	53.7	95.5	47.1	25.3	69.2
30	-1.1	54.9	97.5	48.4	26.1	70.7
31	-0.6	56.2	99.5	49.6	26.9	72.1
32	0.0	57.5	101.6	50.9	27.8	73.8
33	0.6	58.8	103.6	52.1	28.6	75.3
34	1.1	60.2	105.7	53.4	29.5	76.9
35	1.7	61.5	107.9	54.8	30.4	78.5
36	2.2	62.9	110.0	56.1	31.3	80.2
37	2.8	64.3	112.2	57.5	32.2	81.7
38	3.3	65.7	114.4	58.9	33.1	83.5
39	3.9	67.1	116.7	60.3	34.1	85.2
40	4.4	68.6	118.9	61.7	35.0	86.9
41	5.0	70.0	121.2	63.1	36.0	88.6
42	5.6	71.5	123.6	64.6	37.0	90.4
43	6.1	73.0	125.9	66.1	38.0	92.2
44	6.7	74.5	128.3	67.6	39.0	94.0
45	7.2	76.1	130.7	69.1	40.0	95.8
46	7.8	77.6	133.2	70.6	41.1	97.6
47	8.3	79.2	135.6	72.2	42.2	99.5
48	8.9	80.8	138.2	73.8	43.2	101.4
49	9.4	82.4	140.7	75.4	44.3	103.3
50	10.0	84.1	143.3	77.1	45.4	105.3
55	12.8	92.6	156.6	106.0	51.2	115.3
60	15.6	101.6	170.7	116.2	57.4	126.0
65	18.3	111.3	185.7	127.0	64.0	137.4
70	21.1	121.5	201.5	138.5	71.1	149.3
75	23.9	132.2	218.2	150.6	78.6	161.9
80	26.7	143.7	235.9	163.5	86.7	175.4
85	29.4	155.7	254.6	177.0	95.2	189.6
90	32.2	168.4	274.3	191.3	104.3	204.5
95	35.0	181.9	295.0	206.4	113.9	220.2
100	37.8	196.0	316.9	222.3	124.1	236.8
105	40.6	210.8	339.9	239.0	134.9	254.2
110	43.3	226.4	364.1	256.5	146.3	272.5
115	46.1	242.8	289.6	274.9	158.4	291.9
120	48.9	260.0	416.4	294.2	171.1	312.1
125	51.7	278.1	444.5	314.5	184.5	333.4
130	54.4	297.0	474.0	335.7	198.7	355.6
135	57.2	316.7	505.0	357.8	213.5	379.1
140	60.0	337.4	537.6	380.9	229.2	403.7
145	62.8	359.1	571.7	405.1	245.6	429.6
150	65.6	381.7	607.6	430.3	262.8	456.8
155	68.3	405.4	645.2	456.6	281.0	484.8

Italics indicates vacuum (inches of mercury)

Standard font indicates pressure (pounds per inch gauge)

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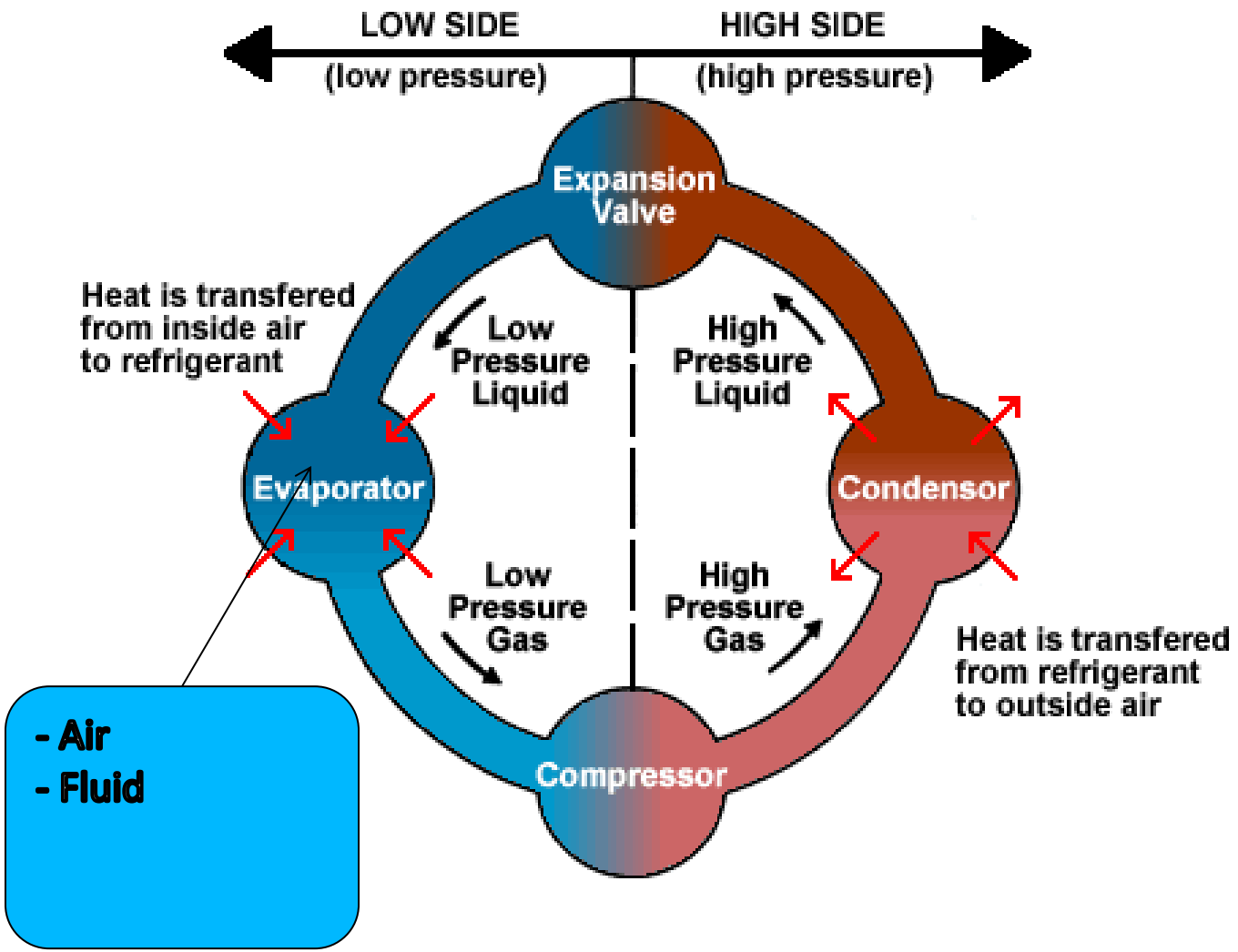
LOW SIDE
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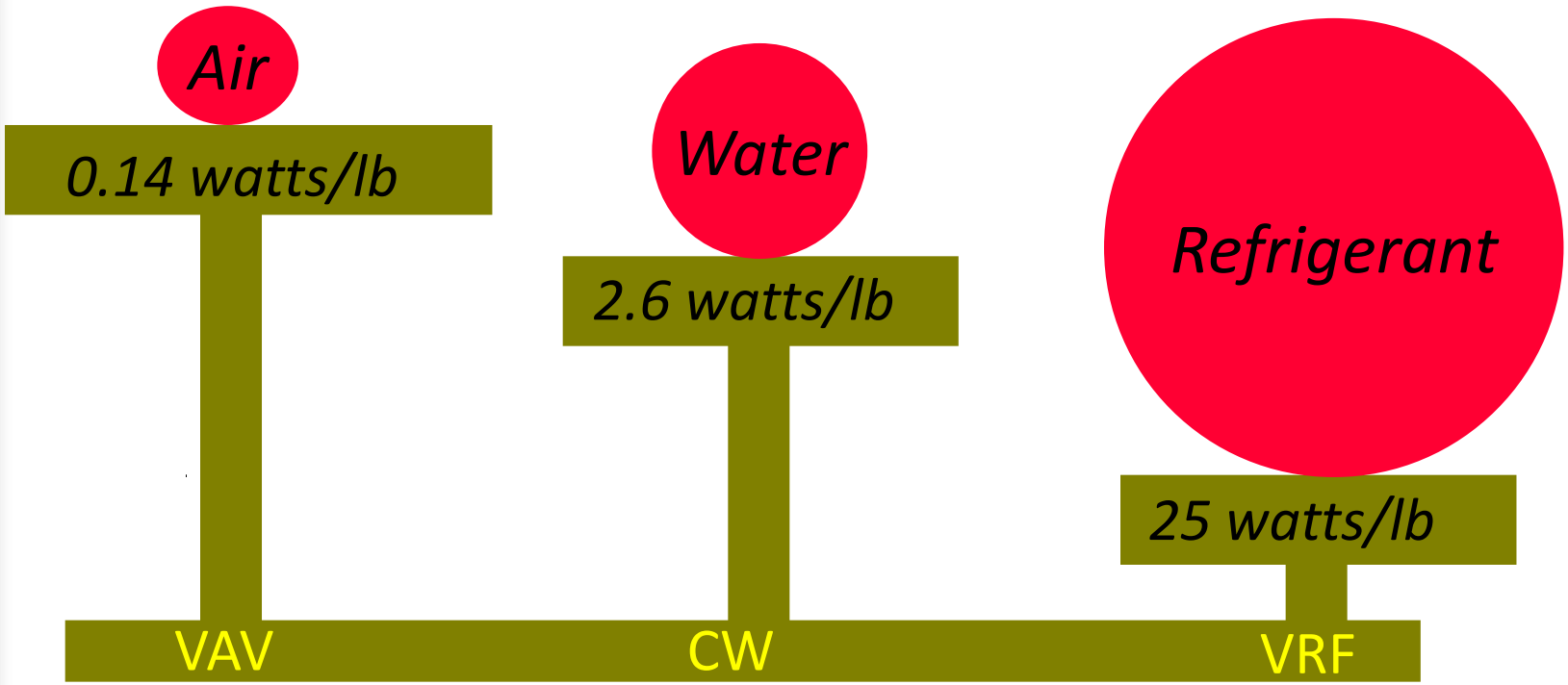
HIGH SIDE
(high pressure)
Expansion Valve
Heat is transfered from inside air to refrigerant
Low Pressure Liquid
High Pressure Liquid
Evaporator
Condensor
Low Pressure Gas
High Pressure Gas
Heat is transfered from refrigerant to outside air
Compressor
- Air
- Fluid

Heat Transfer Media



Basic Terminology:

- Ventilation:
  - Each project requires outside air (OA) for ventilation and Indoor Air Quality (IAQ)
  - Vary based on type of application (hotel, office, hospital, surgery, etc)
- Dedicated Outdoor Air System (DOAS):
  - HVAC system focused on providing ventilation air only (100% OA, or Variable OA)
- Sensible Devices:
  - HVAC devices that can provide sensible cooling only (cannot dehumidify)
- Latent Devices:
  - HVAC devices that can provide dehumidification
- Diversity:
  - Sum of individual max loads vs max demand of entire system
- System Redundancy:
  - Potential backup capacity should a component fail

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Basic Terminology:

- Energy Efficiency Ratio (EER):
  - Ration of btuh output vs energy input in watts
- Seasonal Energy Efficiency Ratio (SEER):
  - Same as EER but only during the cooling season
- Integrated Energy Efficiency Ratio (IEER):
  - Formula utilized to devise a EER based on the operational efficiency at various capacity percentages
- Economizer:
  - Utilizing cool, dry outside air for cooling instead of mechanical cooling

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Packaged Terminal Air Conditioning (PTAC)

PTAC

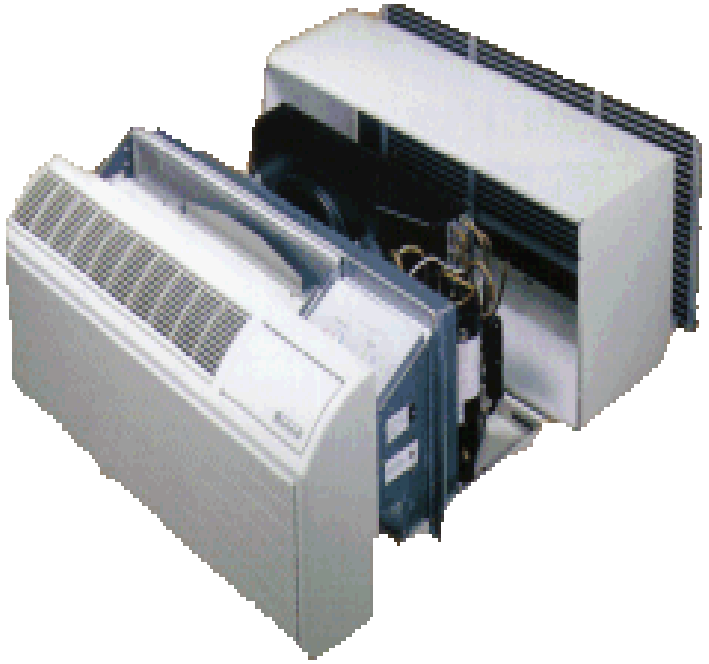
System
- Air Cooled/Heat Pump/Gas Heat
- DOAS
- Separate Systems for Large/Common Areas

Comfort
- Multi Speed Fans (Manual Change)
- Potential IAQ Issues
- Loud

PTAC

Flexibility
- Typically 4 Sizes Ranging 0.5-1.5 Tons
- Any Number Floors
- Eliminate Diversity

Redundancy
- Quick Changeout Of Chassis
- Some Have Dual Fans



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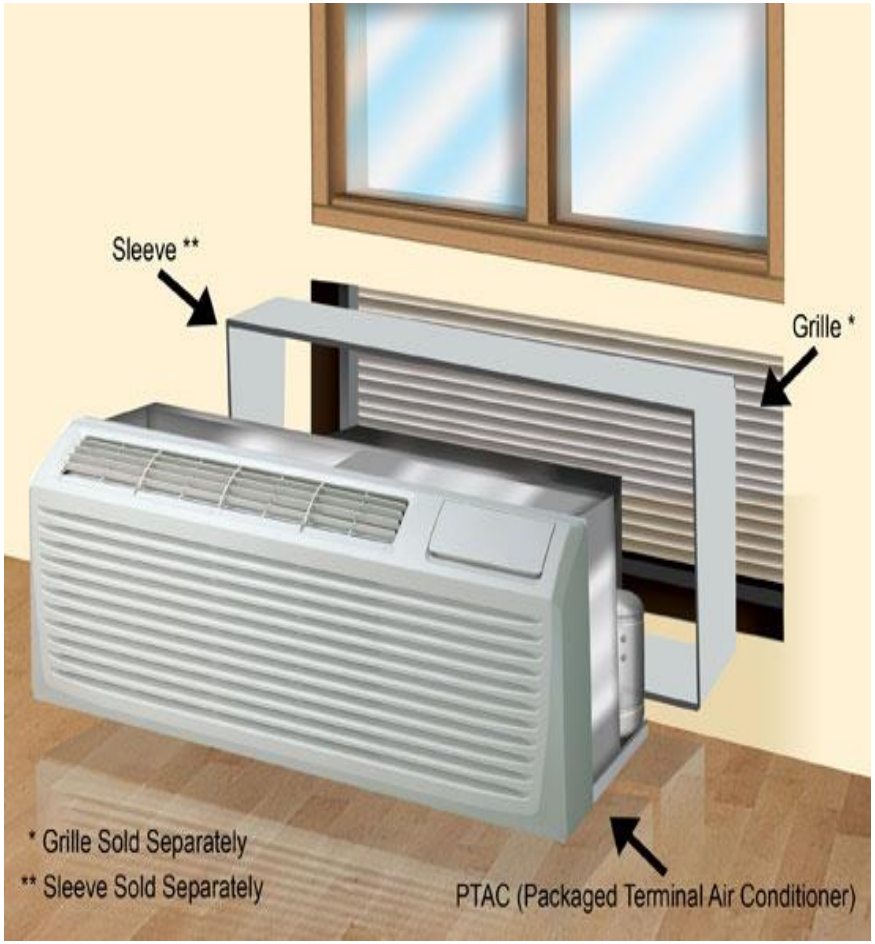
PTAC

Equipment Cost
- Low Cost

Installation Cost
- Wall Sleeve
- Electrical
- Thermostat (?)



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PTAC

Energy Efficiency
- 10-12 EER
- Some Have 2 Stage Compressors

Controls
- Unit Mounted
- Remote Mounted
- Wireless Stat
- InComm Communications

PTAC

Maintenance

- Clean Filters
- Inspect Electrical Connections, Fans, Compressors
- Maintain Spare Chassis And Quick Changeout
- No System Diagnostics
- Multiple Manufacturers Fit Same Chassis
  - Watch Out For Specialty Ones

Applications

- Hotels/Motels
- Apartments/Condominiums
- Dorms
- Spot Cooling/Heating

One To One Mini Splits

Mini Splits

System
- Heat Pump
- Fan Coil Units
- DOAS
- Low Ambient Cooling

Comfort
- Low Sound
- Multi Speed Fans
- Electronic Expansion Valves
- Variable Speed Compressors
- Heat Capacity?

Mini Splits

Flexibility

- 4 Cooling Only/Heat Pump Models From 0.75-2 Tons
- 5 Indoor Models From 0.5 to 2 Tons
- Max Line Length 50-100’
- Max Vertical Rise 25-100’
- Eliminate Diversity

Redundancy

- Each System Is Standalone
  - 1 Goes Down, Doesn’t Affect Entire Building

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SAMSUNG

Mini Splits

Equipment Cost
- Moderate Cost

Installation Cost
- Heat Pump
- Electric Heat (?)
- Refrigerant Piping
- HP, FCU, Thermostat & Comm. Wiring
- Concrete Pad / Roof Rails
- Power For HP, FCU, EH

Mini Splits

Energy Efficiency
- 13-15 EER, 20-23 SEER
- Modulating Compressors
- Multi Speed Evaporator Fans
- Electronic Expansion Valves

Controls
- Wireless or Wired Controller

Mini Splits

Maintenance

- Indoor Units
  - Removable Panels For Filter, Fan, Coil Access
  - Clean Filter
  - Check Fans
  - Check/Clean Fan, Coil, Cond Drain, Elect Conn
- Outdoor Units
  - Check/Clean Condenser Coils, Fans, Elect Conn
  - Check Compressors
- Must Be Replaced With Same Mfr
- Where are the CU/HP's Located?

Constant Air Volume (CAV)

Constant Air Volume (CAV)

System
- Packaged Rooftop
- Split System
- Chilled/Hot Water

Comfort
- Single Speed Fans
- Single Zone

Size & Quantity
- “Unlimited” – 1-300 Tons

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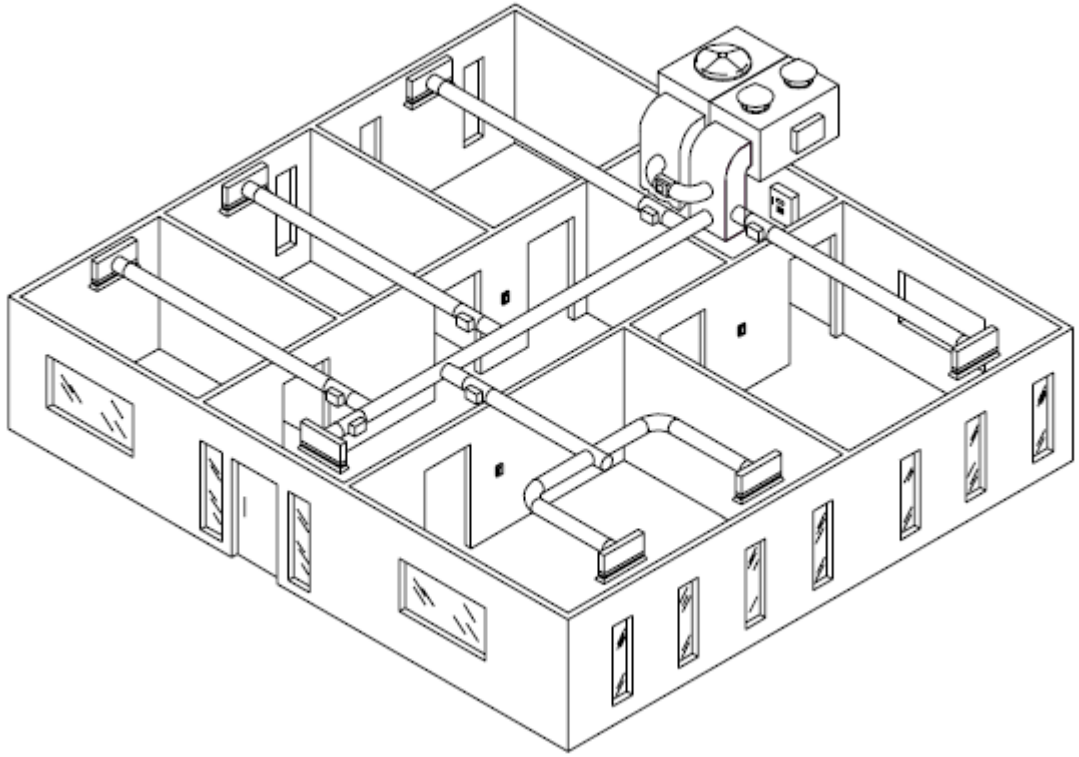
Constant Air Volume (CAV)



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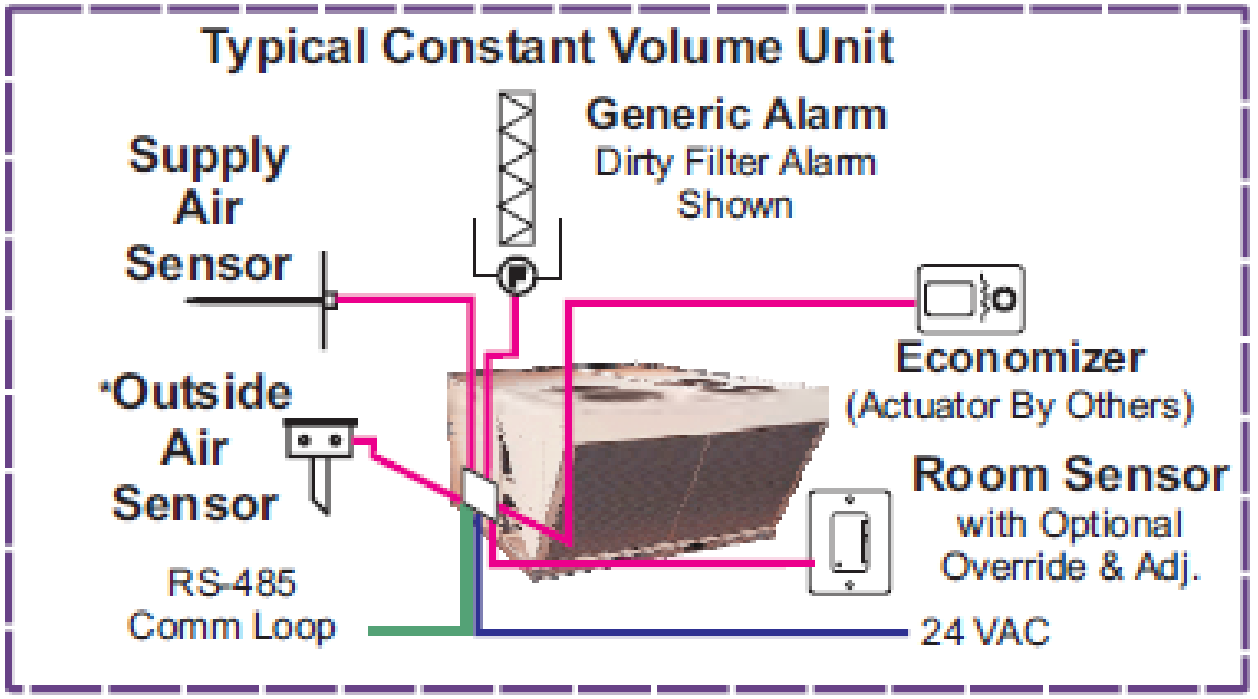
Constant Air Volume (CAV)



Constant Air Volume (CAV)

Applications

- Single Zone Space
- Retail
- Common Areas
- Gyms
- Cafeterias
- Theaters
- Residential

****ASHRAE 90.1, LEED

Single Zone Variable Air Volume (SZAV)

Single Zone Variable Air Volume (SZVAV)

System
- Packaged Rooftop
- Split System
- Chilled/Hot Water

Comfort
- Variable Speed Fans
- Variable Speed Cooling
- Variable Speed Heating?
- Single Zone

Size & Quantity
- “Unlimited” – 1-300 Tons

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Single Zone Variable Air Volume (SZVAV)

ASHRAE Standard 90.1
- Chilled Water >5hp SAF
- DX > 110,000 btuh

ASHRAE Standard 189.1
- Chilled Water >5hp SAF
- DX > 65,000 btuh

REFERENCE LITERATURE
- Aaon Single Zone VAV White Paper
- www.jacco.com/engineeringtools

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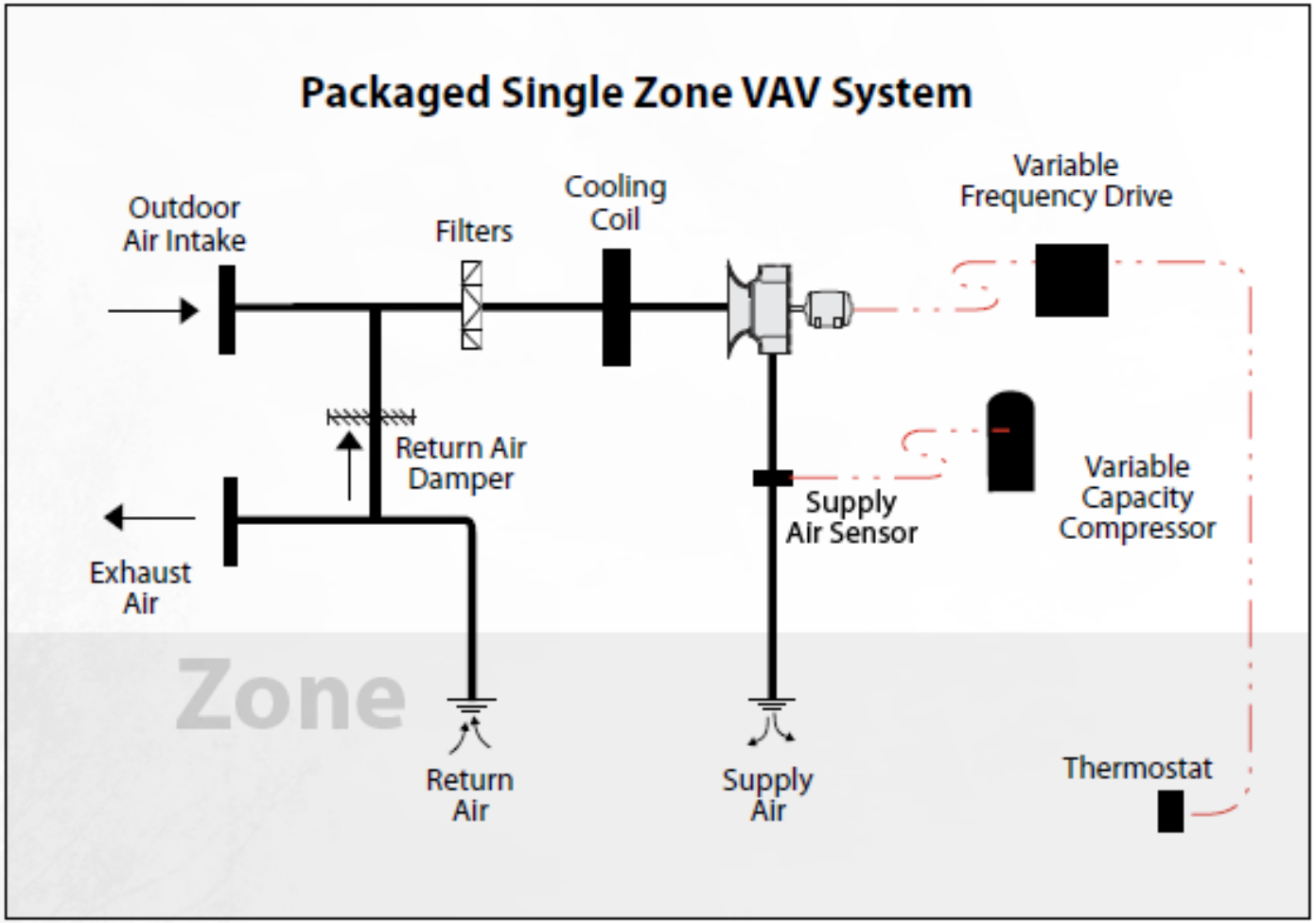
Single Zone Variable Air Volume (SZVAV)



Single Zone Variable Air Volume (SZVAV)

