HVAC Systems

Greg Drensky
Vice President

Jerry Cohen
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

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Who is Jacco

- Established 1968
  - Hudson, Ohio
  - Columbus, Ohio
  - Toledo, Ohio
- Focused on the Engineered Environment
- Systems Knowledgeable
  - HVAC Systems
  - Service & Maintenance
  - Parts

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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
  - –Steve Leister
  - –Alicia Patsva
  - –Jeff Watson

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Who is Jacco

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

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Packaged Terminal Air Conditioning (PTAC)

PTAC

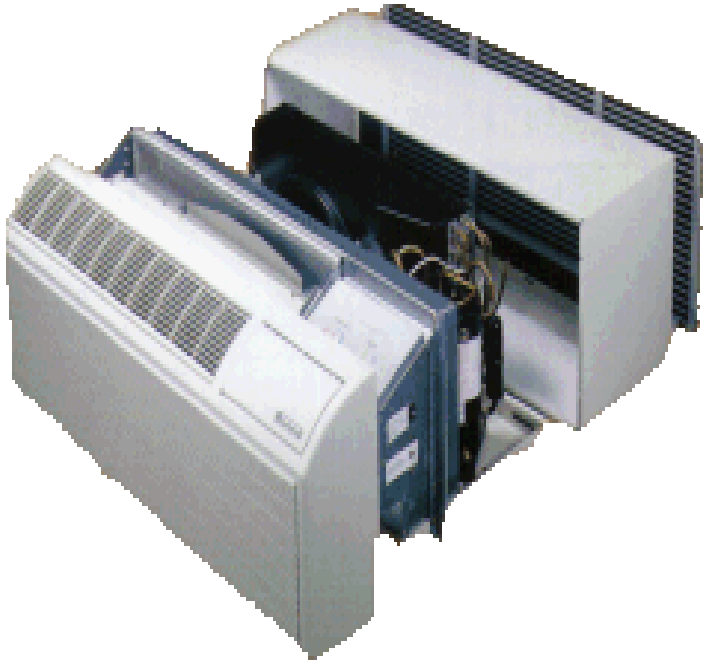
System
- Air Cooled/Heat Pump/Gas Heat
- DOAS
- Separate Systems for Large/Common Areas

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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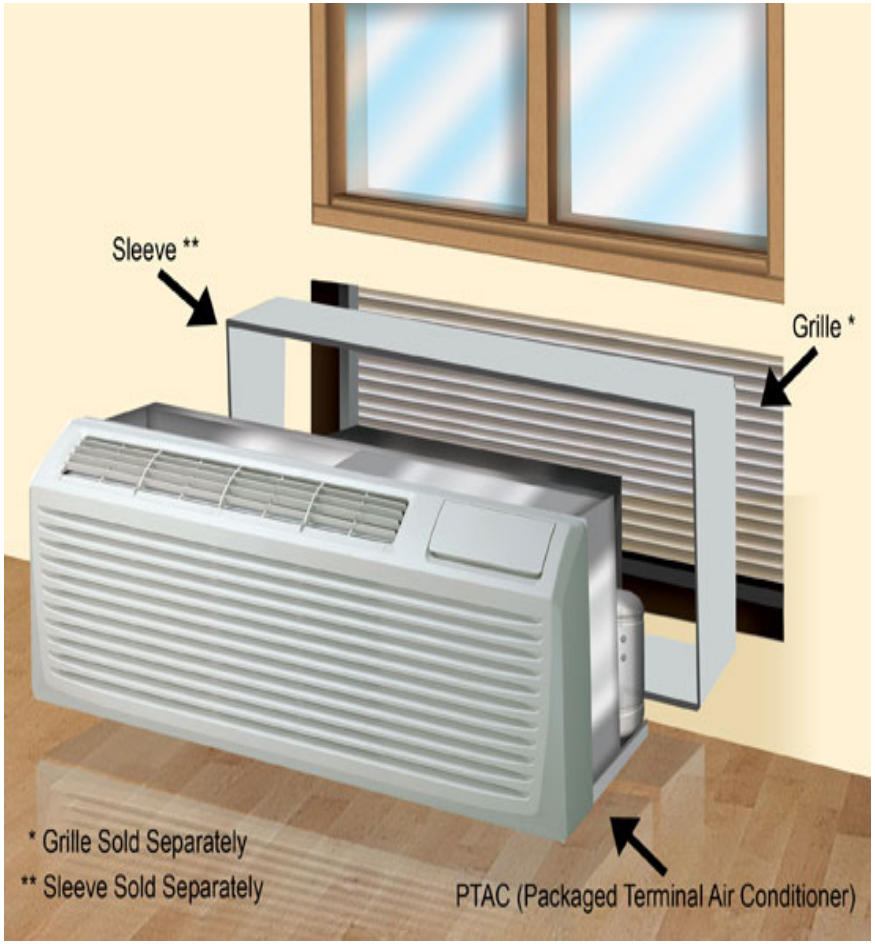
PTAC

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

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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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?

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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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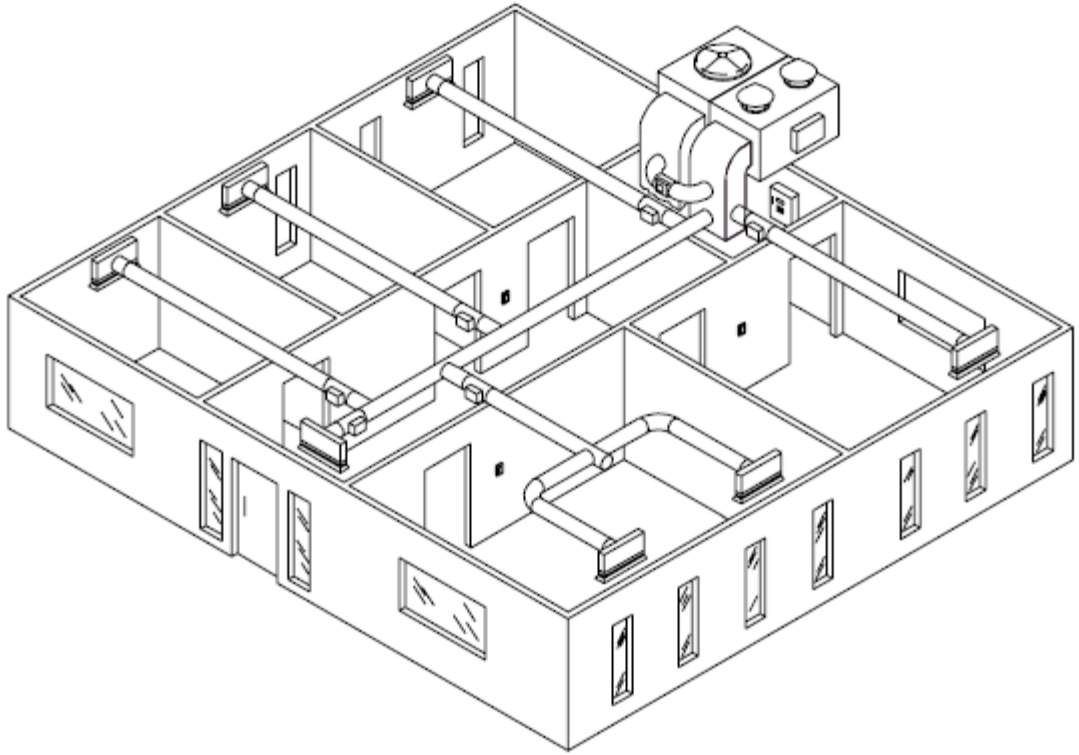
Constant Air Volume (CAV)



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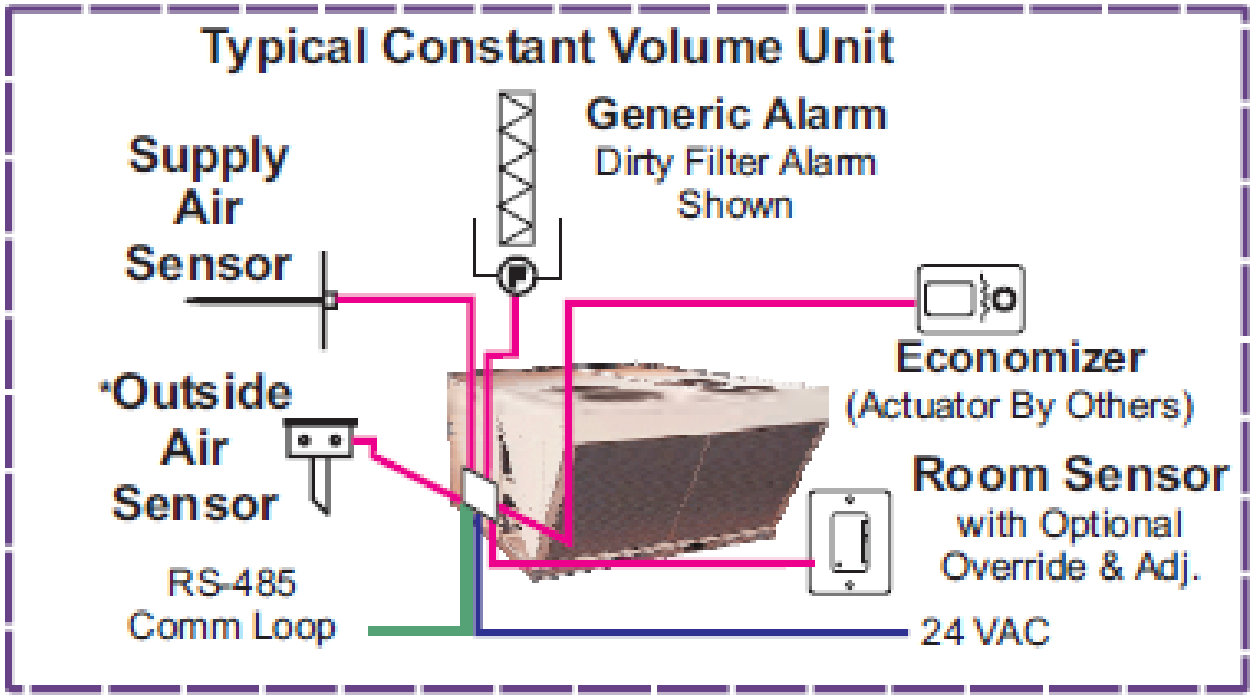
Constant Air Volume (CAV)



Constant Air Volume (CAV)

Applications

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

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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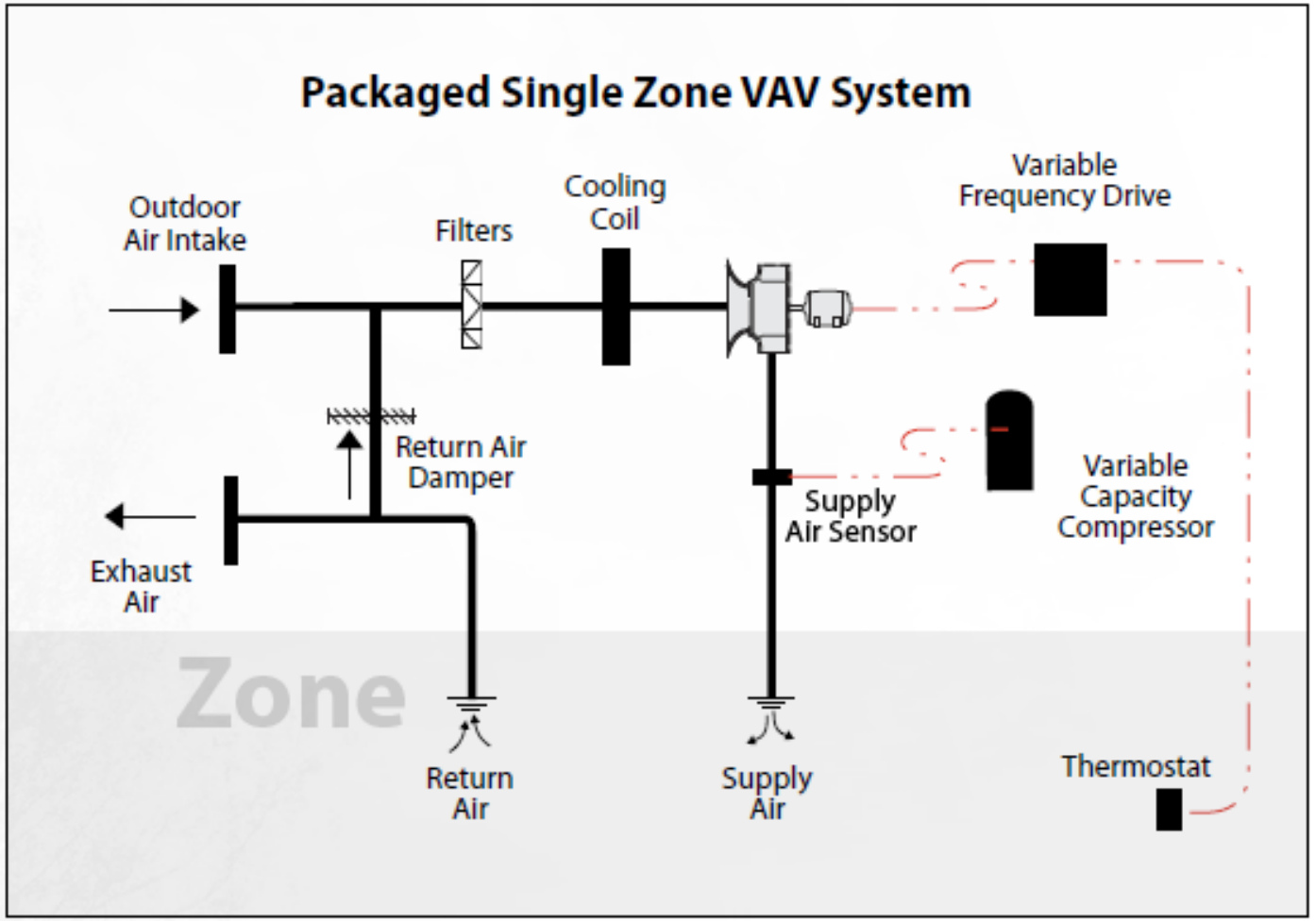
Single Zone Variable Air Volume (SZVAV)



Single Zone Variable Air Volume (SZVAV)

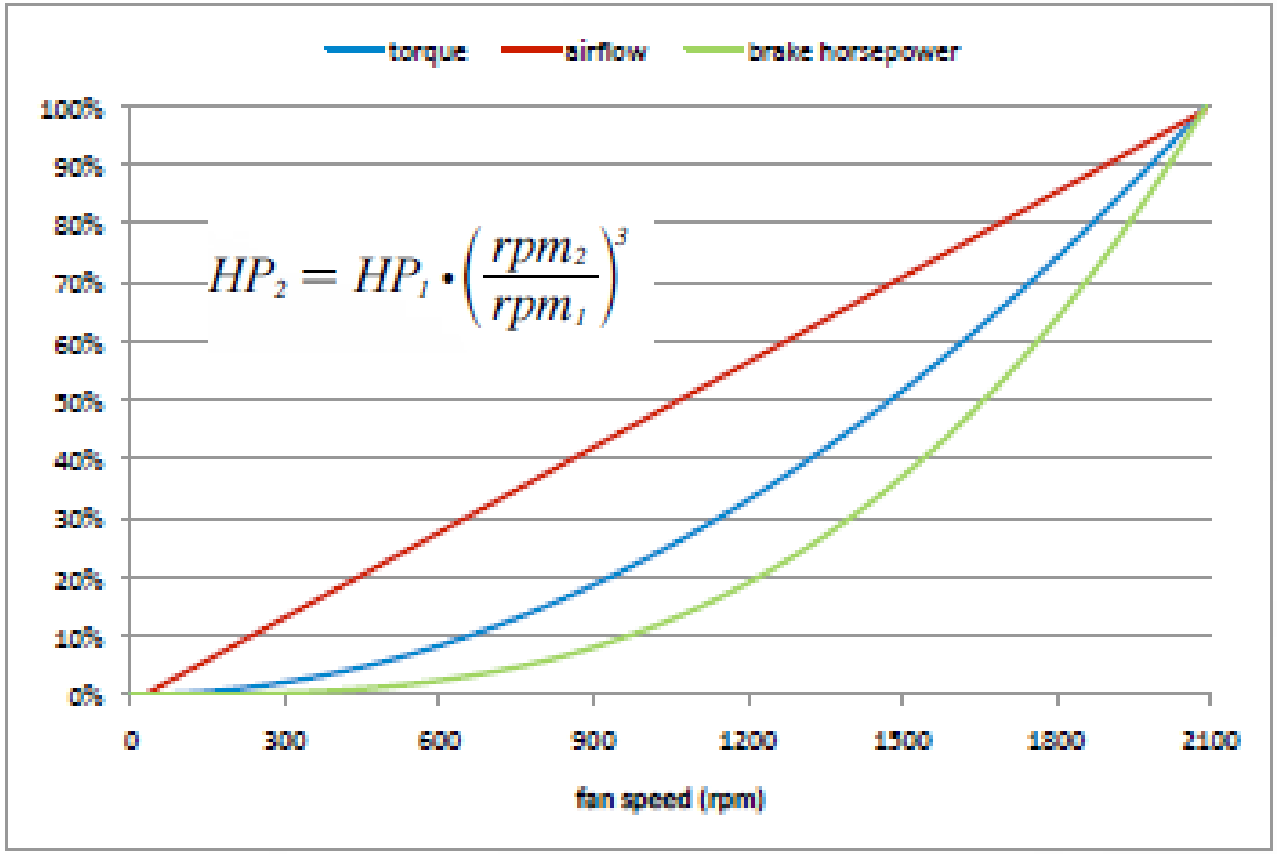


Figure 1: Brake Horsepower, Torque, and Airflow as a Percentage of Full Capacity versus Fan Speed

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Single Zone Variable Air Volume (SZVAV)

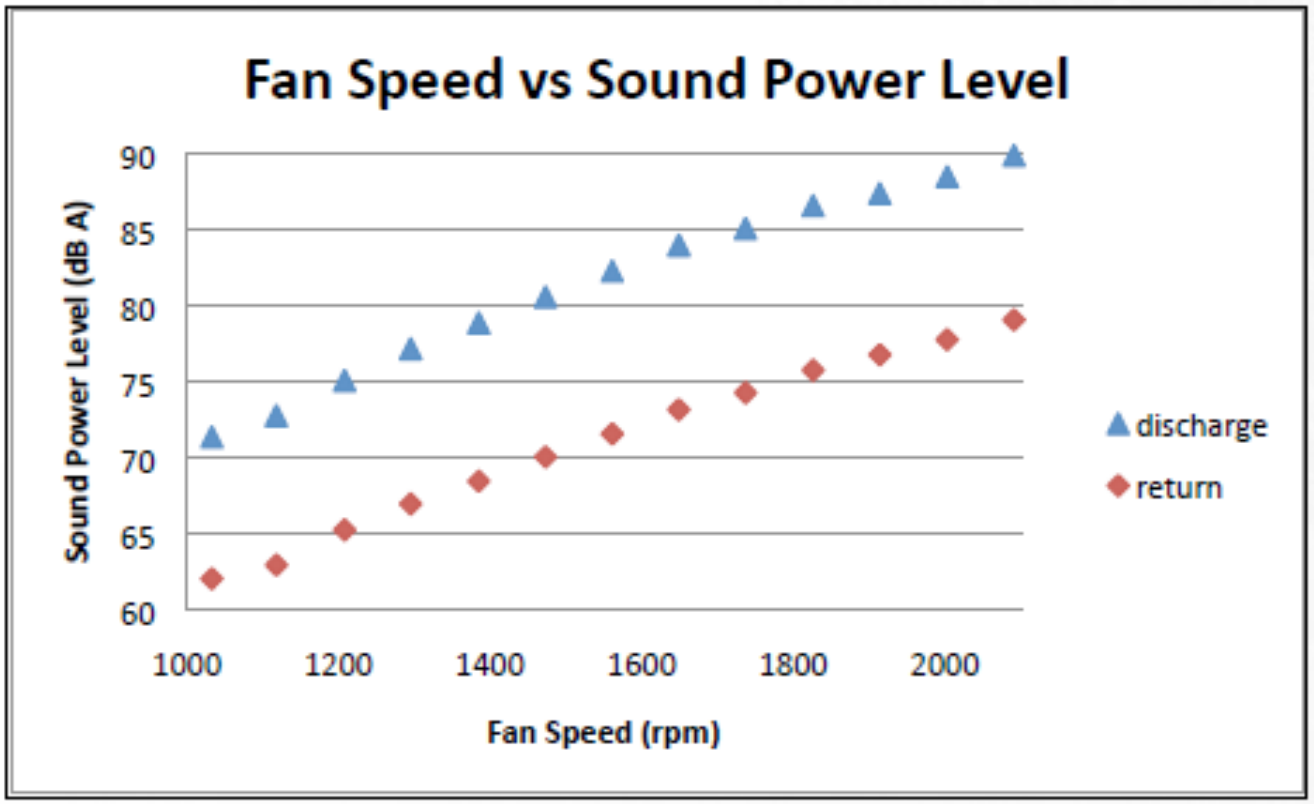

Figure 11: A-weighted Sound Power Level versus Fan Speed

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Single Zone Variable Air Volume (SZVAV)

Room Sensible Heat Ratio	Constant Volume			Single Zone VAV		
	Relative Humidity	Latent Cooling (Btu/hr)	Airflow (cfm)	Relative Humidity	Latent Cooling (Btu/hr)	Airflow (cfm)
0.80	51.0%	27,000	3,000	51.0%	27,000	3,000
0.75	59.7%	23,541	3,000	50.0%	27,347	2,000
0.70	66.3%	20,887	3,000	51.9%	26,604	1,500
0.65	71.5%	18,817	3,000	52.0%	26,565	1,000
0.60	75.7%	17,162	3,000	56.4%	24,852	800
0.55	79.1%	15,812	3,000	61.2%	22,923	600

Figure 16: Relative Humidity and Airflow for Varying System Sensible Loads

Room Sensible Heat Ratio	Constant Volume			Single Zone VAV		
	Relative Humidity	Latent Cooling (Btu/hr)	Airflow (cfm)	Relative Humidity	Latent Cooling (Btu/hr)	Airflow (cfm)
0.80	51.0%	27,000	3,000	51.0%	27,000	3,000
0.75	52.9%	31,612	3,000	48.5%	33,368	2,500
0.70	55.3%	36,847	3,000	51.3%	38,415	2,500
0.65	58.0%	42,887	3,000	50.9%	45,714	2,000
0.60	61.2%	49,934	3,000	55.2%	52,320	1,900
0.55	64.9%	58,262	3,000	61.1%	59,784	1,900

Figure 18: Relative humidity and Airflow for Varying System Latent Loads

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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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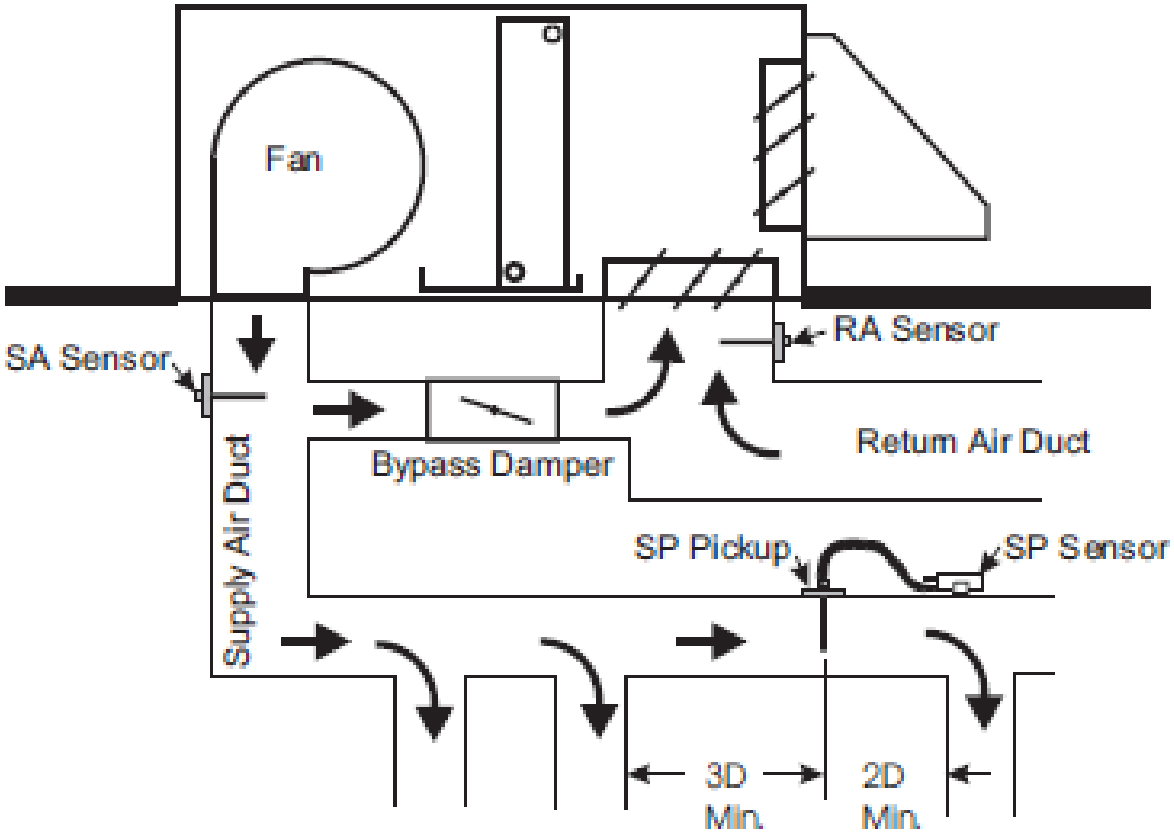
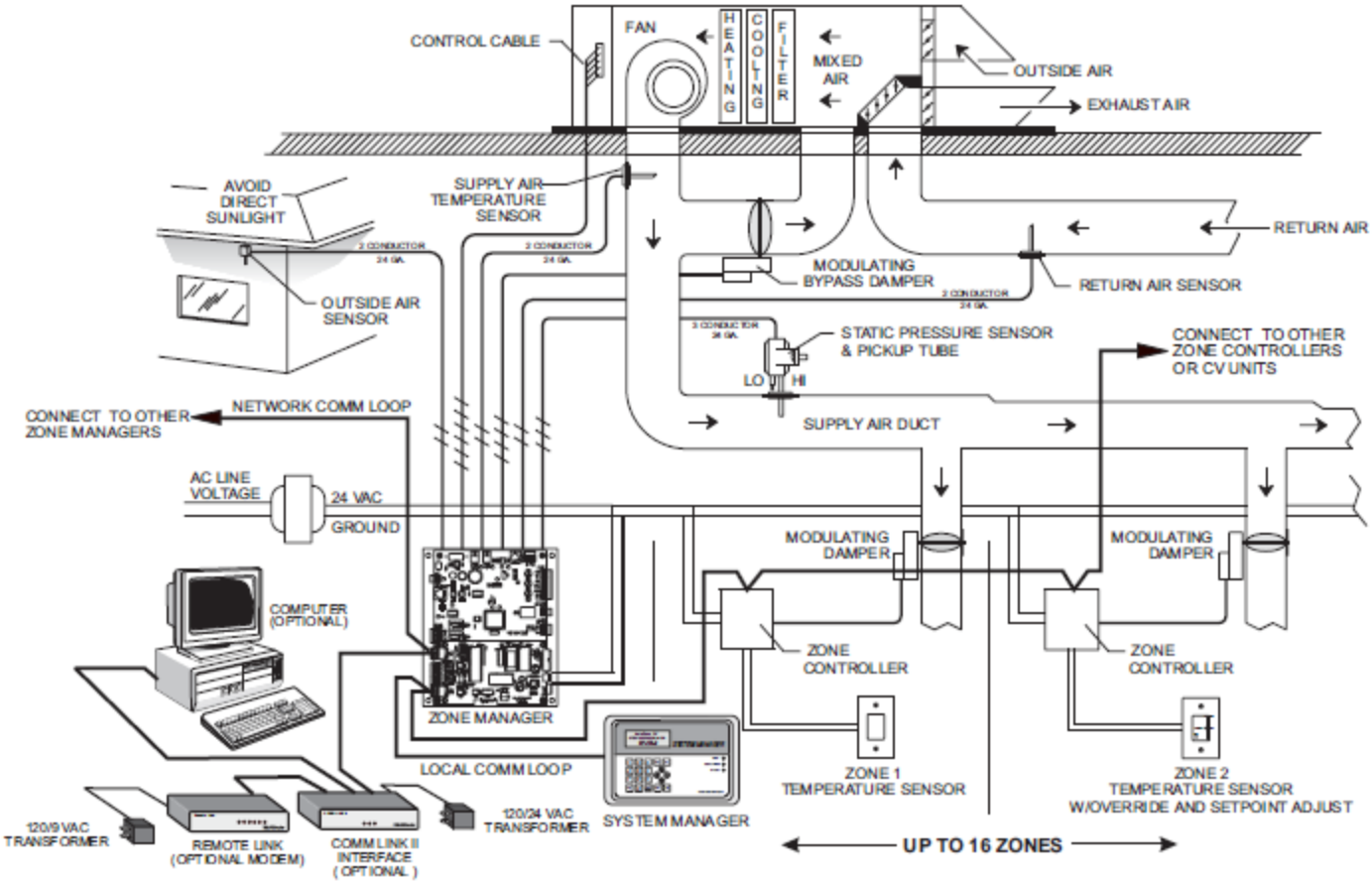
Variable Volume & Temperature (VVT)