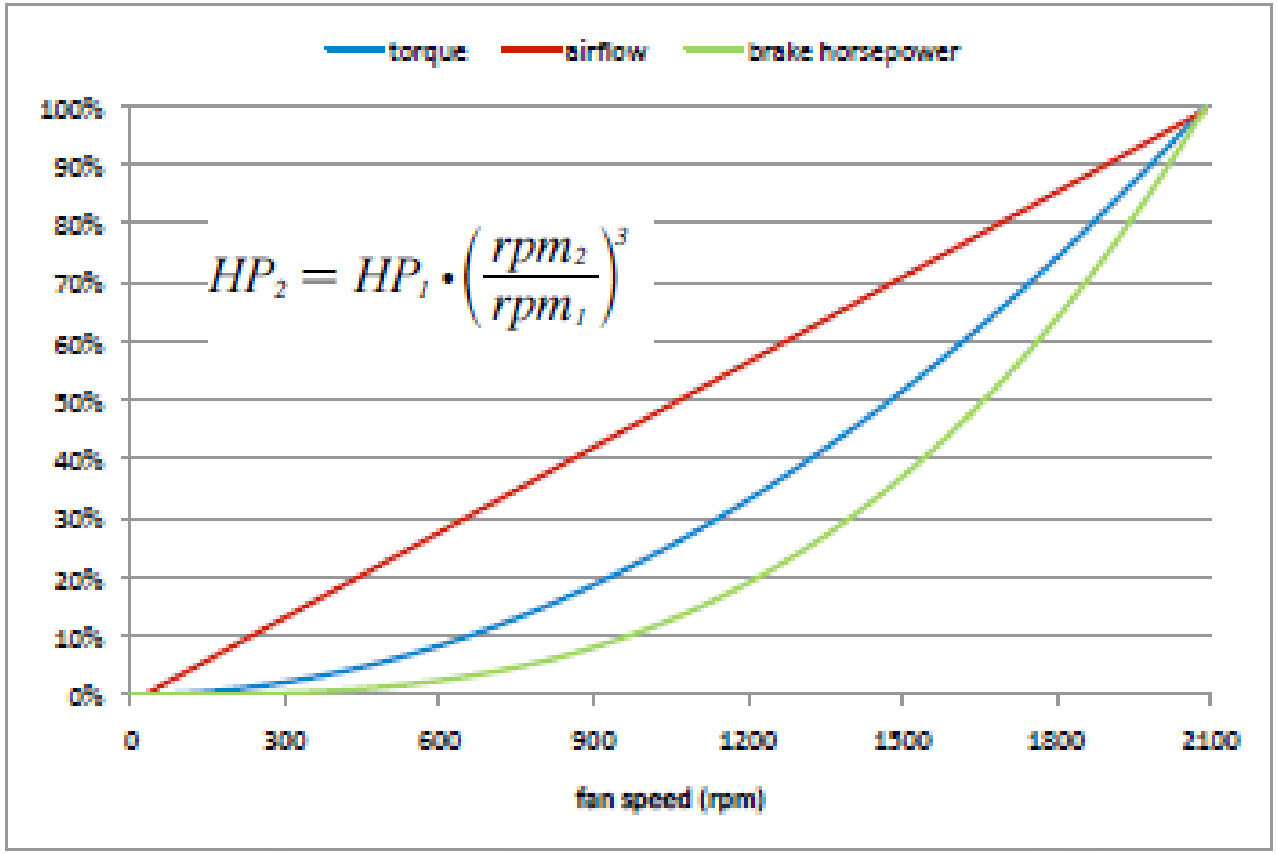


Figure 1: Brake Horsepower, Torque, and Airflow as a Percentage of Full Capacity versus Fan Speed

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Single Zone Variable Air Volume (SZVAV)

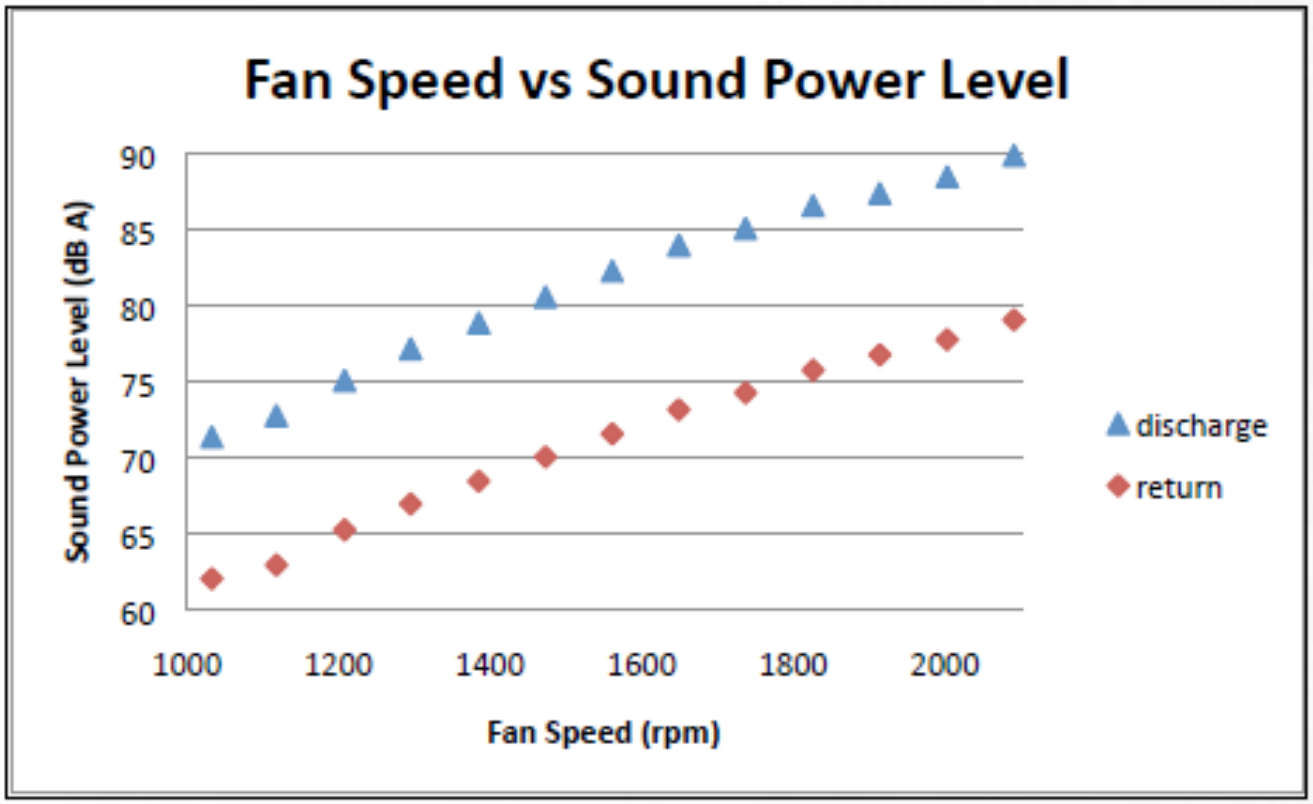

Figure 11: A-weighted Sound Power Level versus Fan Speed

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Single Zone Variable Air Volume (SZVAV)

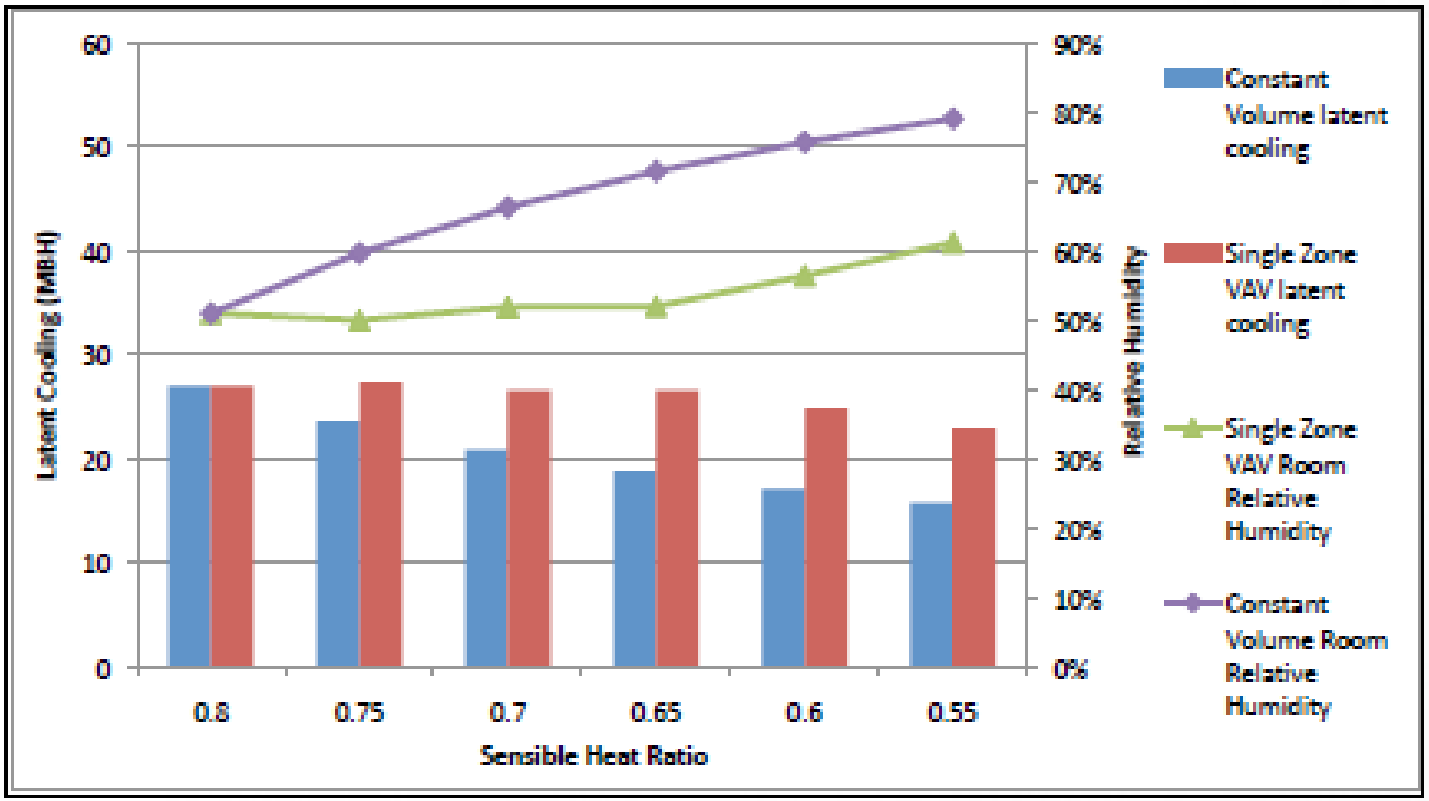

Figure 17: Latent Cooling and Relative Humidity (Decreased Sensible Load) versus Sensible Heat Ratio

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Single Zone Variable Air Volume (SZVAV)

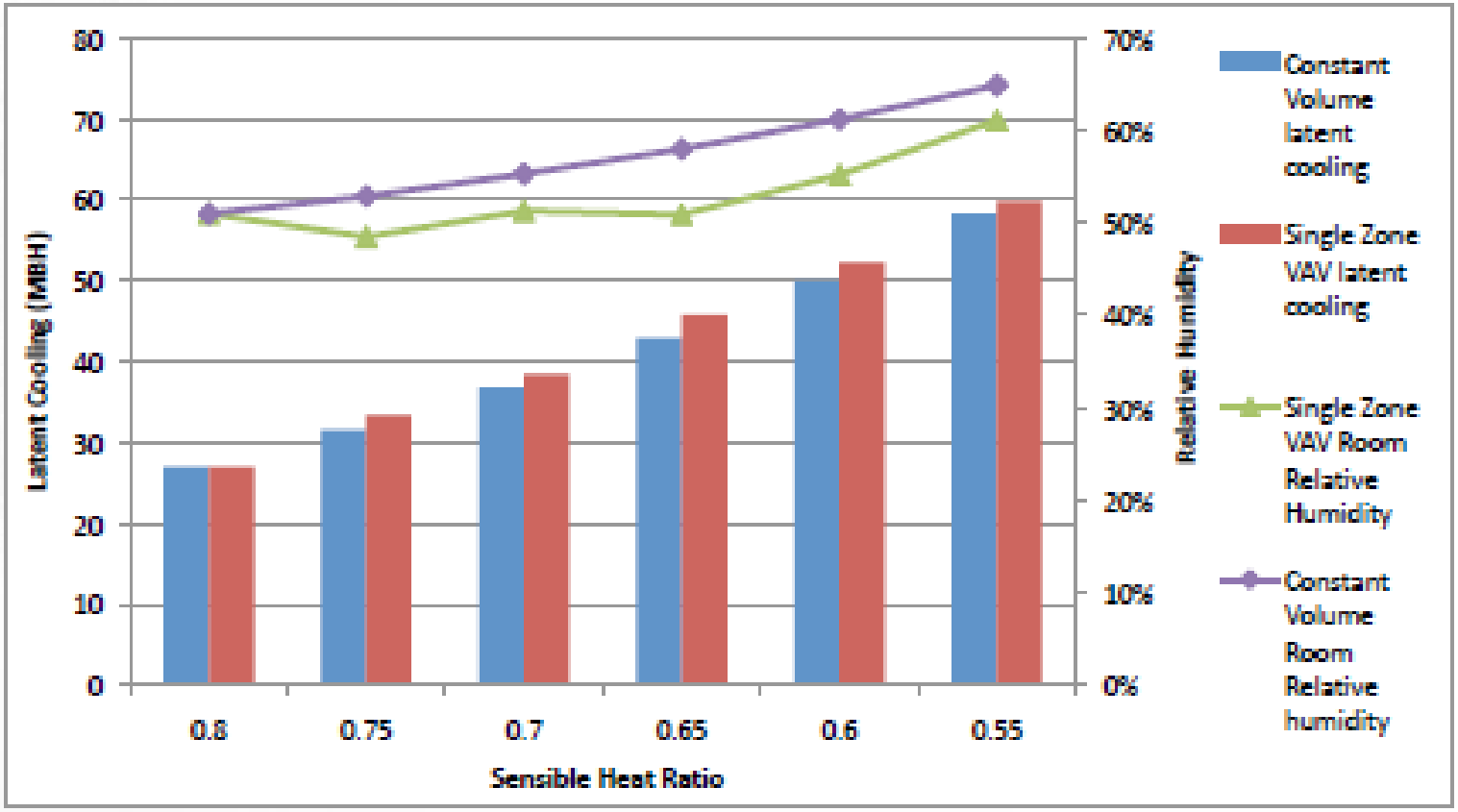

Figure 19: Latent Cooling and Relative Humidity (Increased Latent Load) versus Sensible Heat Ratio

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Single Zone Variable Air Volume (SZVAV)

Applications

- Single Zone Space
- Retail
- Churches
- Gyms
- Cafeterias
- Theaters
- Office Bullpens

Variable Volume & Temperature (VVT)

Variable Volume & Temperature (VVT)

System
- Packaged Rooftop
- Split System

Comfort
- Single Speed Fans
- On/Off Heating/Cooling
- Multiple Zones

Size & Quantity
- “Unlimited” – 1-300 Tons
- Typical 2-15 Tons

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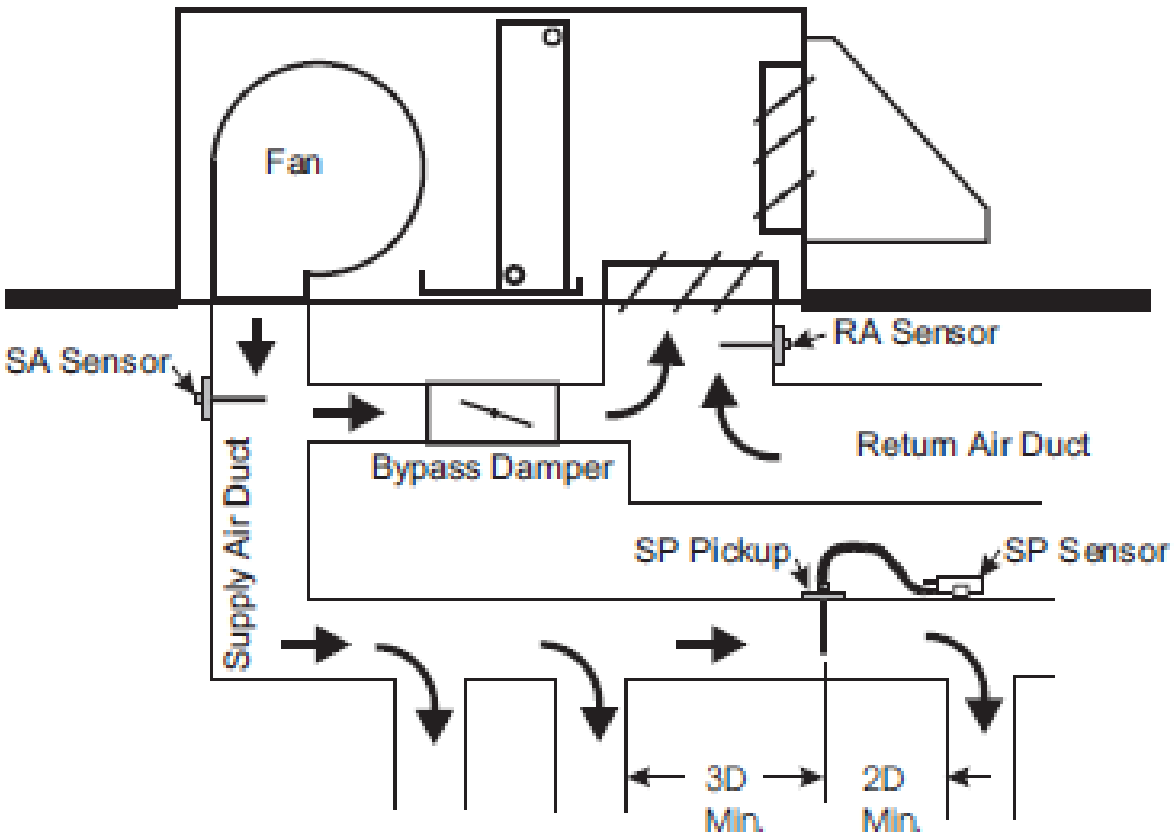
Variable Volume & Temperature (VVT)



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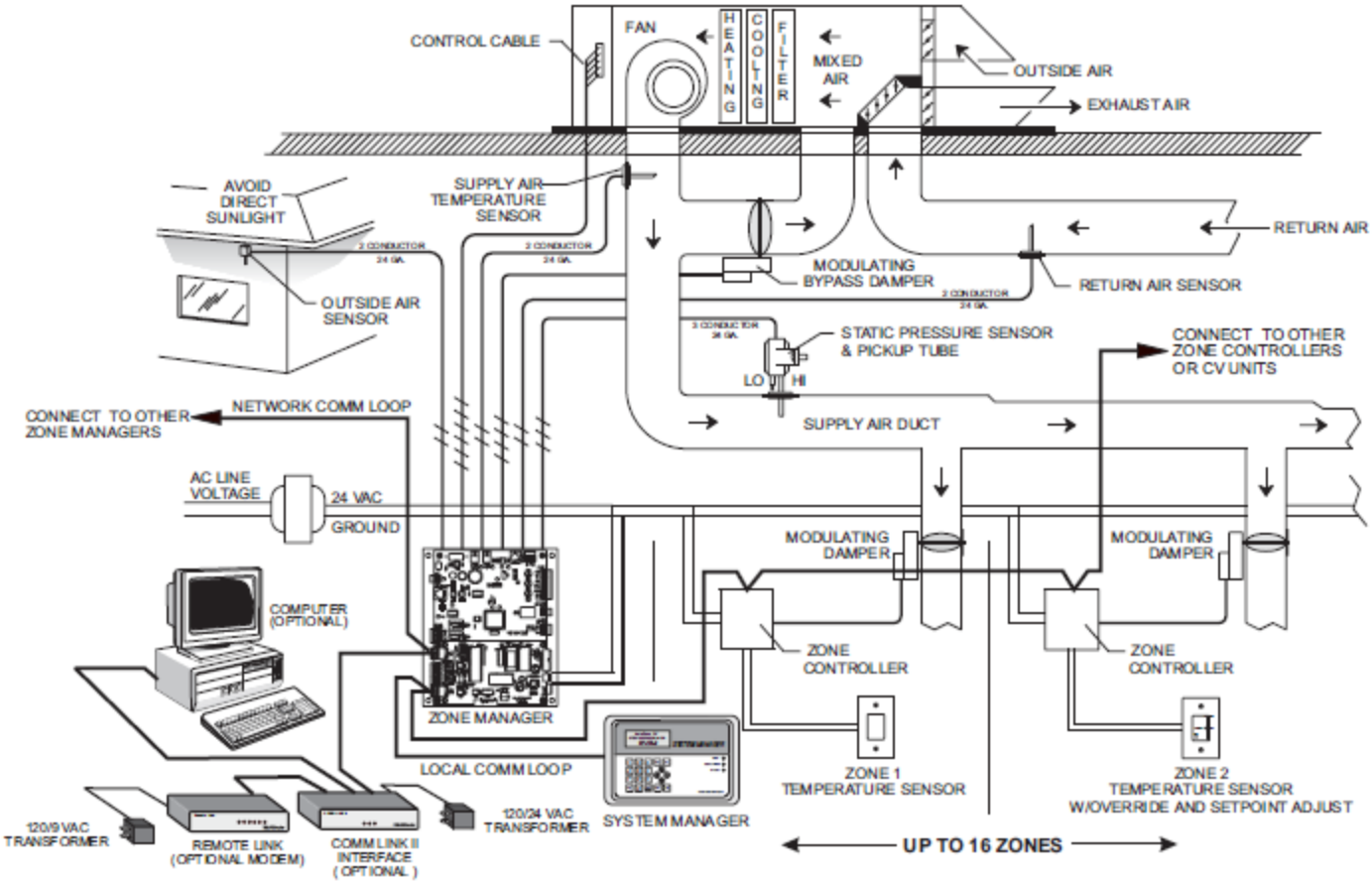
Variable Volume & Temperature (VVT)



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Variable Volume & Temperature (VVT)

- Bypass Should Be Designed For About 60% Airflow
- Airflow Determines Round Or Rectangular Damper
- Place In Non Sound Critical Location

Figure 1-6: Round Bypass Damper

Figure 1-7: Rectangular Bypass Damper & Kit

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Variable Volume & Temperature (VVT)

Pressure Dependent Damper

- Min/Max Airflow Based On Damper Position
- Damper Position Moves Based On Static Pressure

Figure 1-11: Pressure Dependent Damper

Pressure Independent Damper

- Min/Max Airflow Based On Airflow
- Residential

Figure 1-12: Pressure Independent Damper

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Variable Volume & Temperature (VVT)

Design Considerations

- Group Zones With Similar Load Characteristics
- Do Not Mix Interior & Exterior Zones
- Sequences
  - Priority Heating
  - Polling
  - Master Zone

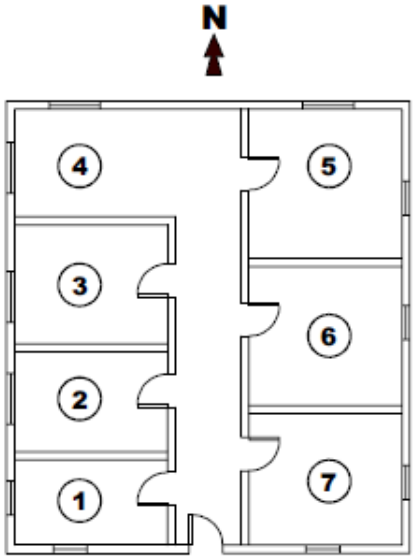

Figure 1-3: Zone Layout With External Zones Only.

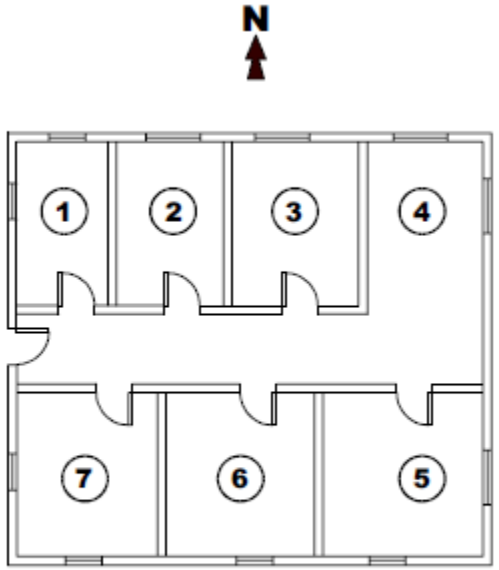

Figure 1-4: Zones With North And South Exposures.

Variable Air Volume (VAV)

Variable Air Volume (VAV)

System
- Packaged Rooftop
- Split System

Comfort
- Variable Speed Fans
- Variable Capacity Cooling
- On/Off Heating
- Multiple Zones

Size & Quantity
- “Unlimited” – 1-300 Tons

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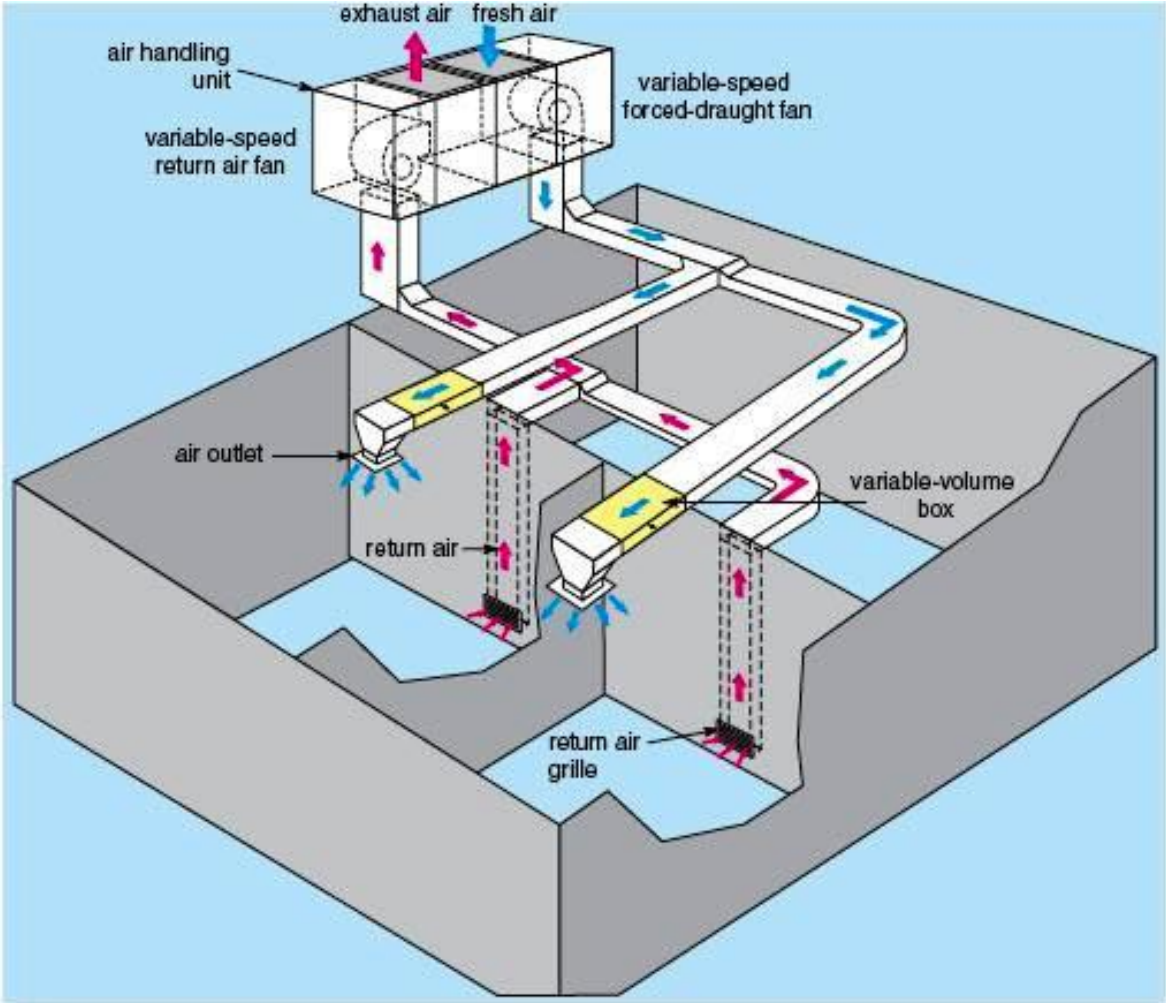
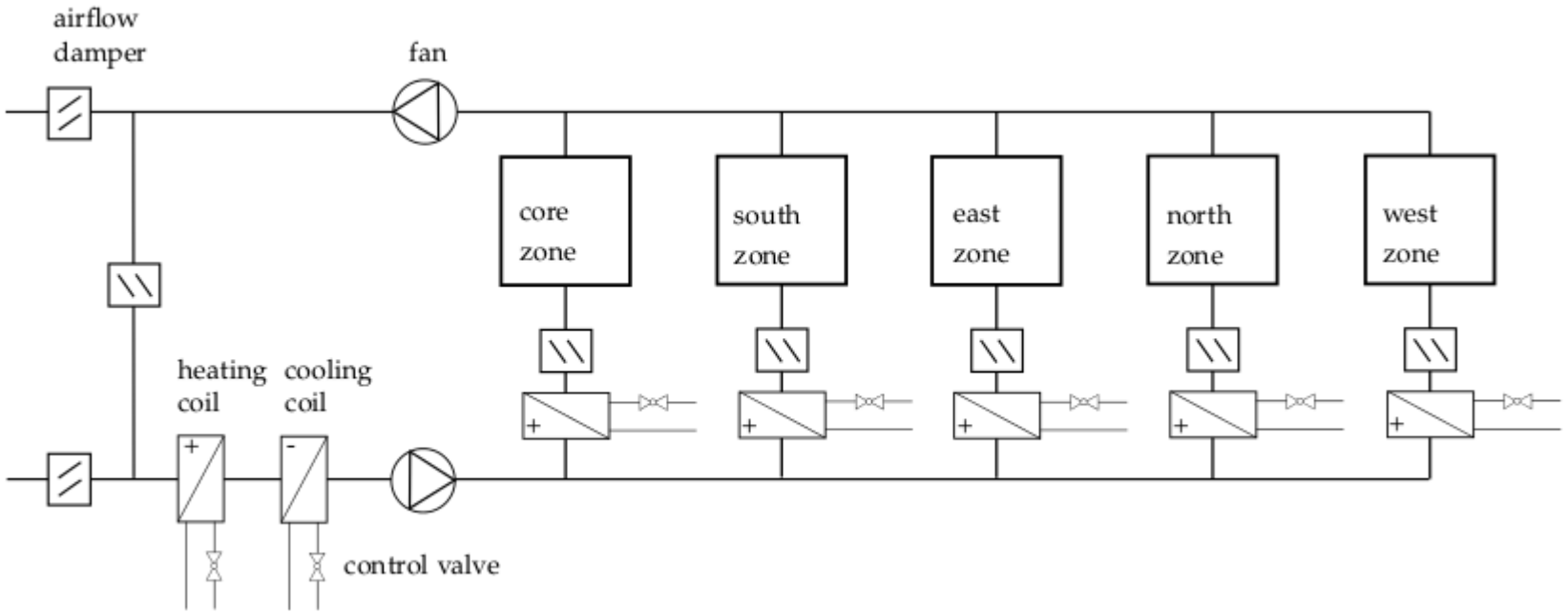
Variable Air Volume (VAV)