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

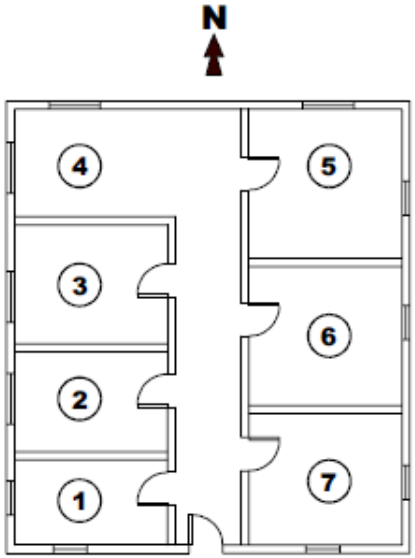

Figure 1-3: Zone Layout With External Zones Only.

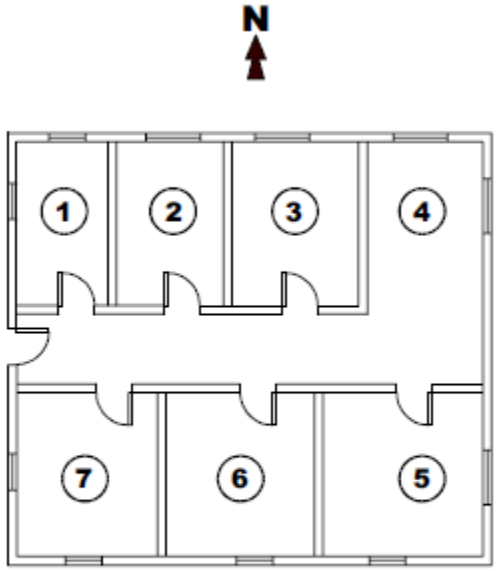

Figure 1-4: Zones With North And South Exposures.

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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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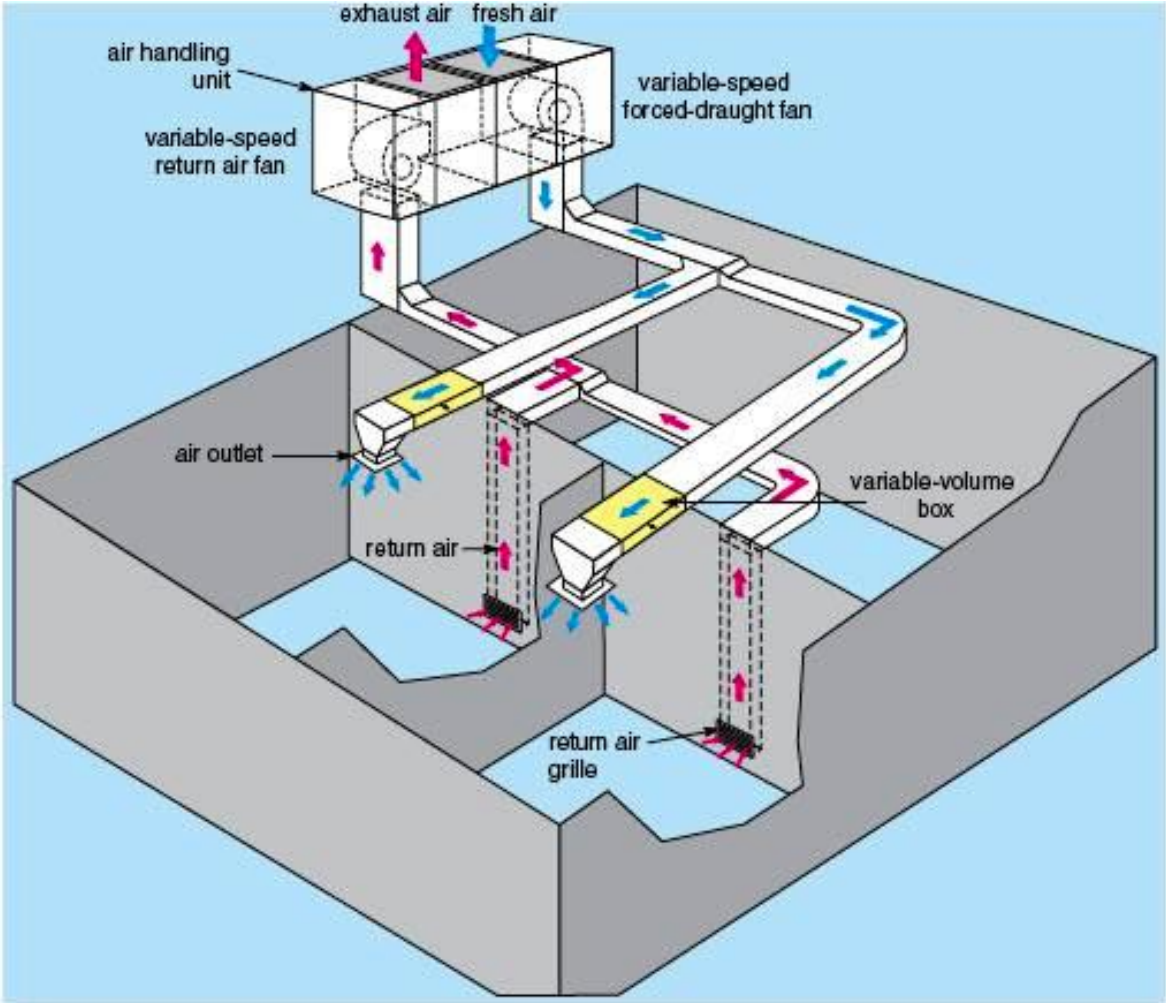
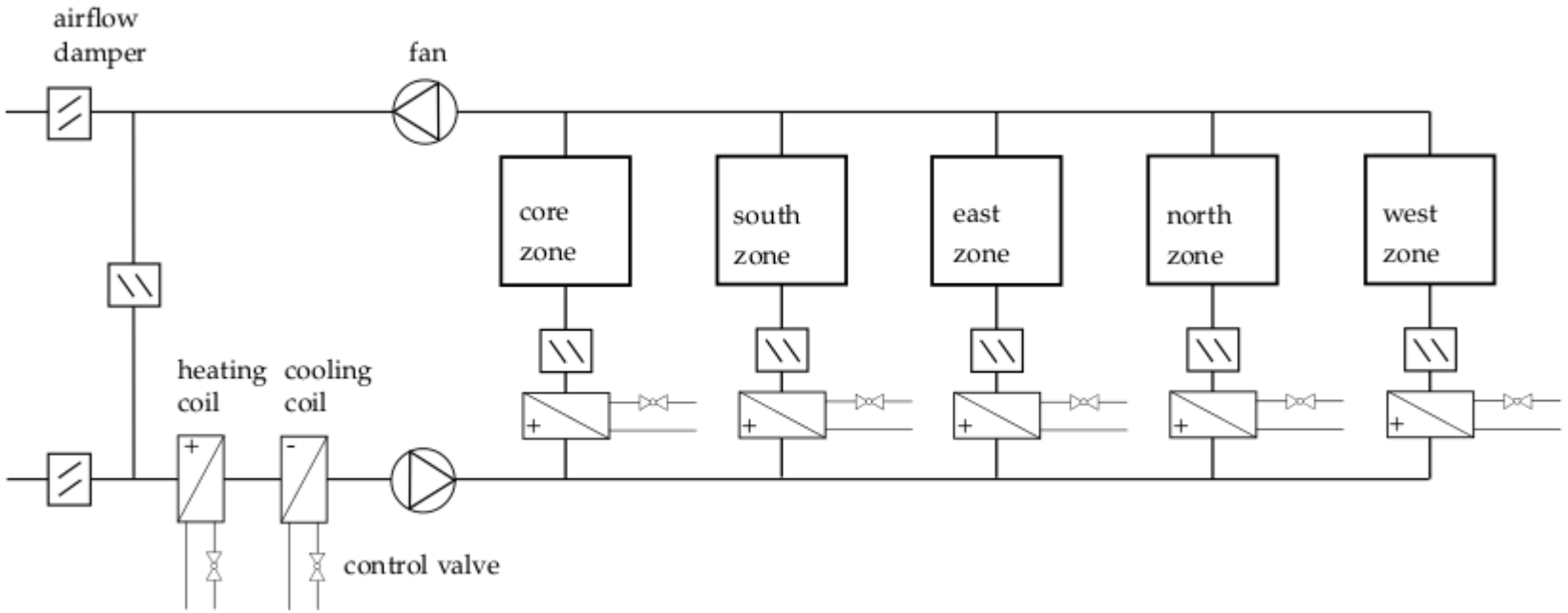
Variable Air Volume (VAV)



Variable Air Volume (VAV)



Variable Air Volume (VAV)

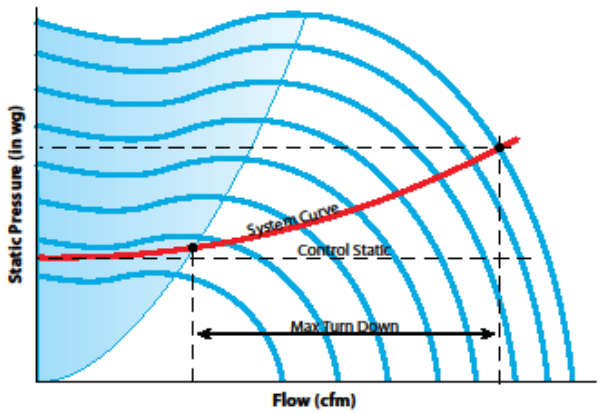


Fig. 25: VAV System Selected Further Right of Peak Static

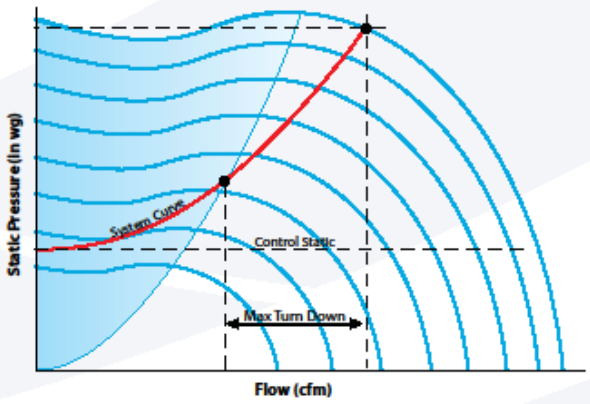


Fig. 24: VAV System Selected Close to Peak Static & Efficency

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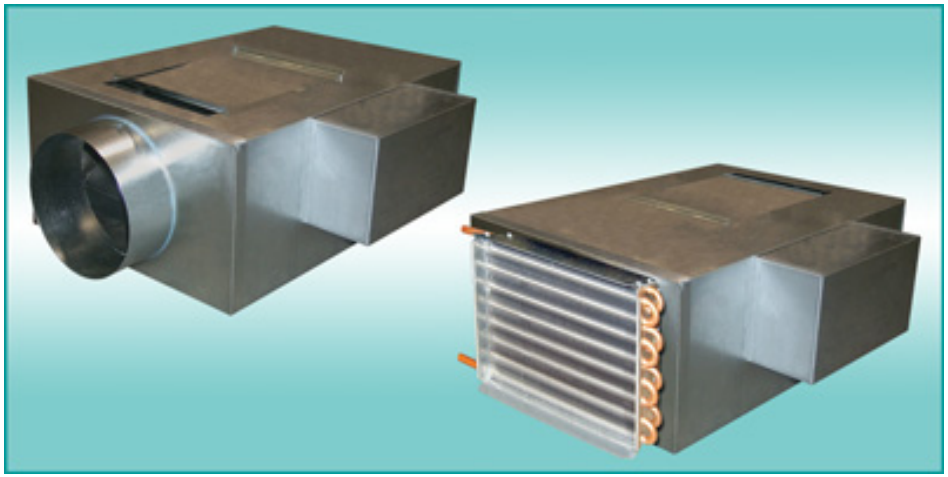
Variable Air Volume (VAV)

- 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

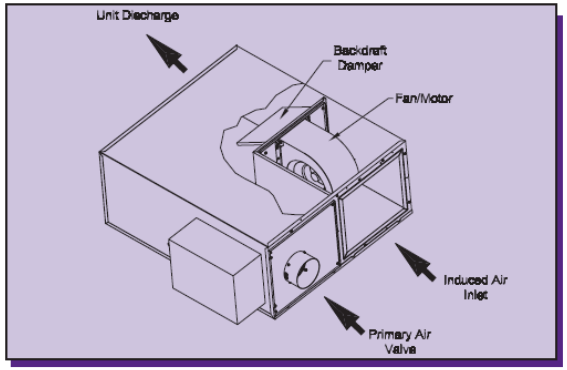

Figure 1. Parallel Flow, Fan Powered Terminal

Series Flow Fan Powered

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

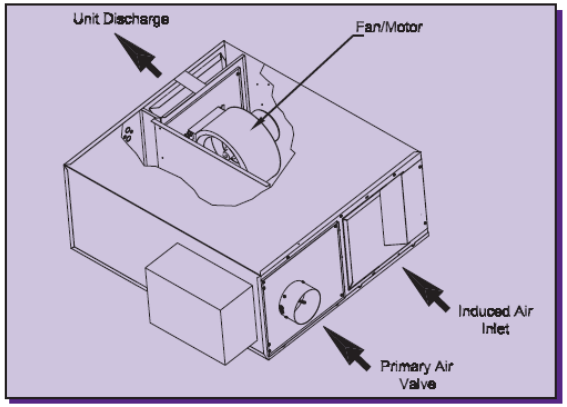

Figure. 2. Series Flow, Fan Powered Terminal

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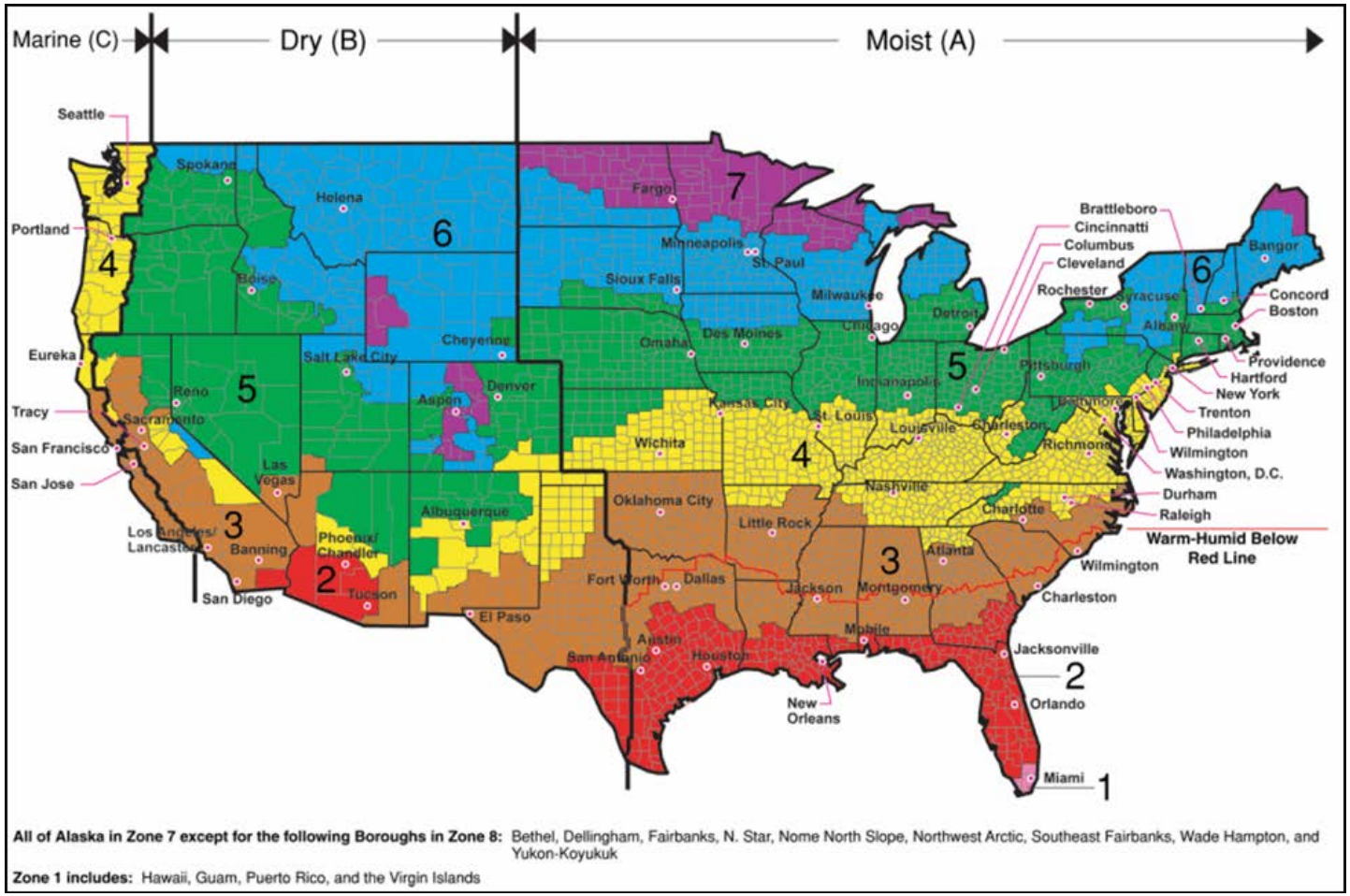
Dedicated Outdoor Air Systems (DOAS)
Energy Recovery Systems

Why Use Energy Recovery?



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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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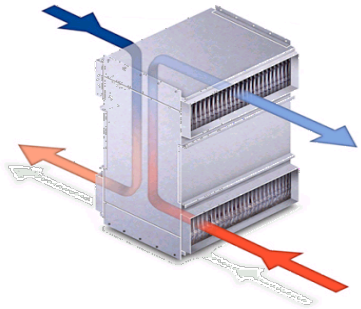
Types of Energy Recovery:

- 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 Wheels:

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

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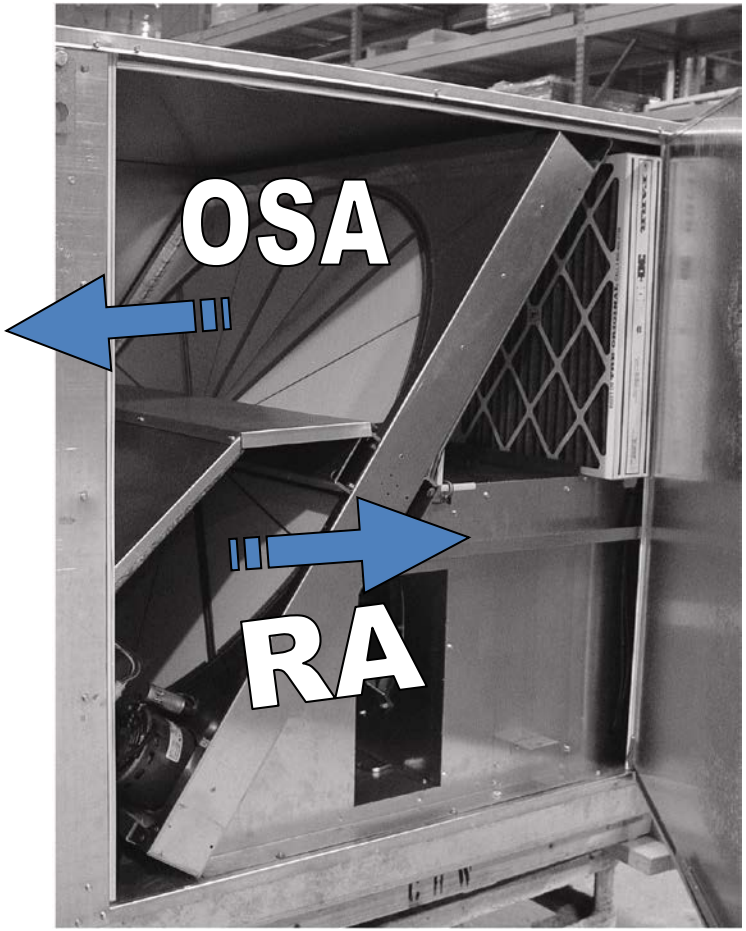
Heat Wheel:



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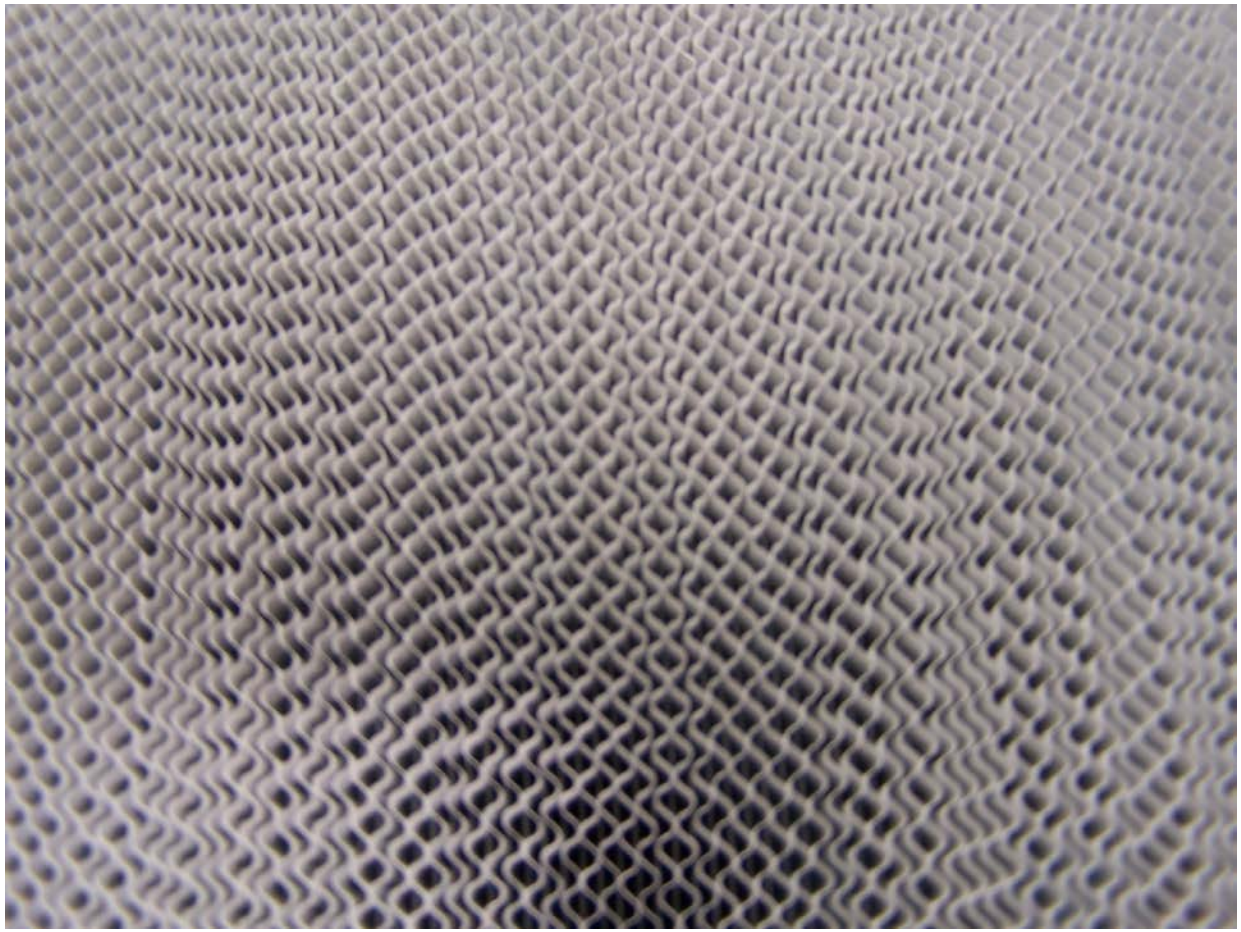
Heat Wheel:

Heat Wheel:



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Heat Wheel:

Bypass Dampers

- Excess Air
- Economizer Operation

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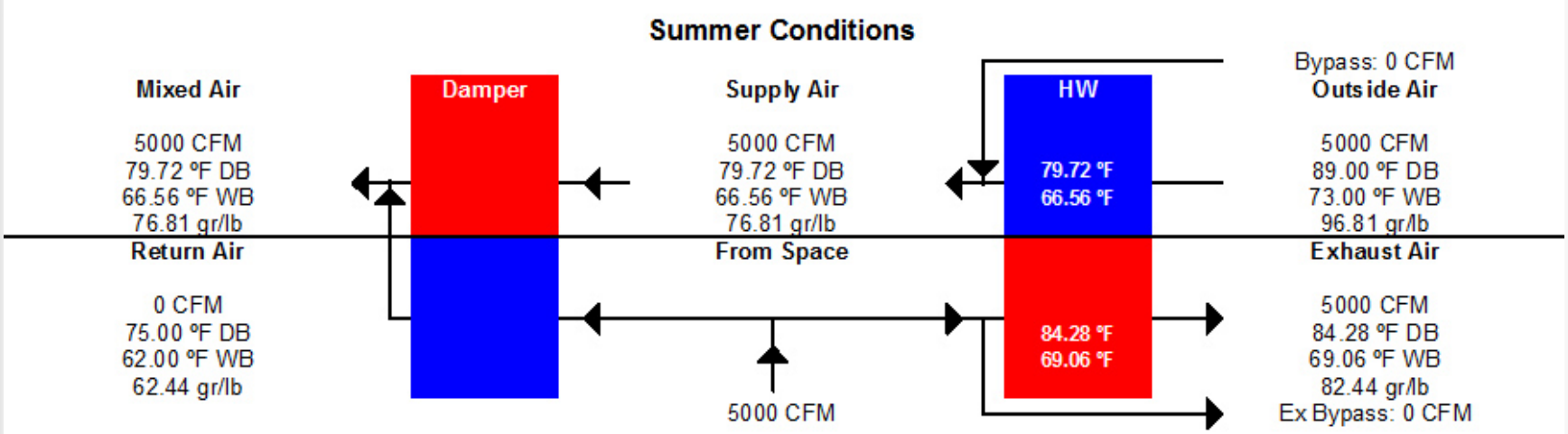
Heat Wheel Performances:



	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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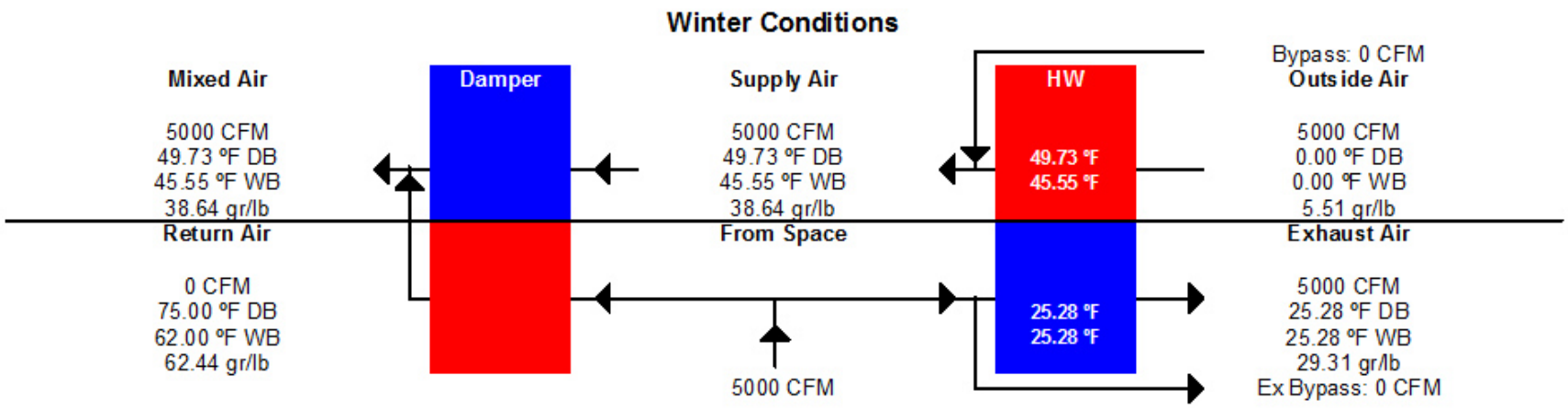
Heat Wheel Performances:



	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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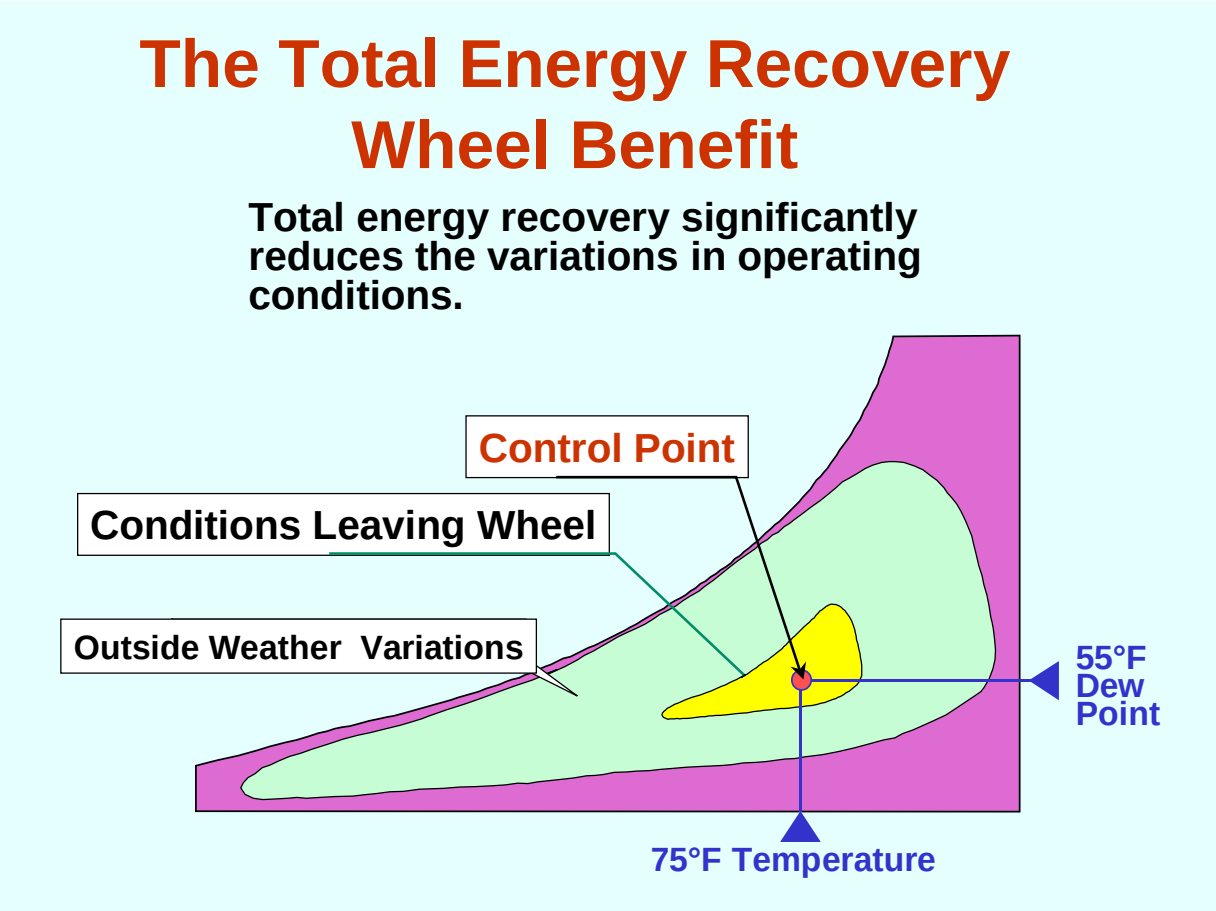
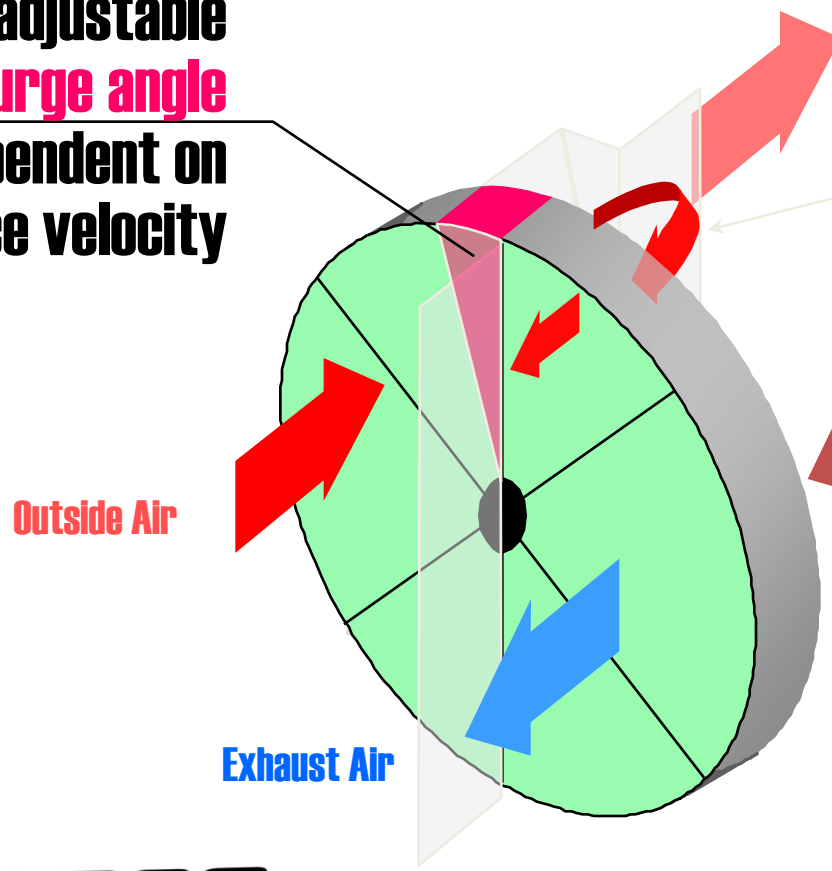
Heat Wheel Benefit:



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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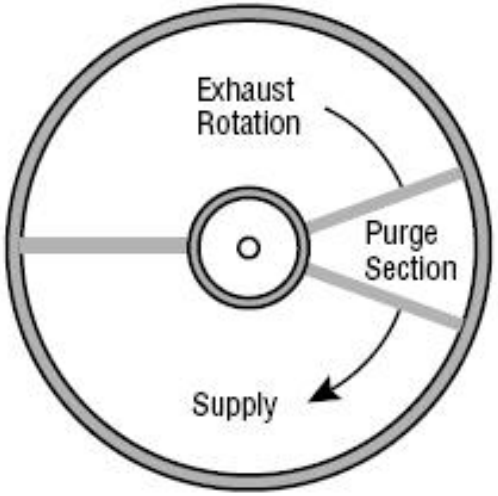
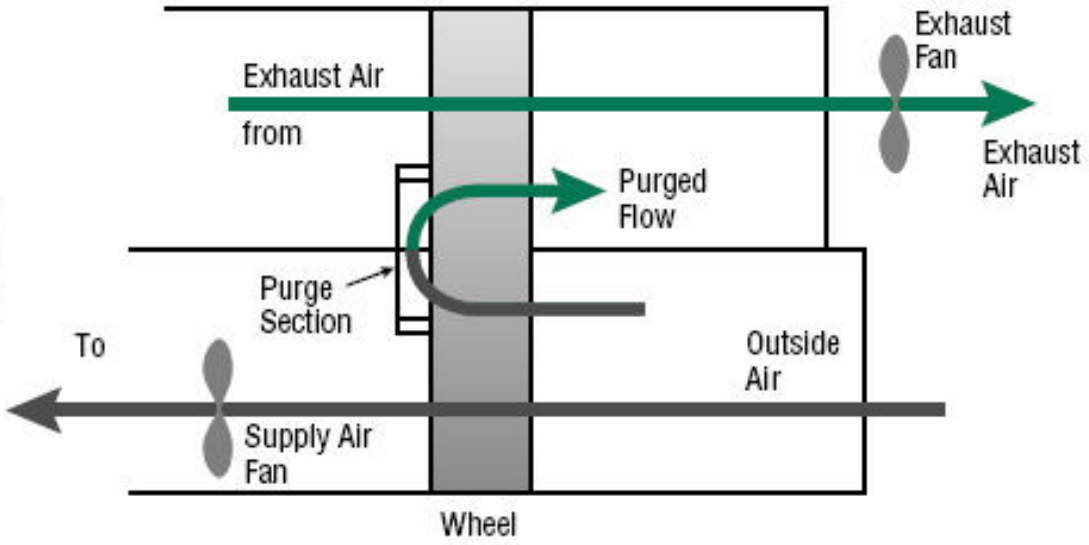
Purge System:



Front Cross Section
with Upstream Exhaust



Side Cross Section
with Purge Section

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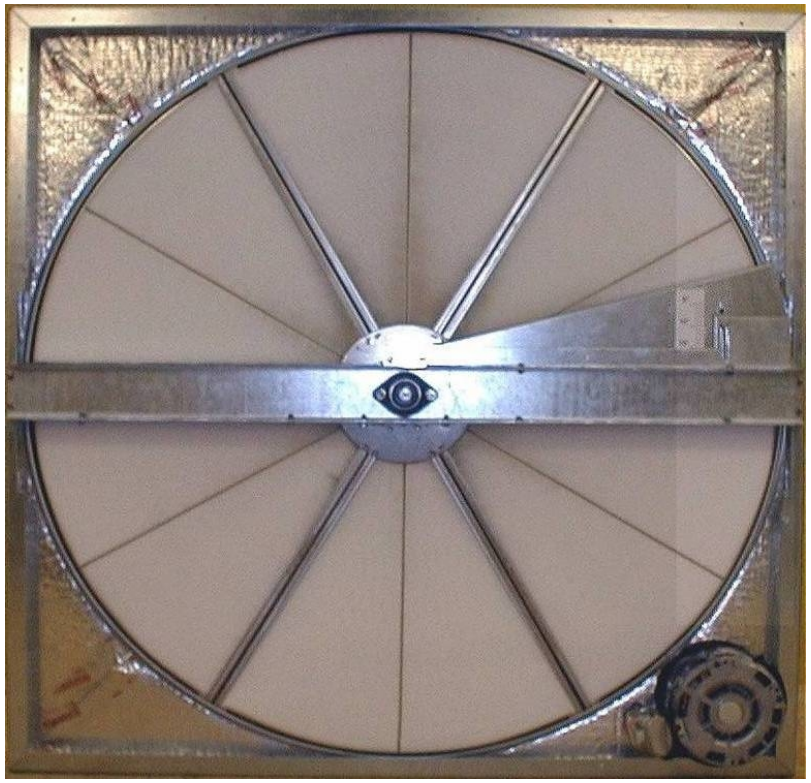
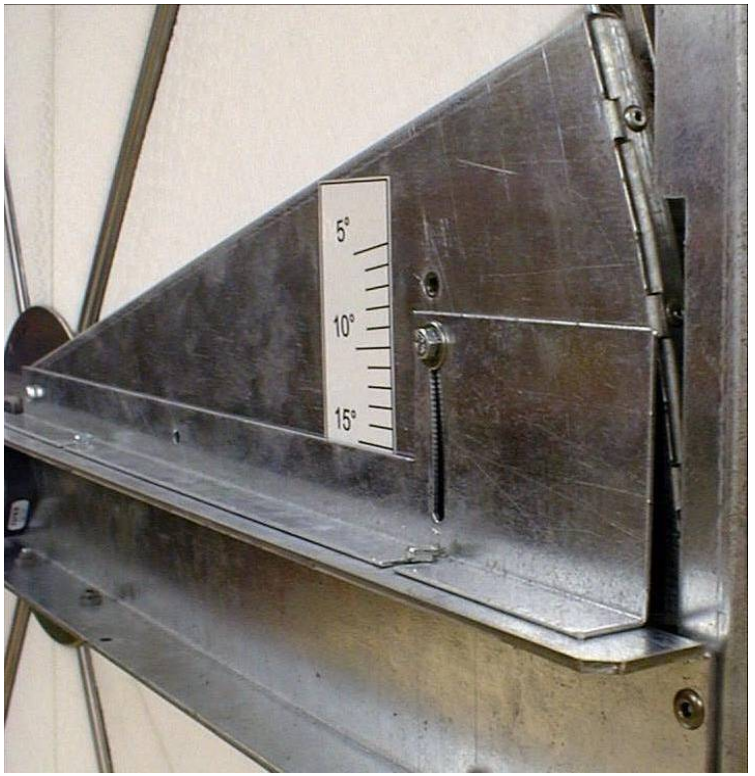
Heat Wheel With Purge:





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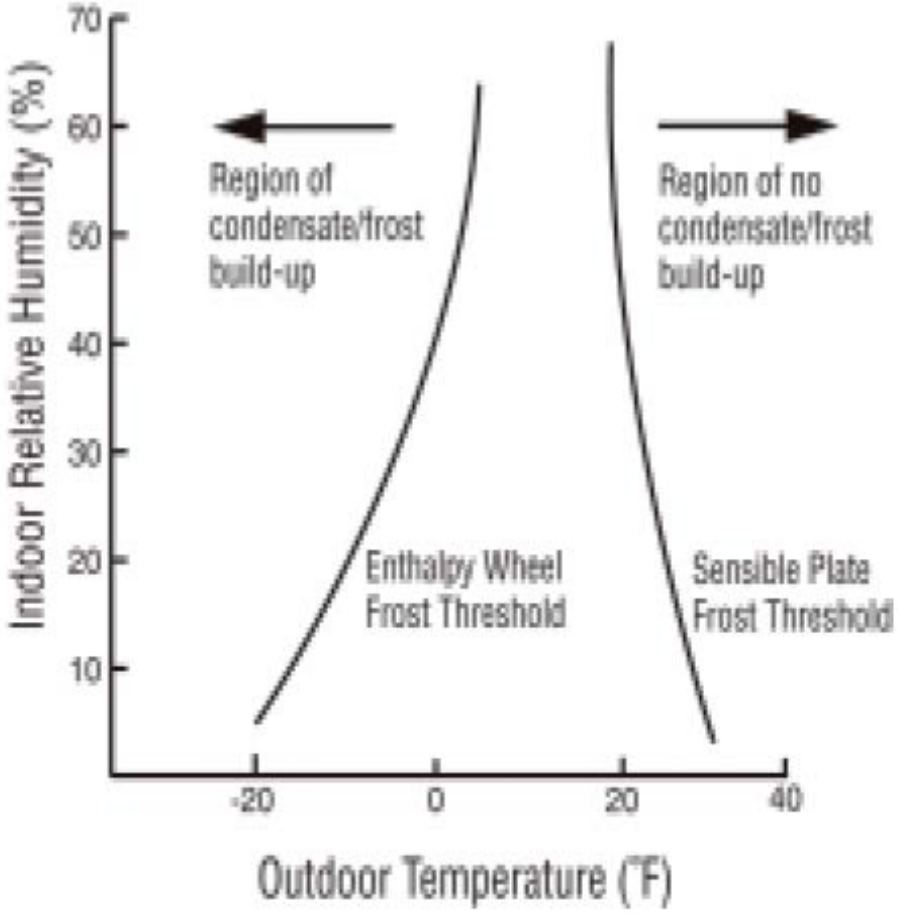
Heat Wheel Frost Control:



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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

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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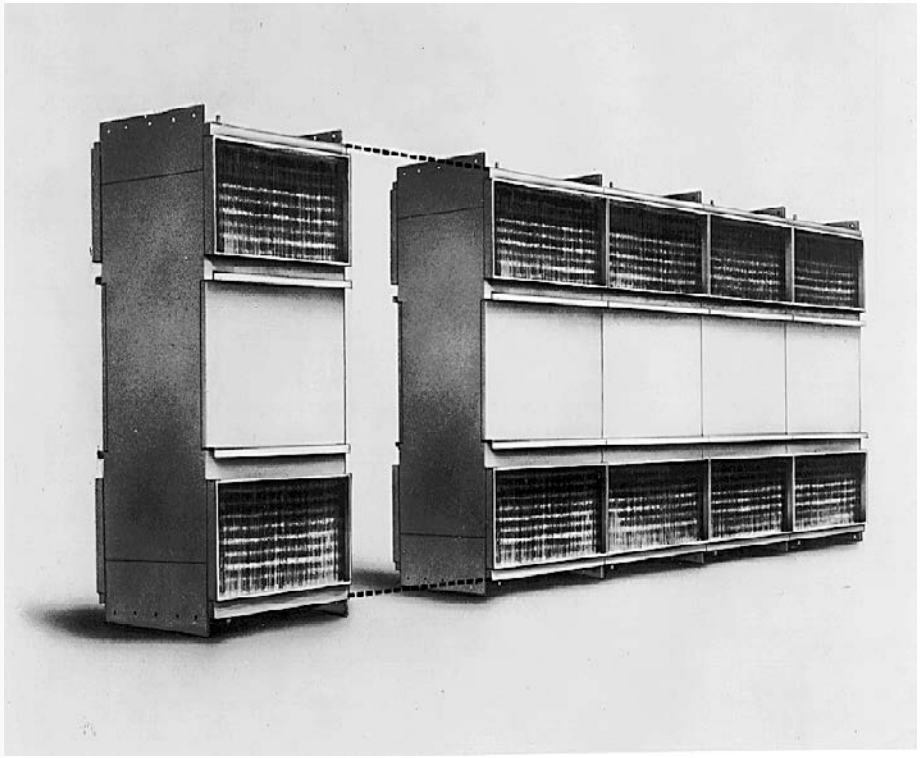
Plate Heat Exchanger:

- 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

JACCO

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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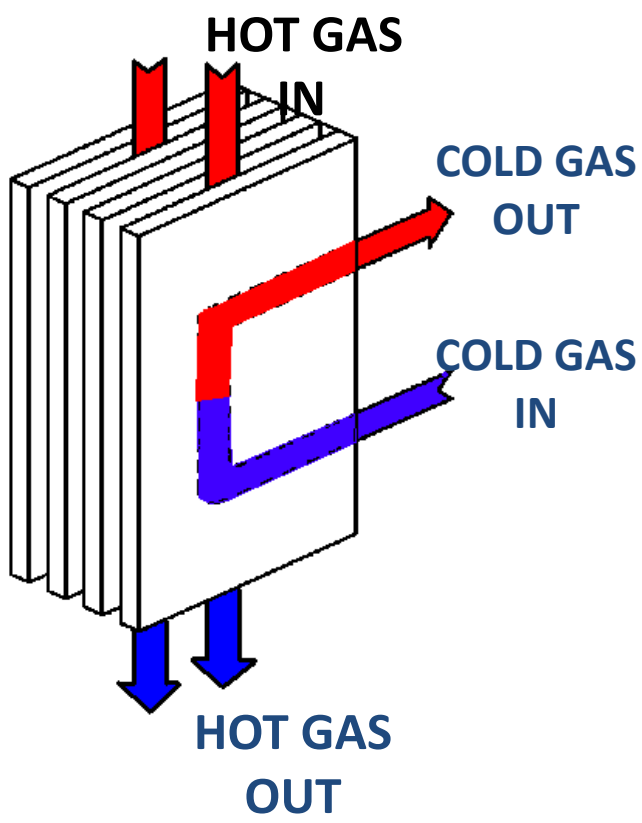
Counter Flow Plate Heat Exchanger:



- 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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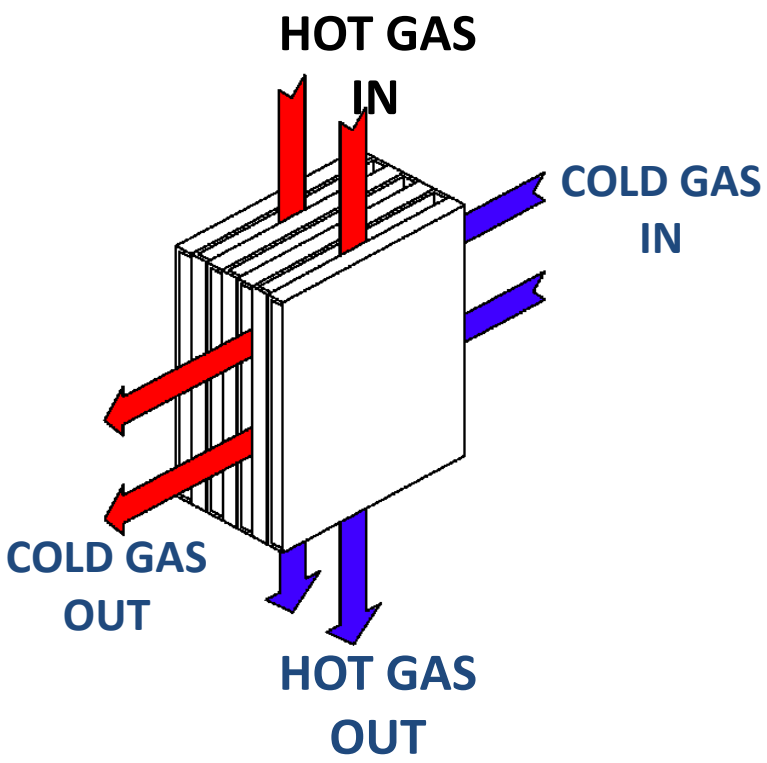
Cross Flow Plate Heat Exchanger:



- Two air streams are 90° from each other

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Plate Heat Exchanger:

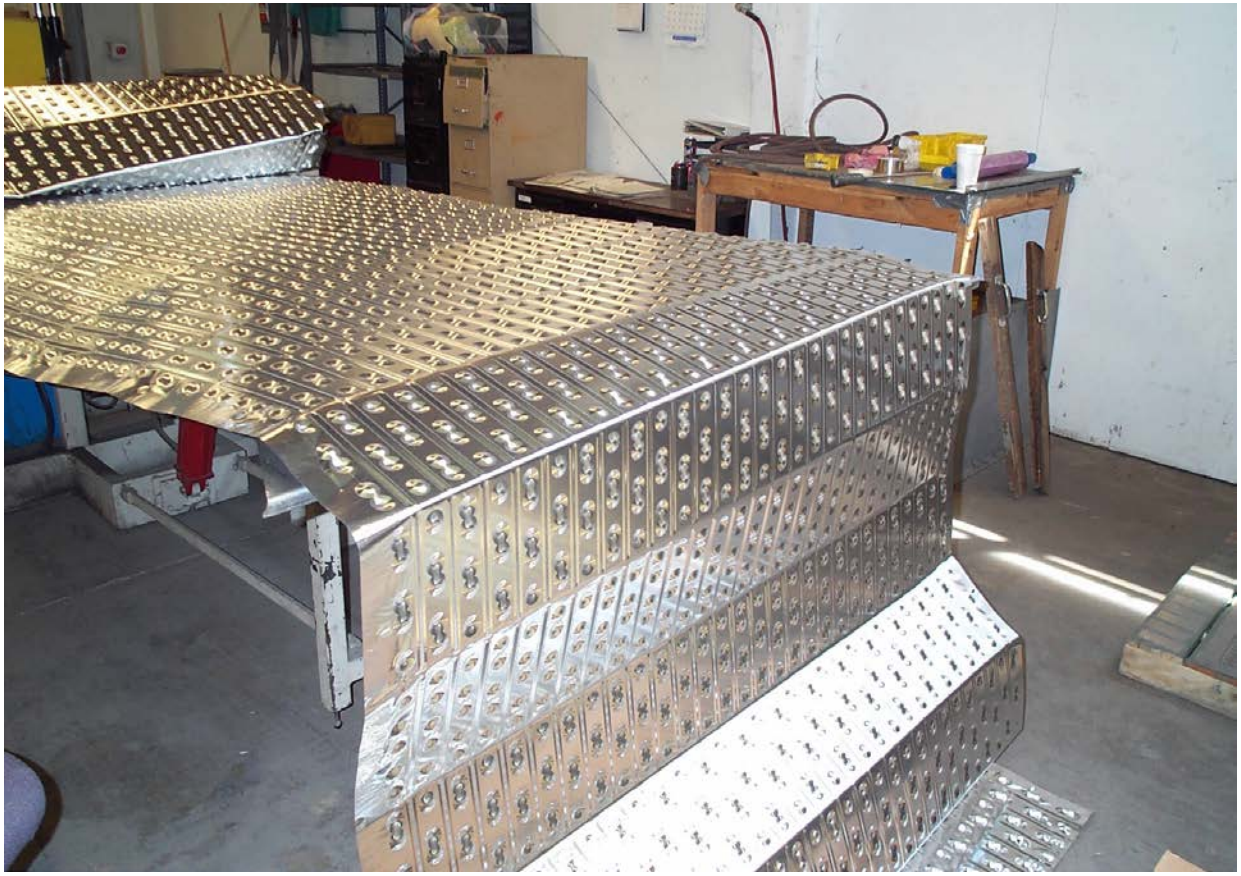

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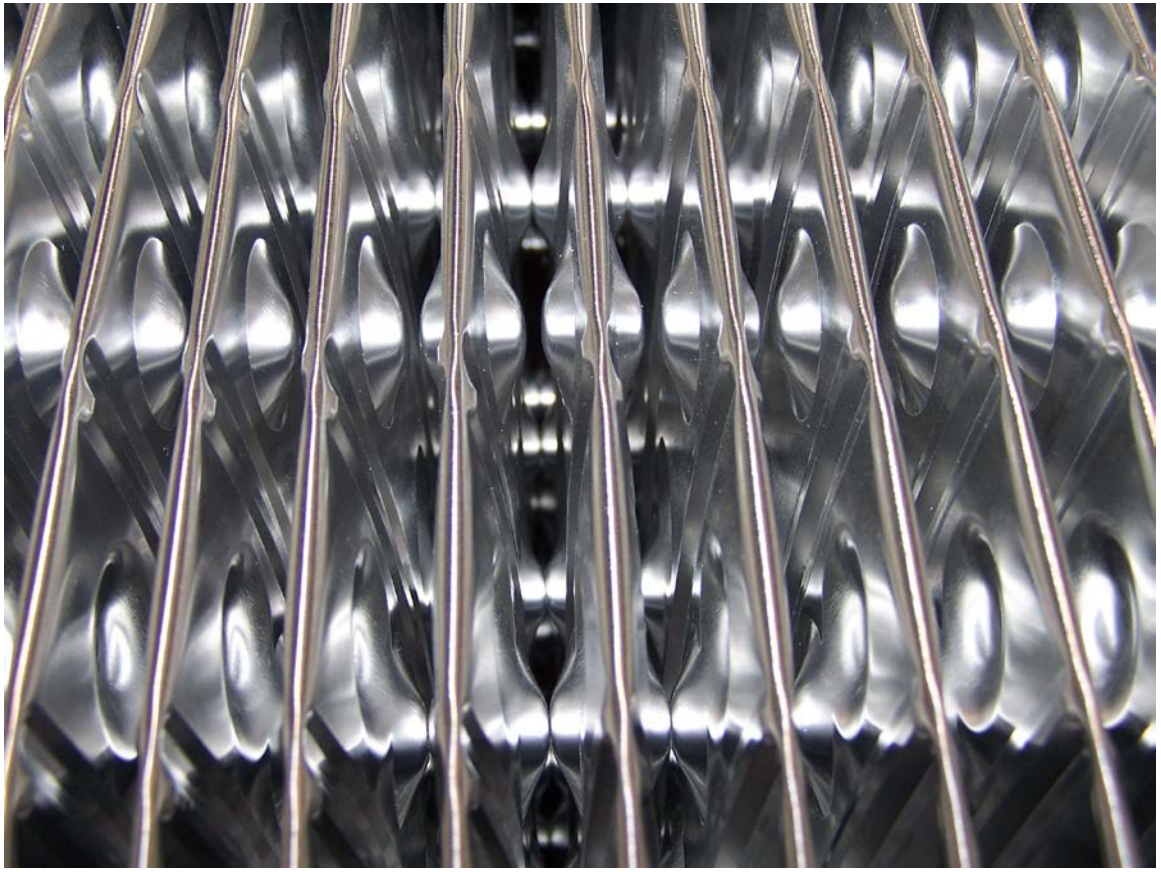
Plate Heat Exchanger:



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Cross Flow Plate Heat Exchanger:

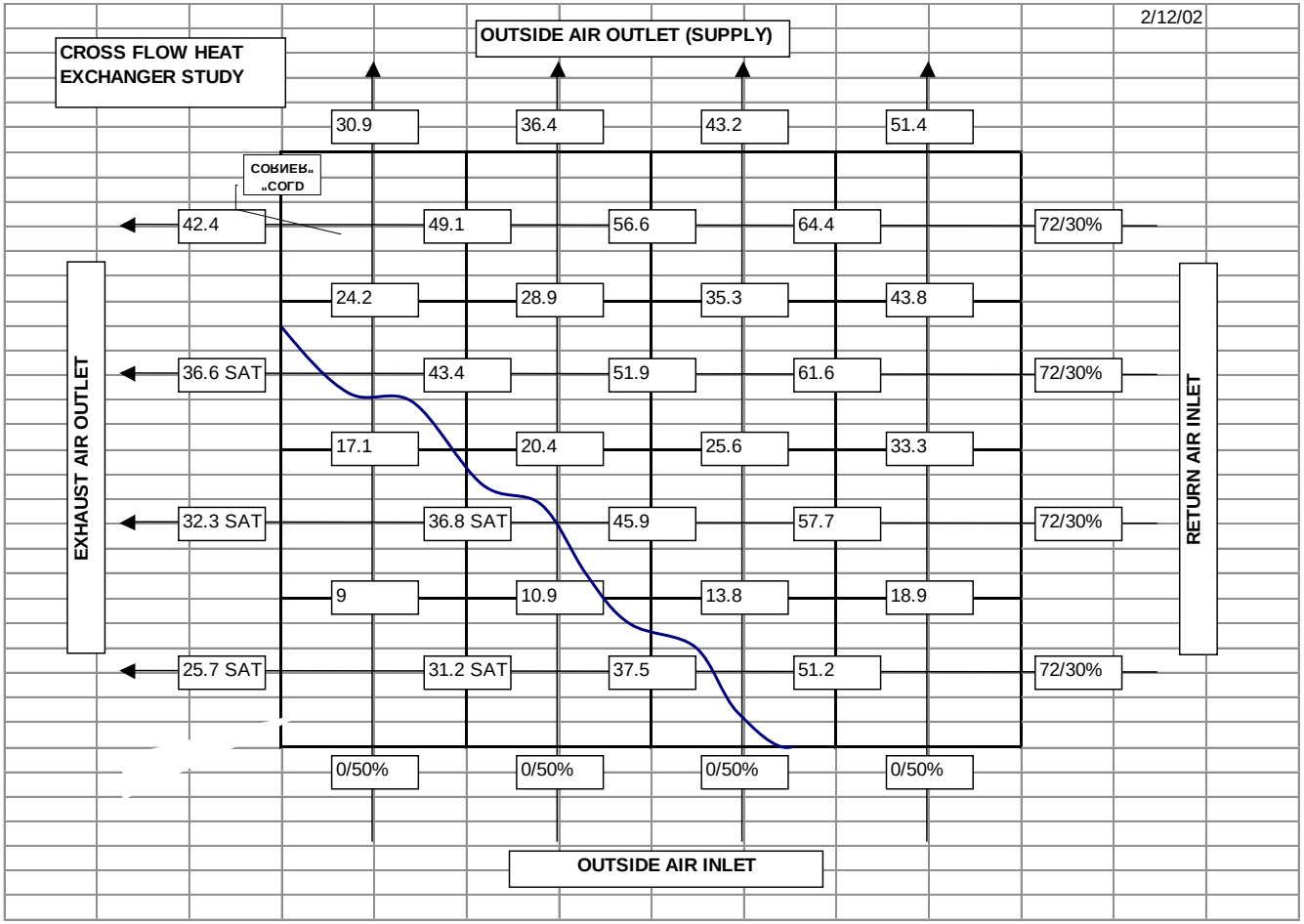

Plate Heat Exchanger Applications:

- 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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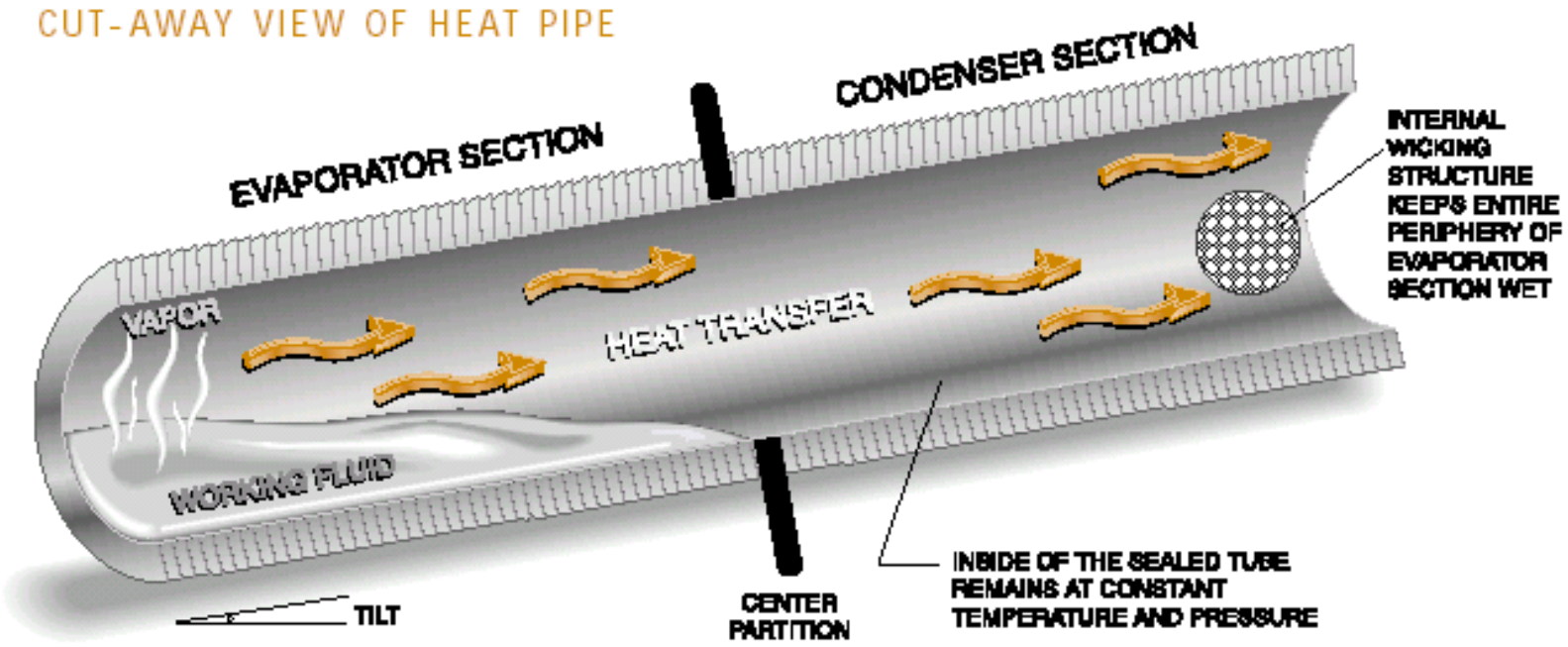
Heat Pipe:



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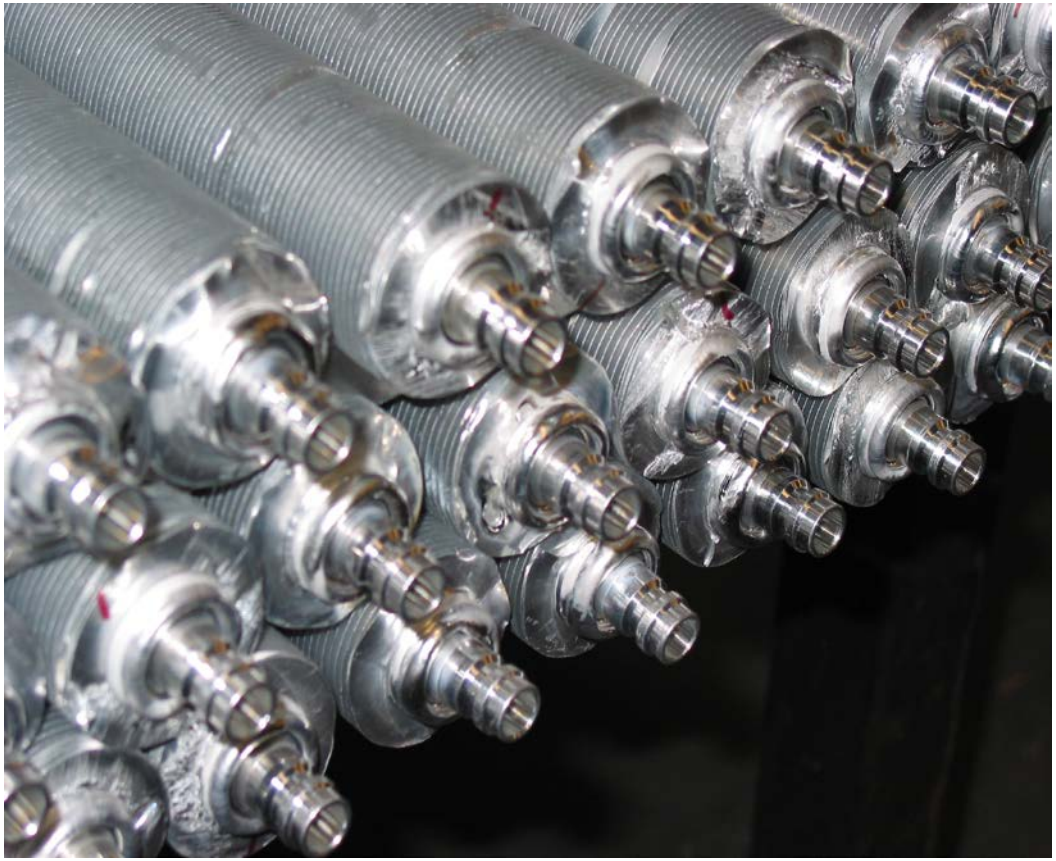
Heat Pipe:



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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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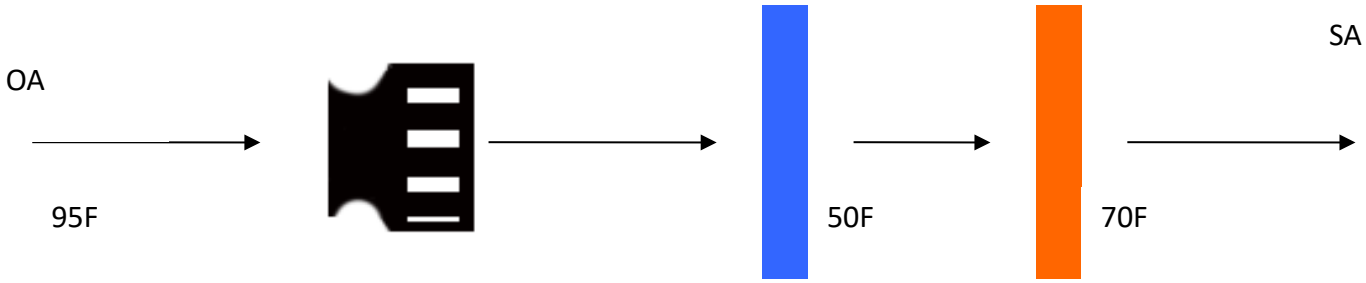
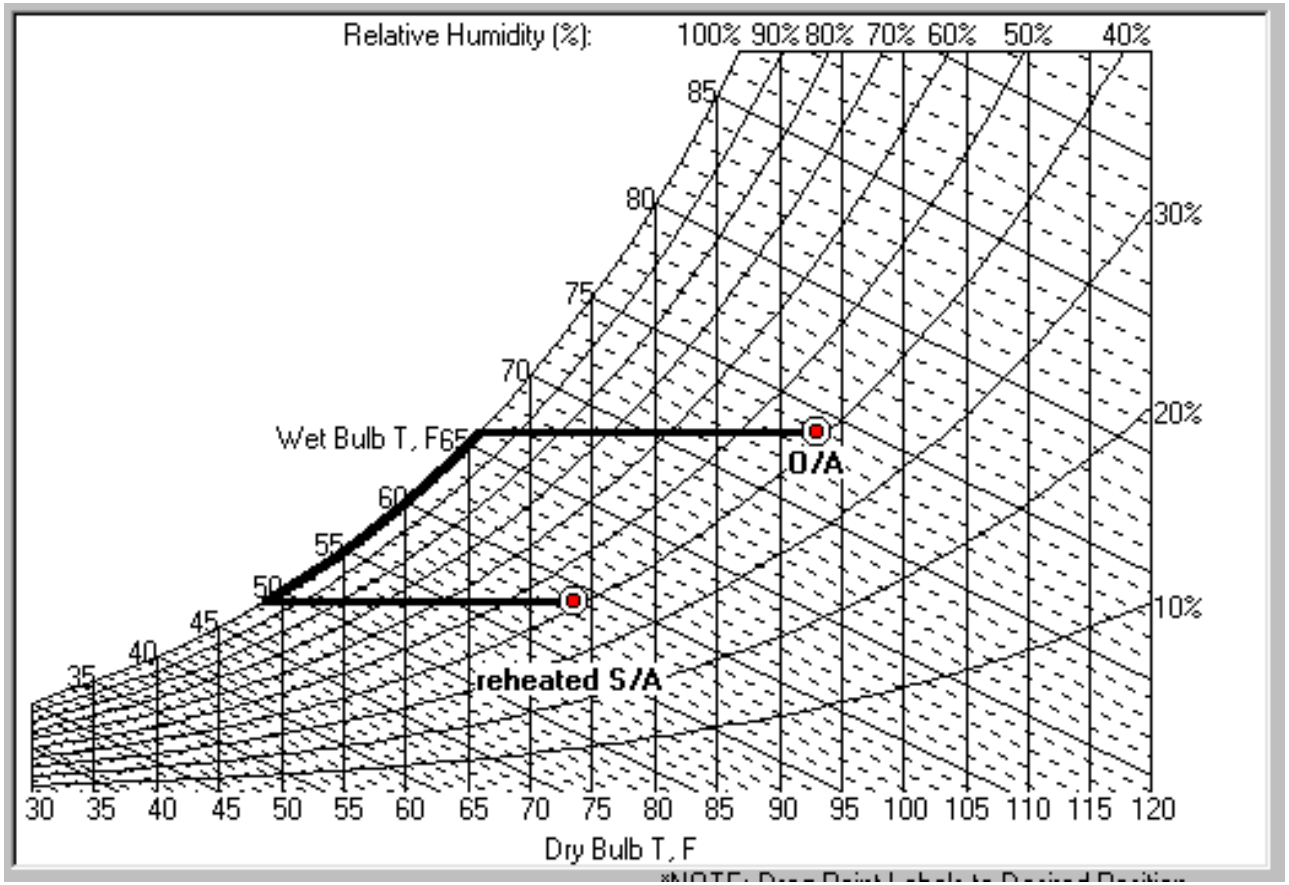
Brute Force:



Brute Force:



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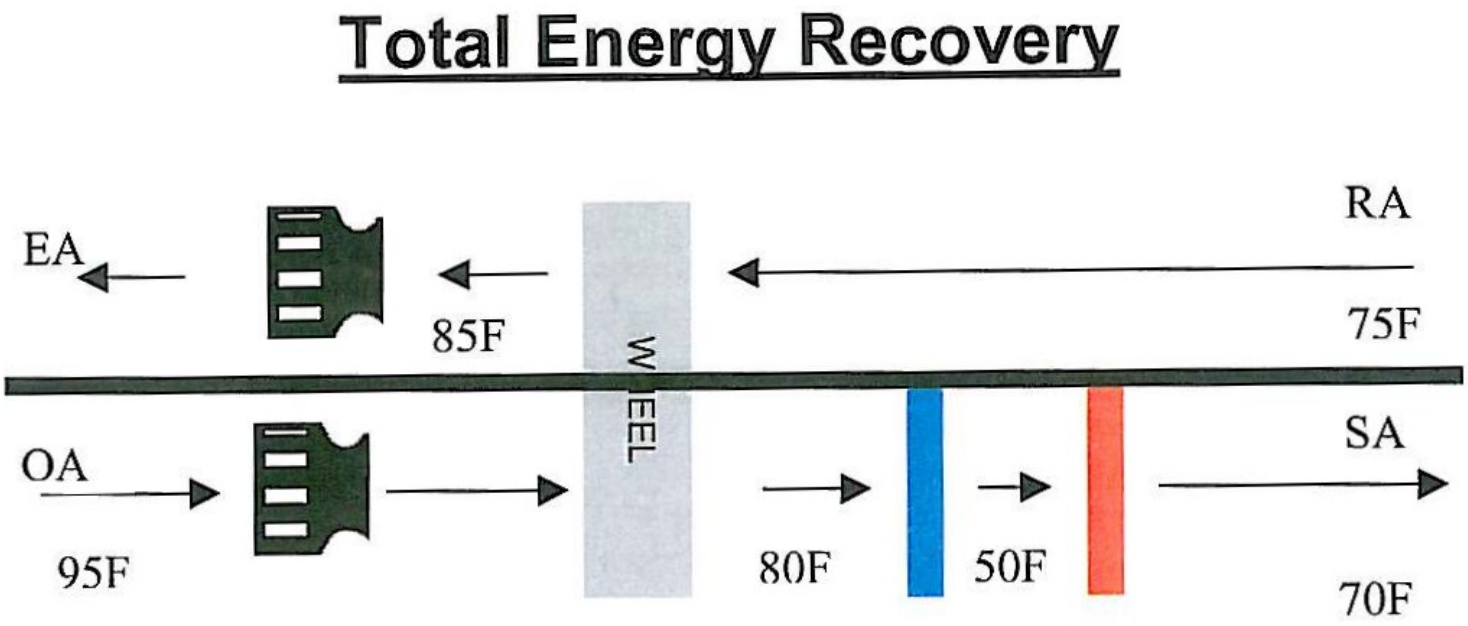
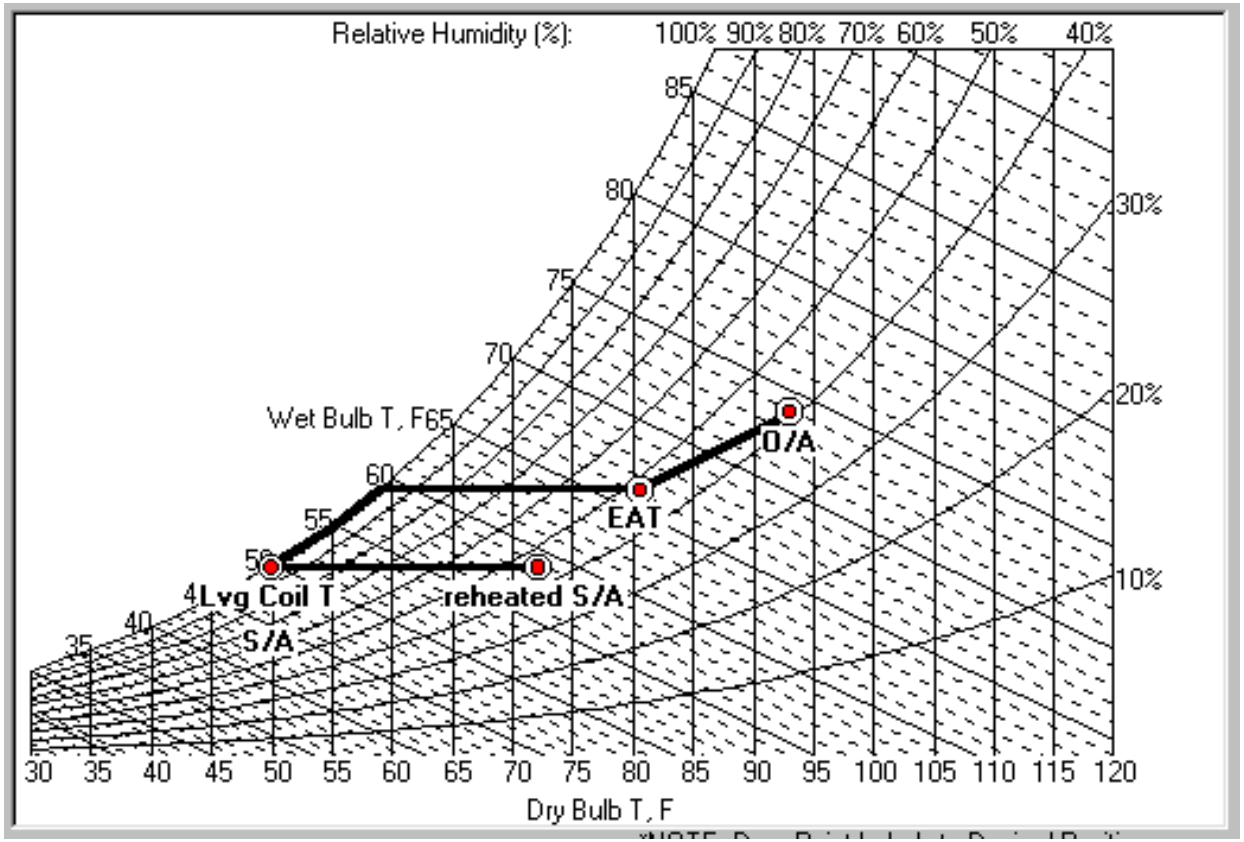
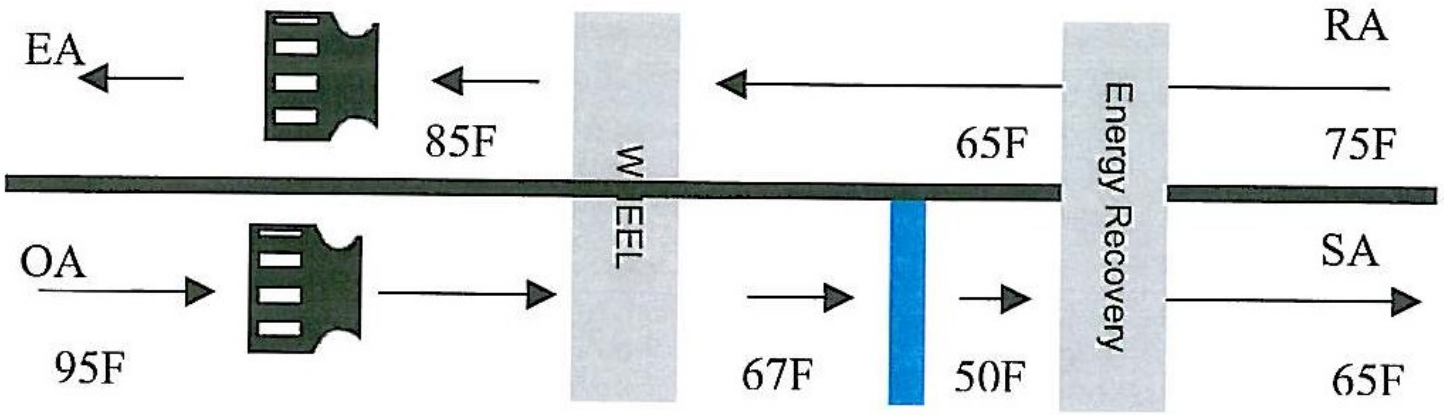
Total Energy Recovery:



Total Energy Recovery:



Dual Energy Recovery System:



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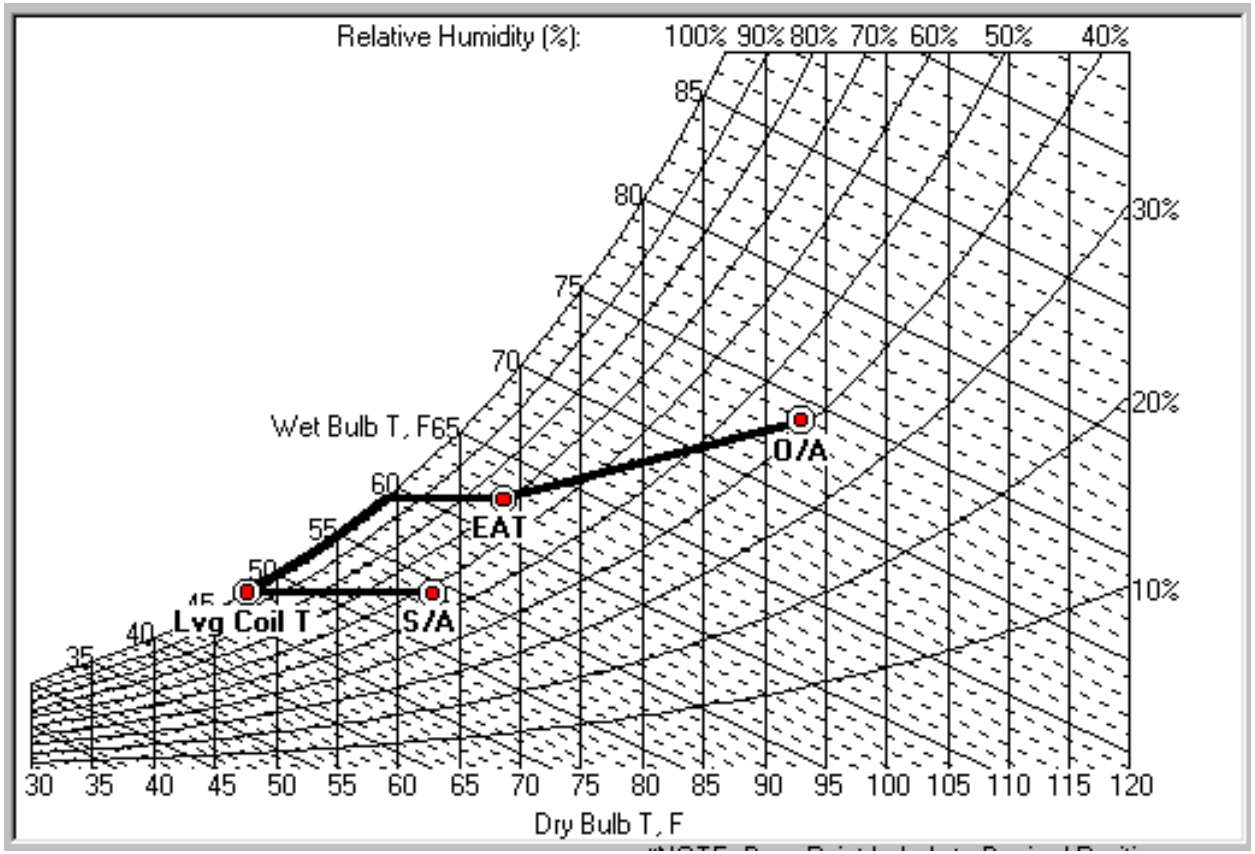
Dual Energy Recovery System:



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Cost Comparison:

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

Akron, OH

TEMPERATURES DRY BULB	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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The Whalen Company

Fan Coil Units

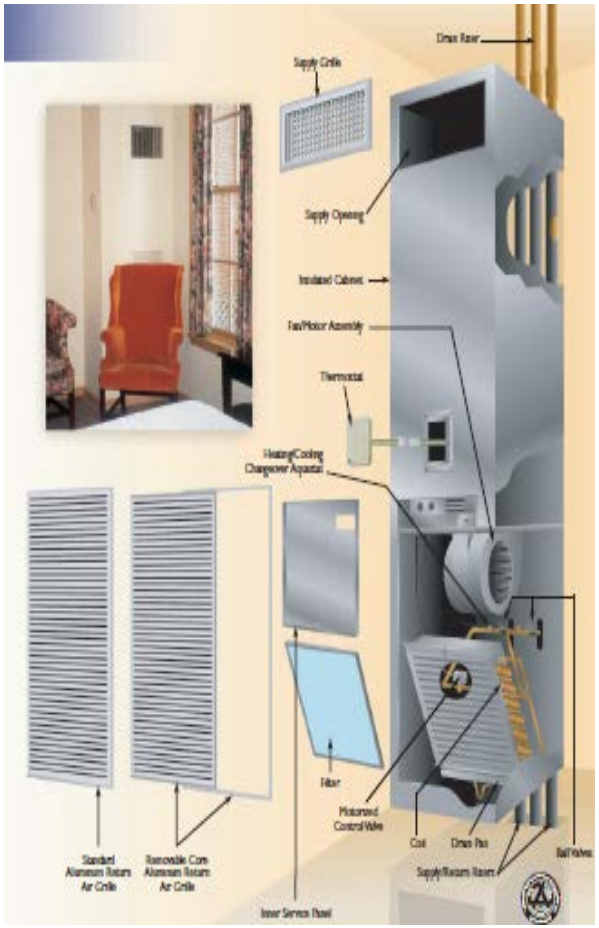
Flexibility
- Unlimited FCU/AHU Sizing, Position
  - Horizontal, Vertical, Stacker
- Unlimited Chiller/Boiler/Pump Sizing

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

Fan Coil Units

Equipment Cost
- Moderate To High

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



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The Whalen Company

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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The Whalen Company

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.

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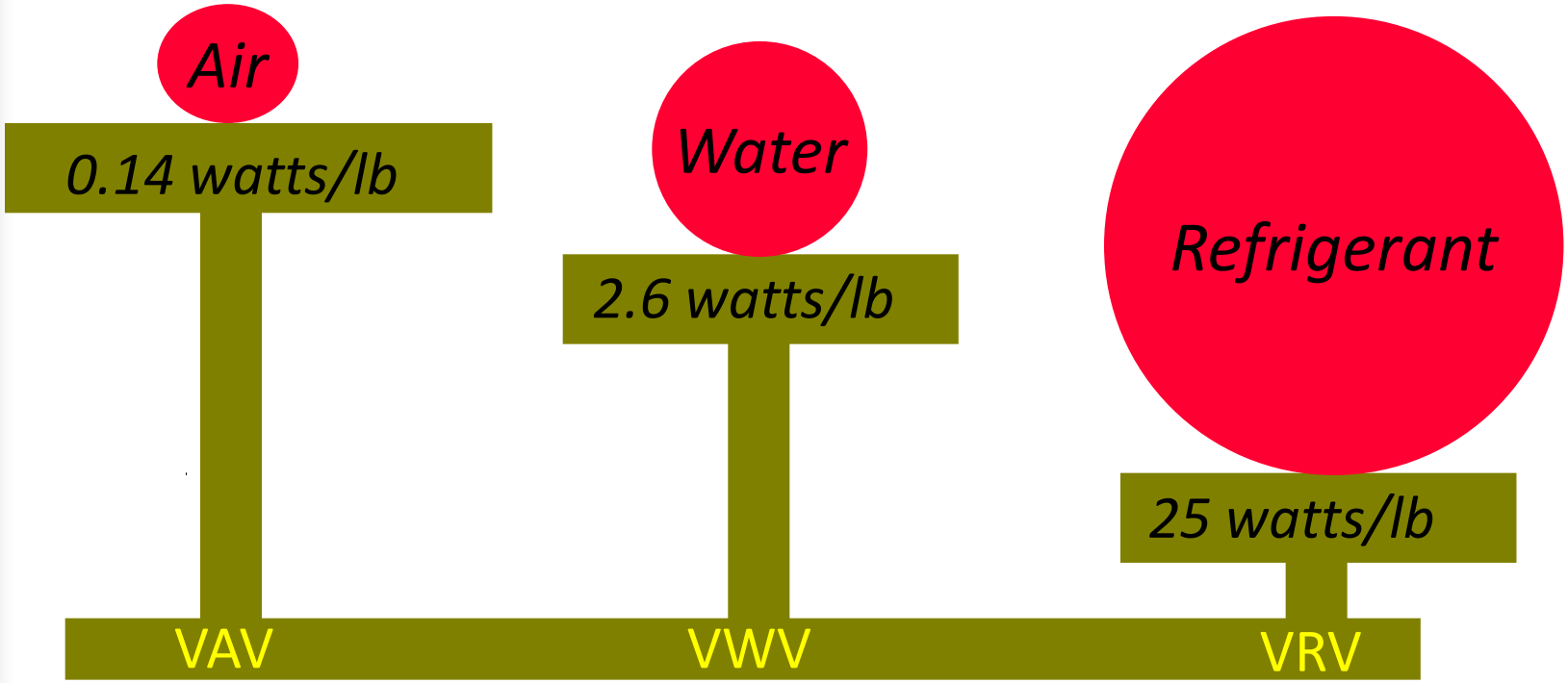
Heat Transfer Media



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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

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

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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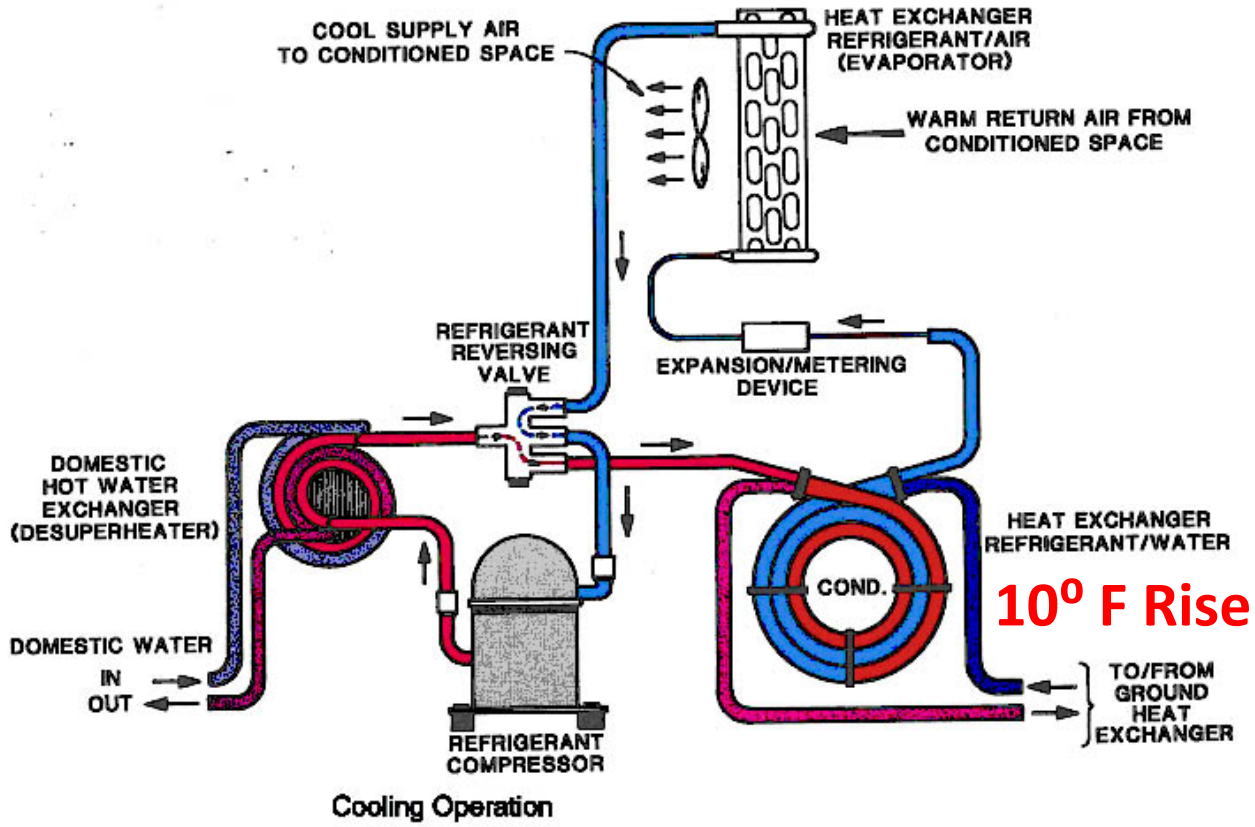
Commercial WSHP Basics

Refrigeration Basics – Cooling Mode



Cooling Operation

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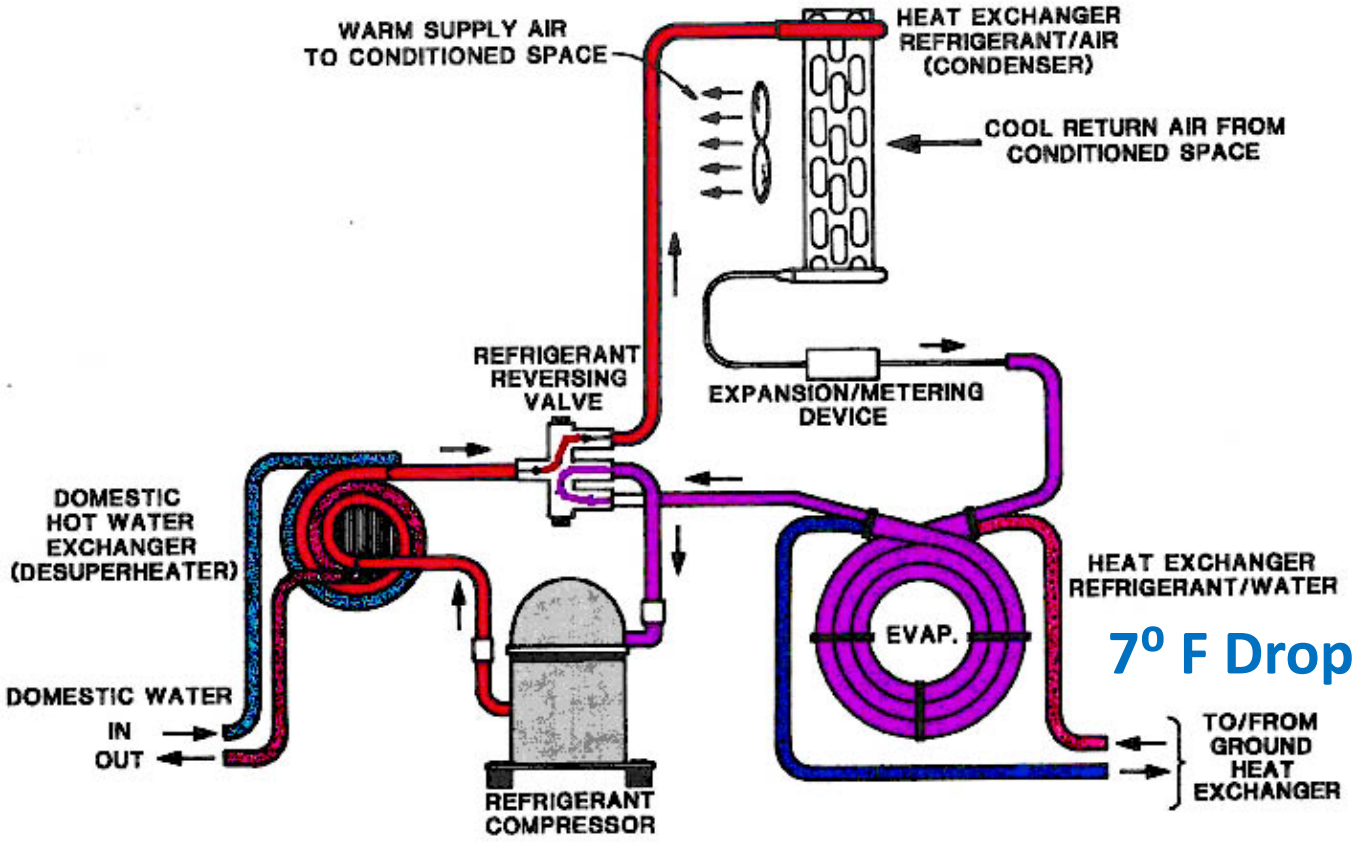
Commercial WSHP Basics

Refrigeration Basics – Heating Mode



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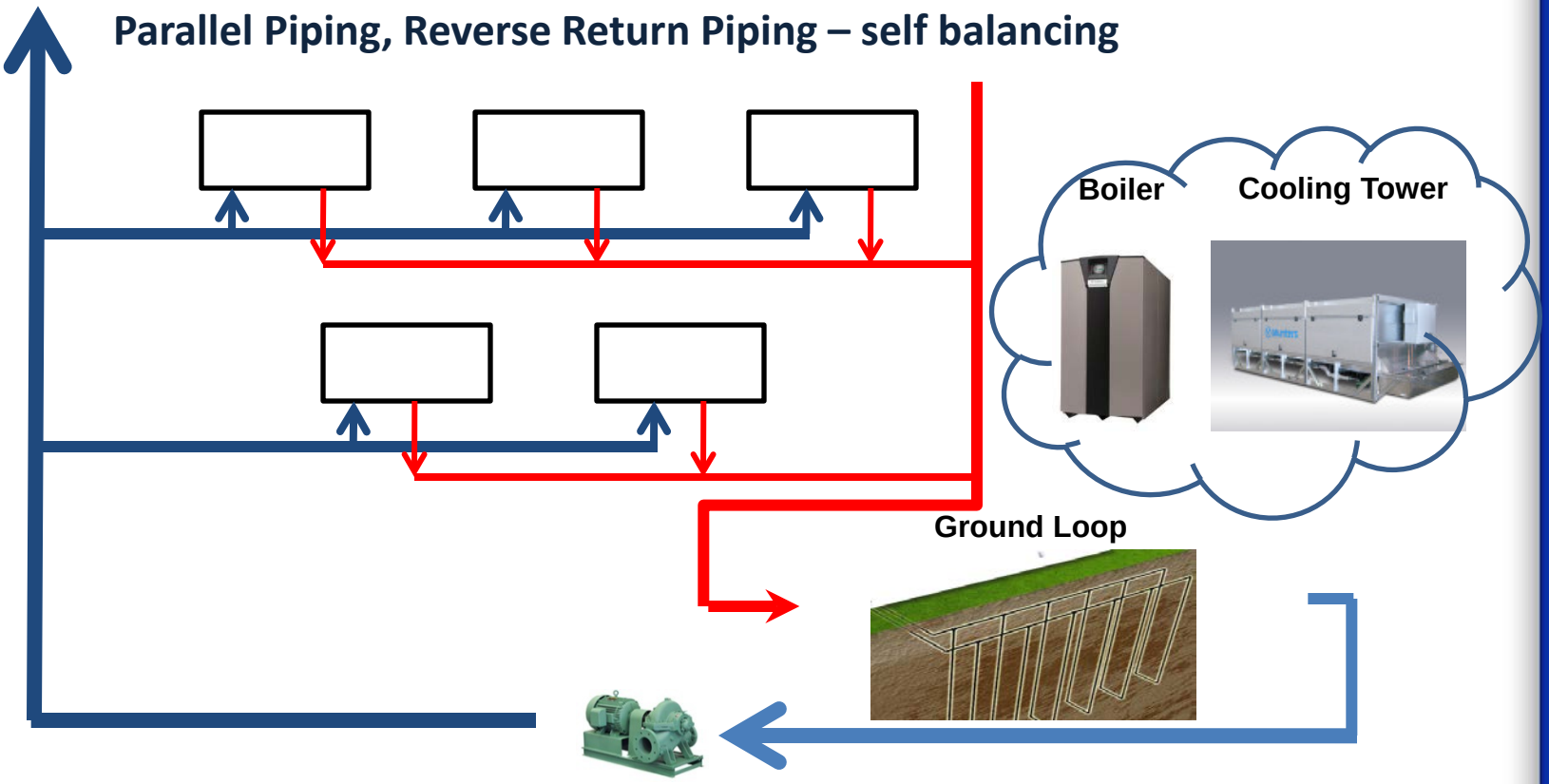
Commercial WSHP Basics