Variable Air Volume (VAV)



Variable Air Volume (VAV)

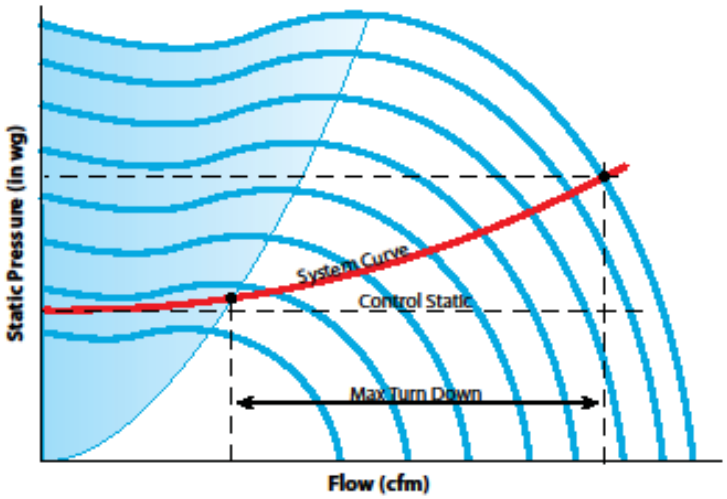


Fig. 25: VAV System Selected Further Right of Peak Static

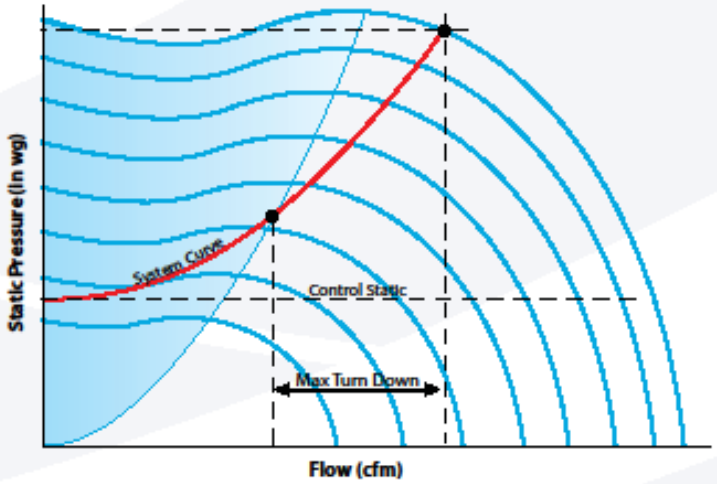
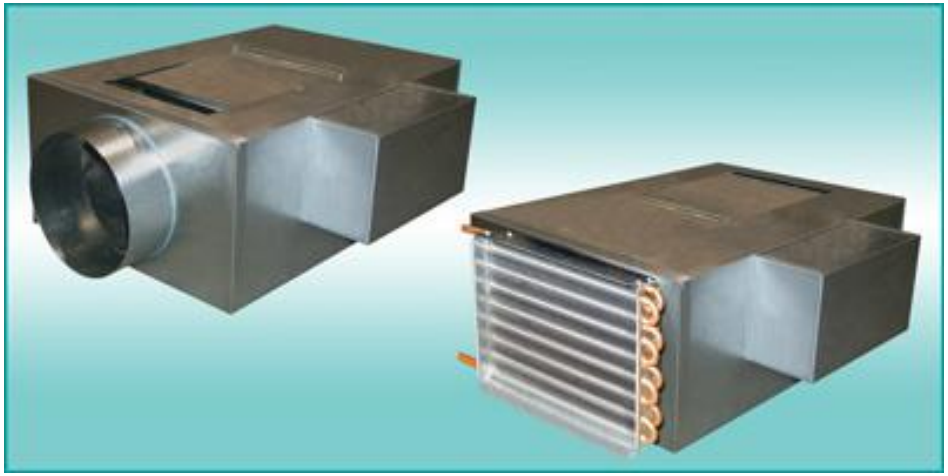


Fig. 24: VAV System Selected Close to Peak Static & Efficency

Variable Air Volume (VAV)

- Staged Heat For Morning Warm Up
- RTU Provides 55F During Occupied Hours
- VAV Boxes Control Delivery of Cold/Hot Air Individually
- Airflow Measurement Controls CFM At VAV Box
- Static Pressure Sensor To Keep Pressure For Boxes, Filters, Coils, etc.
- Single Duct For Interior Zones
- Fan Powered For Exterior Zones
- Heat Options
  - Hot Water
  - Electric



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Variable Air Volume (VAV)

Parallel Flow Fan Powered
- Variable Volume
- Pulls Air (Heat) From Plenum/RA Duct
- Intermittent Fan
- Fan Outside Of Airstream
- Need Static Pressure From RTU

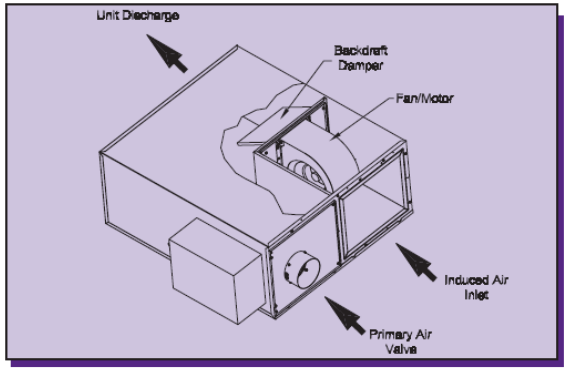

Figure 1. Parallel Flow, Fan Powered Terminal

Series Flow Fan Powered
- Constant Volume
- Pulls Air (Heat) From Plenum/RA Duct
- Constant Fan
- Fan In Airstream
- Fan Boosts Air Through Duct

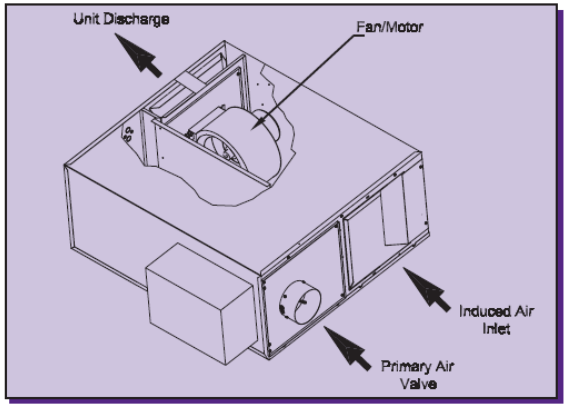

Figure. 2. Series Flow, Fan Powered Terminal

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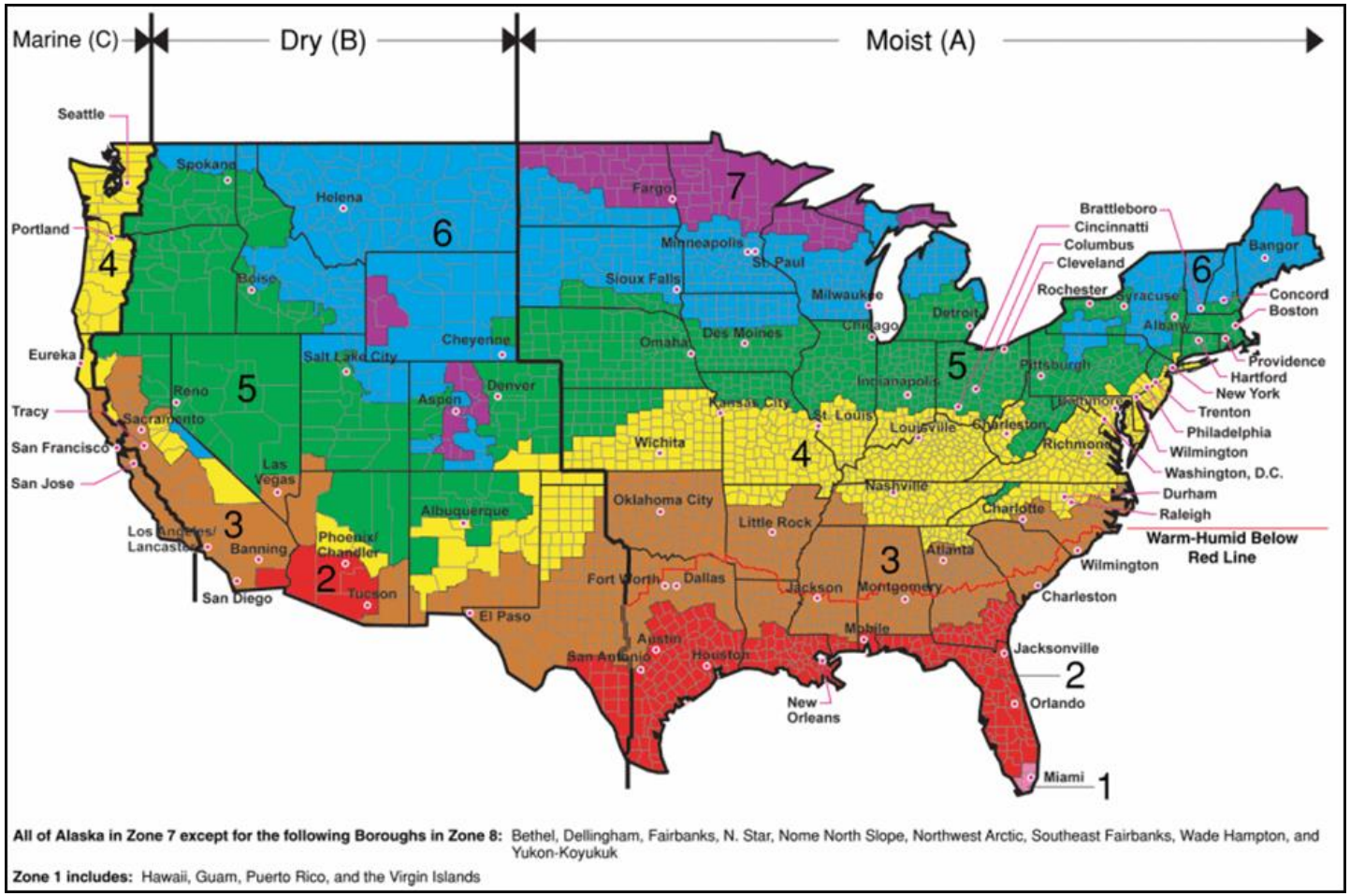
Dedicated Outdoor Air Systems (DOAS)
Energy Recovery Systems

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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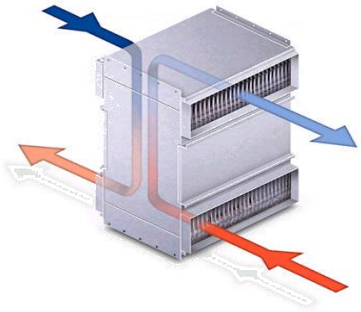
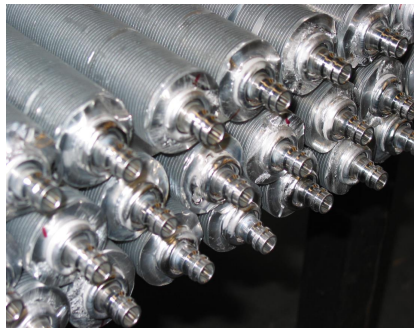
Types of Energy Recovery:

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





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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

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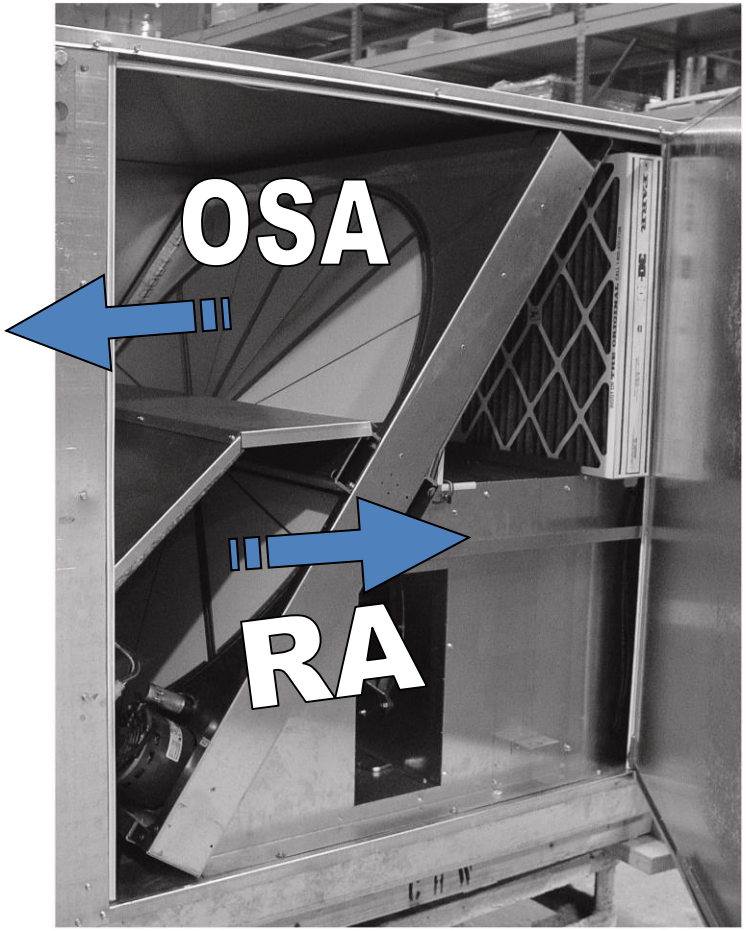
Heat Wheels:

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

Heat Wheel:



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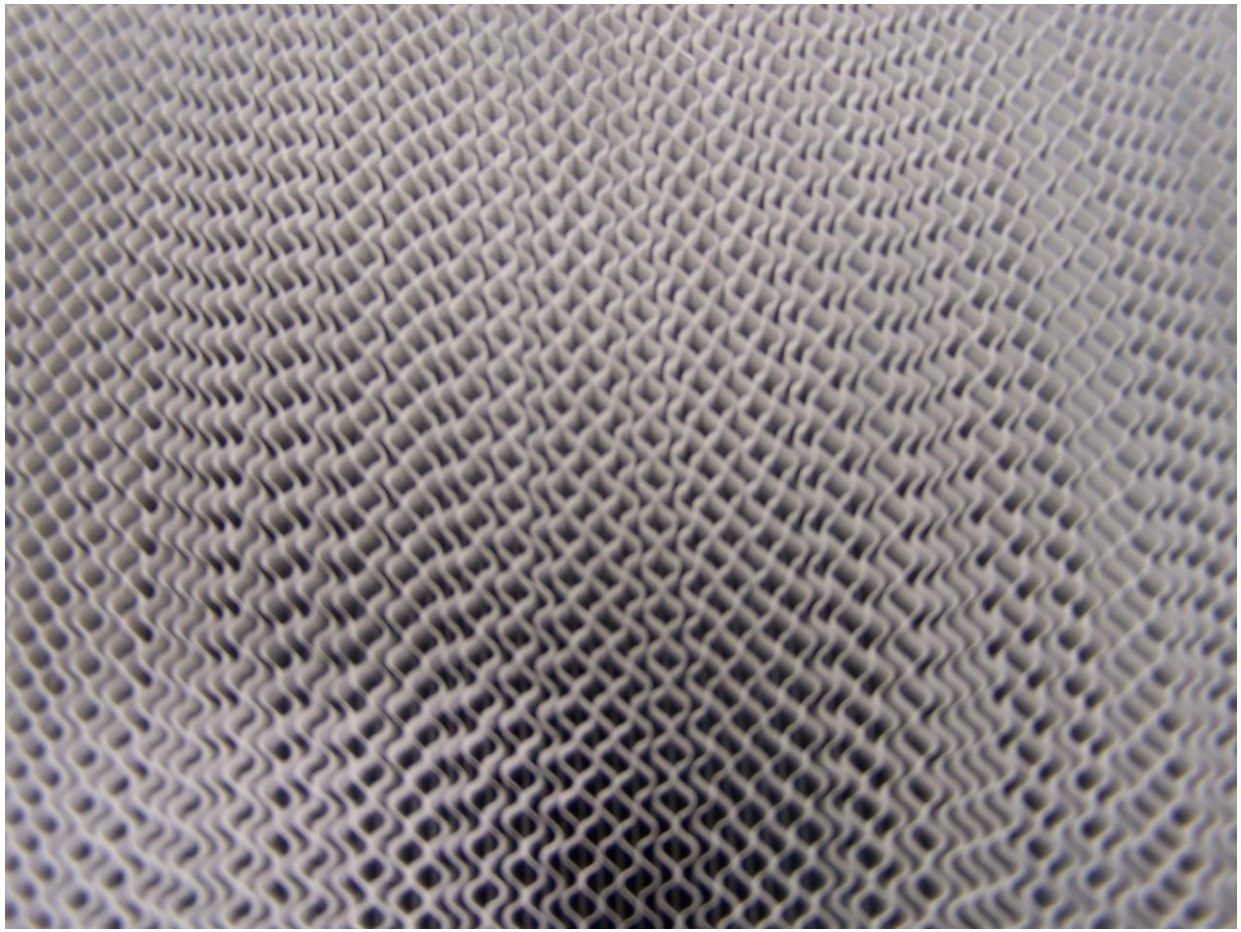
Heat Wheel:

Heat Wheel:



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Heat Wheel:

Bypass Dampers

- Excess Air
- Economizer Operation

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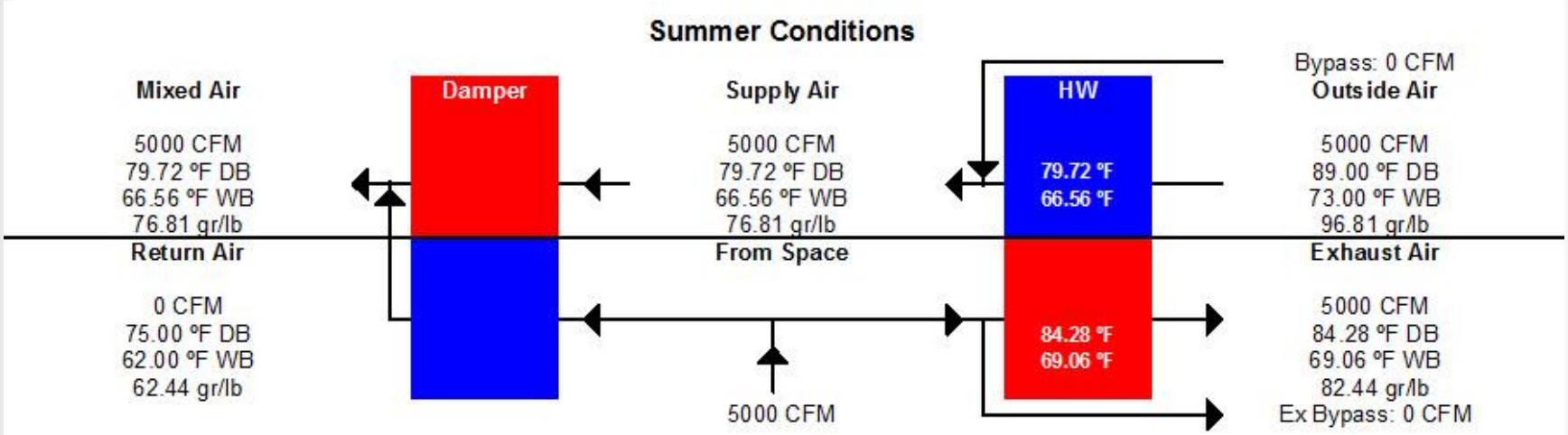
Heat Wheel Performances:



	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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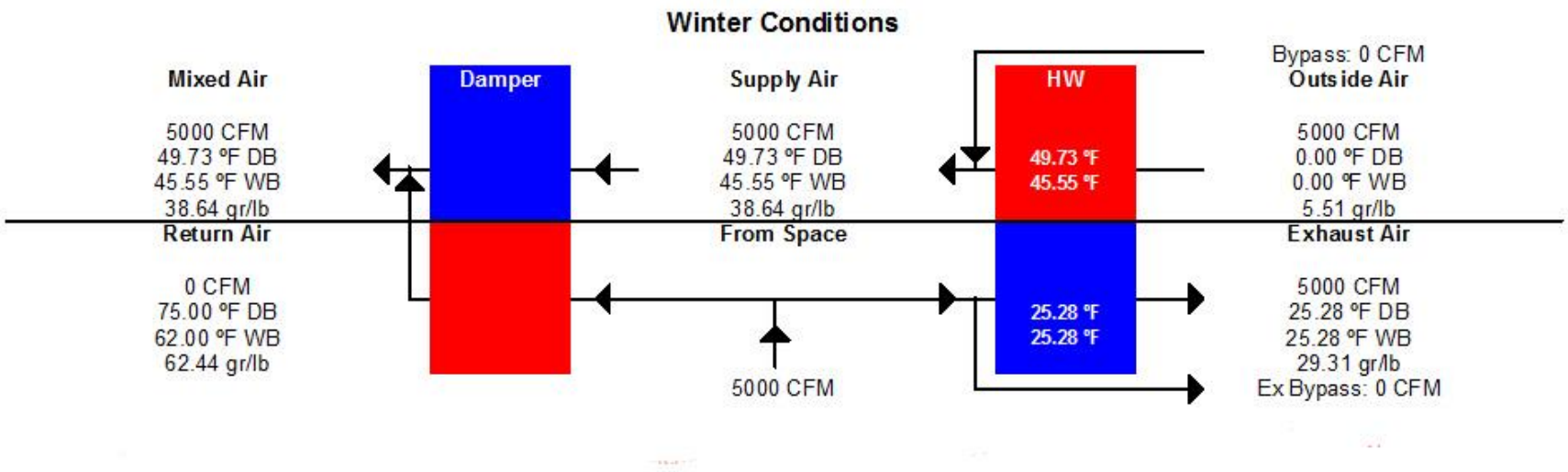
Heat Wheel Performances:



	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**

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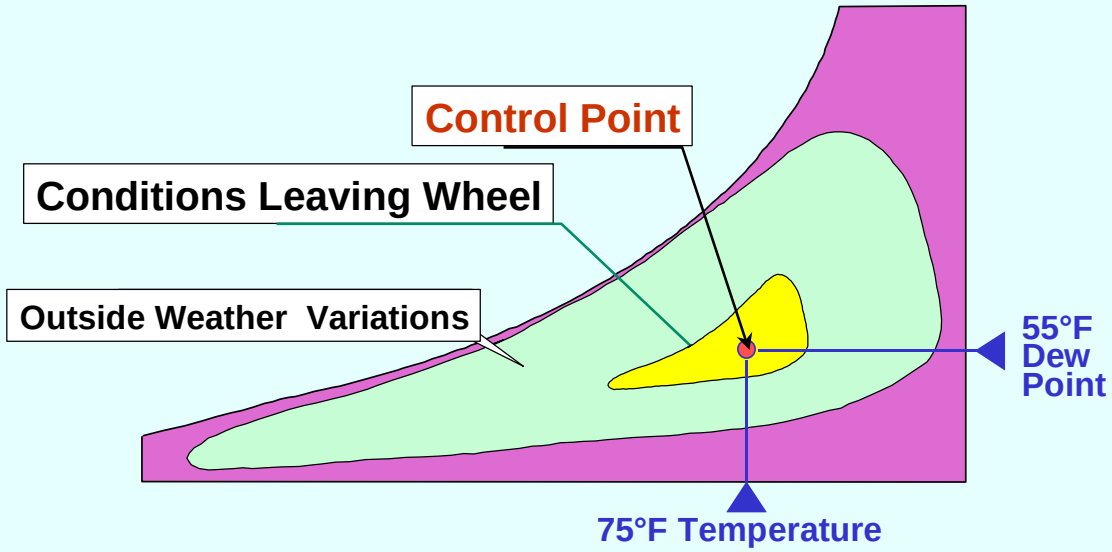
Heat Wheel Benefit:

The Total Energy Recovery Wheel Benefit

Total energy recovery significantly reduces the variations in operating conditions.