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

Parallel Piping, Reverse Return Piping – self balancing



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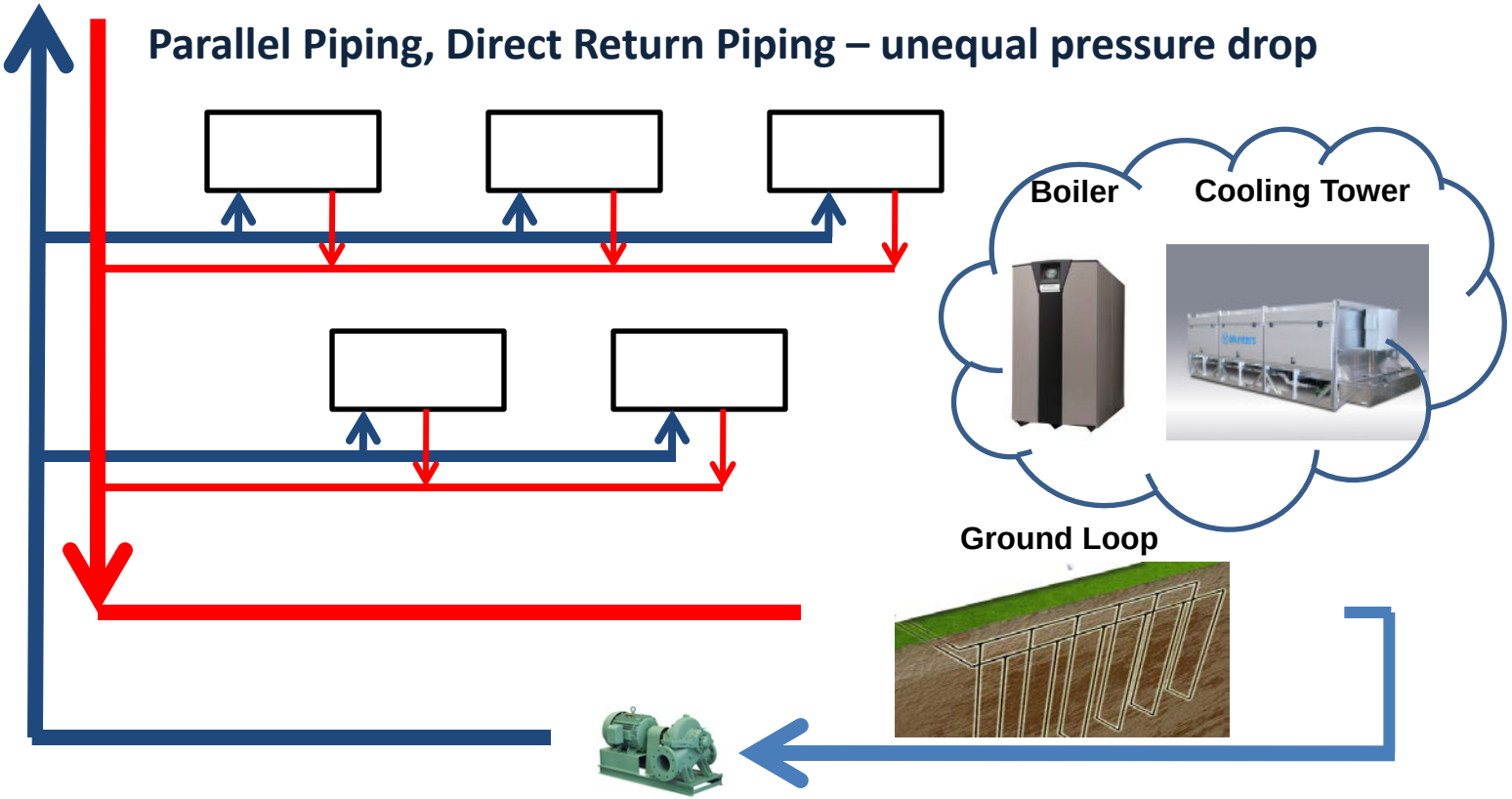
Commercial WSHP Basics

Most common because it is lower cost, BUT…



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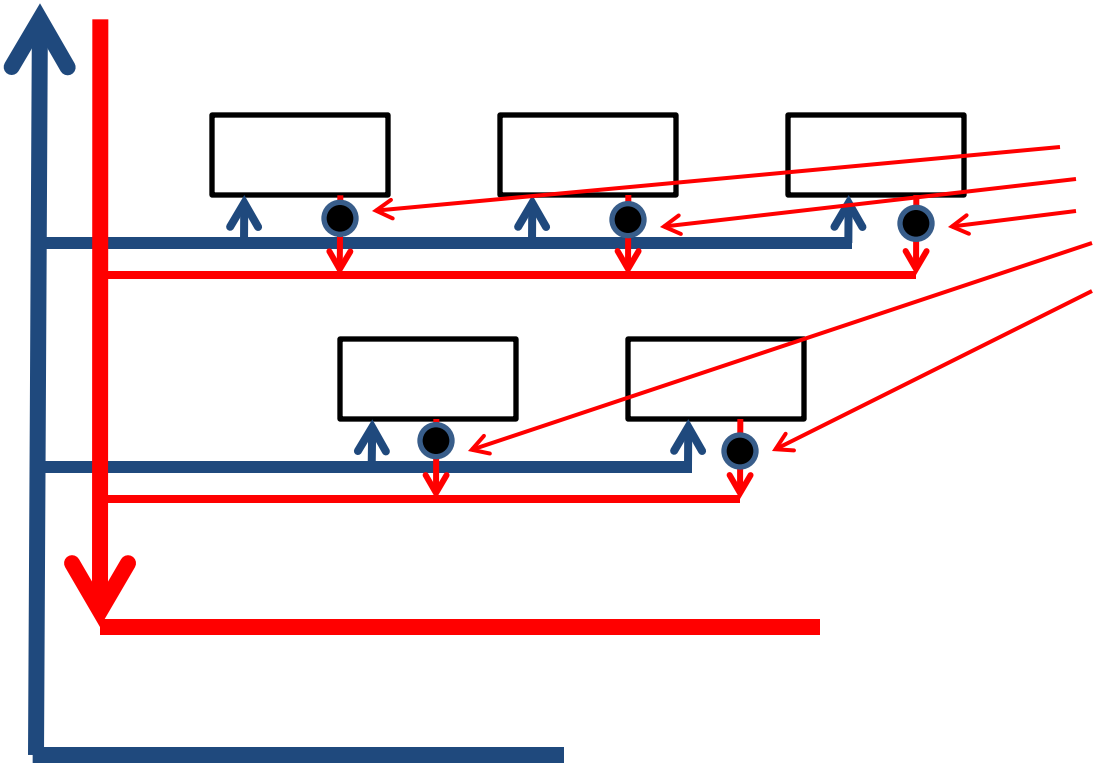
Commercial WSHP Basics

Direct Return Piping



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

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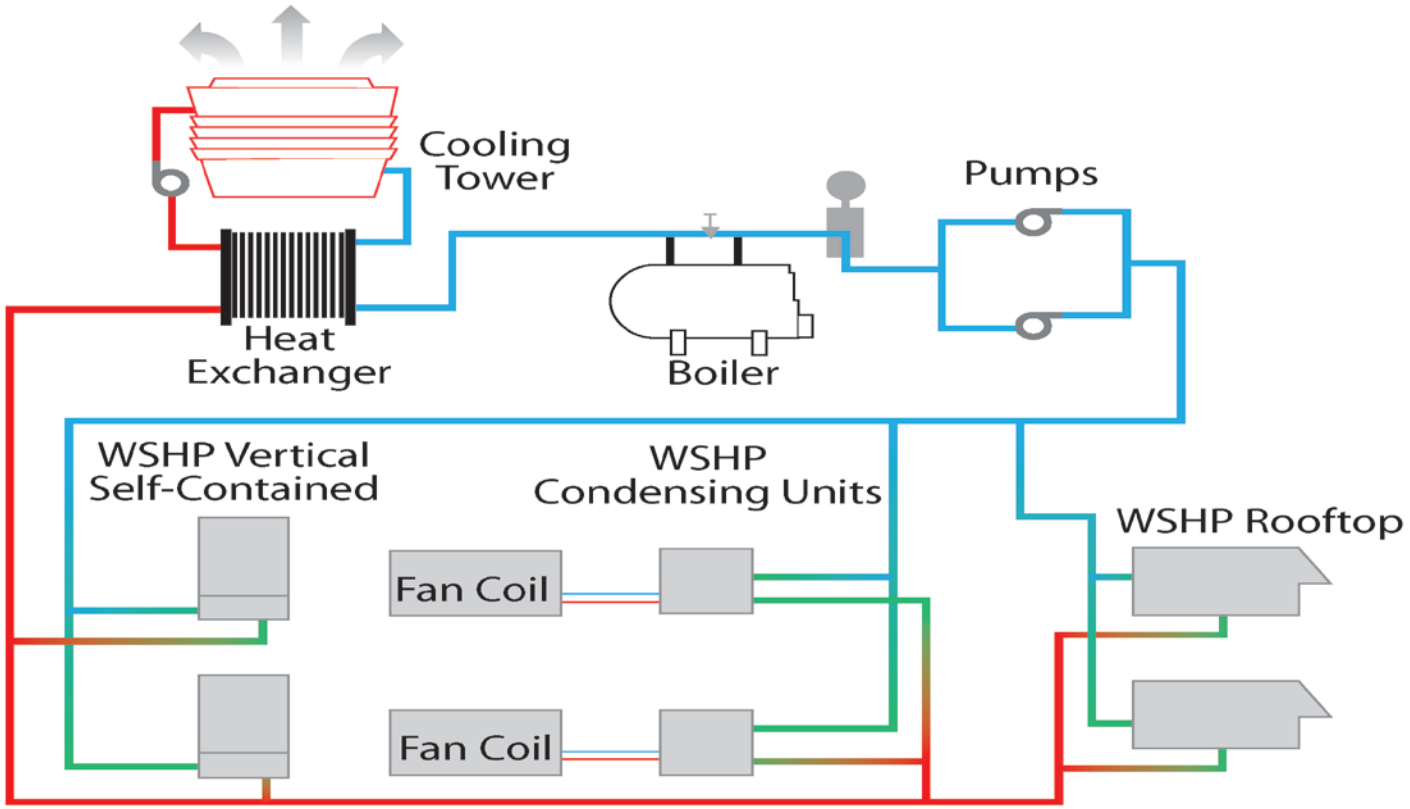
Water Source Heat Pumps



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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

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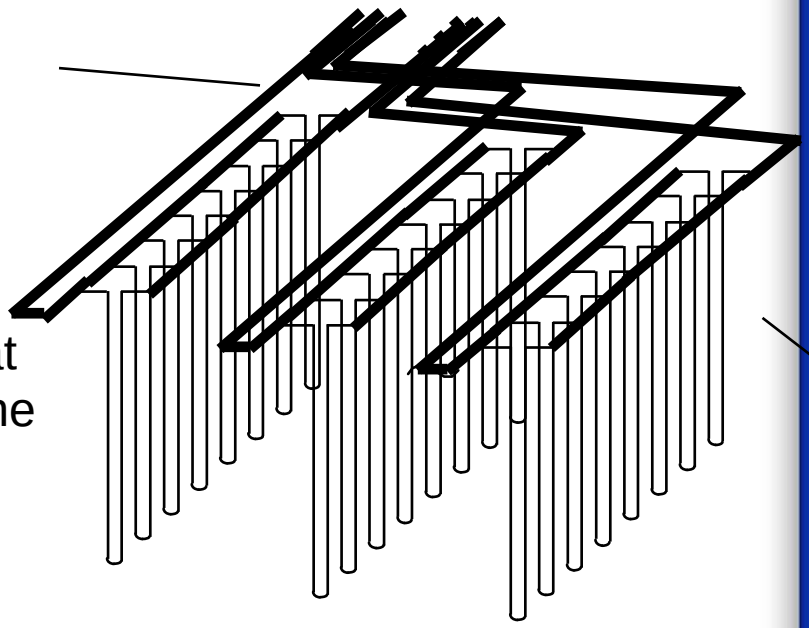
Vertical Loops

- 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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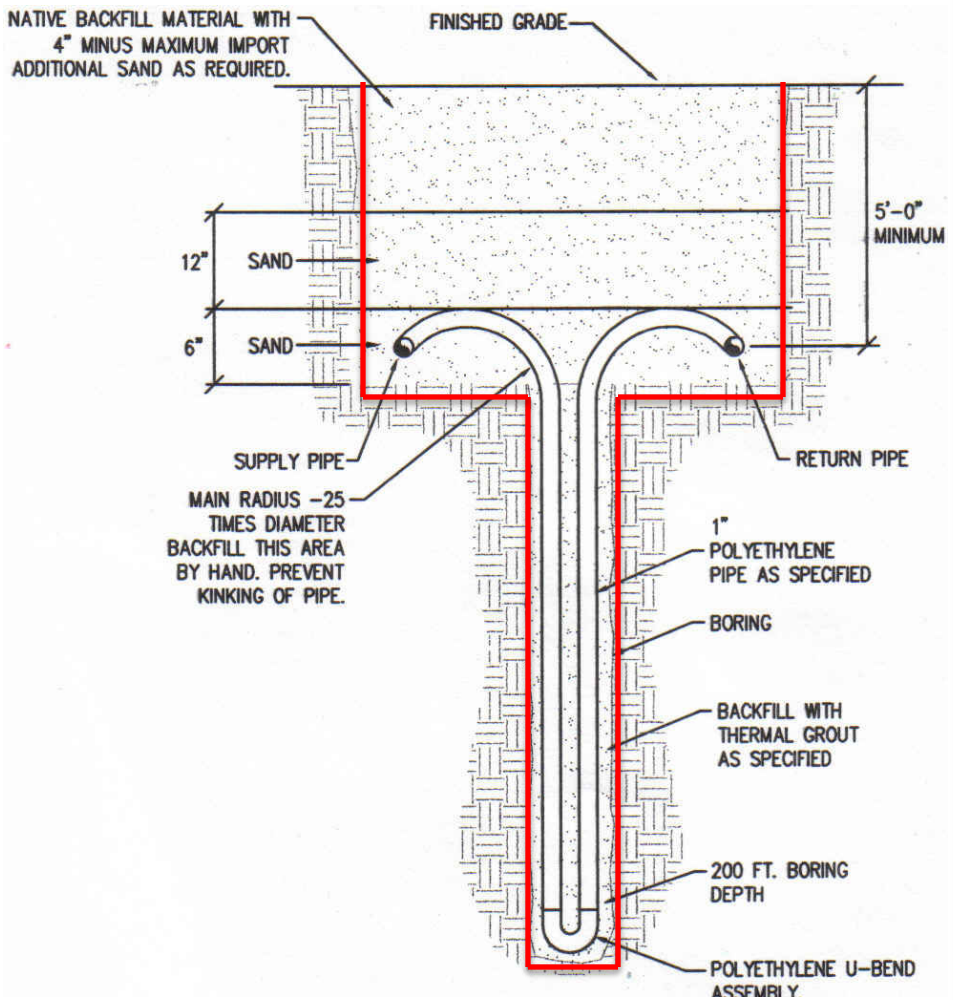
Geothermal Systems Operation

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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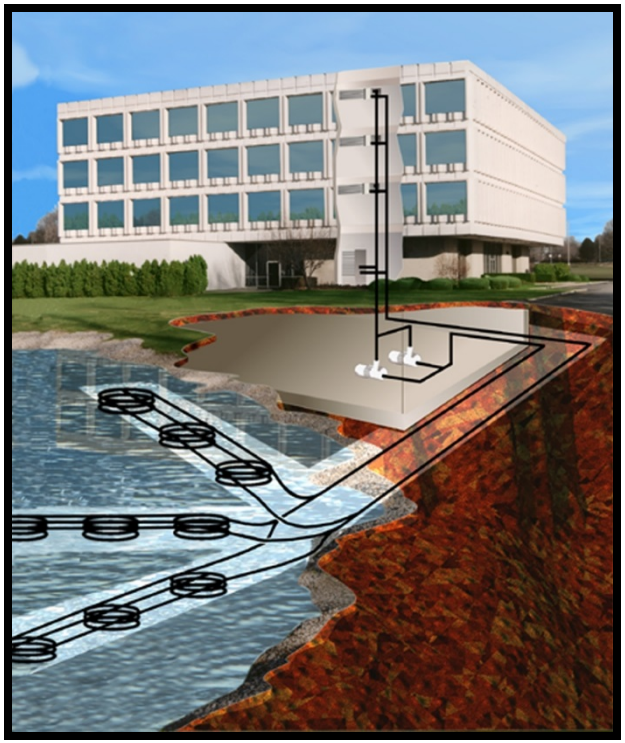
Closed Pond
Traditional Plastic Pipe on Pond Floor

- 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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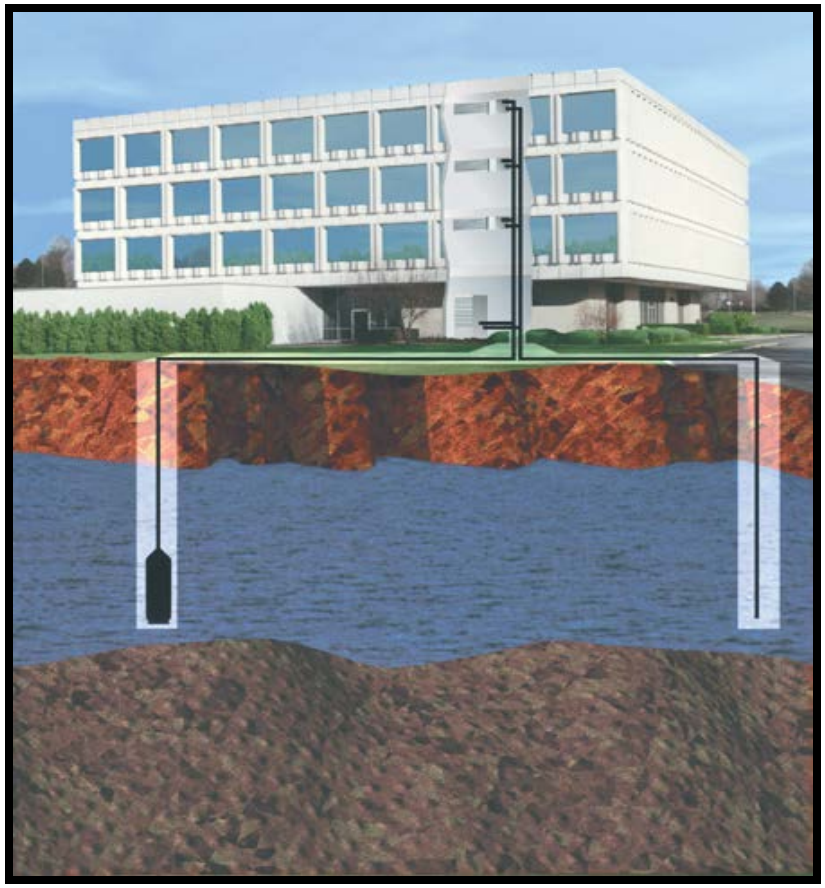
Open Loop

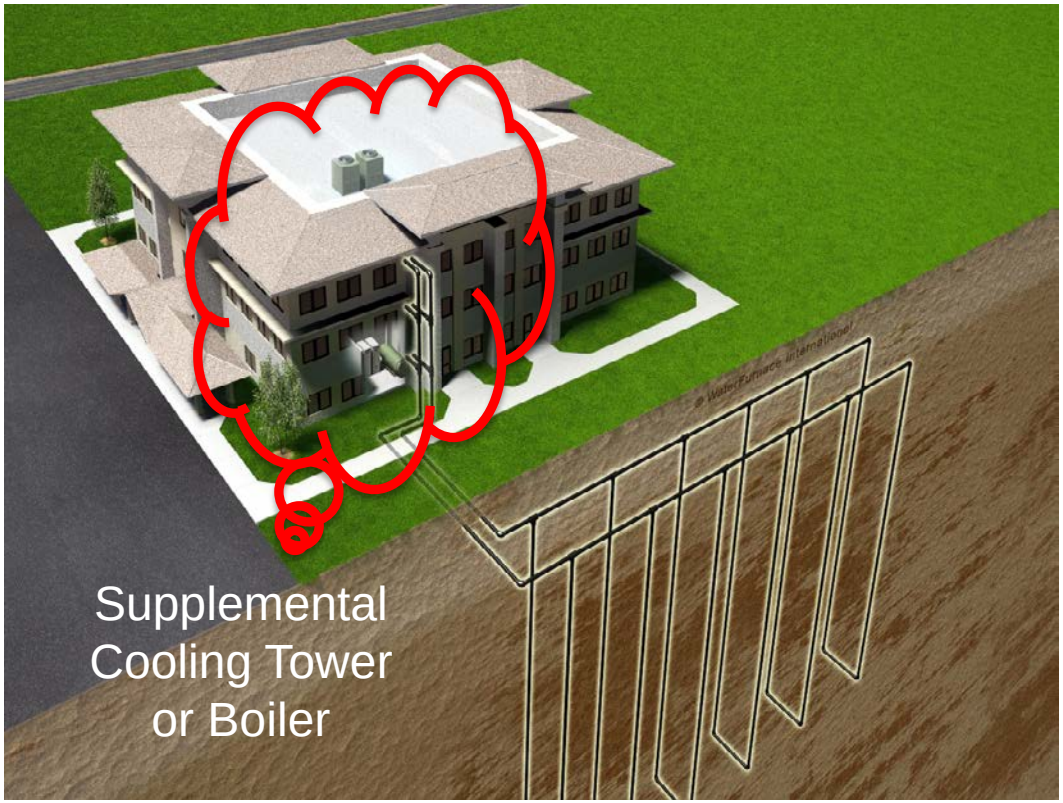
- “Pump and Dump”
- Colder water in cooling
- Filter out debris in the water
- Intermediate heat exchanger
- Water conservation and contamination issues
- Regulatory issues



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



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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

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

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Heat Pumps

Maintenance

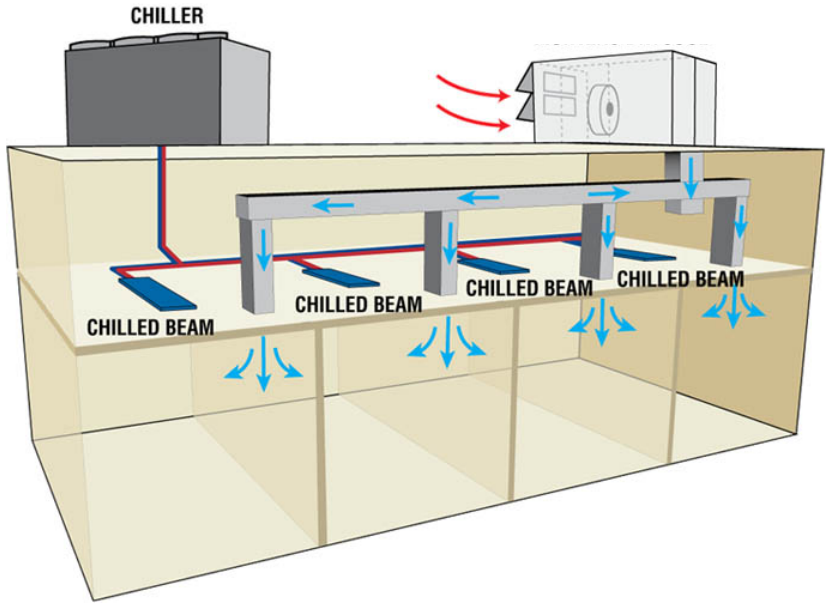
- Indoor Units
  - Removable Panels For Filter, Fan, Coil Access
  - Clean Filter
  - Check Fans
  - Check/Clean Fan, Coil, Cond Drain, Comp, Elect Conn
- Cooling Tower
  - Check/Clean Fan, Coil, Water Quality, Chemicals
- Boiler
  - Check/Clean Burner, Water Quality, Elect Conn
- Well Field
  - Check/Clean 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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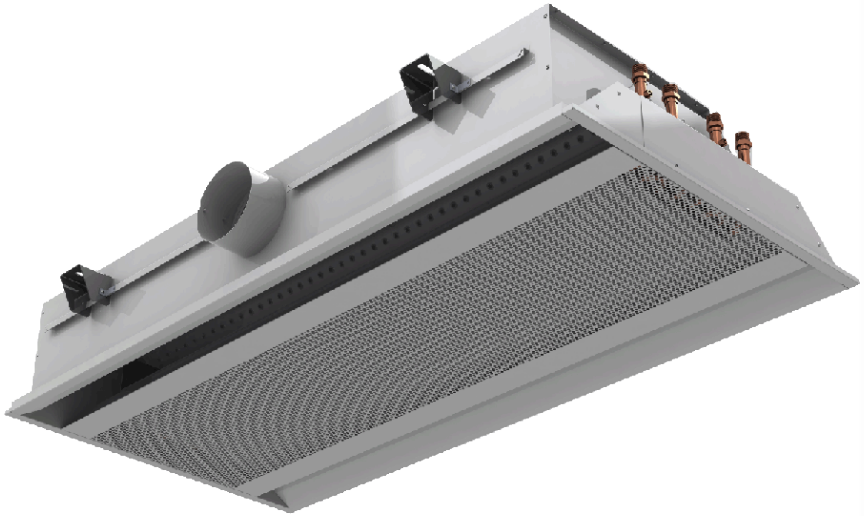
Chilled Beams

Flexibility

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



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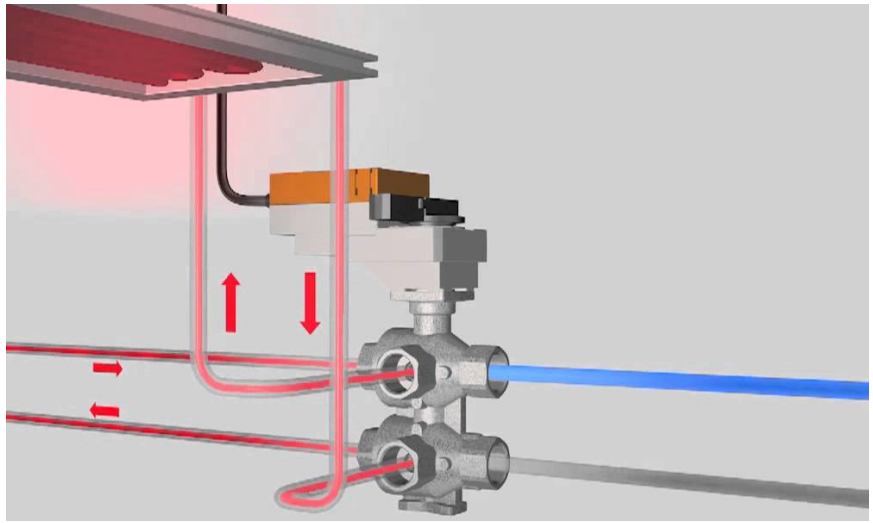
Chilled Beams