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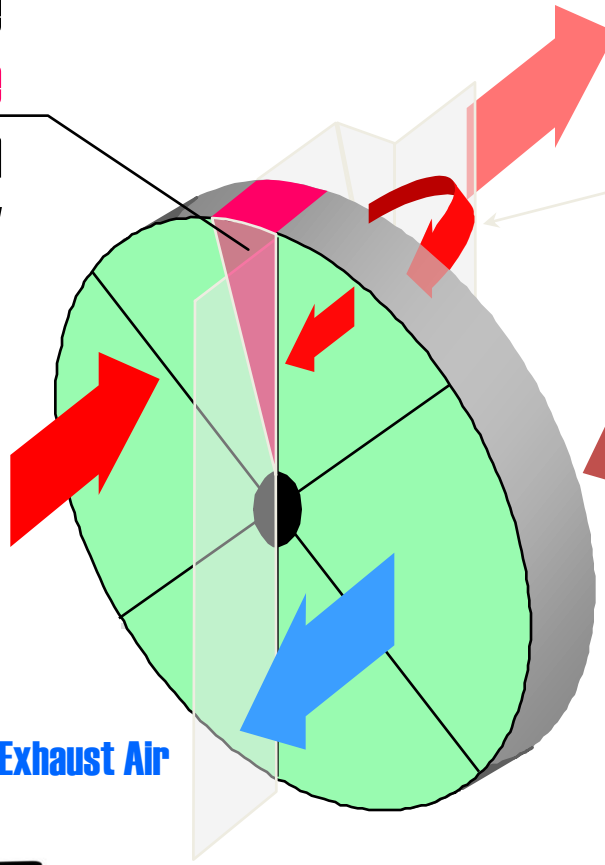
Purge System:

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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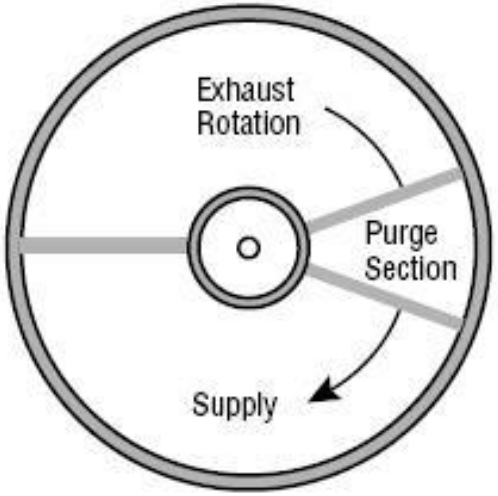
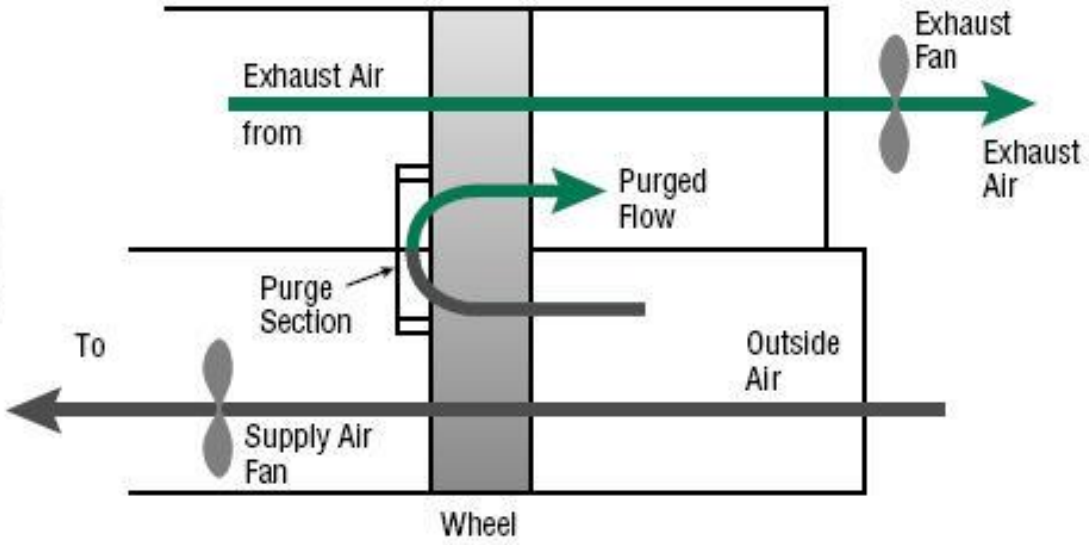
Purge System:



Front Cross Section
with Upstream Exhaust



Side Cross Section
with Purge Section

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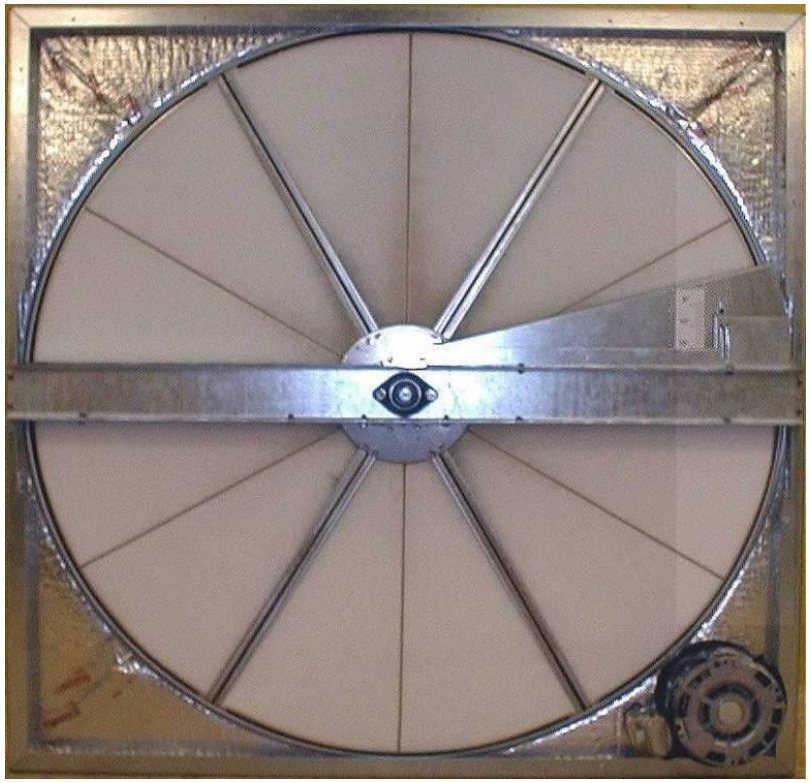
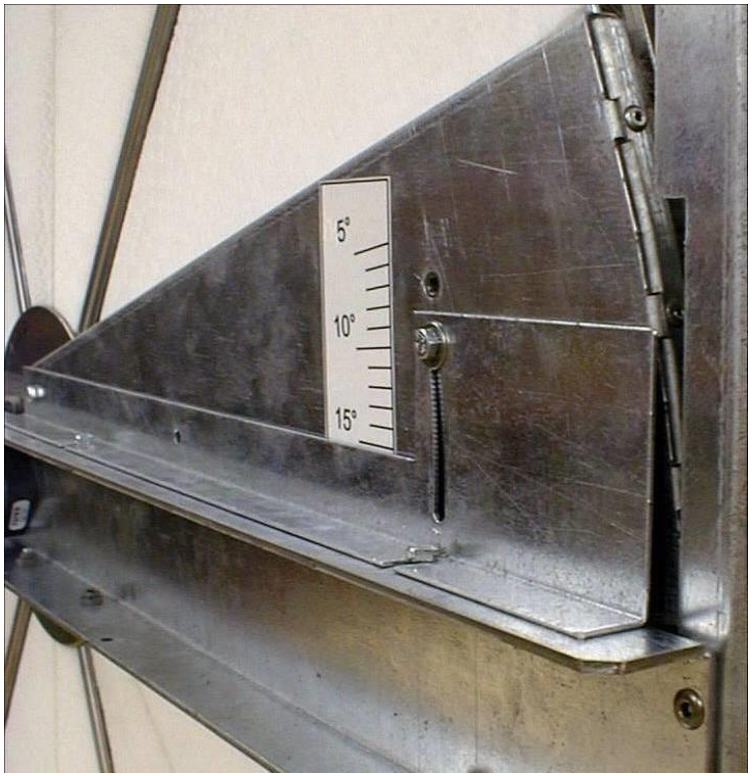
Heat Wheel With Purge:





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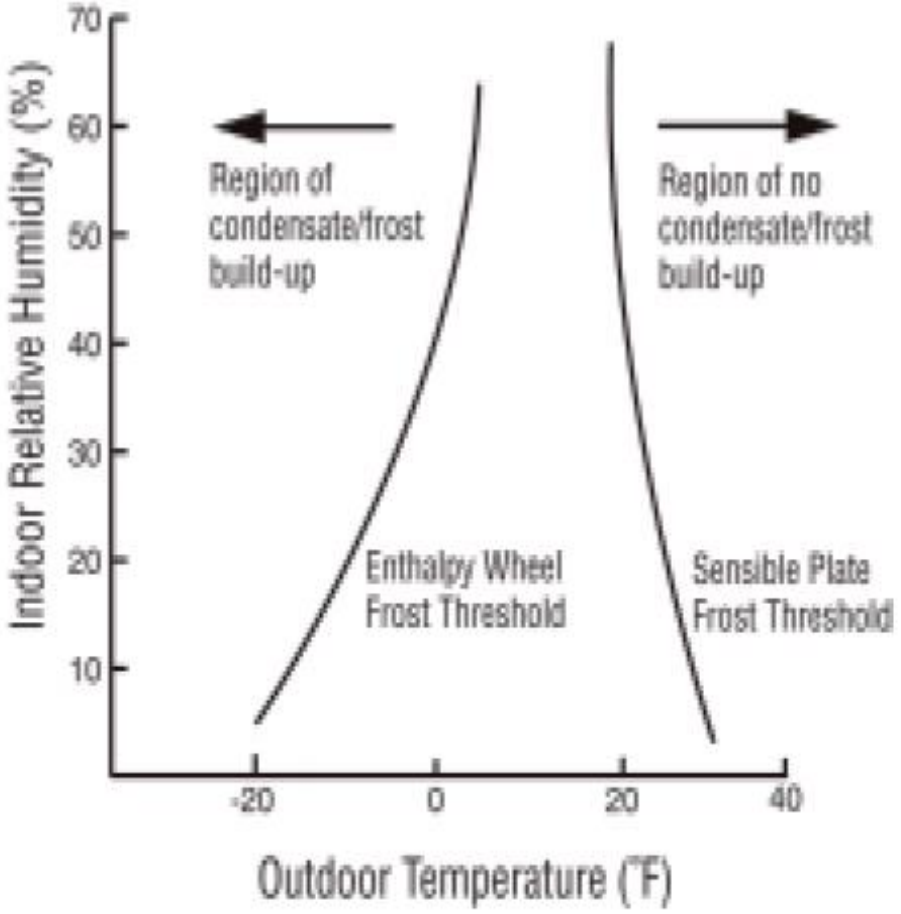
Heat Wheel Frost Control:



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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

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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

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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

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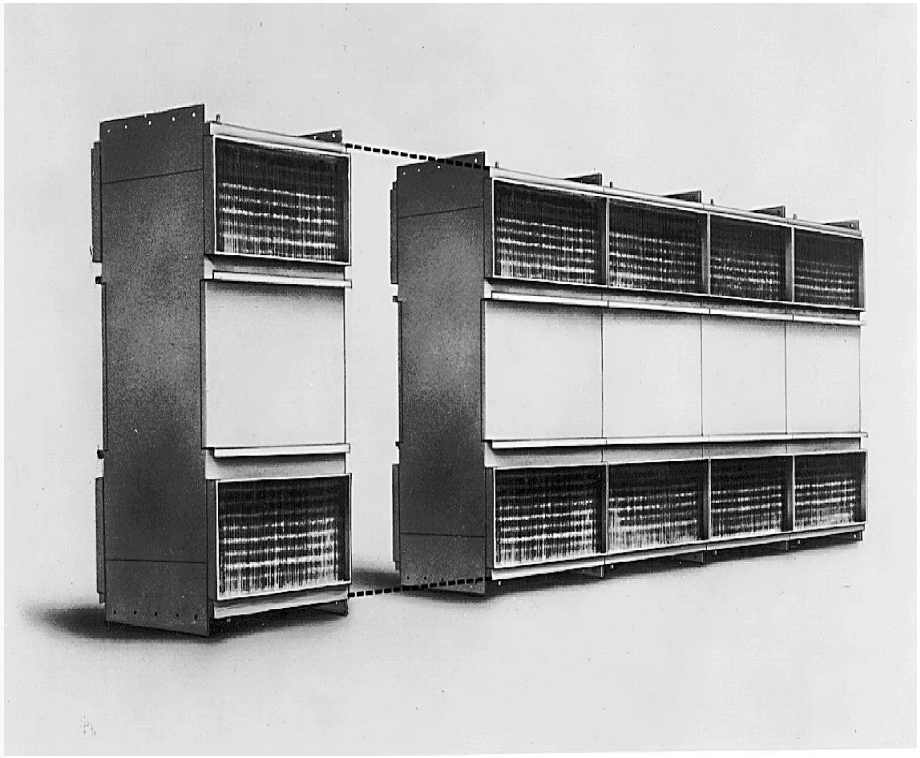
Plate Heat Exchanger:



- 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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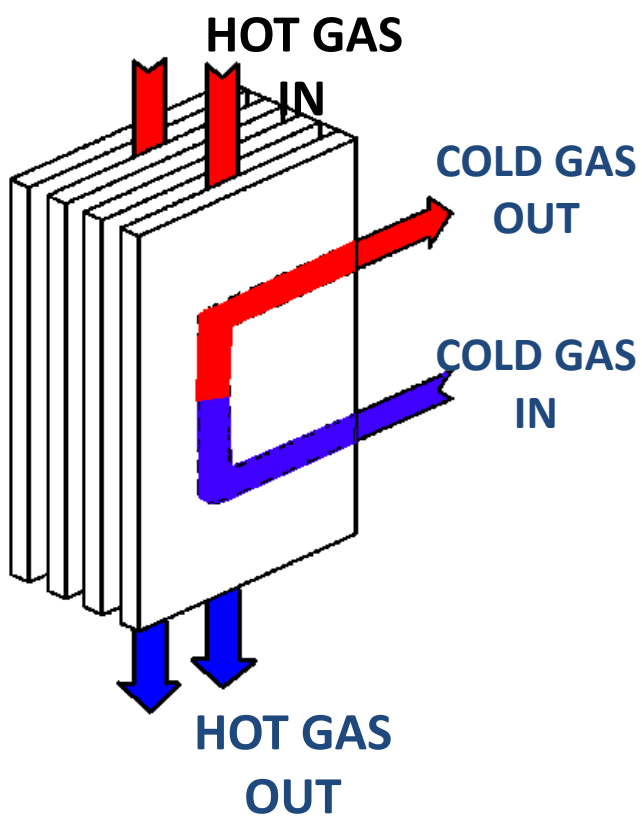
Counter Flow Plate Heat Exchanger:



- 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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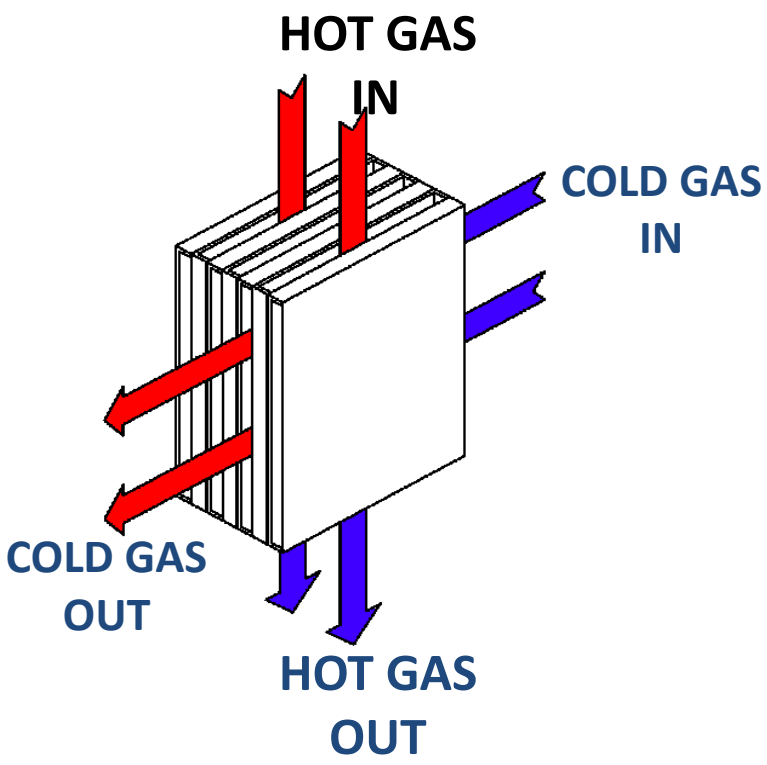
Cross Flow Plate Heat Exchanger:



- Two air streams are 90° from each other

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Plate Heat Exchanger:

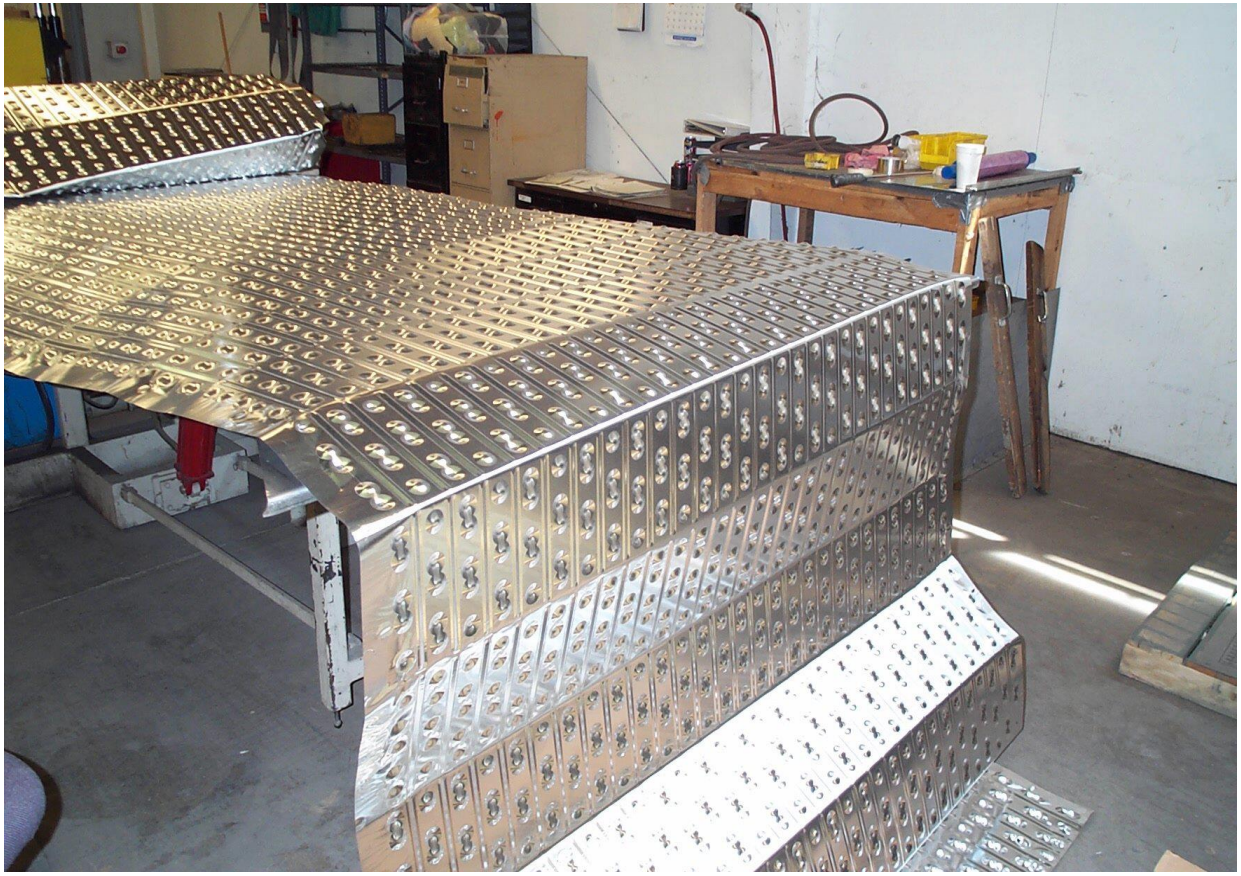

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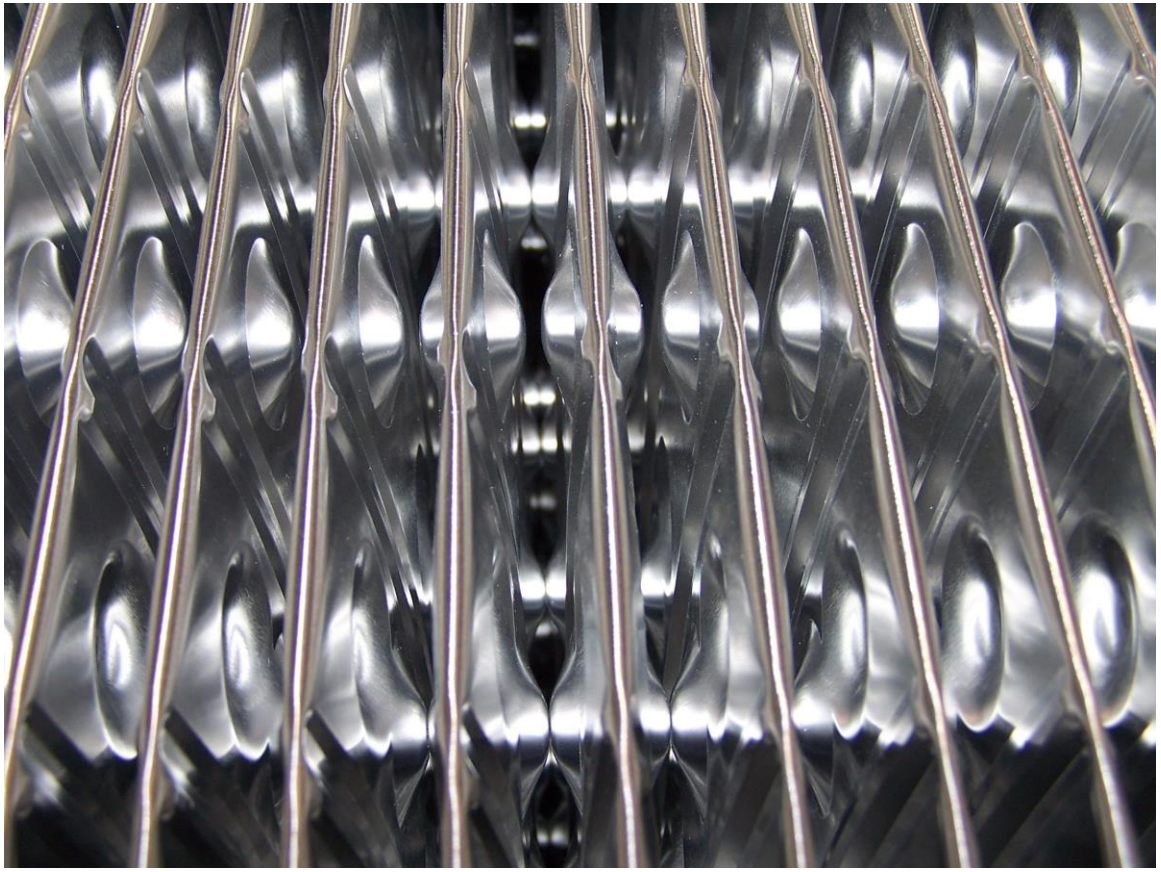
Plate Heat Exchanger:



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Cross Flow Plate Heat Exchanger:

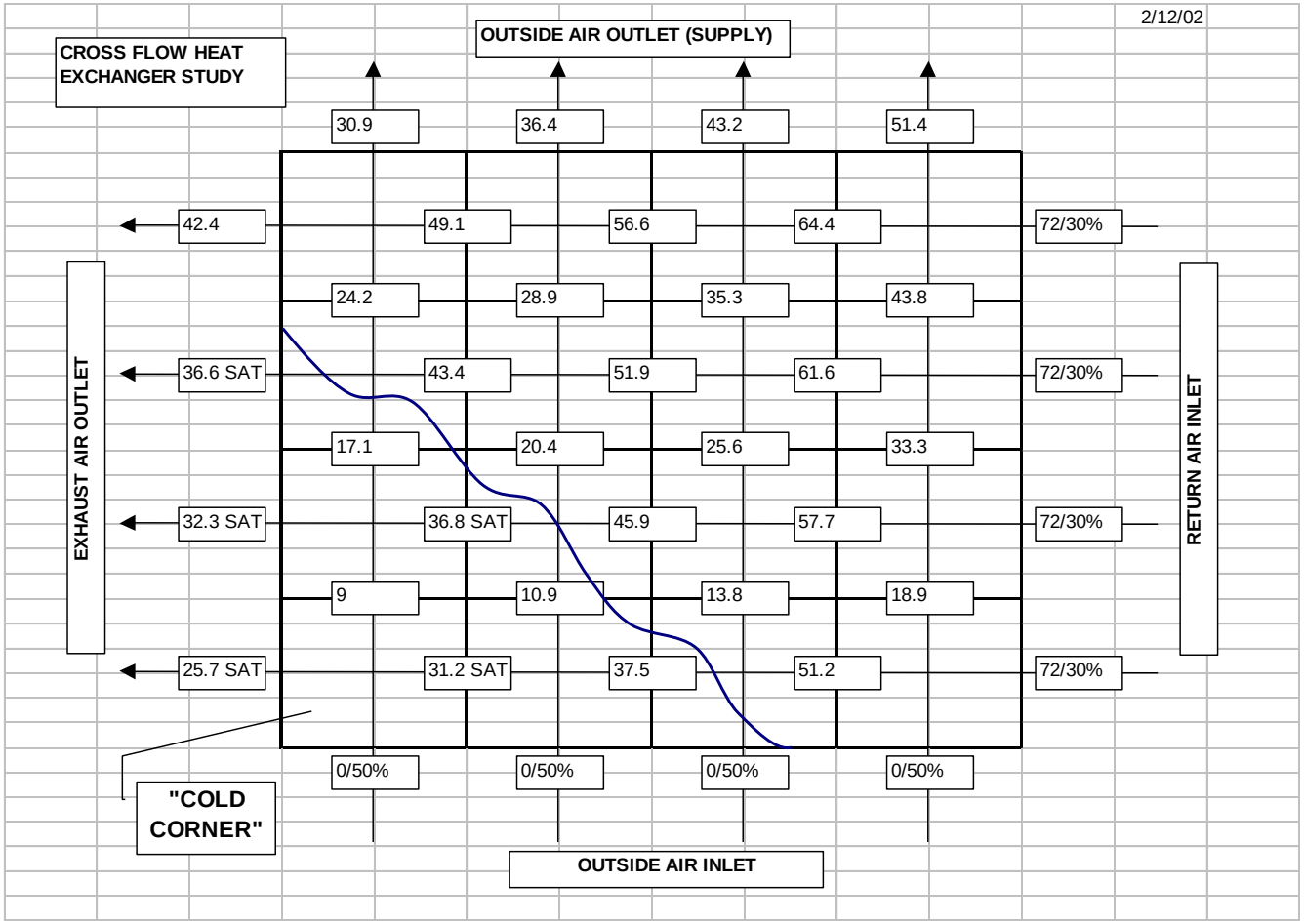

Plate Heat Exchanger Applications:

- 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

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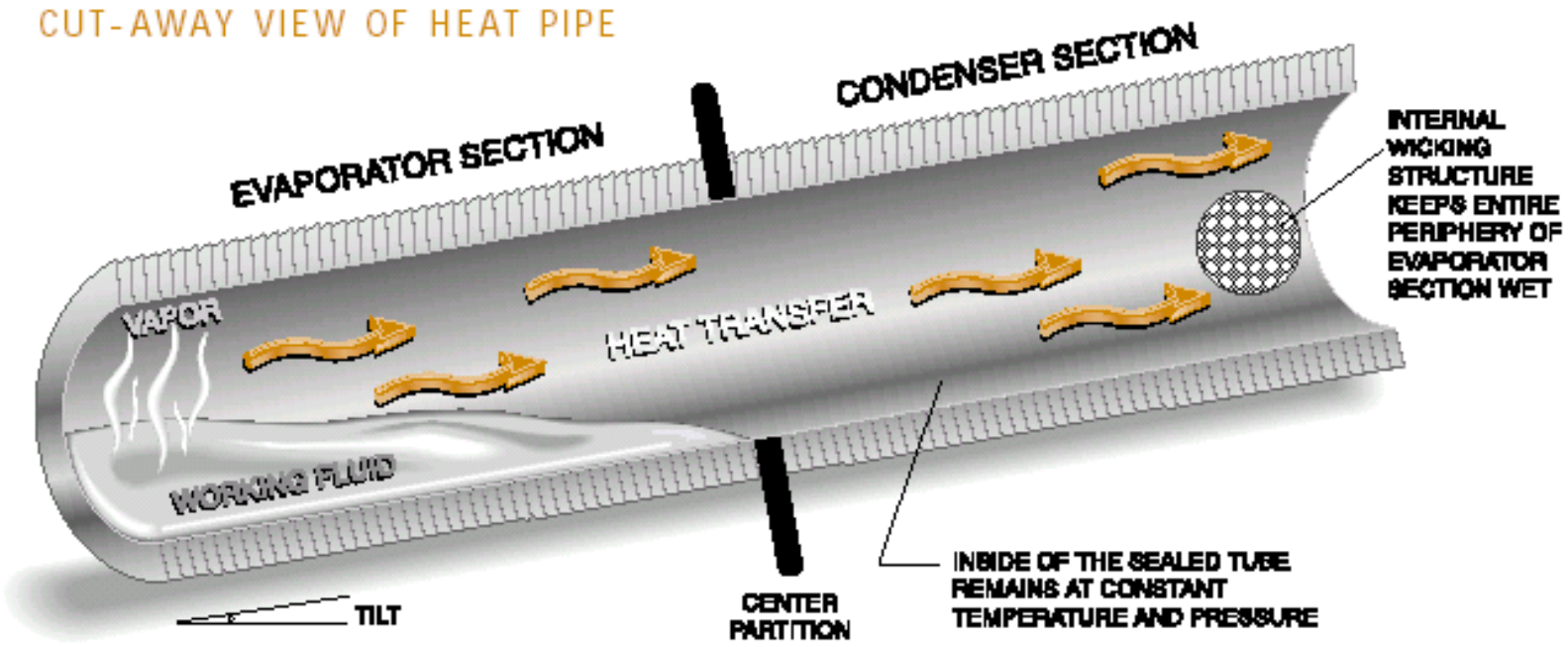
Heat Pipe:



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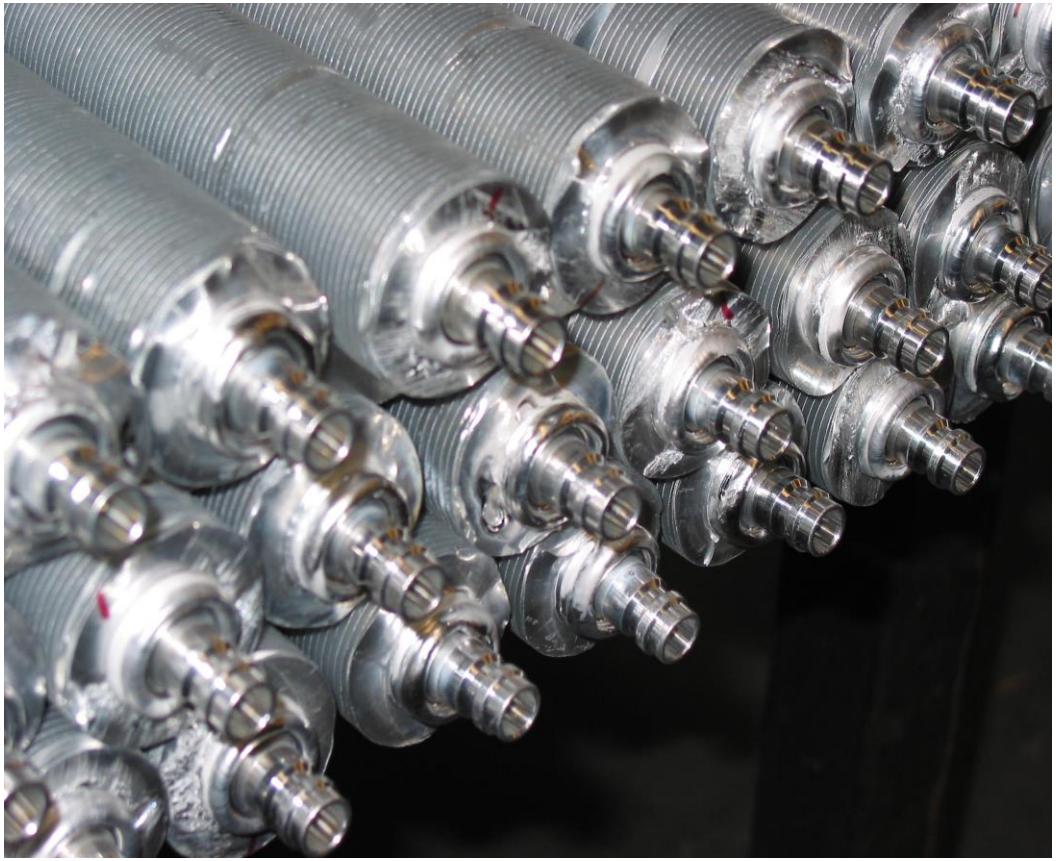
Heat Pipe:



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Heat Pipe:

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Heat Pipe Applications:

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

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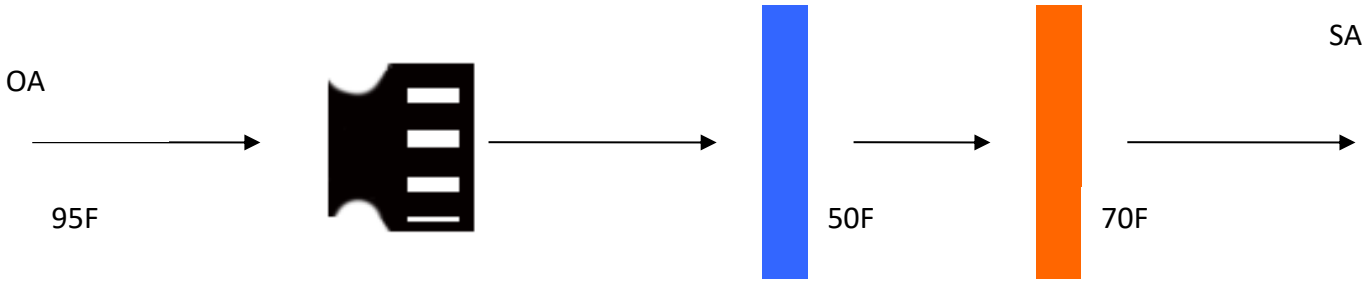
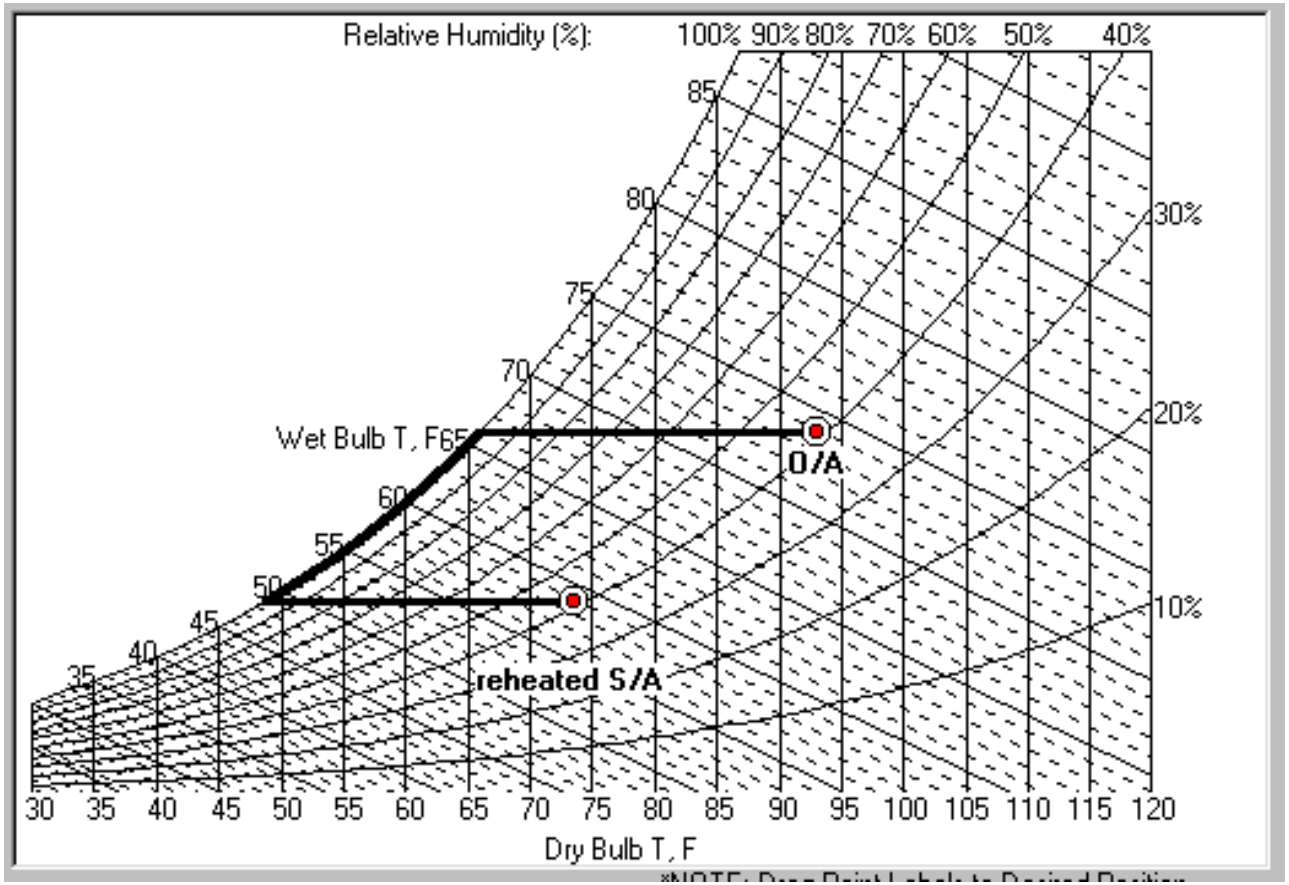
Brute Force:



Brute Force:



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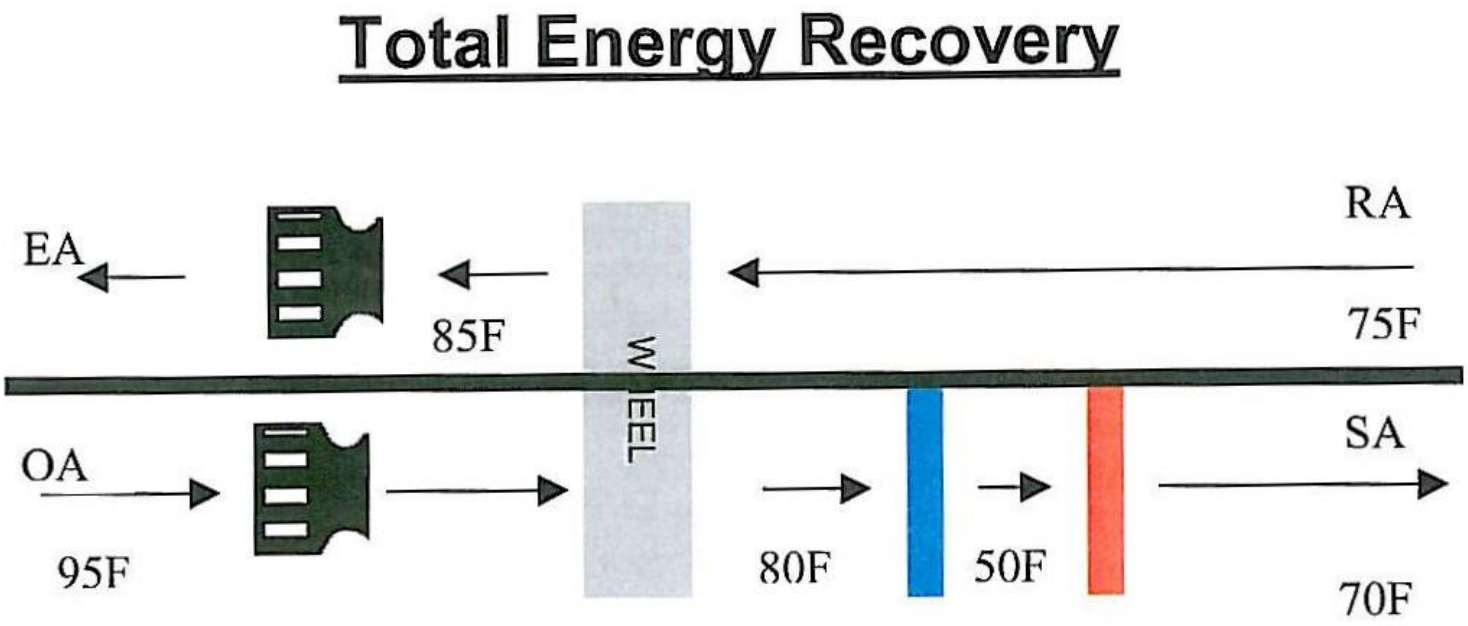
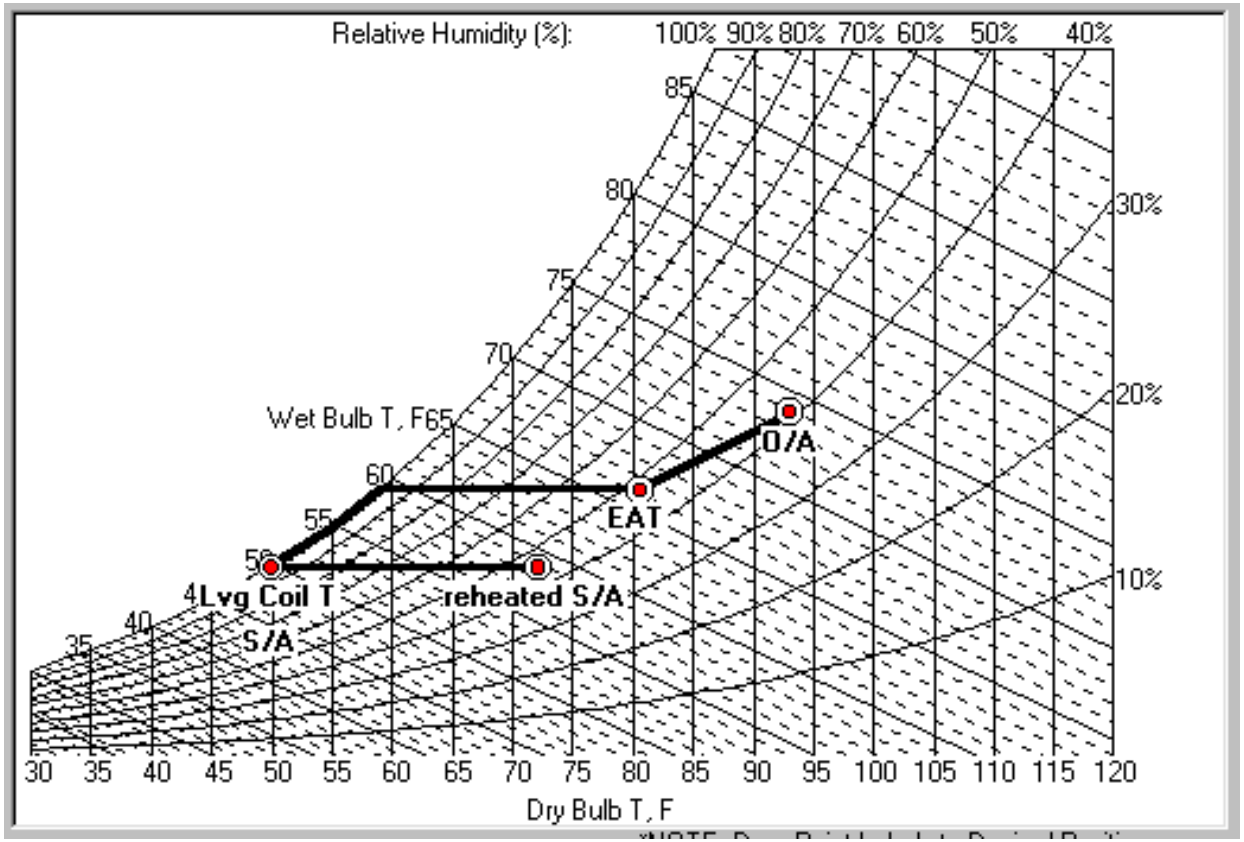
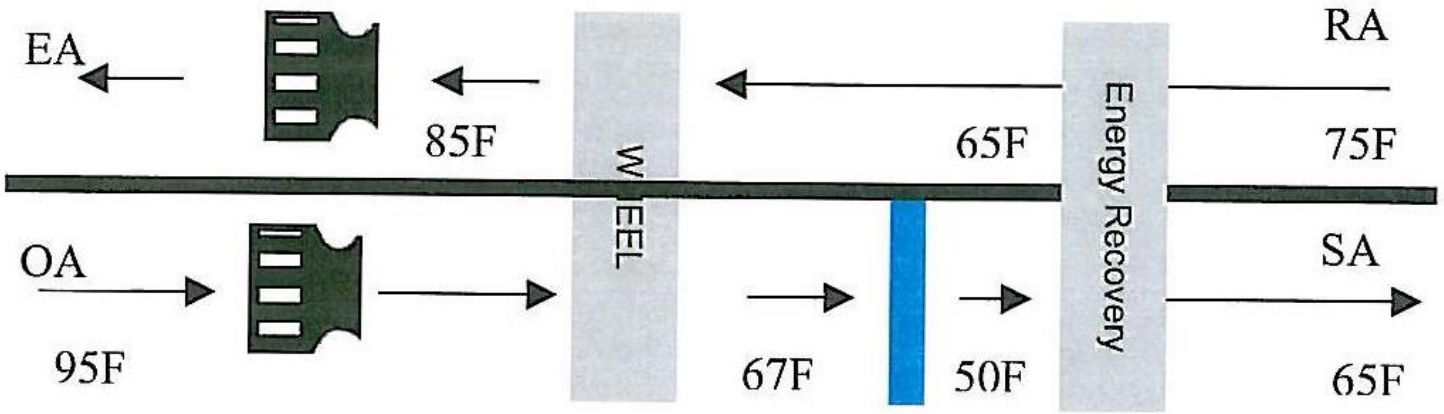
Total Energy Recovery:



Total Energy Recovery:



Dual Energy Recovery System:



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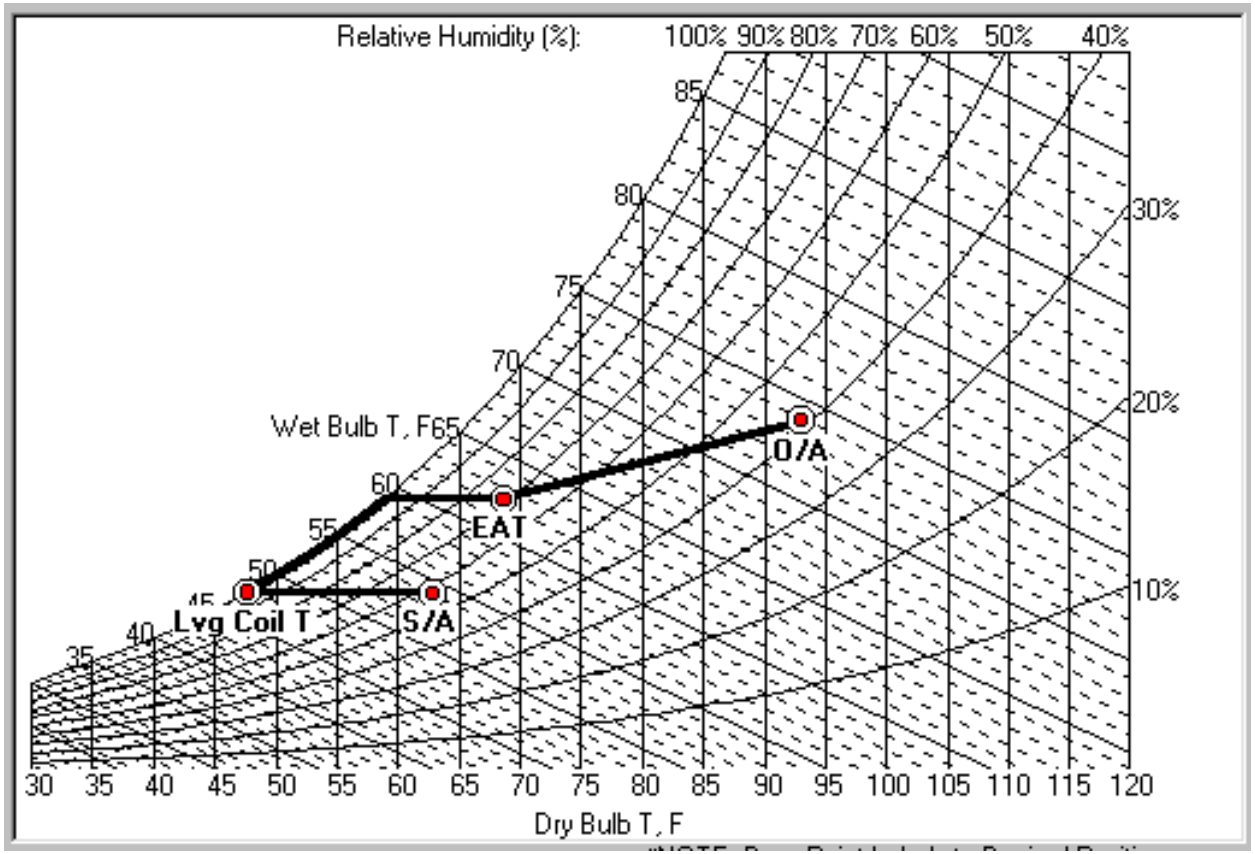
Dual Energy Recovery System:



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Cost Comparison:

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

Akron, OH

TEMPERATURES DRY BULB	TEMPERATURES MCWB	TOTAL HOURS AT CONDITION	TOTAL HOURS OF OPERATION	SUMMARY 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**

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Fan Coil Units

Fan Coil Units

System
- Indoor CW/HW Fan Coils
- Typical 4 Pipe
- DOAS (?)
- AHU’s For Larger Areas
- Chiller
- Boiler
- Pumps
- Controls

Comfort
- Modulating Heating & Cooling
- ECM/VFD Controlled Fans

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Fan Coil Units

Flexibility

- Unlimited FCU/AHU Sizing, Position
  - Horizontal, Vertical, Stacker
- Unlimited Chiller/Boiler/Pump Sizing

Redundancy

- Each FCU/AHU Is Standalone
  - 1 Goes Down, Doesn't Affect Entire Building
- Redundancy In Chillers, Boilers, Pumps?
  - Need For Space, Power, Etc.

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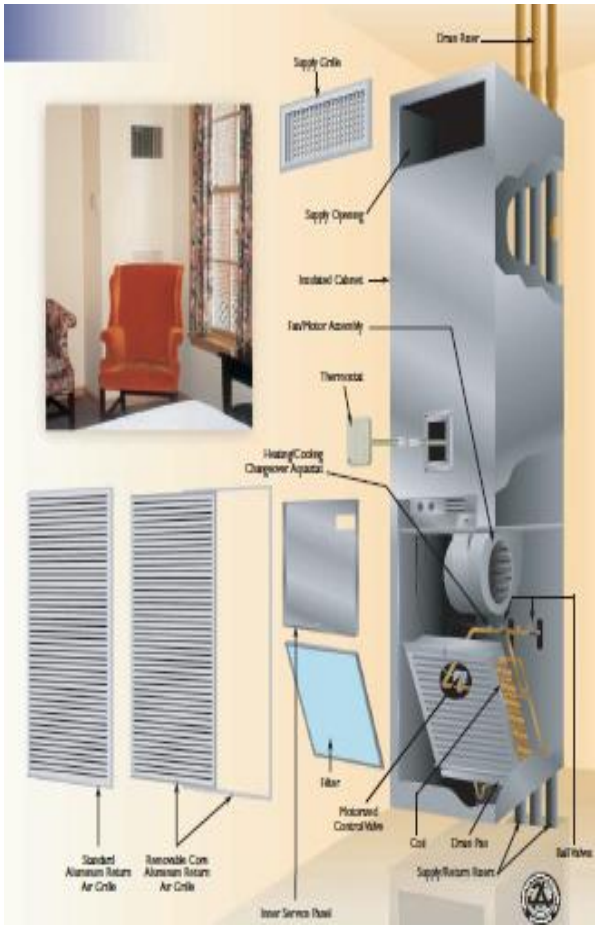
Fan Coil Units

Equipment Cost
- Moderate To High

Installation Cost
- Fan Coil
- Chiller
- Boiler
- Pumps
- Electrical For Each
- Gas Piping
- Individual Control & System Communication



Fan Coil Units

Energy Efficiency

- Each Component Has Own Efficiency
  - Chillers Up To 28 EER
  - Boilers Up To 98%
  - Pumps Up To 90%
- Modulating Compressors
- Multi Speed Evaporator Fans
- Modulating Valves

Controls

- Individual Thermostat
- Communications System With PC Front End

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Fan Coil Units

Maintenance

- FCU Units
  - Removable Panels For Filter, Fan, Coil Access
  - Clean Filter
  - Check Fans
  - Check/Clean Fan, Coil, Condensate Drain, Electrical Connections
- Chiller
  - Check Compressor, Electrical Connections
  - Tubes? Brazed Plate?
  - Air Cooled/Water Cooled?
- Boiler
  - Check Burner, Water, Electrical Connections
- Pumps
  - Check Pump, Electrical Connections
- Units Can Be Replaced With Different Manufacturer

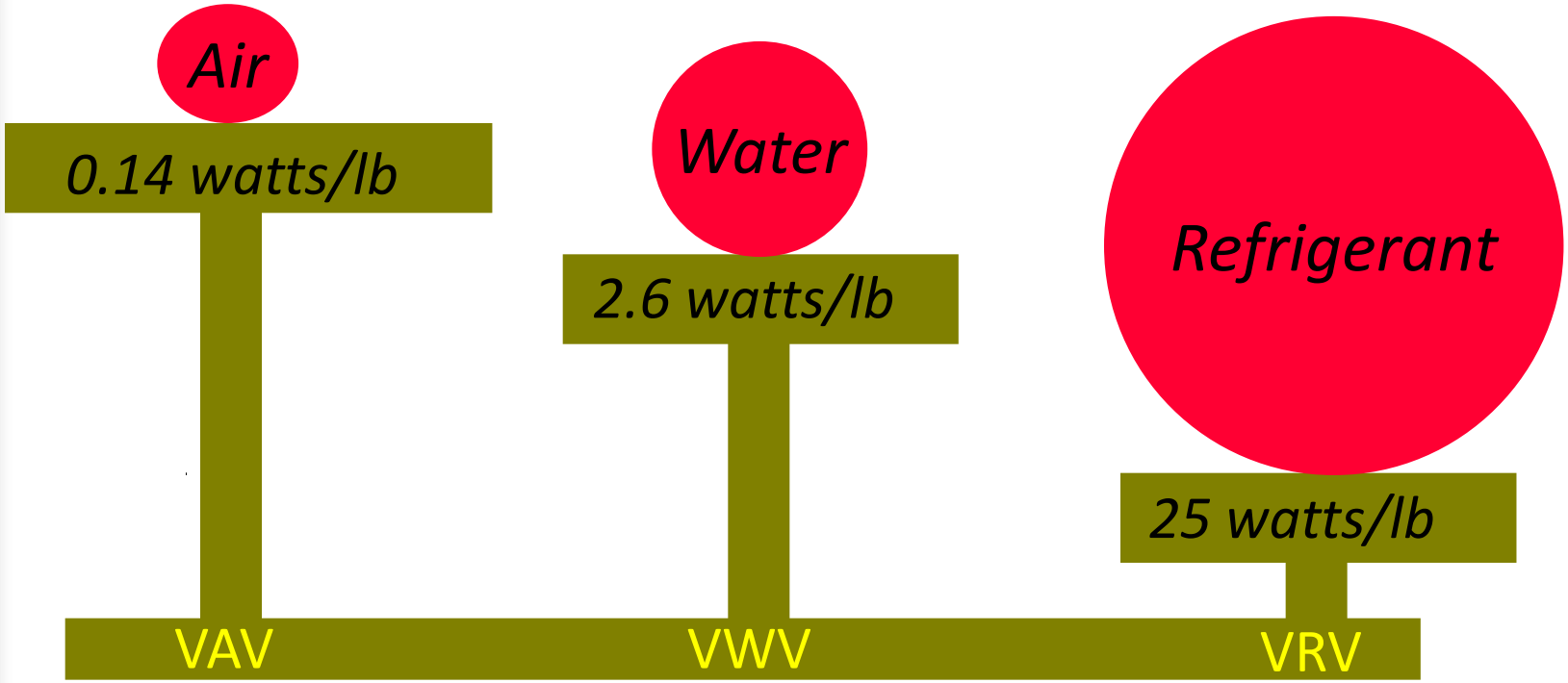
Geothermal Heat Pumps

What is Geothermal Heating and Cooling?

- **ge·o·ther·mal** - Of or relating to the internal heat of the earth.

- **Geothermal Heating & Cooling** - the process of using low grade heat supplied by the earth to heat and cool a given facility.

Heat Transfer Media



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What Type of Buildings use Geothermal Systems?

Virtually Any Building can use a Geothermal Heating and Cooling System

- Schools
- Office Buildings
- Religious
- Hotels
- Government Buildings
- Museums

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Advantages of Geothermal

- Environmentally friendly
  - Reduction in energy consumption results in less emissions
- Design flexibility
  - Terminal units (decentralized)
  - Central Plant
- Low energy costs – reduce or eliminate natural gas usage
- Long term Solution – extended life cycle
  - Majority of equipment is indoors
  - Ground loops last a long time
- Lower maintenance
  - No cooling tower or boiler
  - Limited water treatment

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What limits the use Geothermal Systems?