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

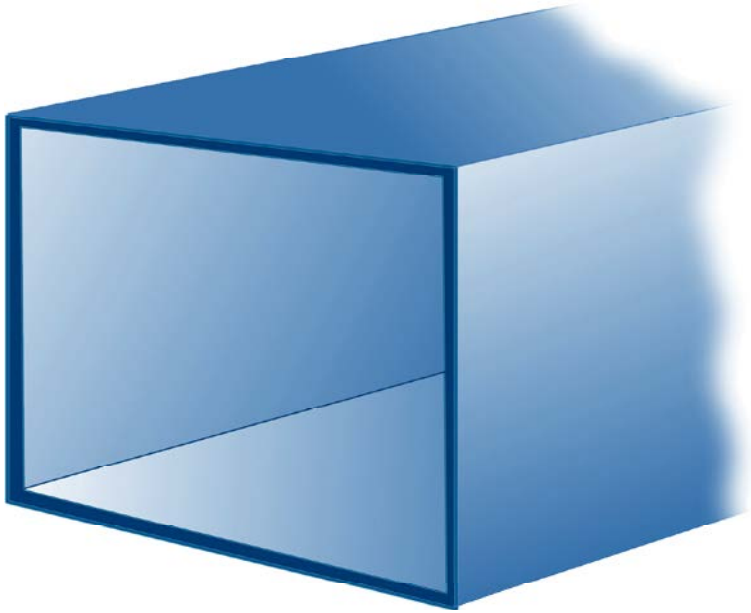
- Beams
  - Inspect Coils
- Chiller
- Boiler
- Pumps

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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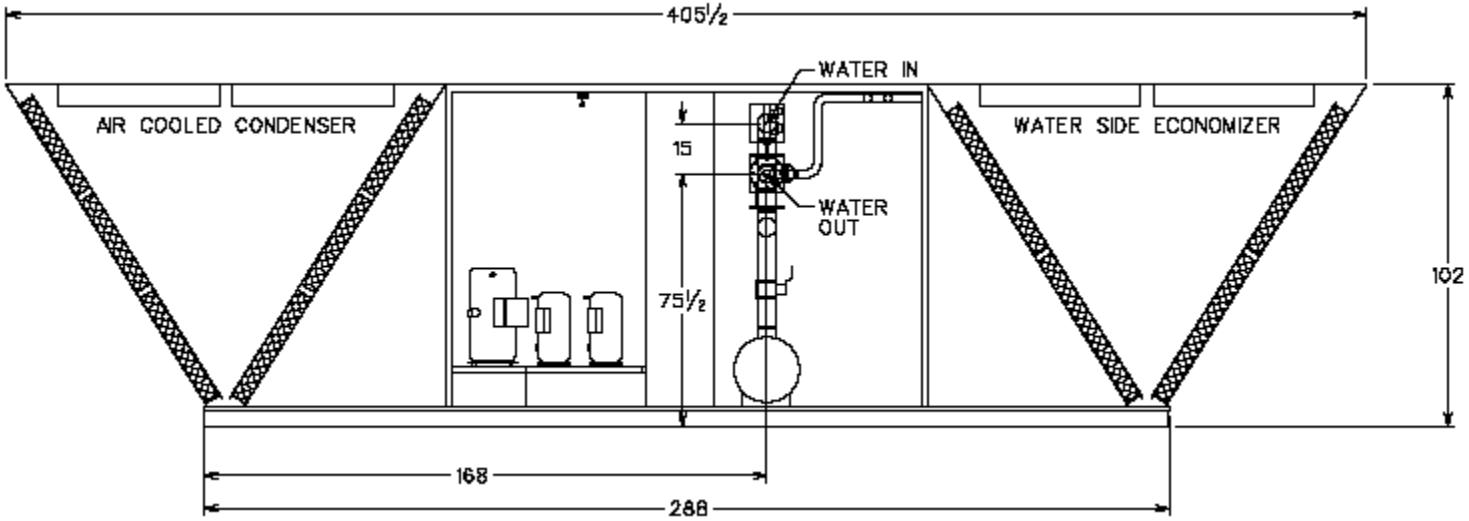
Chilled Beams

- 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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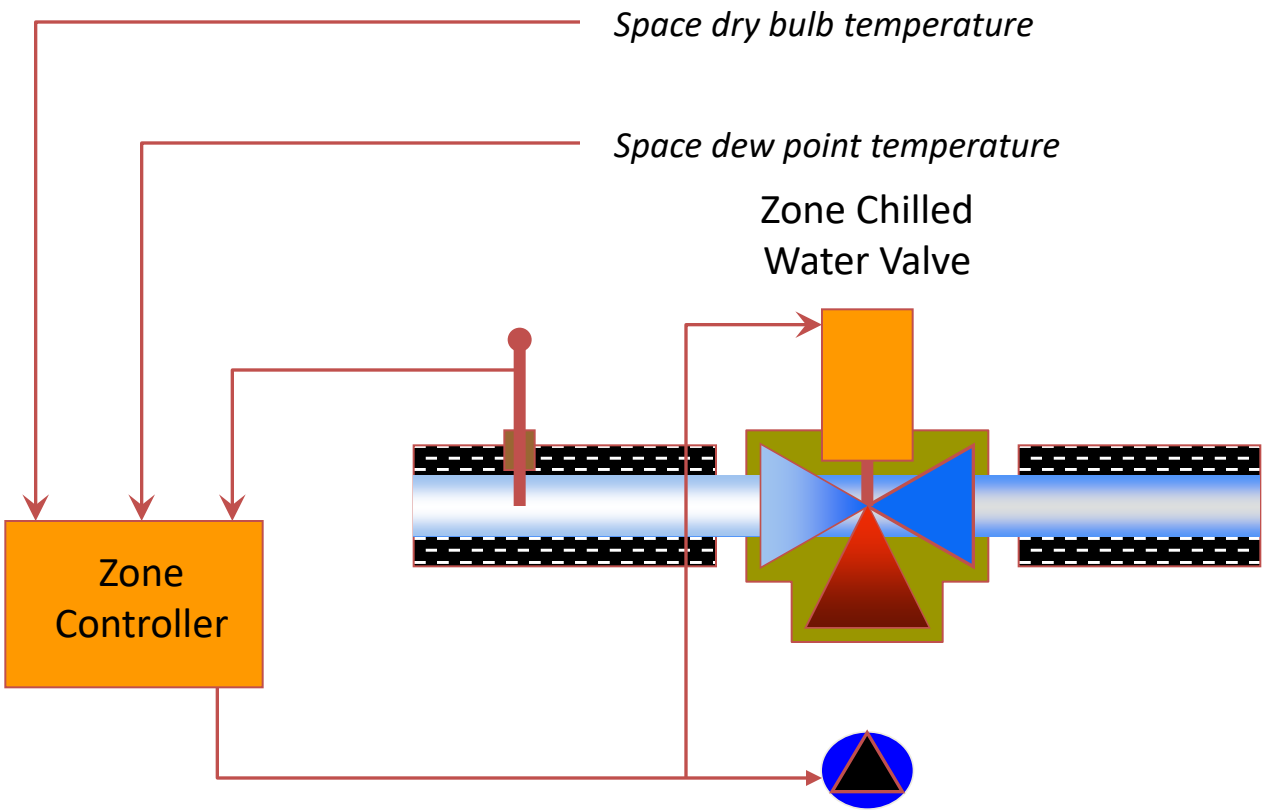
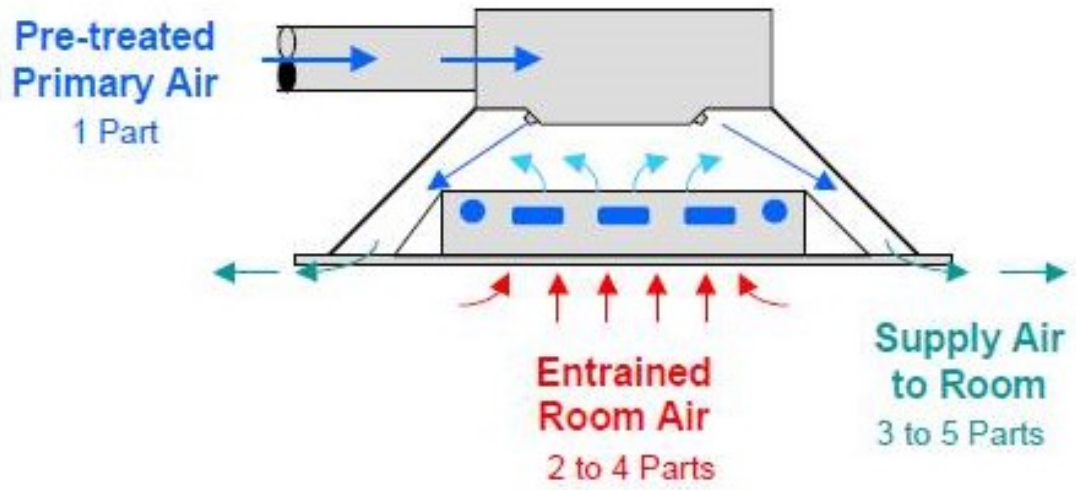
Chilled Beams

May be performed on an individual or multiple zone basis



Chilled Beams

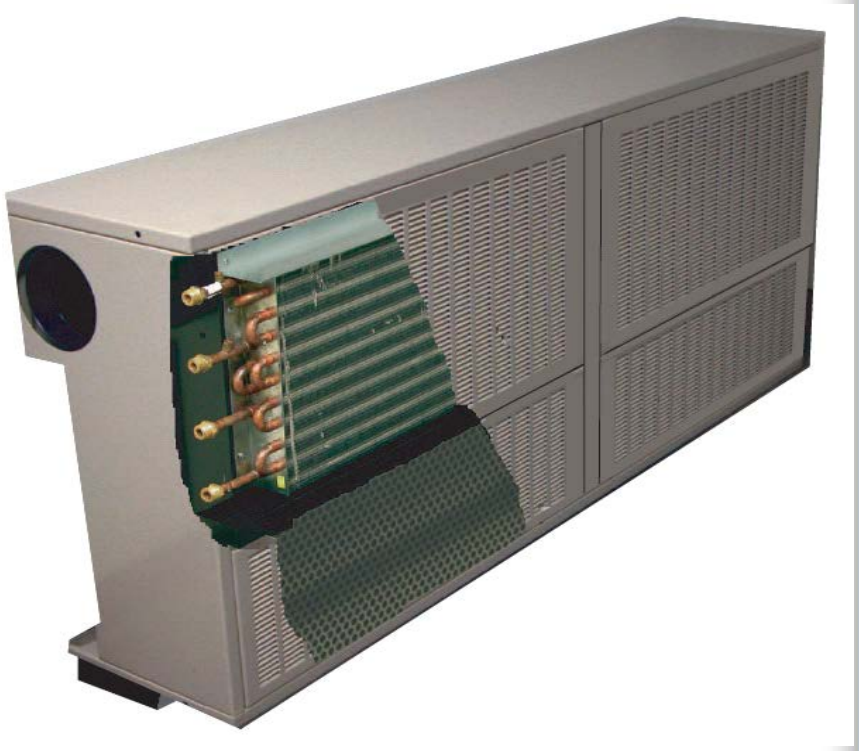


- Combines sensible, latent cooling and ventilation
- Room air induction ratio determined by nozzle size
- Modular design for ceiling integration

JACCO

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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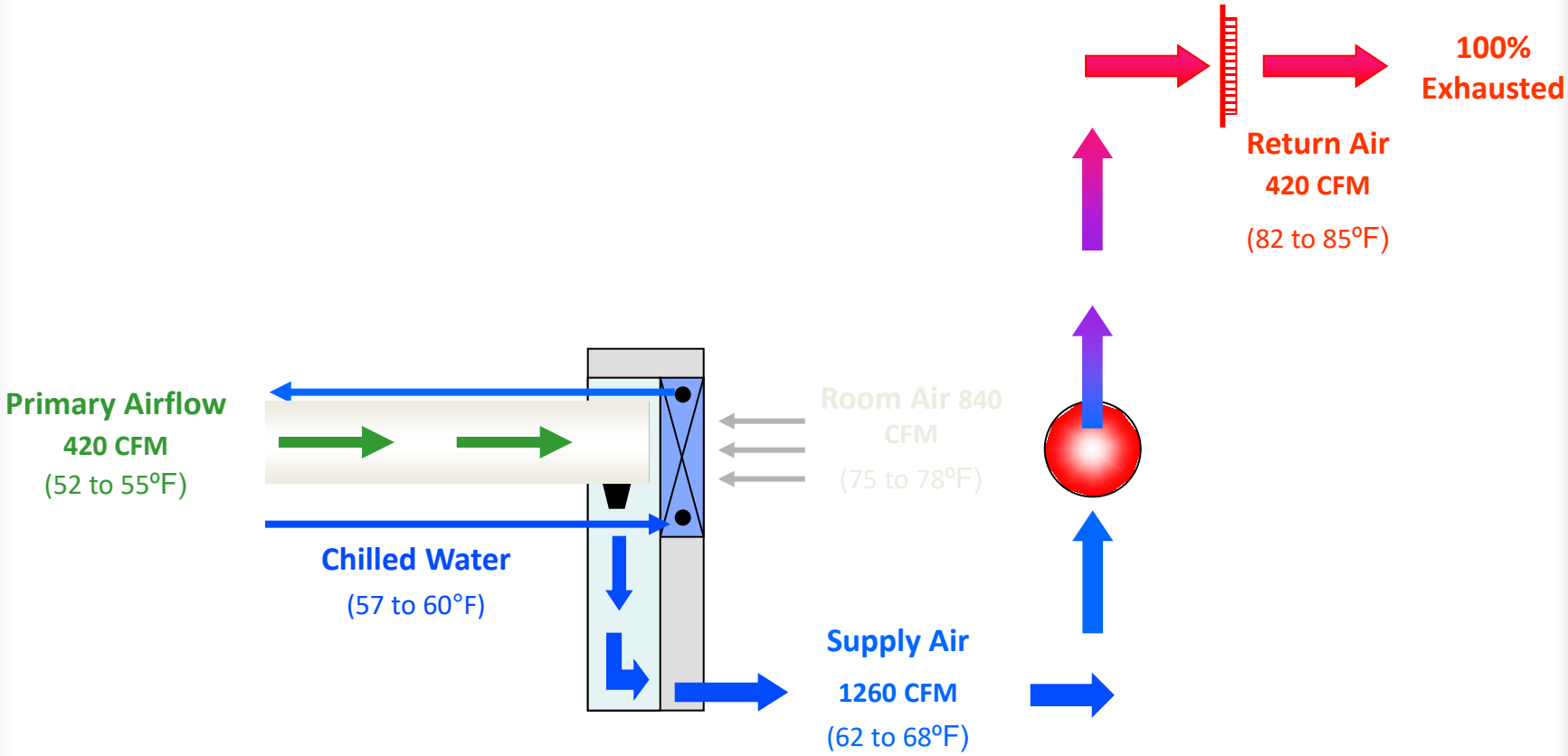
Chilled Beams



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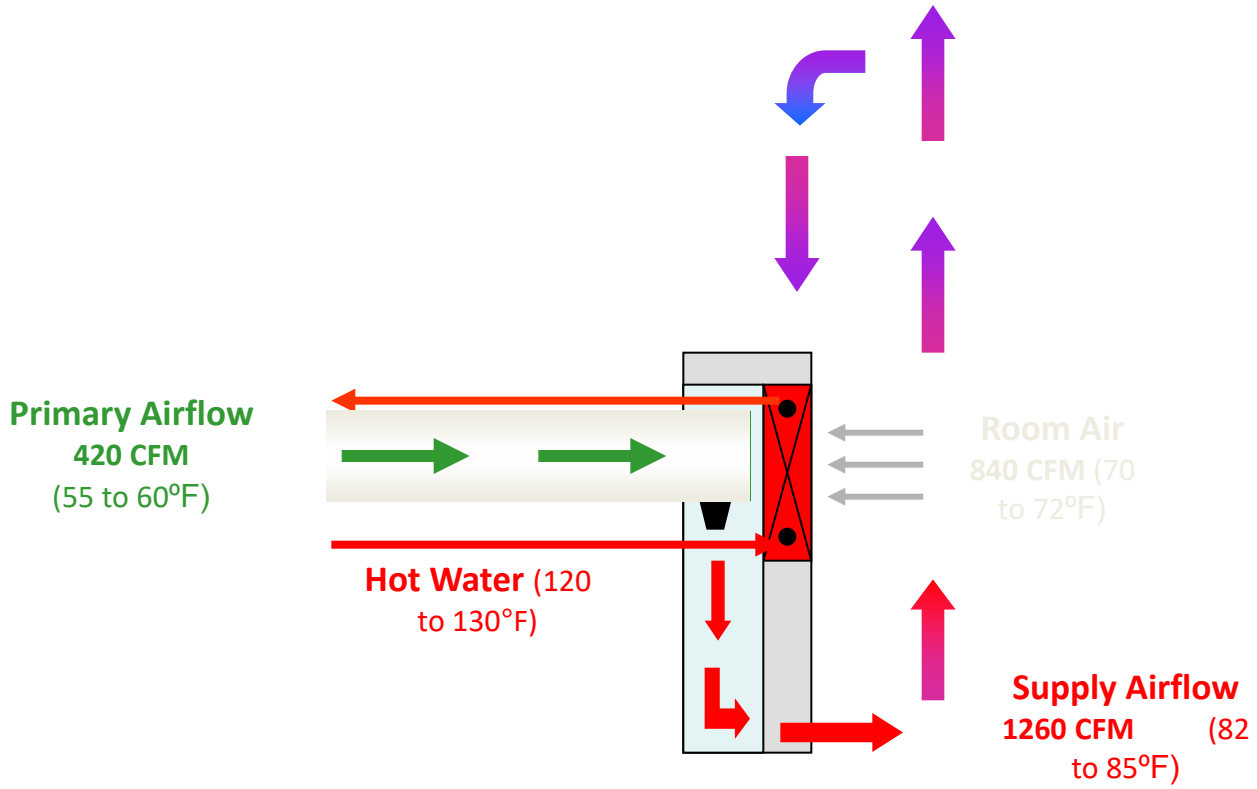
Chilled Beams



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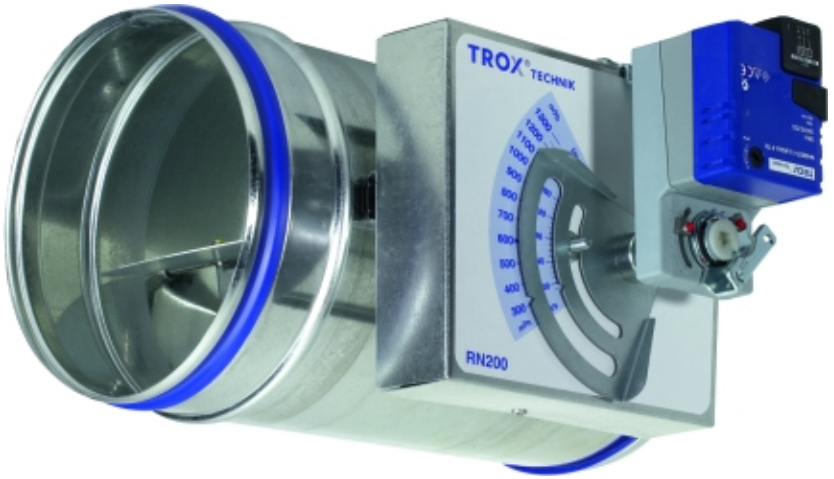
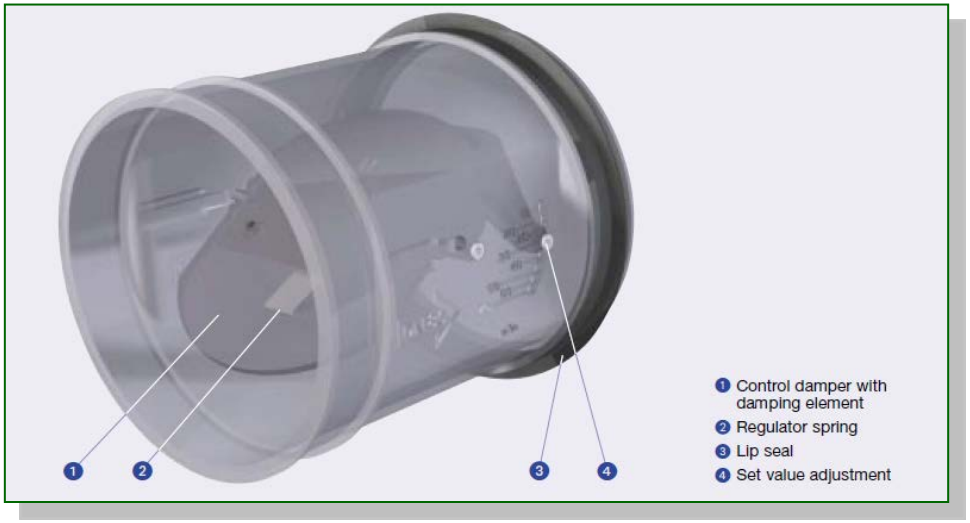
Chilled Beams

JACCO

Chilled Beams

Chilled Beams





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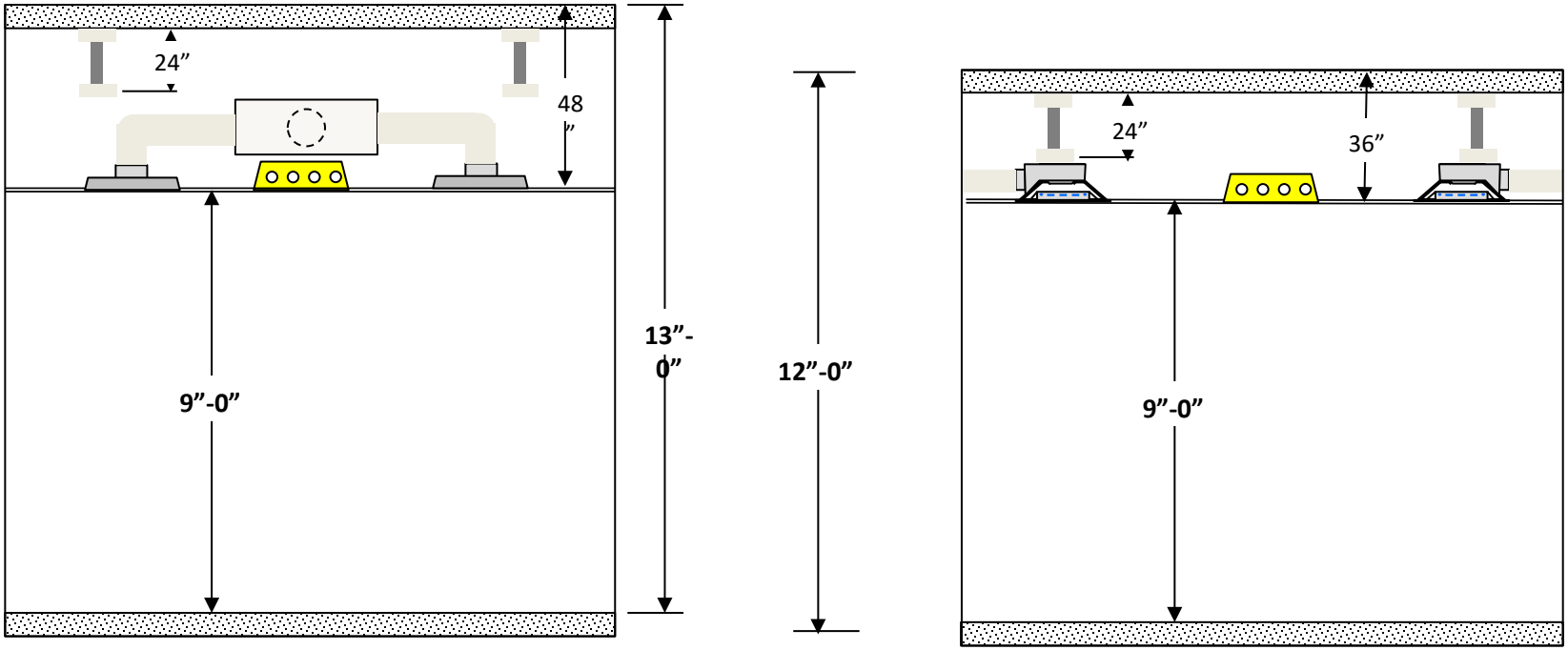
Chilled Beams