- Insufficient or limited land for ground loop
- Budget constraints
  - High cost of capital
  - Severely limited service life cycle expectations for calculating return on investment
  - Opportunity cost vs. alternative use of capital
- Inadequate soil conditions or excessive drilling requirements
- Severely imbalanced heating & cooling loads
- Limited knowledge of system capabilities

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Heat Pumps

System
- HP’s
- DOAS
- Tower/Boiler/Pumps
- Geothermal Well Field/Pumps

Comfort
- Multi Speed Fans
- Variable Speed Compressors
- Moderate Noise

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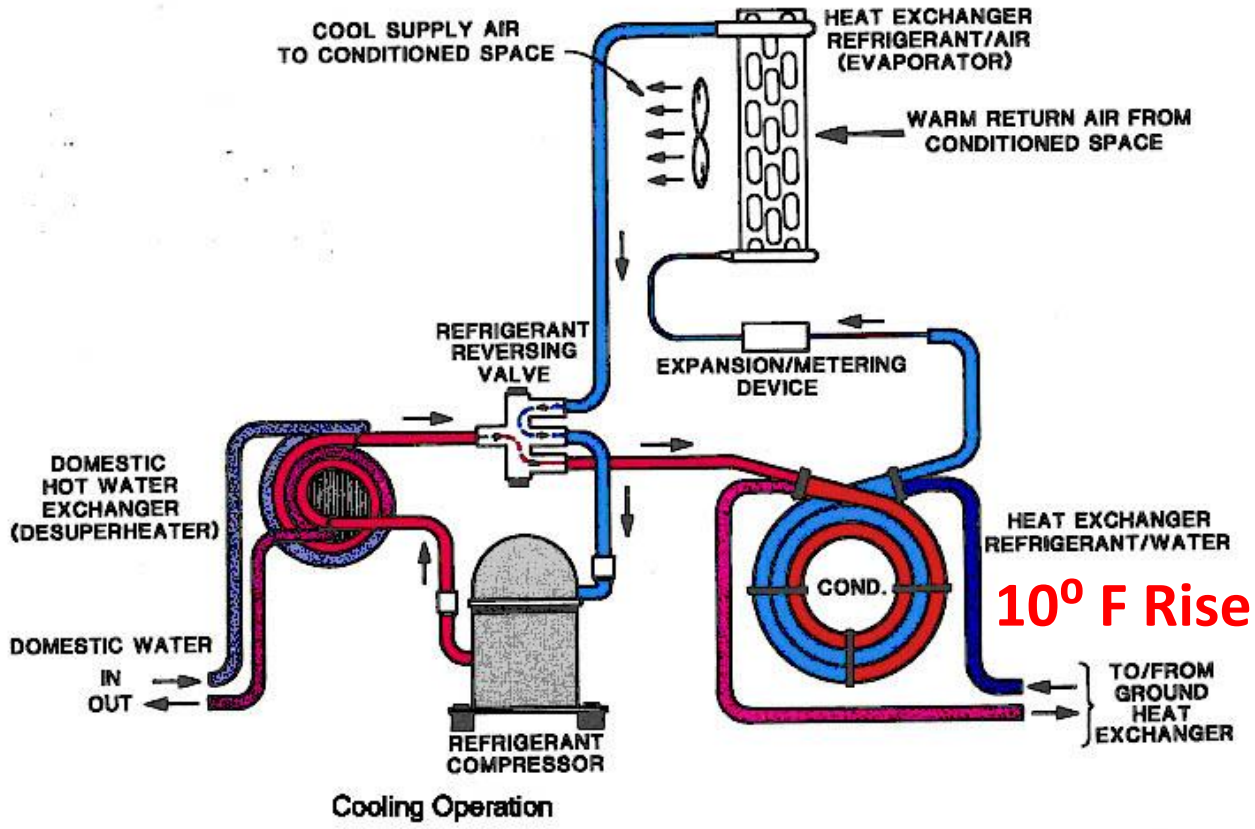
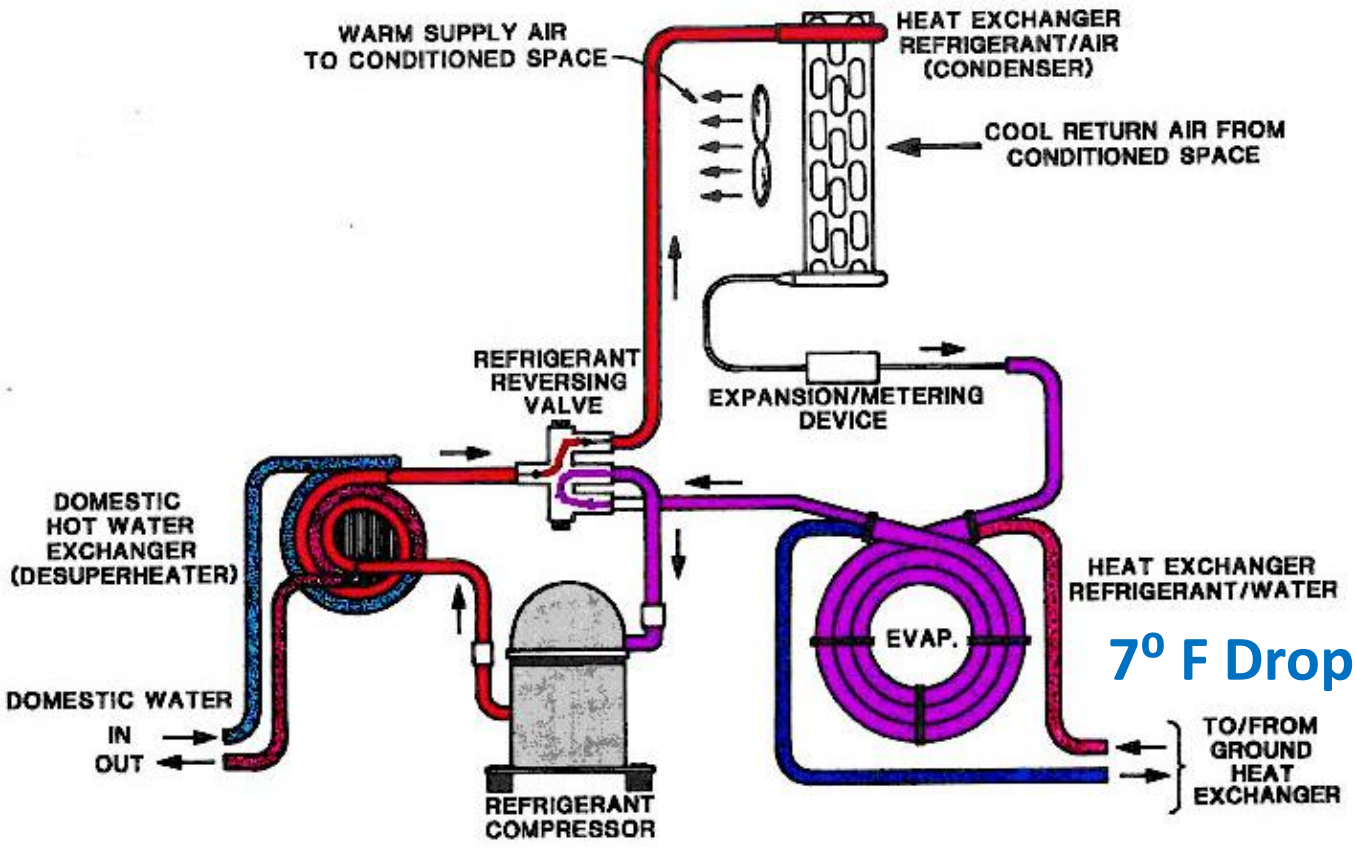
Commercial WSHP Basics

Refrigeration Basics – Cooling Mode



Commercial WSHP Basics

Refrigeration Basics – Heating Mode



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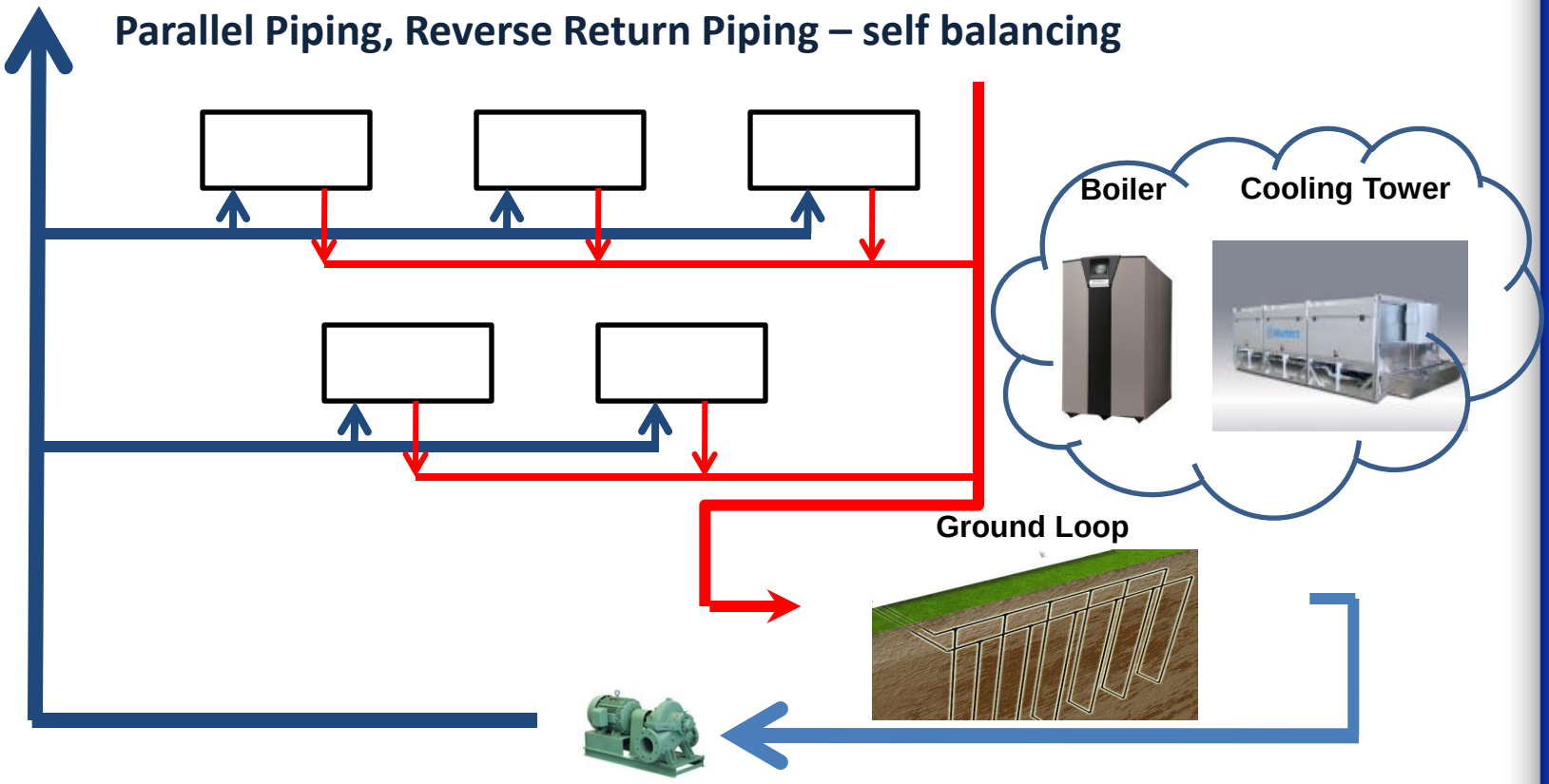
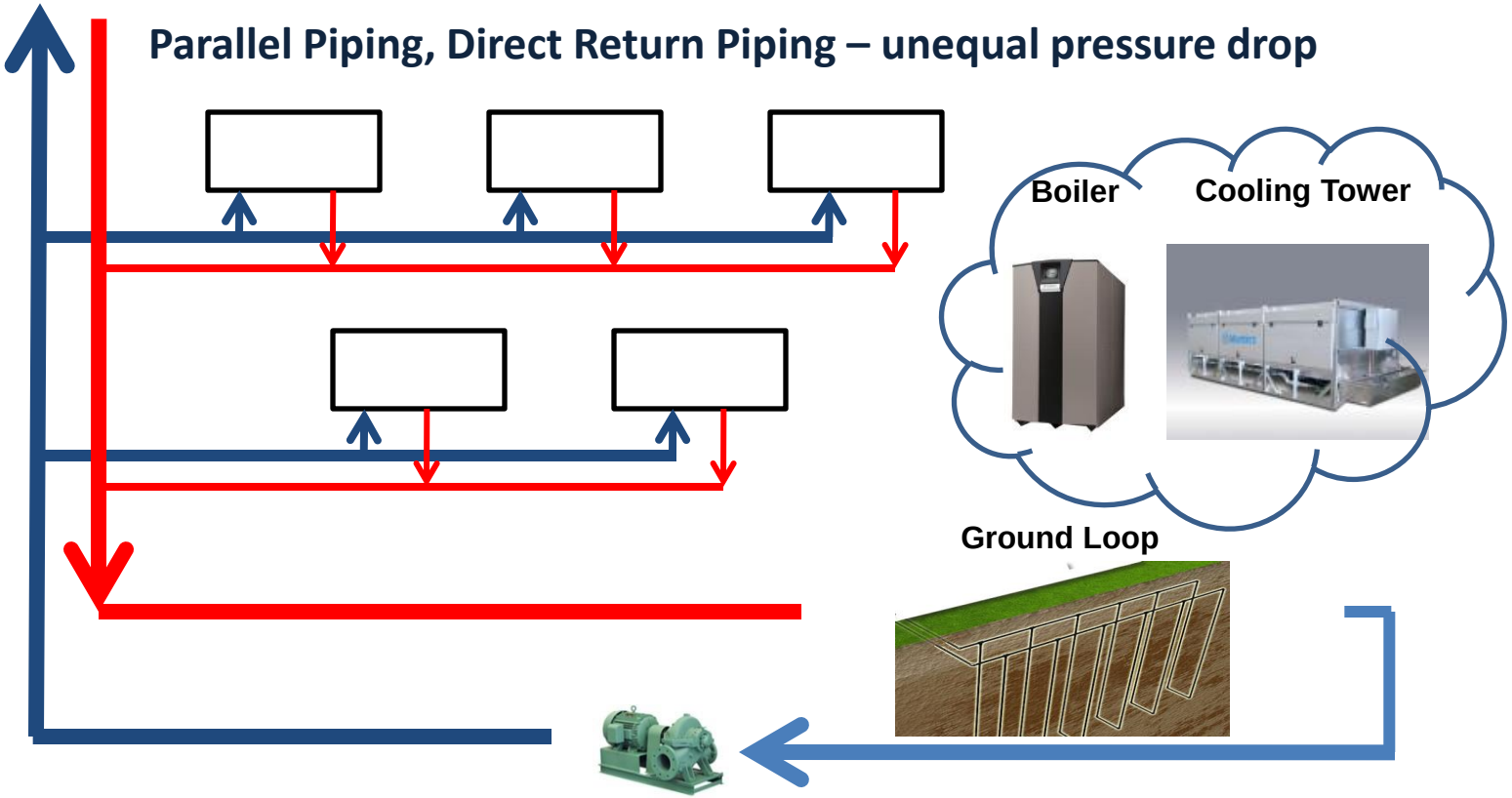
Commercial WSHP Basics

How your system is piped and pumps controlled are key to understanding proper water flow through the system



Commercial WSHP Basics

Most common because it is lower cost, BUT…



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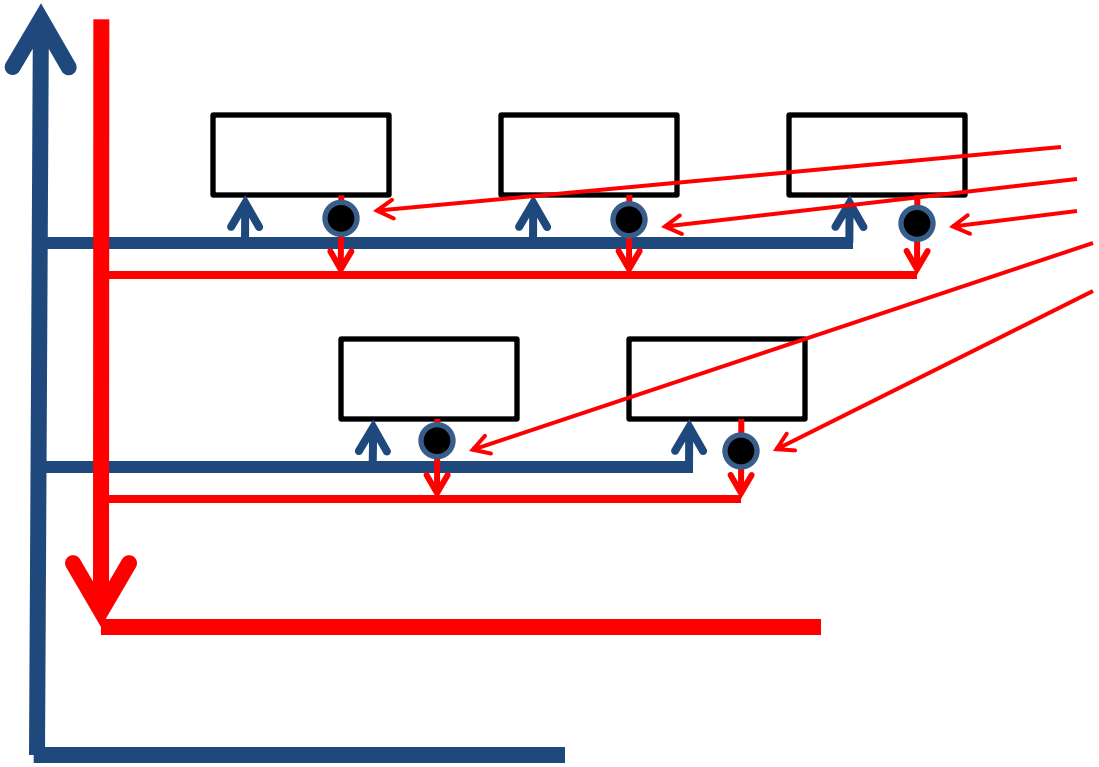
Commercial WSHP Basics

Direct Return Piping



Requires water flow control valves at every connected source of pressure drop to balance the water flow

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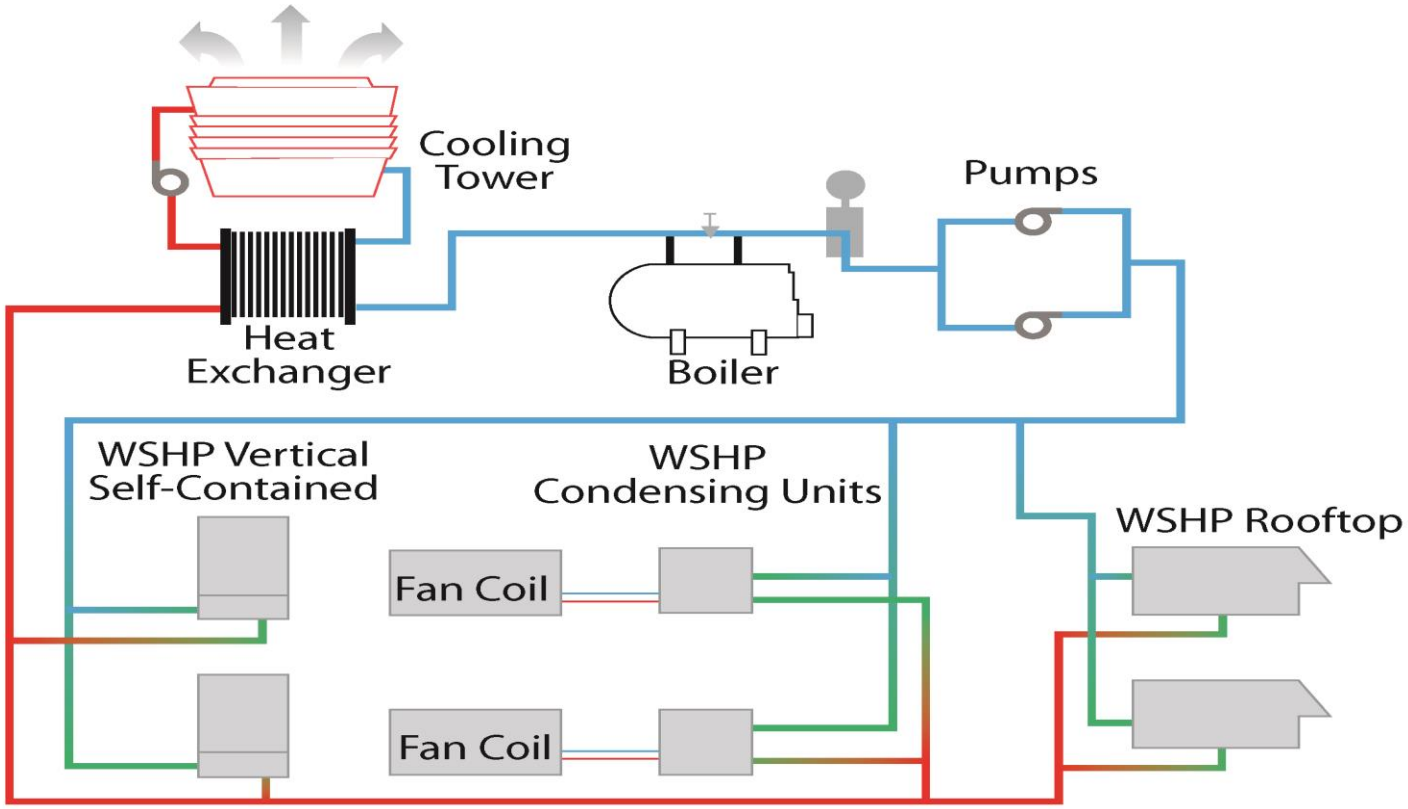
Water Source Heat Pumps



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Earth Coupled Water Loop

- **Geothermal Loop**
  - Closed loop
    - Horizontal
    - Vertical
    - Closed Pond
  - System temperatures range from 35 to 90

- **Open Loop**
  - “Pump and Dump”
    - Directly into the heat pump with suitable water
    - Intermediate heat exchanger if the water is a problem
  - System temperatures typically range from 45 to 60

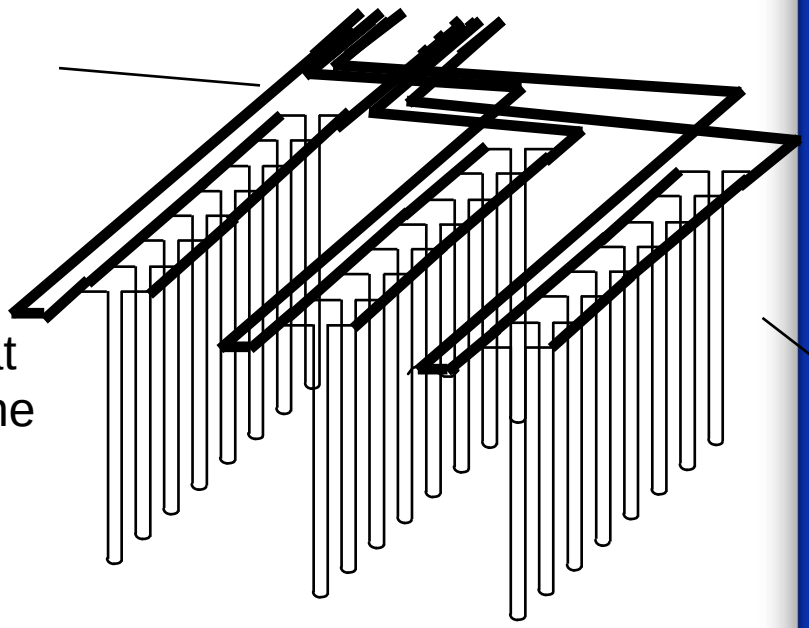
Vertical Loops

Most common for commercial projects

JACCO

Vertical Loops

- Smaller Land Requirement
  - 150 to 250 feet per ton
  - 250 square feel per ton (15 foot on center spacing min.)
- Soil conditions
  - Thermal conductivity of soil will dictate the amount of pipe
- Vertical bores
  - High Density Polyethylene pipe
  - Pipe is joined by heat fusion that makes the joints stronger that the pipe itself
  - Grouting



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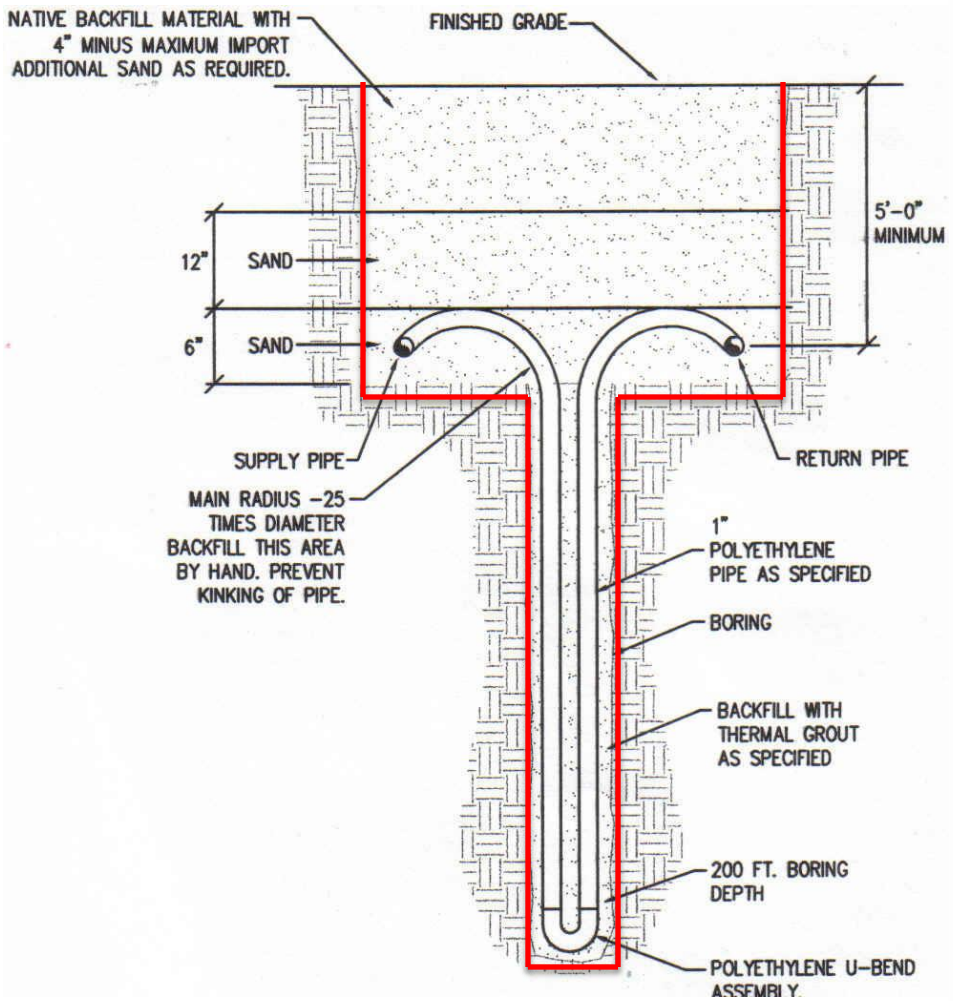
Geothermal Systems Operation

Vertical Closed Loop - Cross Section

- Maximum of 12 wells connected to a single “run out” circuit
- Piping connections to run out is made 4-5’ below grade
- Continuous length of pipe with factory assembled U-bend fitting heat fused at the base of the well
- After pipe is installed, bore is backfilled with grout



Geothermal Systems Operation

HDPE Pipe with U-Bend Assembly (below)

Vertical Well with Pipe Installed (right - not grouted)

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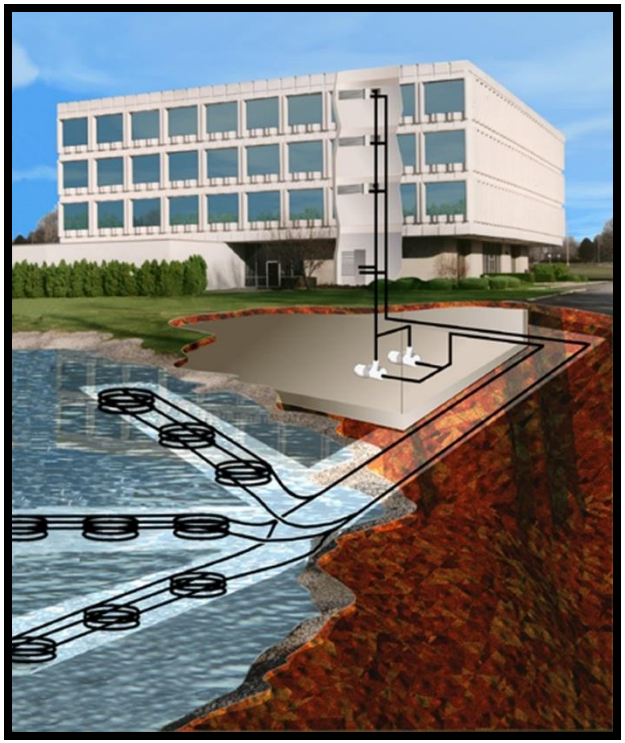
Closed Pond
Traditional Plastic Pipe on Pond Floor

- 300 to 350 feet of plastic pipe per ton
- Pipe coils separated by spacers
- Reverse Return piping
- Float out the pipes and then fill them with water to sink to the floor of the pond
- Labor intensive



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Closed Pond
Geo Lake Plate Heat Exchangers

- Long lasting
- Simplified installation
- Custom configurations
- Lower labor costs

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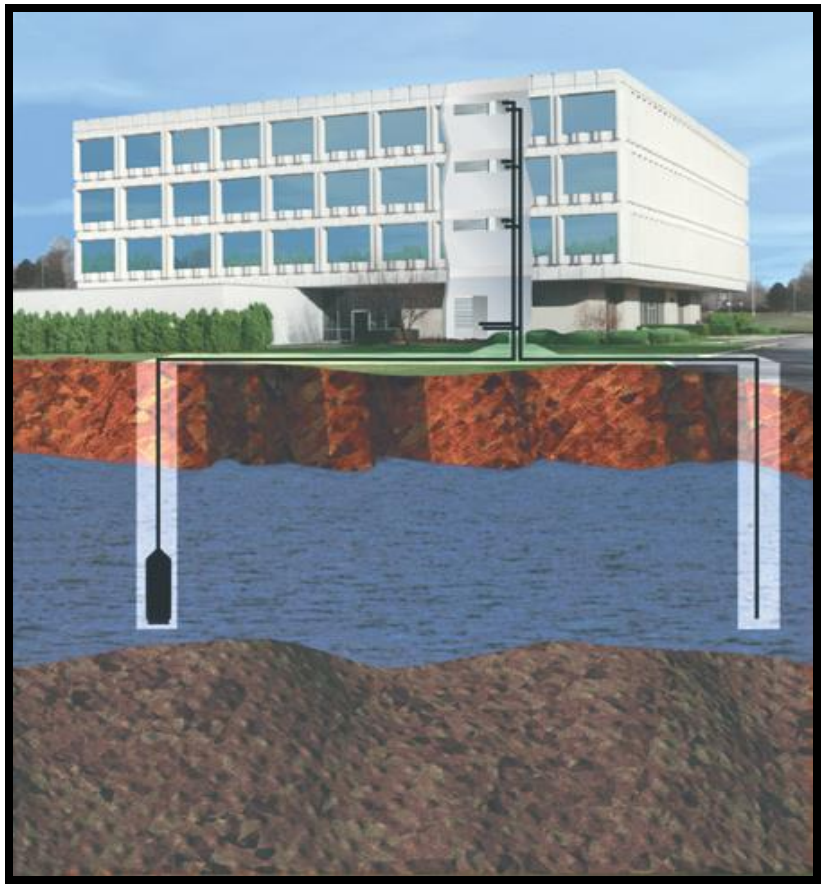
Open Loop

- “Pump and Dump”
- Colder water in cooling
- Filter out debris in the water
- Intermediate heat exchanger
- Water conservation and contamination issues
- Regulatory issues



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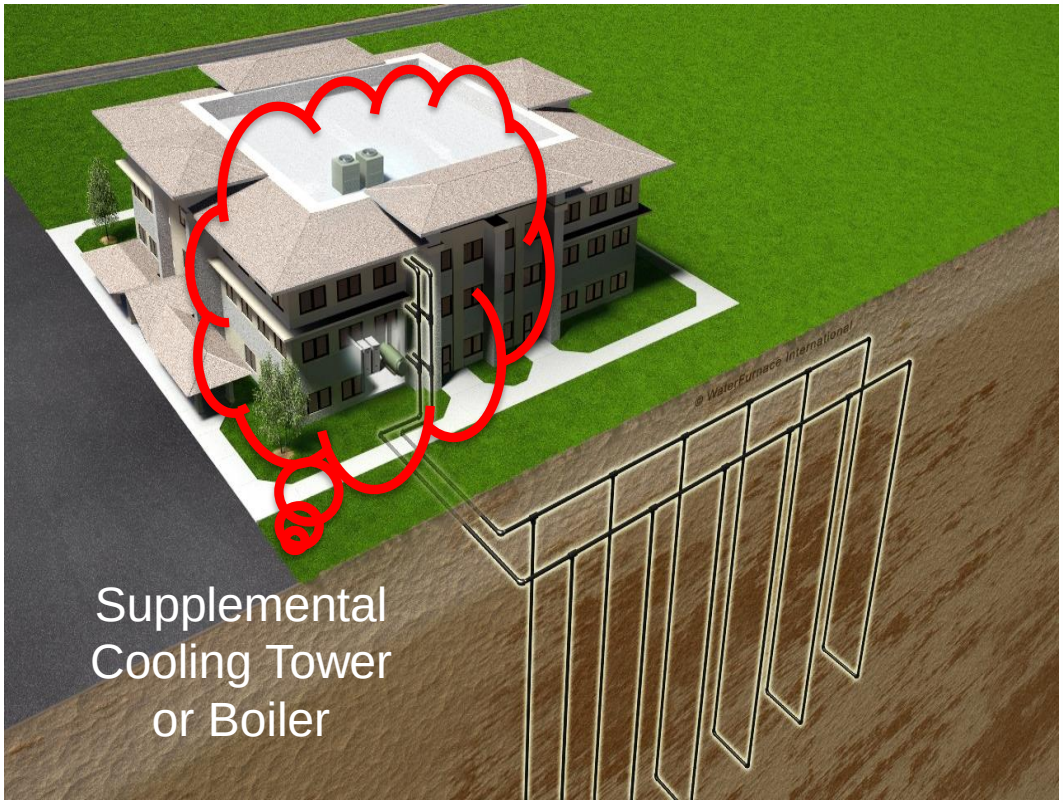
Geothermal Systems Operation

Hybrid Loop

- Minimizes first installed costs by reducing wells
- Maximizes ground loop investment by equalizing heat of extraction and rejection of the system
- Allows adoption of advanced system control strategies for managing energy costs



Earth Coupled Water Loop

- **Hybrid Loop**
  - Any combination of the two – typically a boiler and/or cooling tower attached to a closed loop
  - Lower first cost due to smaller loop
  - Popular with Geo retrofits

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Heat Pumps

Flexibility
- Available Indoor/Outdoor from 0.5-300 Tons

Redundancy
- Each HP Own System

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Heat Pumps

Equipment Cost
- Moderate To High

Installation Cost
- Geothermal (High)
- Water Source (Moderate)
  - Cooling Tower
  - Pumps
  - Boiler

Heat Pumps

Energy Efficiency
- Up To 22 EER
- Heat Recovery
- Modulating Compressors
- ECM/VFD Evaporator Fans

Controls
- BACnet, Lon

Heat Pumps

Maintenance

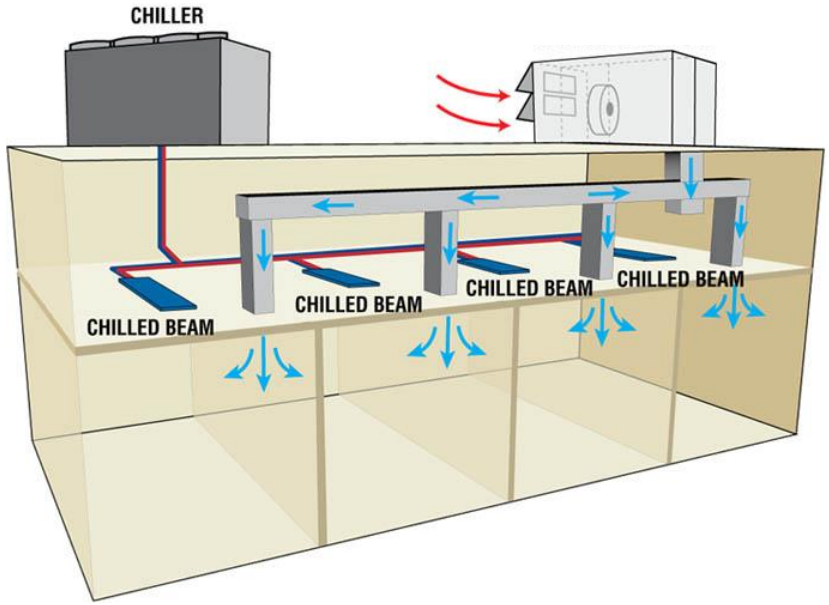
- Indoor Units
  - Removable Panels For Filter, Fan, Coil Access
  - Clean Filter
  - Check Fans
  - Check/Clean Fan, Coil, Cond Drain, Comp, Elect Conn
- Cooling Tower
  - Check/Clean Fan, Coil, Water Quality, Chemicals
- Boiler
  - Check/Clean Burner, Water Quality, Elect Conn
- Well Field
  - Check/Clean Strainers, Water Quality
- Units Can Be Replaced With Different Manufacturers

Chilled Beams

Chilled Beams

System
- Chiller With Pumps
- Boiler With Pumps
- DOAS
- Chilled Beams

Comfort
- Variable Speed Compressors
- Variable Speed Pumping
- No Need For Reheat
- Extreme Low Sound



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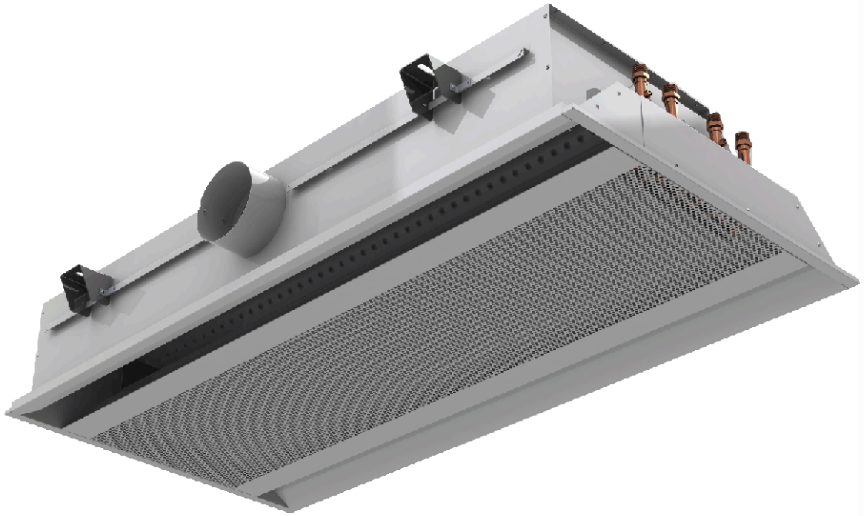
Chilled Beams

Flexibility

- Various Size and Capacity Beams
- 1 Way, 4 Way, Linear With Adjustable Lengths
- Minimum Duct & Pipe



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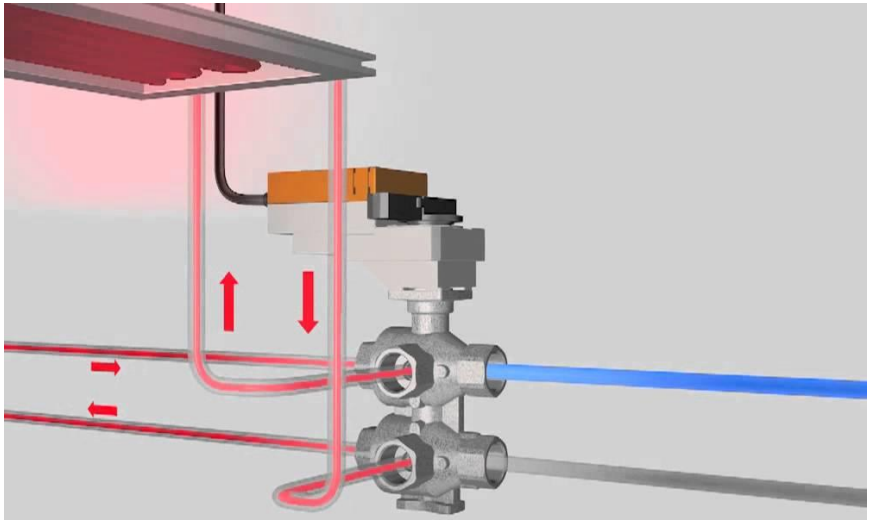
Chilled Beams

Equipment Cost
- Moderate To High

Installation Cost
- Chilled Water / Hot Water Lines
- Can True 4 Pipe Or Changeover 4/2 Pipe
- Primary Power For Chiller, Boiler, Pumps, DOAS
- Low Voltage Power For Controls



Chilled Beams

Energy Efficiency

- Up To 30 EER Chiller
- Heat Recovery
- Modulating Compressors
- Multi Speed Evaporator Fans
- Reduced Fan Power

Controls

- Typical Factory Chiller/Boiler/Pump Controls
- 2/6 Way Valves For Beams

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Chilled Beams

Maintenance

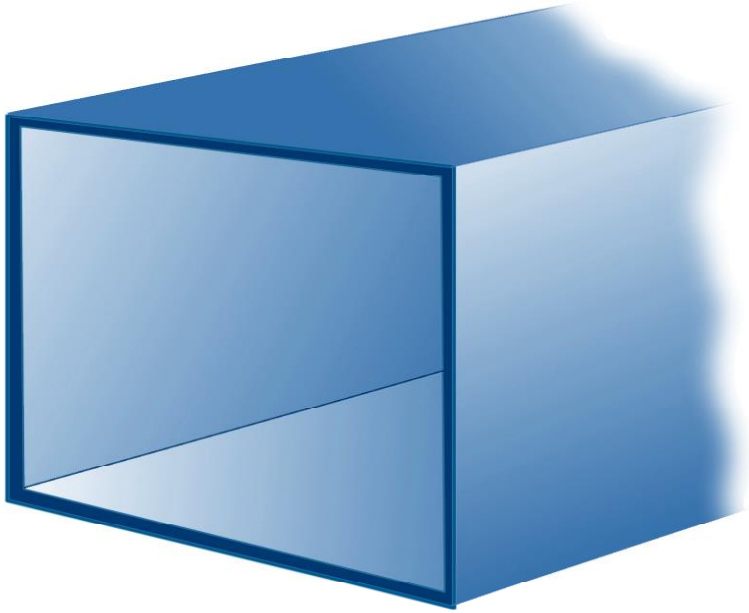
- Beams
  - Inspect Coils
- Chiller
- Boiler
- Pumps

Chilled Beams

- Smaller ductwork and air handling units
  - Reduced vertical (ceiling) space requirements
  - Increased utilization of floor space

14“ x 14“

Air Duct



1“ diameter

Water Pipe

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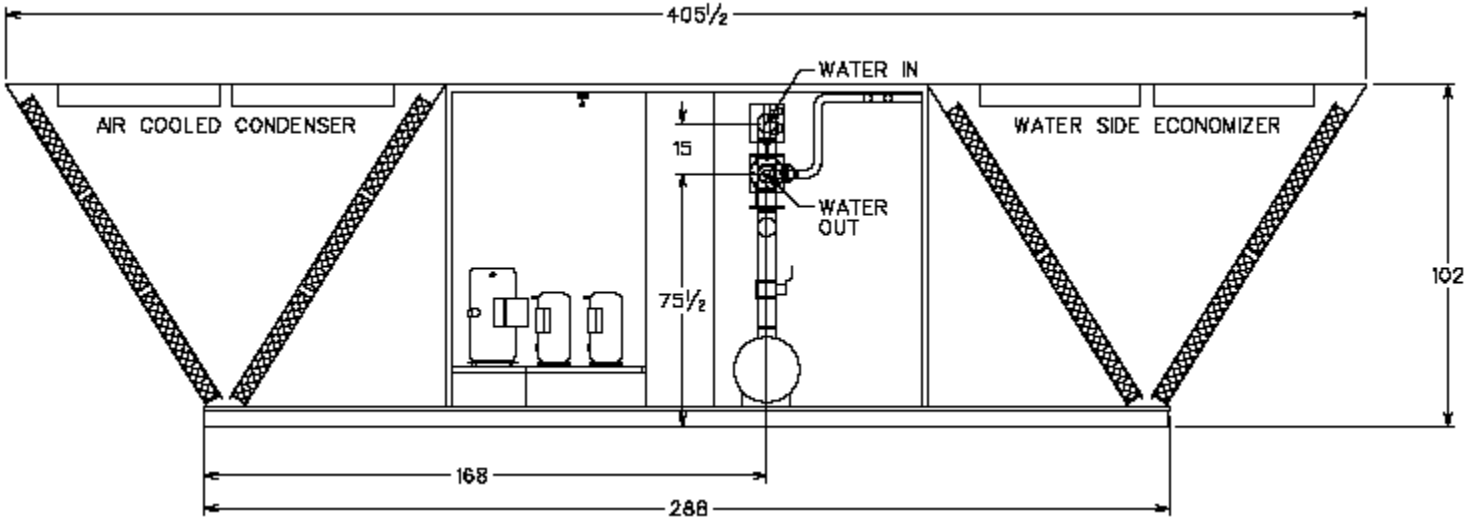
Chilled Beams

- Deliver 57-58°F Water
  - Air Cooled Chiller (Factory Installed Pumping Systems)
  - Geothermal (Minimal Compressor Run Time)
  - Waterside Economizers (Reduce Compressor Run Time)



Chilled Beams

- Deliver 55°F Dehumidified Air
  - Packaged or Air Handlers
  - Vertical or Horizontal
  - Energy Recovery Wheels
  - Desiccant (Below 50°F Dewpoint)

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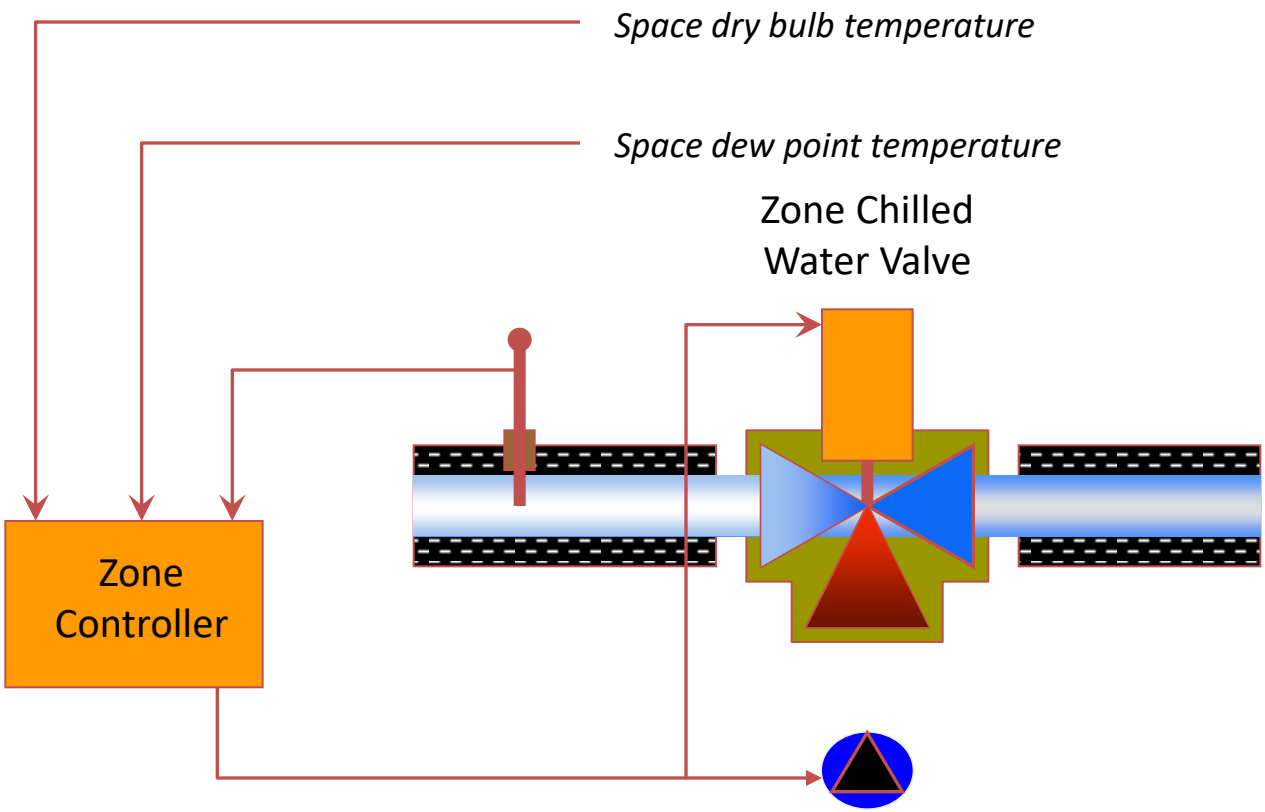
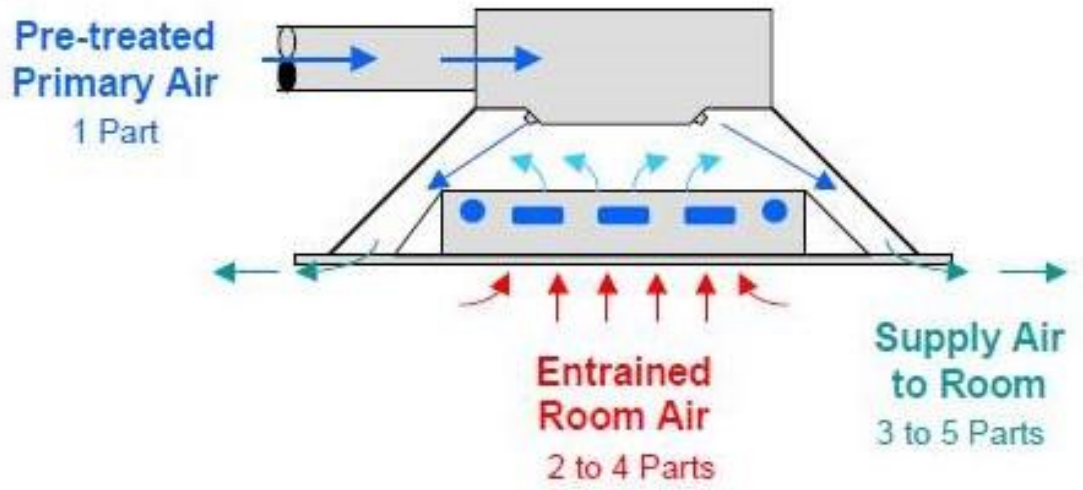
Chilled Beams

May be performed on an individual or multiple zone basis



Chilled Beams



- Combines sensible, latent cooling and ventilation
- Room air induction ratio determined by nozzle size
- Modular design for ceiling integration

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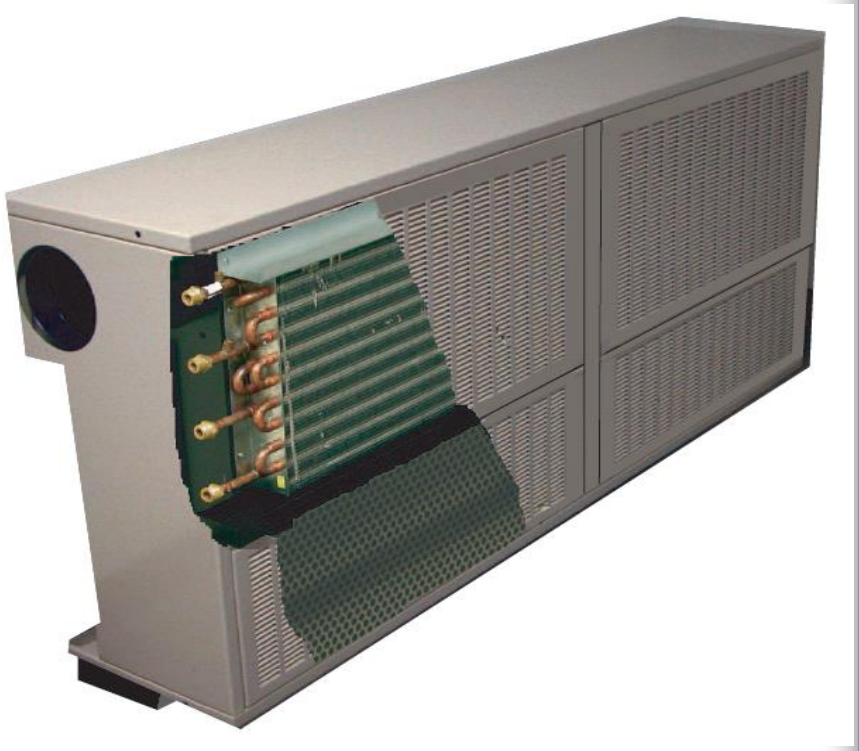
Chilled Beams

- Induction Nozzles
  - **Primary air delivered at 50 to 55ºF**
  - **Mixing within terminal elevates supply air to appropriate temperature**
- Integral Heat Transfer Coil
  - **Room air induced through coil**
  - **Supplements space cooling**
  - **Eliminates separate heating system**



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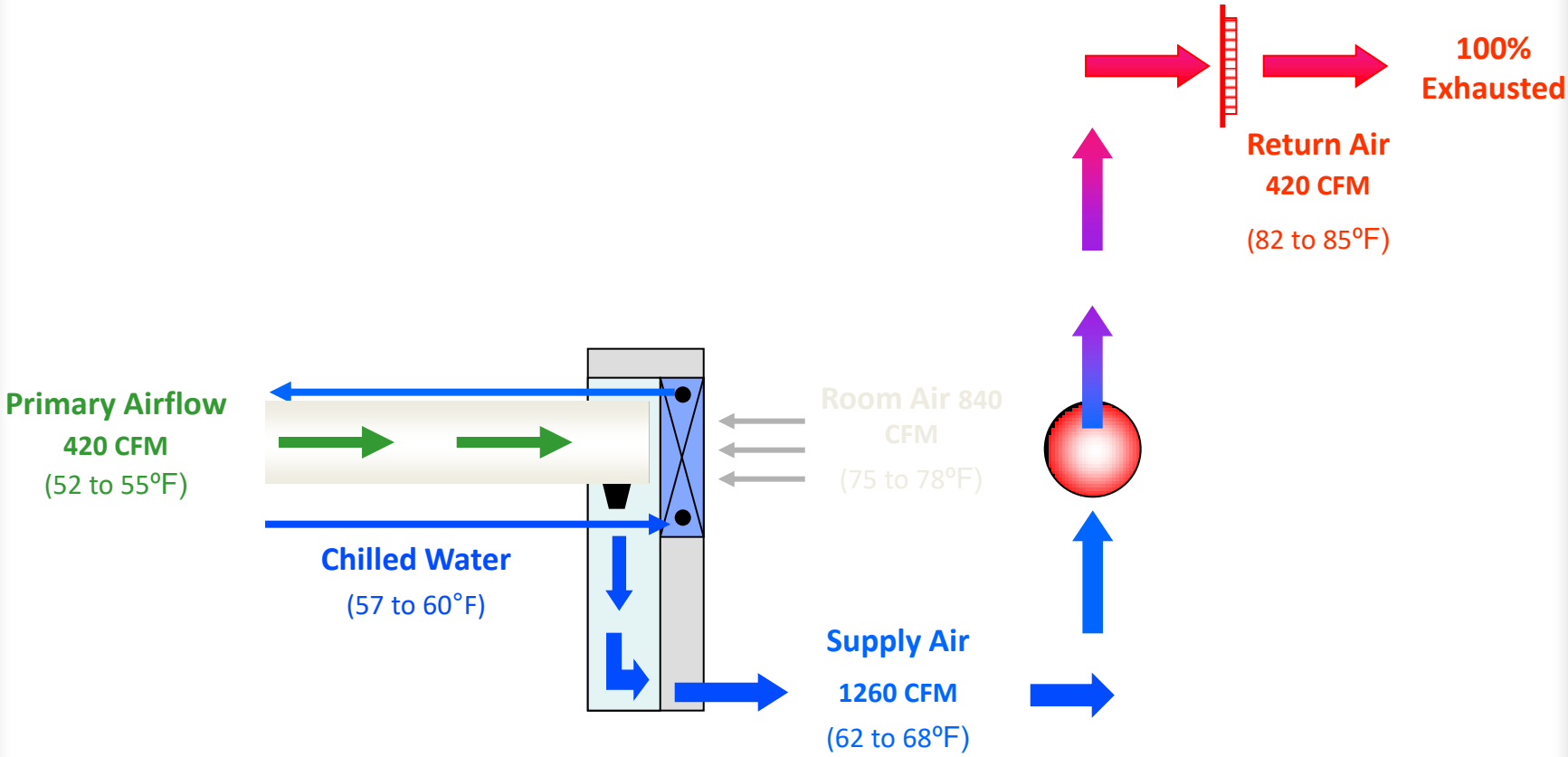
Chilled Beams



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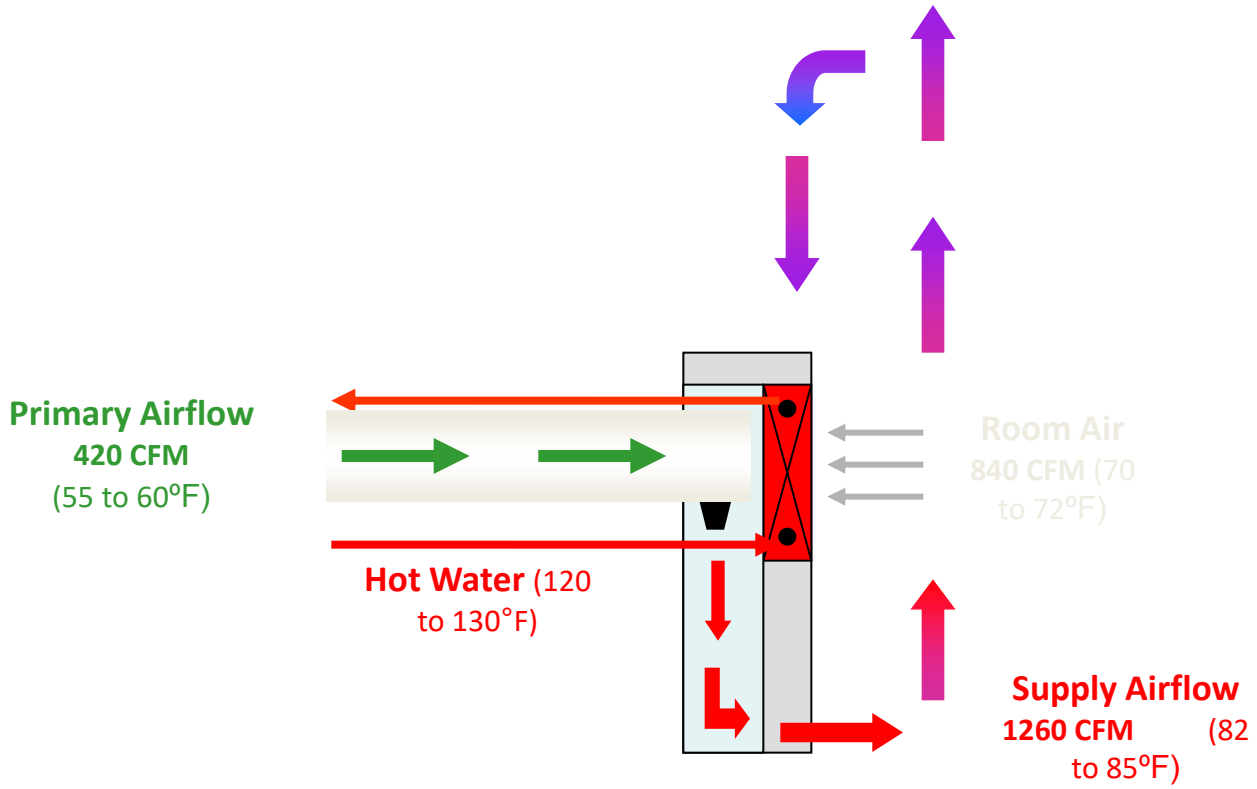
Chilled Beams



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Chilled Beams

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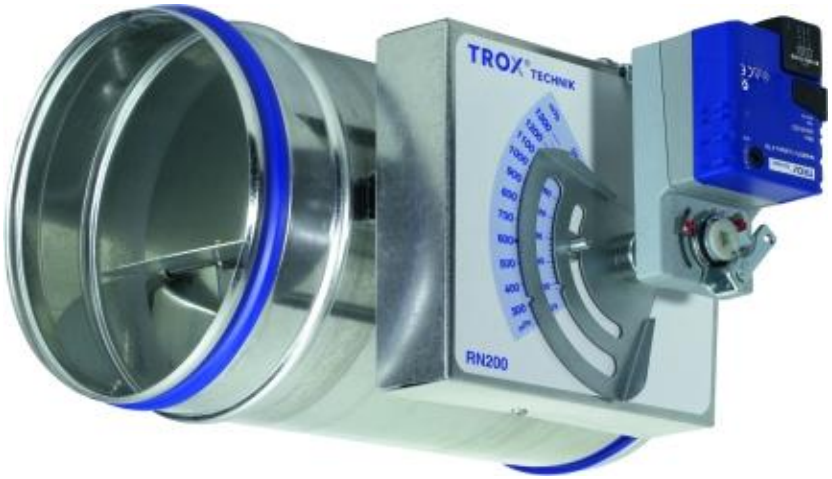
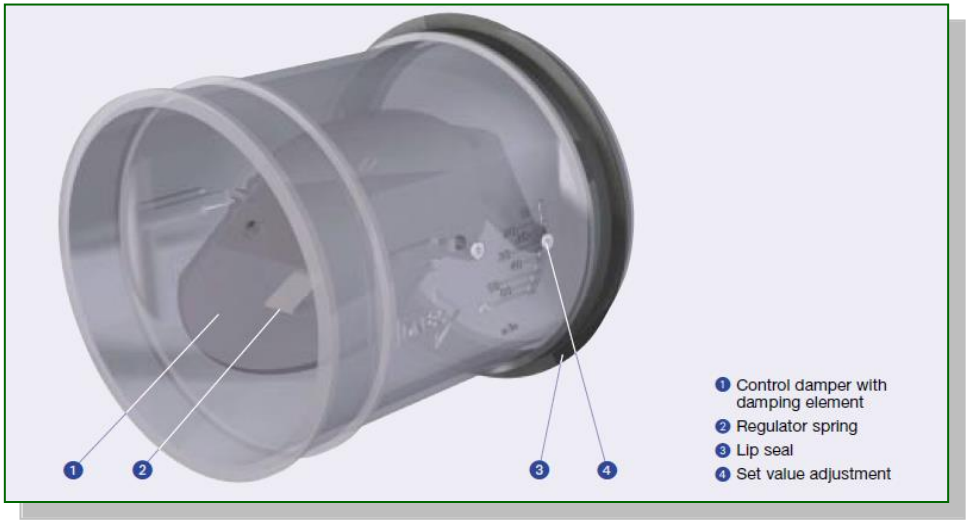
Chilled Beams

Chilled Beams





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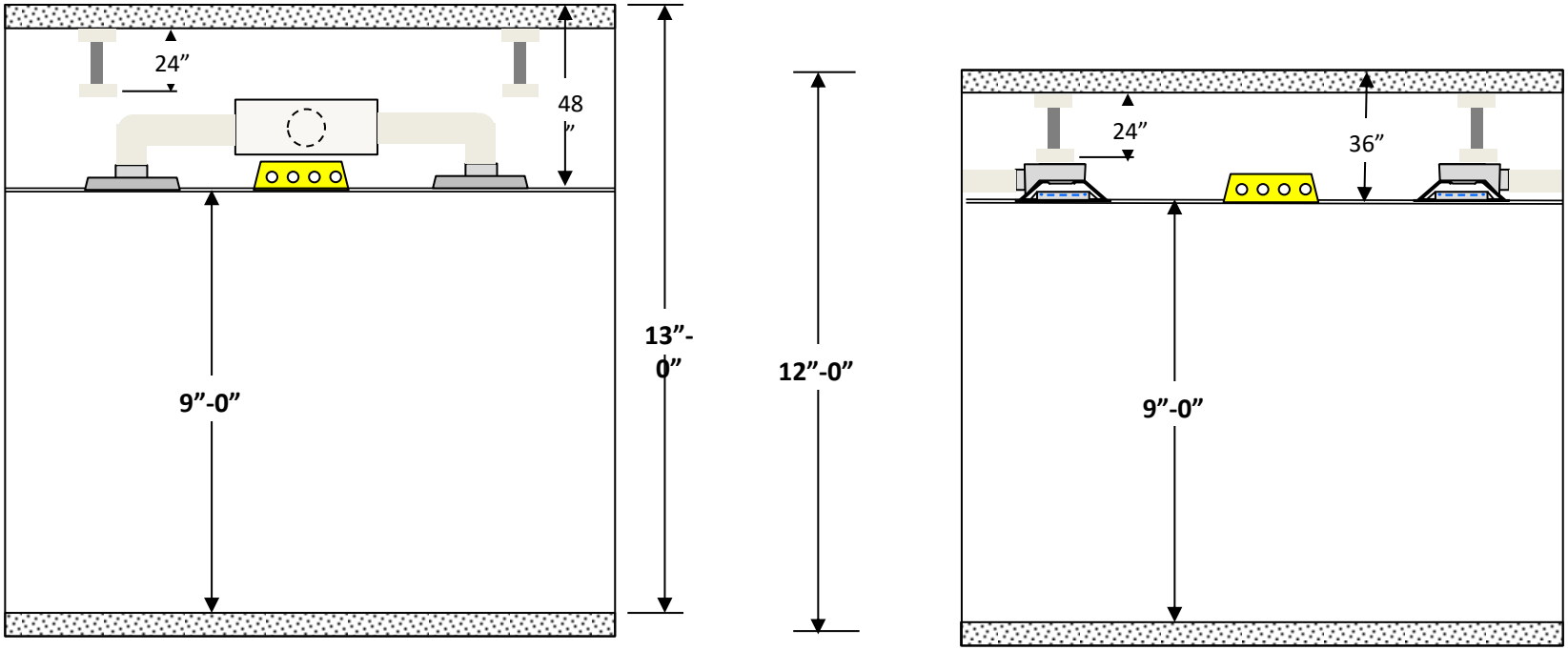
Chilled Beams



Chilled Beams

- Ductwork and component sizes
  - Duct area reduced by 50 % or more
  - Fire and smoke dampers smaller
  - Supply and return chases reduced by 50%
- Air handling unit size reduced
  - AHU footprint reduced by 30 to 40%
  - Potential increase in usable floor space

JACCO

Chilled Beams

Air handling unit savings

- Design BHP reduced by 50%
- Annual fan energy savings of 30 to 40%

Chiller savings

- Dependent upon chiller strategy
- Higher return water temperature to chiller increases COP by 2 to 4%
- Dedicated chiller COP's increased by 25 to 30%

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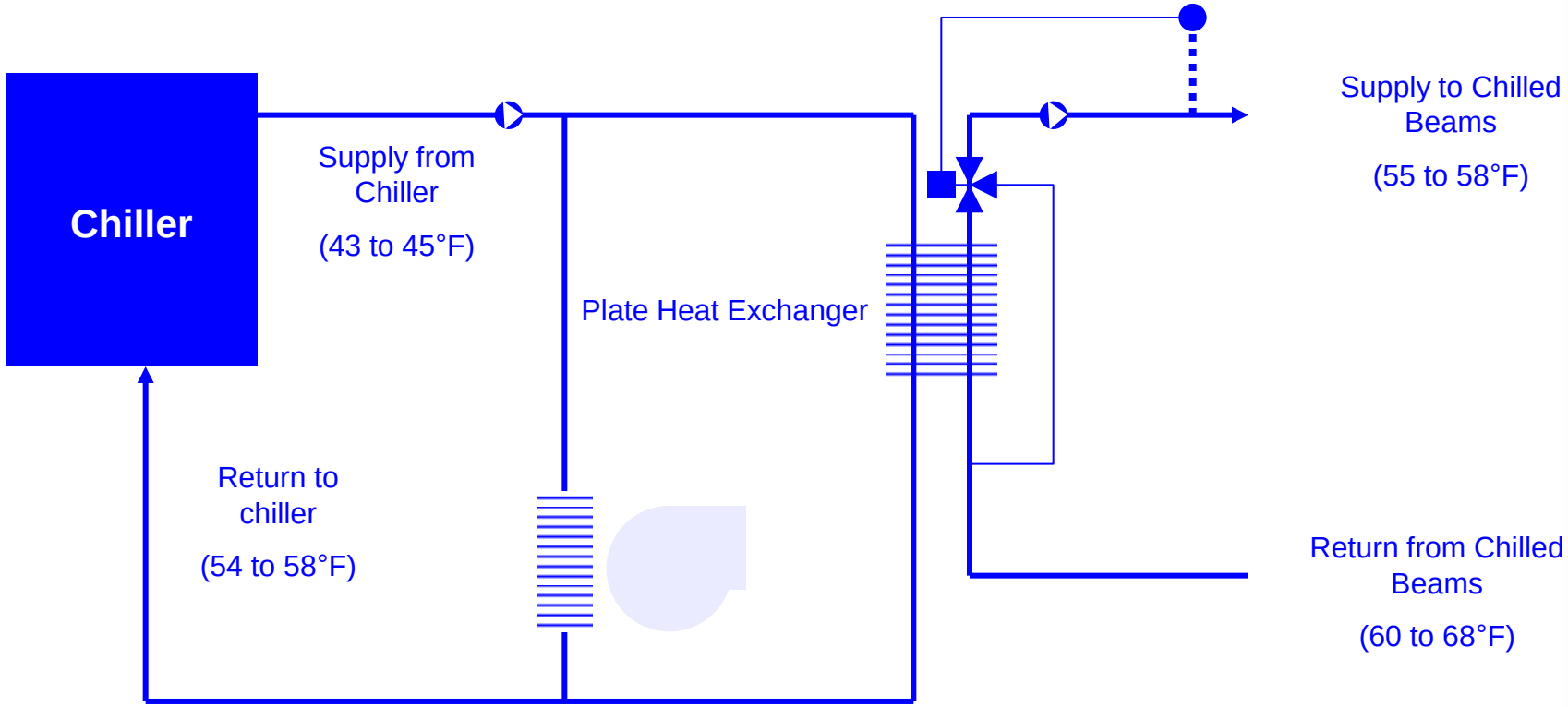
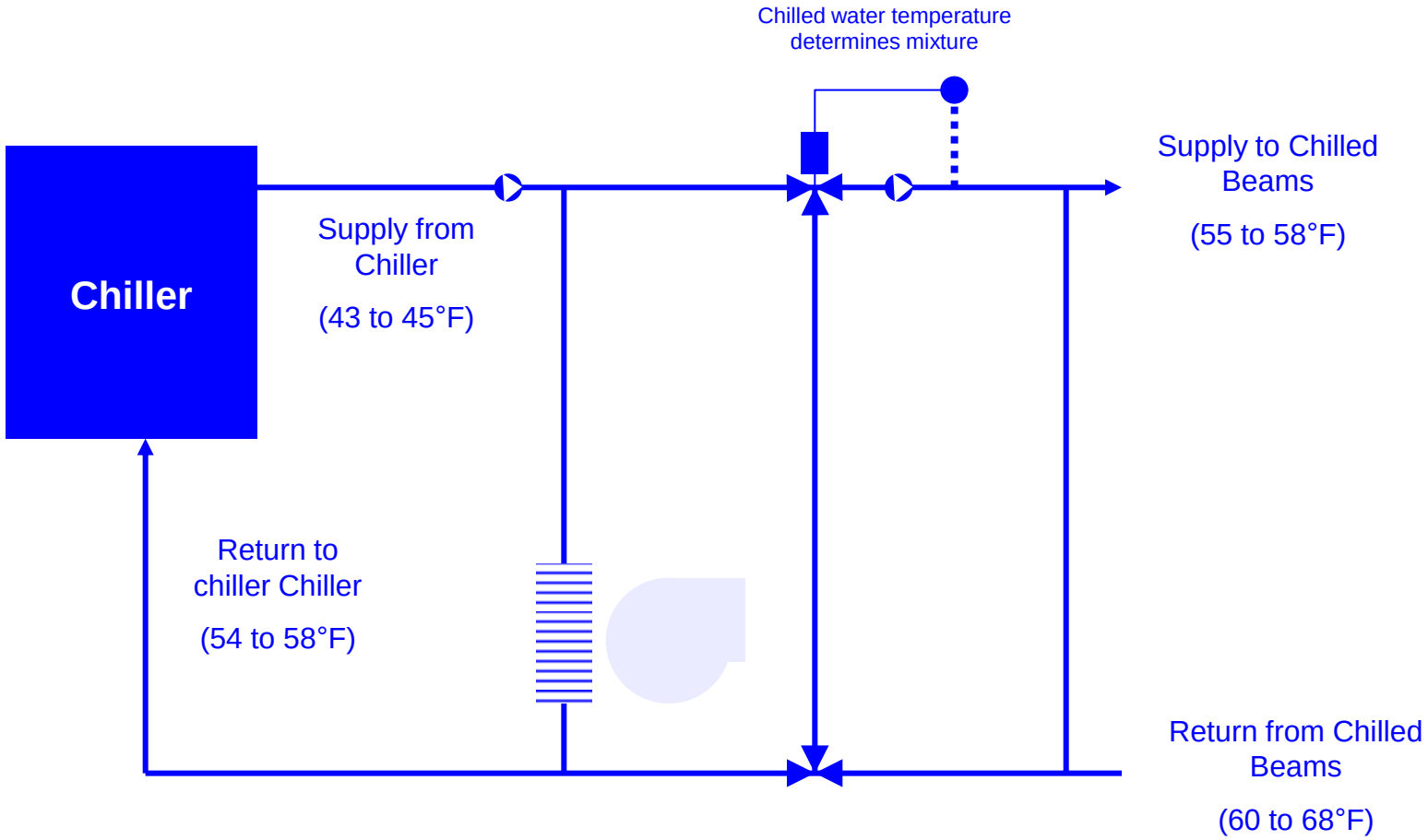
Chilled Beams – Closed Loop, Shared Chiller



Chilled Beams – Open Loop, Shared Chiller



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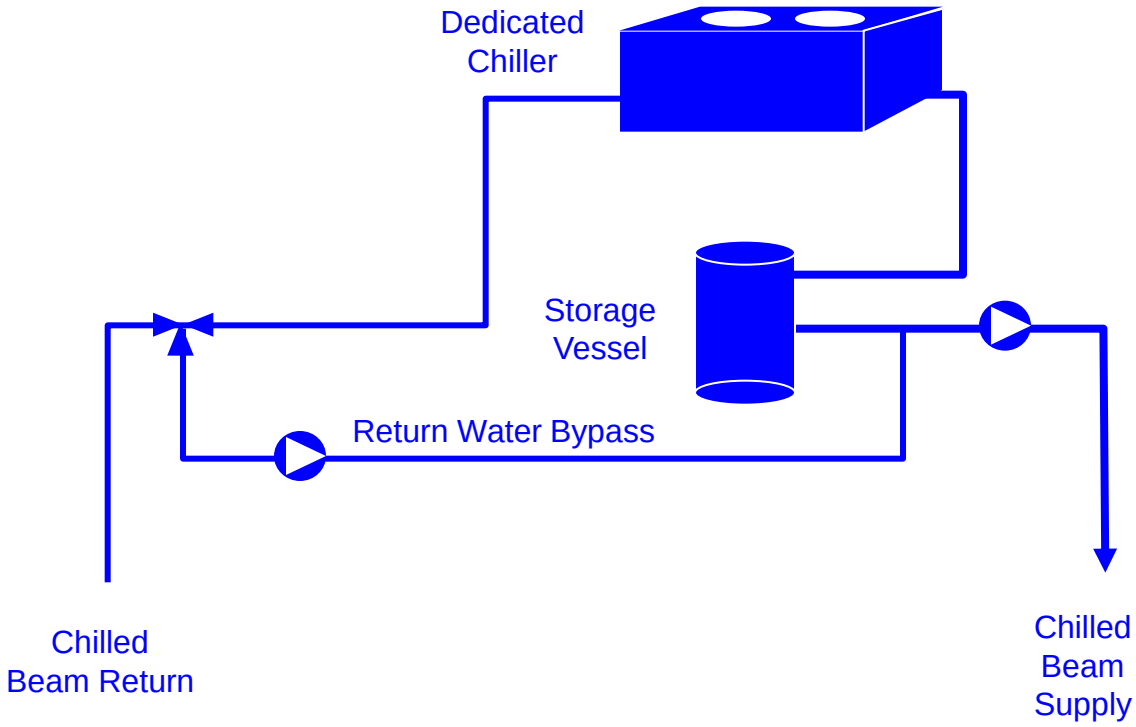
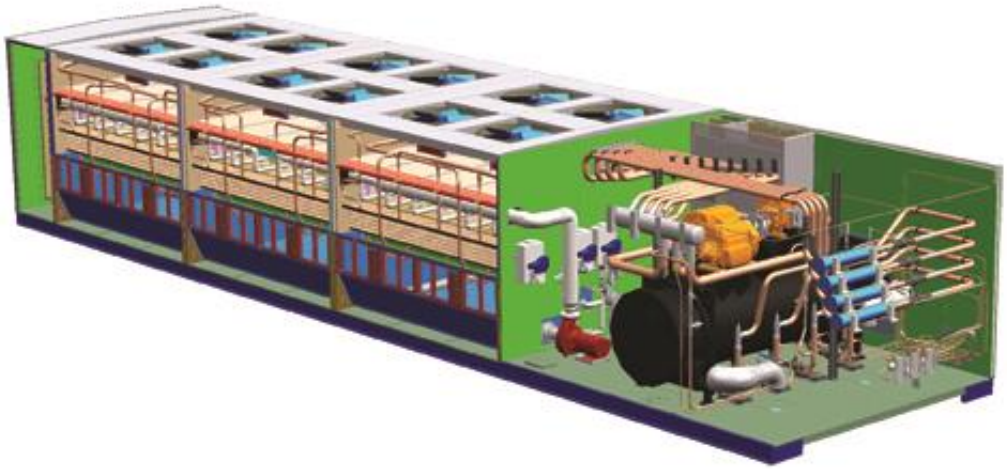
Chilled Beams – Dedicated Chiller



Chillers

- Evap Cooled Chiller
  - Less Water Cooling Tower
  - Less Energy Air Cooled
- TurboCor Compressor
  - High Energy Efficiency
  - Decreased Maintenance
- Factory Pump Package
  - Redundant Pumps
- Boiler
  - Factory Installed



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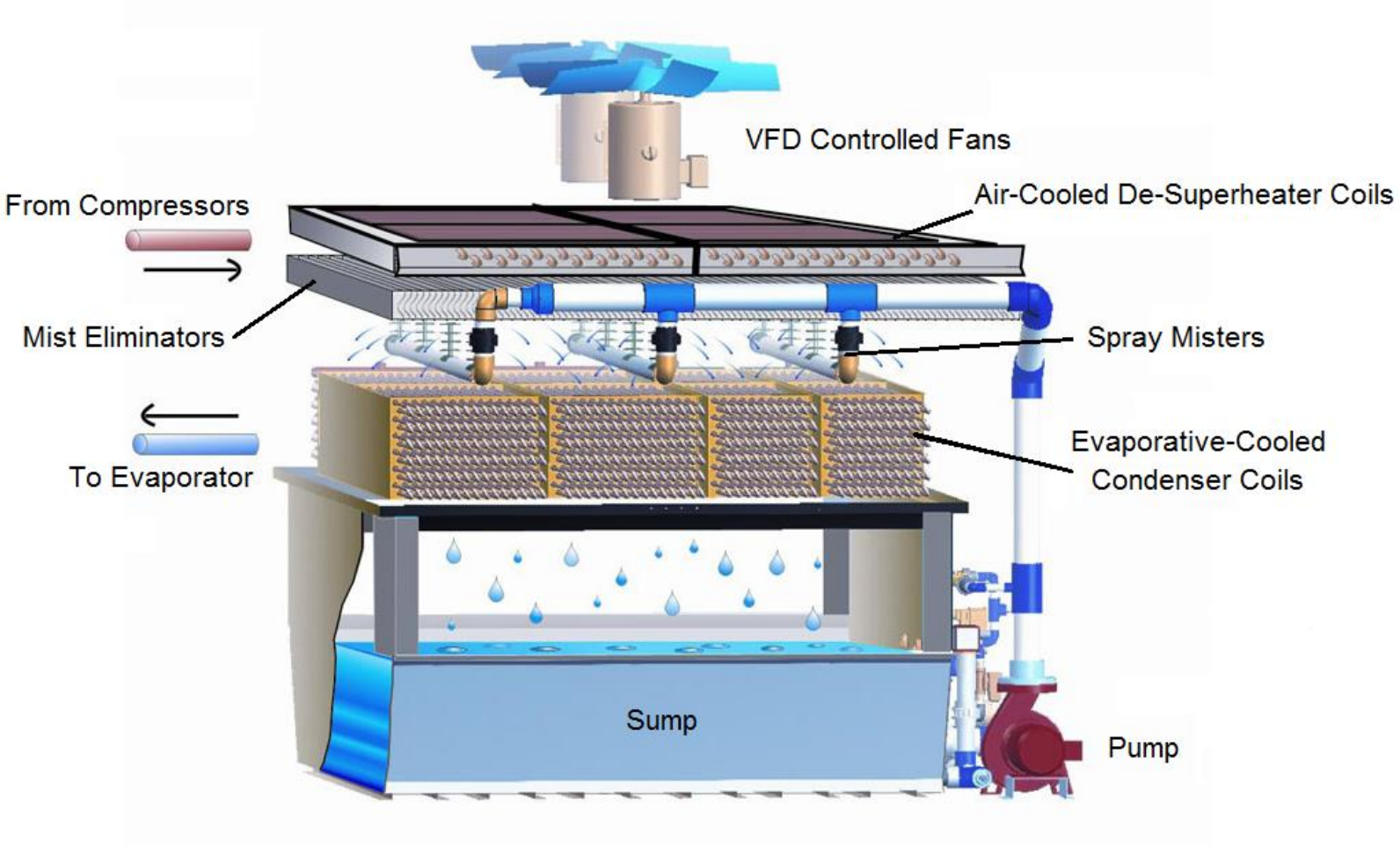
Chillers

- Samsung DVMS Simultaneous Chilled/Hot Water
  - 10 & 15 Ton Capacities
  - Up To 16 Modules
  - System Redundancy
  - Cooling 14-77F
  - Heating 77-130F
  - 60dBA
  - Compact Design

Chillers

- Water Furnace Modular Chiller/Boiler
  - Simultaneous Heat & Cool
  - Modular With Redundancy
  - Multiple LWTs
  - Water Cooled

Chilled Beams



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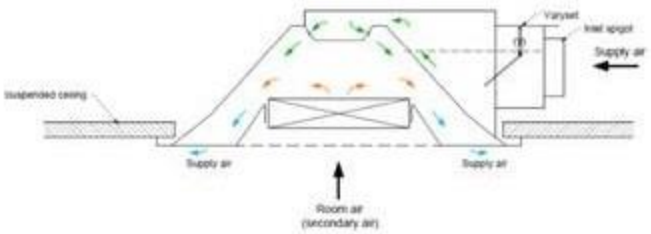
Chilled Beams

Basic concept of initial prototypes

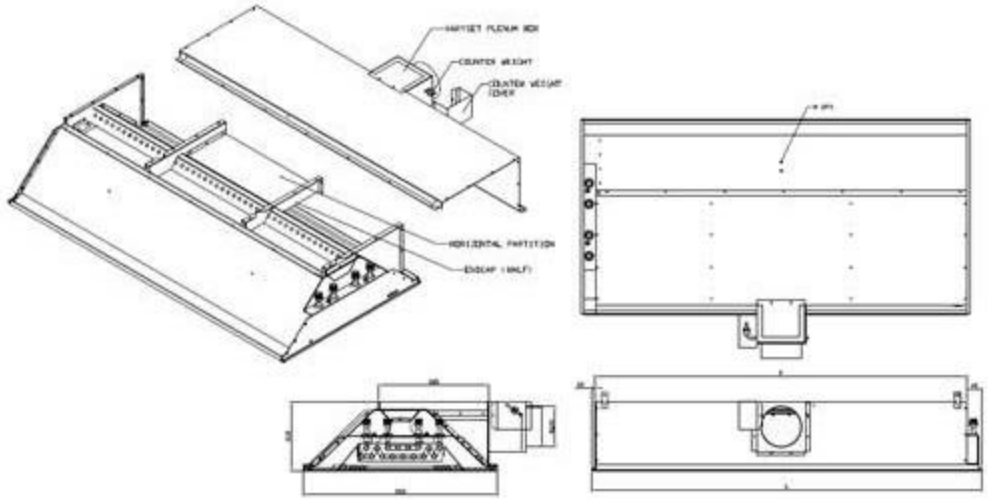


First concept was dividing beam in 3 chambers

Full flow = 3 chambers

Partial flow = 3 chambers in partial flow

Minimum flow = 1 chamber at their full flow



Chilled Beams

Figure 1: With Varyset; V= 15 l/s; Δt= - 12 K
Coanda Effect is maintained.

Figure 2: Without Varyset; V= 15 l/s; Δt= - 12 K
Dumping is evident.

Variable Refrigerant Flow

VRF

System
- Heat Pump/Heat Recovery Units
- Fan Coil Units
- Mode Change Units
- DOAS

Comfort
- Multi Speed Fans
- Electronic Expansion Valves
- Variable Speed Compressors
- 100% Heat Capacity Available To -13F

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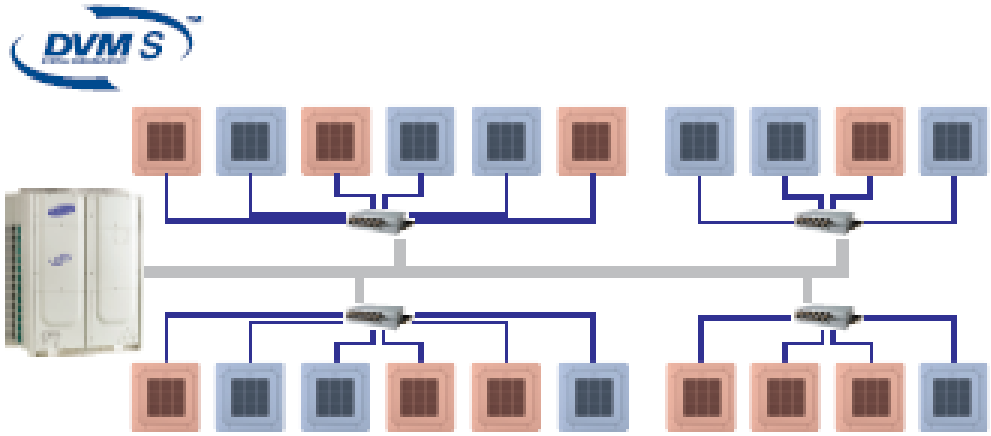
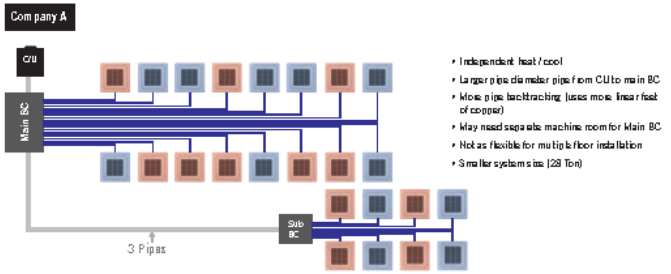
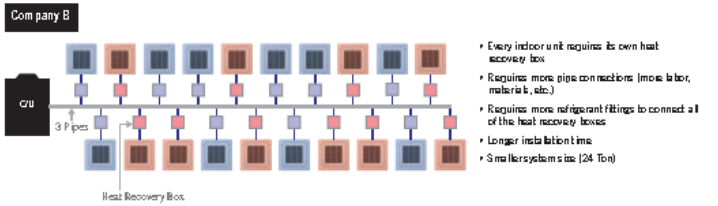
VRF



- Totally independent indoor unit heating and cooling operation (simultaneous heating and cooling)
- Better heating performance than 2 pipe heat recovery systems at low ambient temperatures (liquid / gas mixture type)
- Less refrigerant pipe backtracking
- Flexible installation with 4 and 6 port MCU options (can connect 1 – 6 indoor units to MCU's)
- Highest simultaneous heat and cool efficiency
- Lower installation and running energy cost





VRF

Flexibility

- 20 Heat Recovery Systems Available From 6 to 44 Tons
- Heat Pumps Can Be Indoor/Outdoor and Air Cooled/Water Cooled
- 13 Indoor Models From 0.5 to 8 Tons
- Diversity Range 50-130% Capacity
- 656’ Available Piping (130-360’ drop/lift)

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VRF

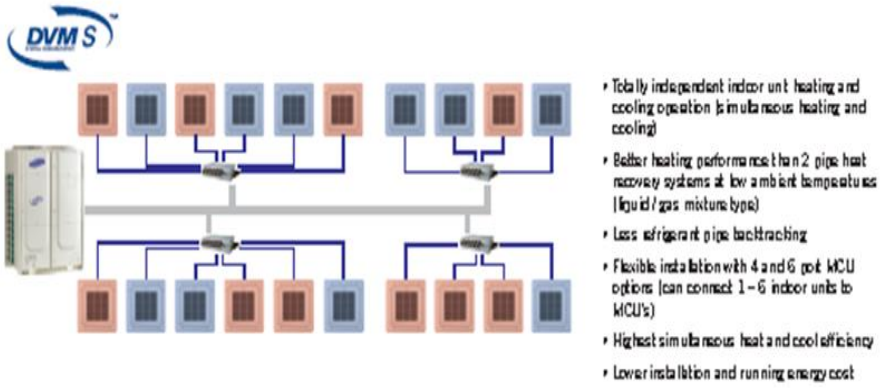
Redundancy

- Each HP/HR Has Minimum 2 Compressors
- Multiple HP/HR Per System
- Multiple Systems Per Project

VRF

Equipment Cost
- Moderate To High
- Depends On Type/Quantity Of FCU

Installation Cost
- Refrigerant Piping
- Three Phase Power For HP
- Single Phase Power For FCU, MCU
- Control Wiring



VRF

Energy Efficiency

- 38 SCHE (Simultaneous Cooling & Heating Efficiency)
- Heat Recovery
- Modulating Compressors
- Multi Speed Evaporator Fans
- Electronic Expansion Valves
- Constantly Compared To Water Source & Geothermal

Controls

- BACnet, Lon
- Touchscreen Or PC Interface

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VRF

Maintenance

- Indoor Units
  - Removable Panels For Filter, Fan, Coil Access
  - Clean Filter
  - Check/Clean Fan, Coil, Cond Drain, Elect Conn
- Heat Pump
  - Check/Clean Fan, Coil, Elect. Connection
- System Diagnostics
- Units Can Not Be Replaced With Different Manufacturers

Thank You!

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