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

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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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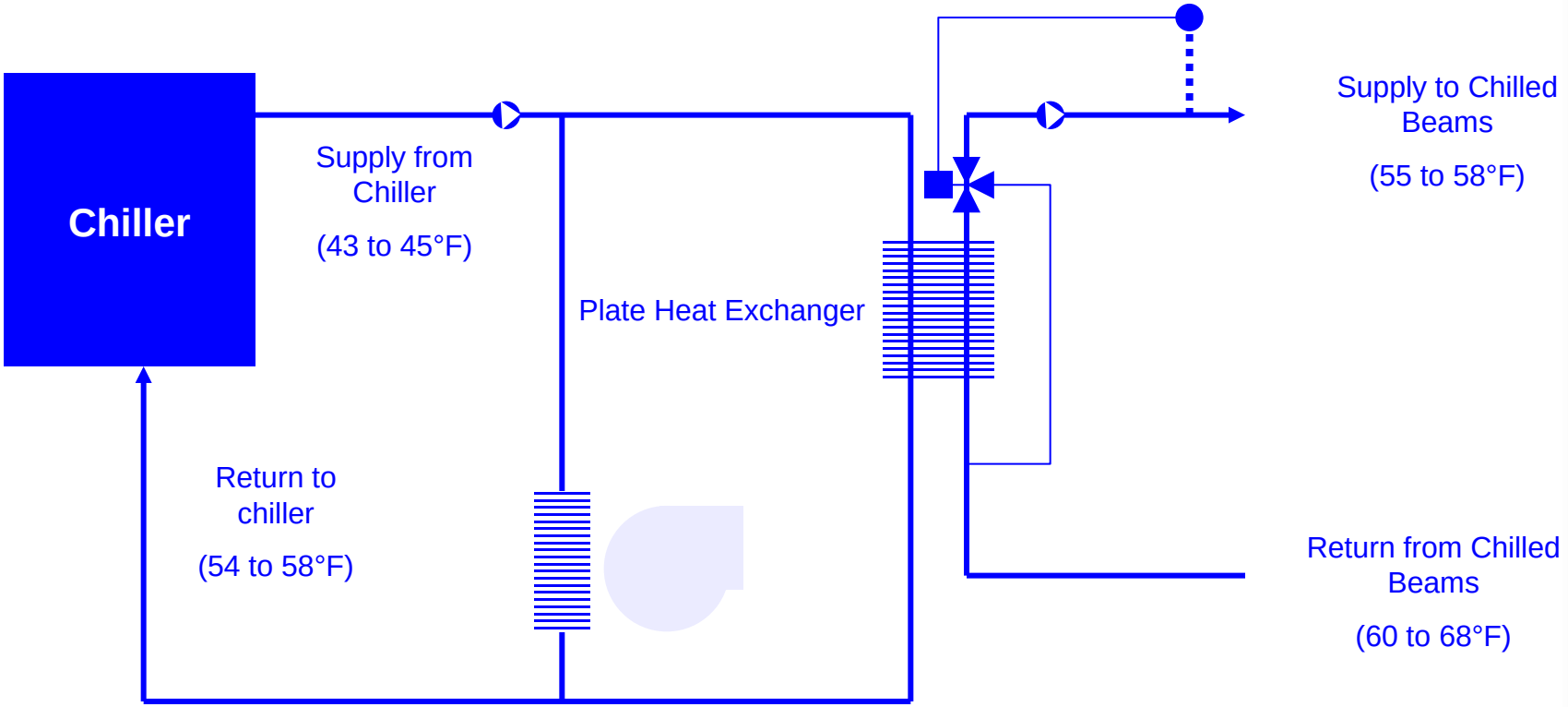
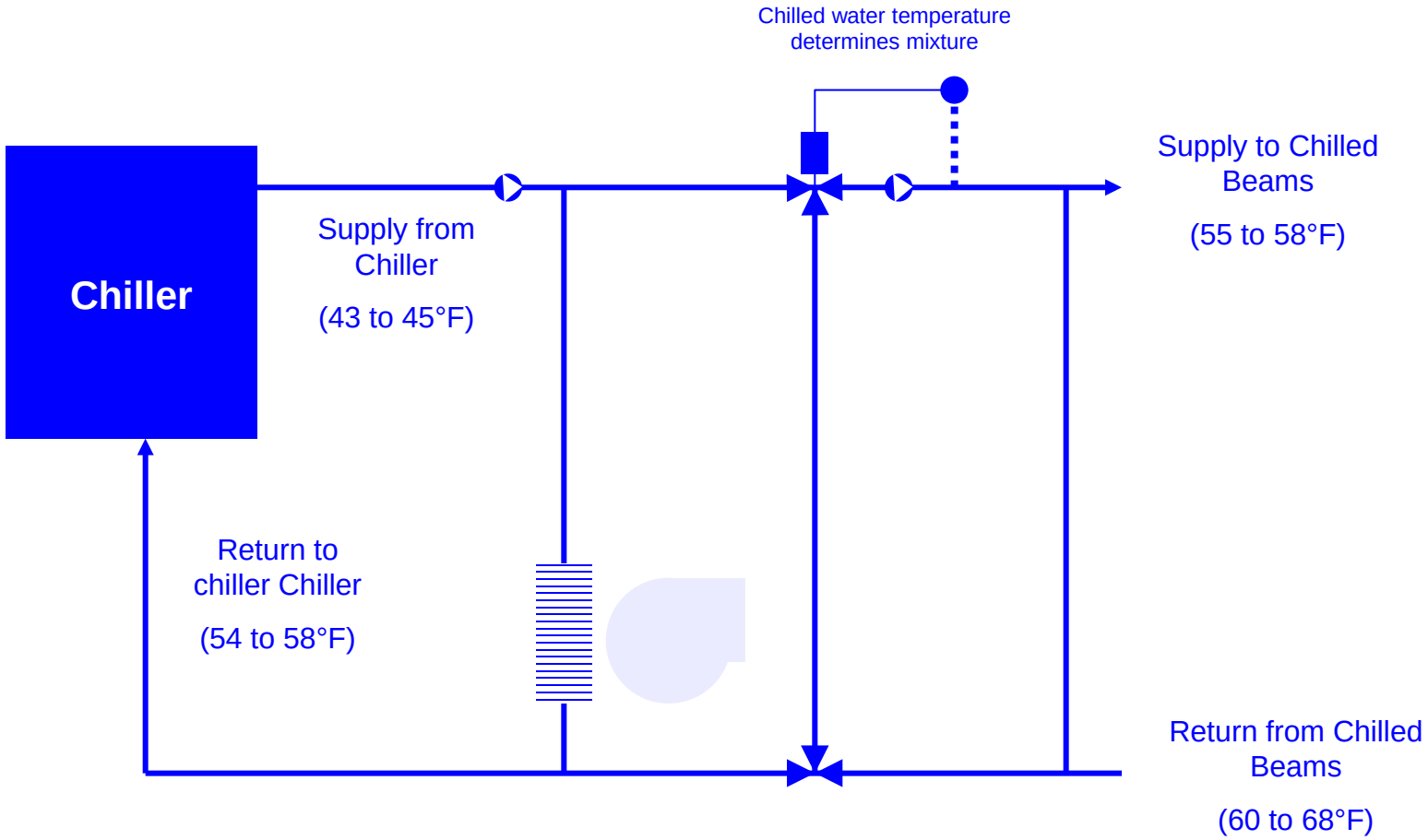
Chilled Beams – Closed Loop, Shared Chiller



Chilled Beams – Open Loop, Shared Chiller



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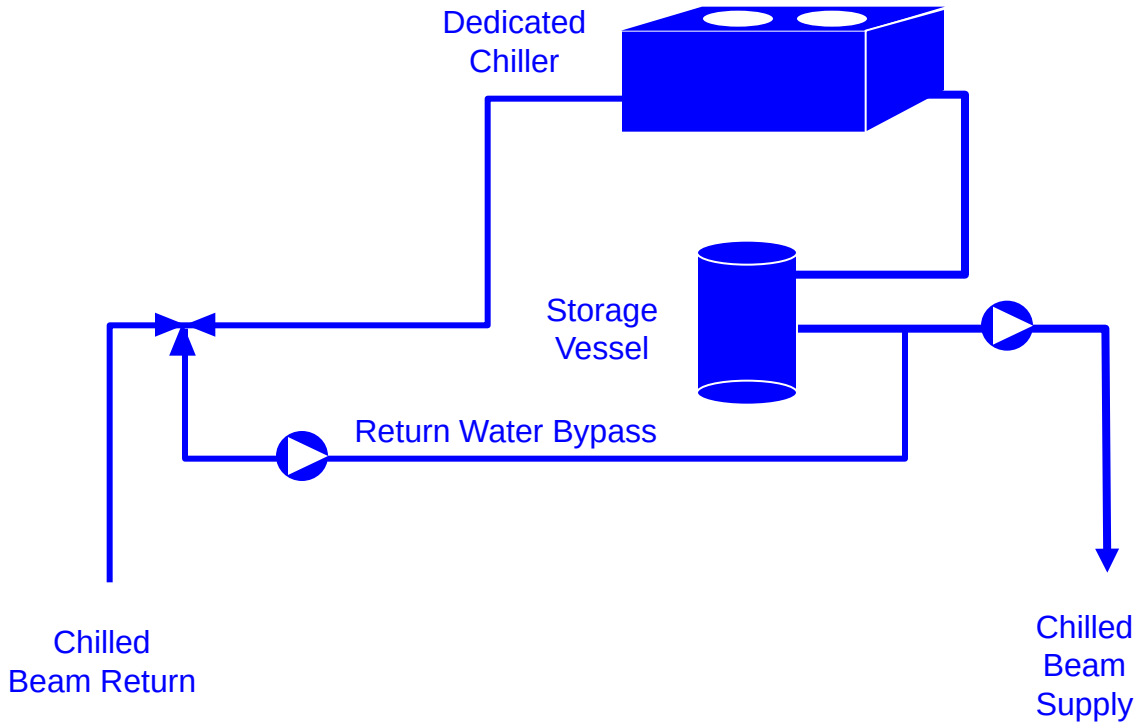
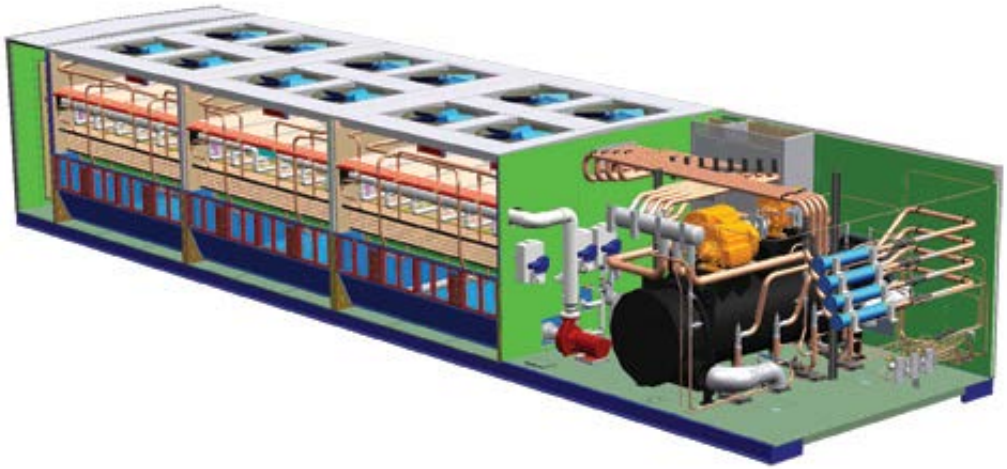
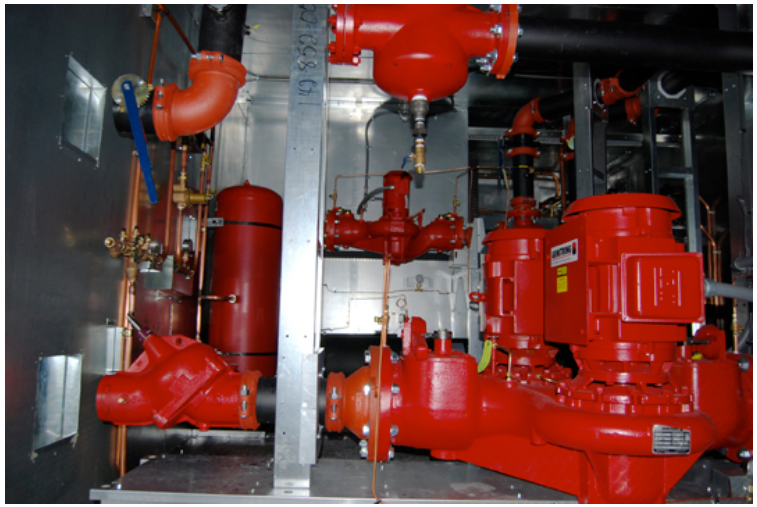
Chilled Beams – Dedicated Chiller



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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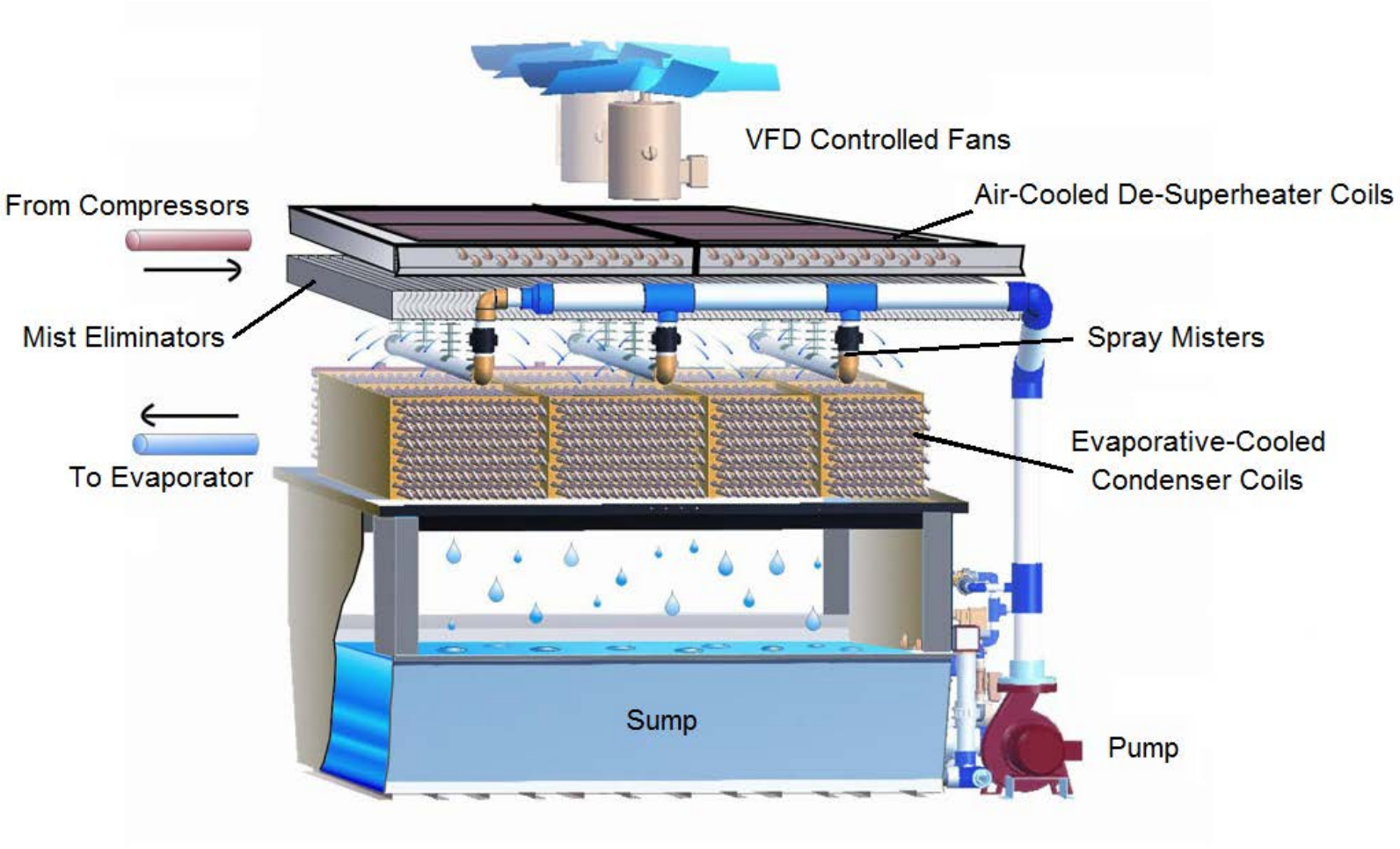
Chillers

- 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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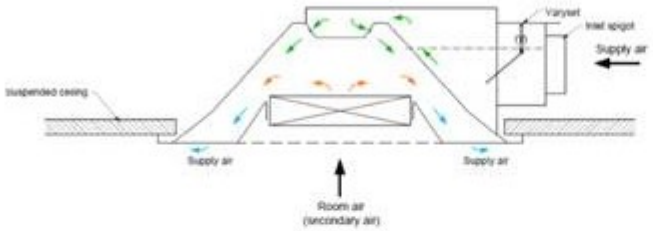
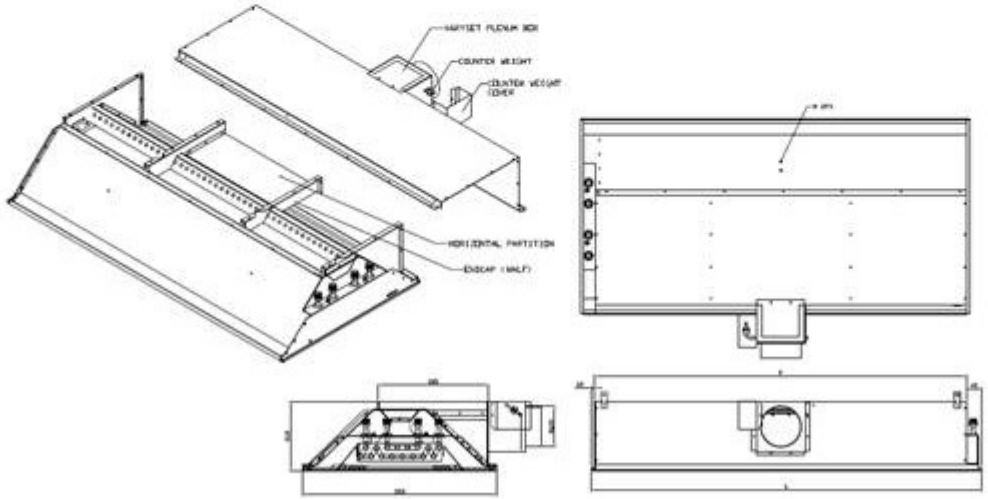
Chilled Beams

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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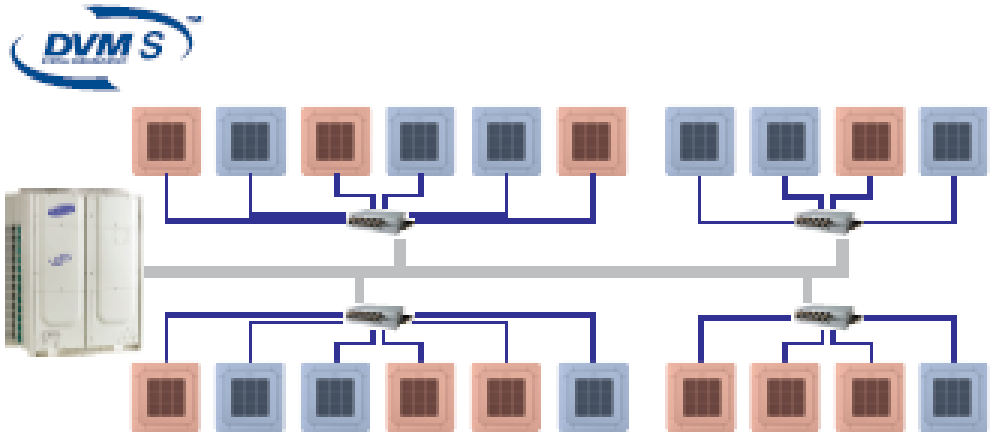
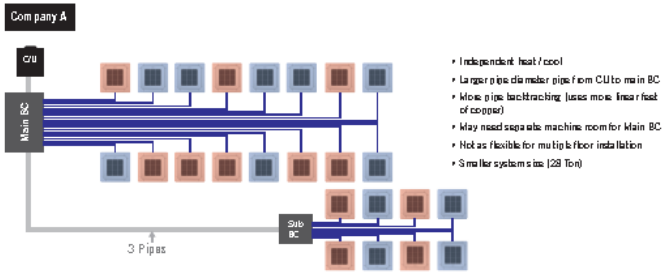
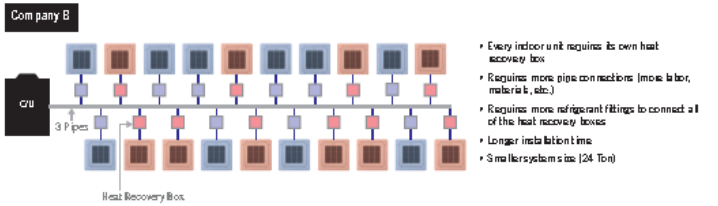
VRF



- 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

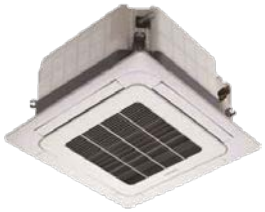




VRF

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)



VRF

Redundancy

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

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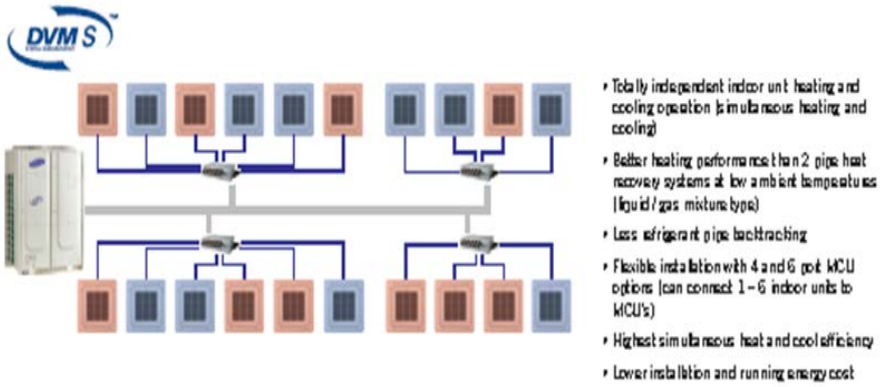
SAMSUNG

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

JACCO

SAMSUNG

VRF

Maintenance

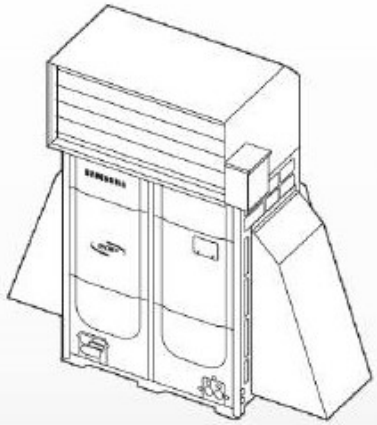
- Indoor Units
  - Removable Panels For Filter, Fan, Coil Access
  - Clean Filter
  - Check/Clean Fan, Coil, Cond Drain, Elect Conn
- Heat Pump
  - Check/Clean Fan, Coil, Elect. Connection
- System Diagnostics
- Units Can Not Be Replaced With Different Manufacturers

VRF Changes & Improvements

Accessories

Low Ambient Cooling Hood

- Low ambient hood for DVM S Heat Pump systems that allows cooling operation down to -13°F for current DVM S heat pump systems (firmware upgrade required)
- Will be applied to 2017 DVM S Heat Recovery systems
- 100% cooling capacity at -13°F (before de-rating for pipe length, etc.)
- Cooling down to -13°F will require installation of LACH-*** side, rear, and front (18 ton chassis) guards



New low ambient guard	Description
LACH-SL	Left guard
LACH -SR	Right guard
LACH-SLR	18 Ton DVM right and left guard
LACH-R1	Small chassis rear guard
LACH-R2	Large chassis rear guard
LACH-R3	18 Ton DVM rear guard
LACH-F1	18 Ton DVM front guard

DVM S Indoor Units

Smaller Capacity DVM S Cassette Models

- To help secure more projects, 5,000 and 7,500 Btu/h mini 4-way cassette indoor units will be added to the lineup

- Smaller capacity units may help reduce outdoor unit size due to current lack of smaller cassette units

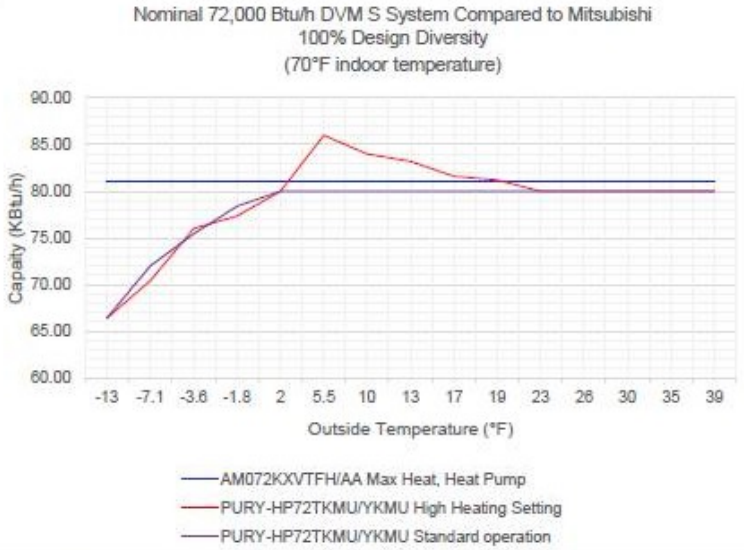
- RTS: October 22, 2016

VRF

Heat Recovery DVM S Max Heat Systems

- 100% heating capacity at -13°F
- Low ambient heating DVM S systems are currently heat pump only
- Heat recovery options will be added to the DVM S Max Heat Product line in 2017
- RTS: Q1 2017

MAX HEAT
LOW AMBIENT SERIES



Comparison

6 ton DVM S Max Heat, Heat Pump system to Mitsubishi Hyper Heat
NOTE: "High heat setting" = higher power consumption

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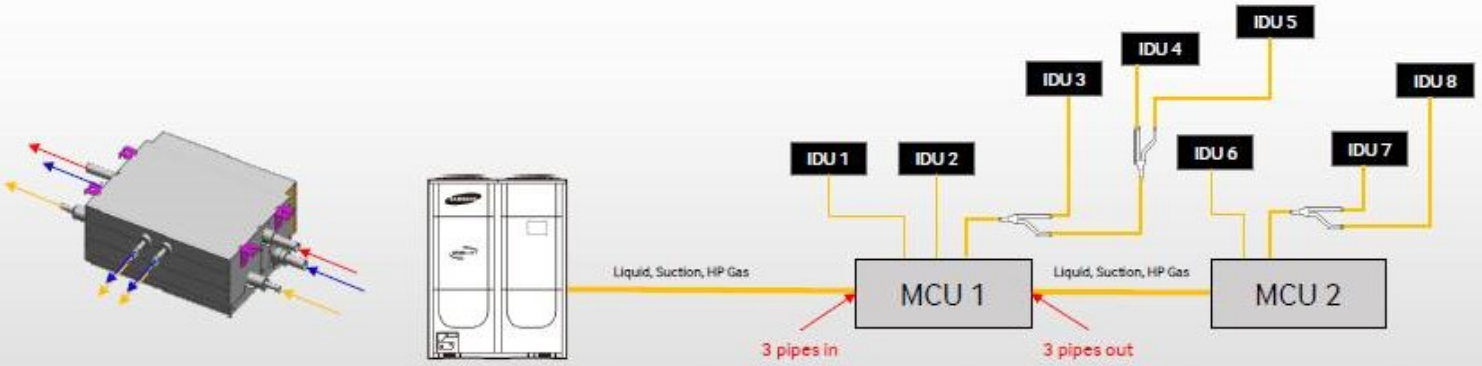
Heat Recovery MCU

New DVM S Heat Recovery Mode Control Units (MCU) - Continued

- Multiple indoor unit connection to a single MCU port
- Serial connection (see below)

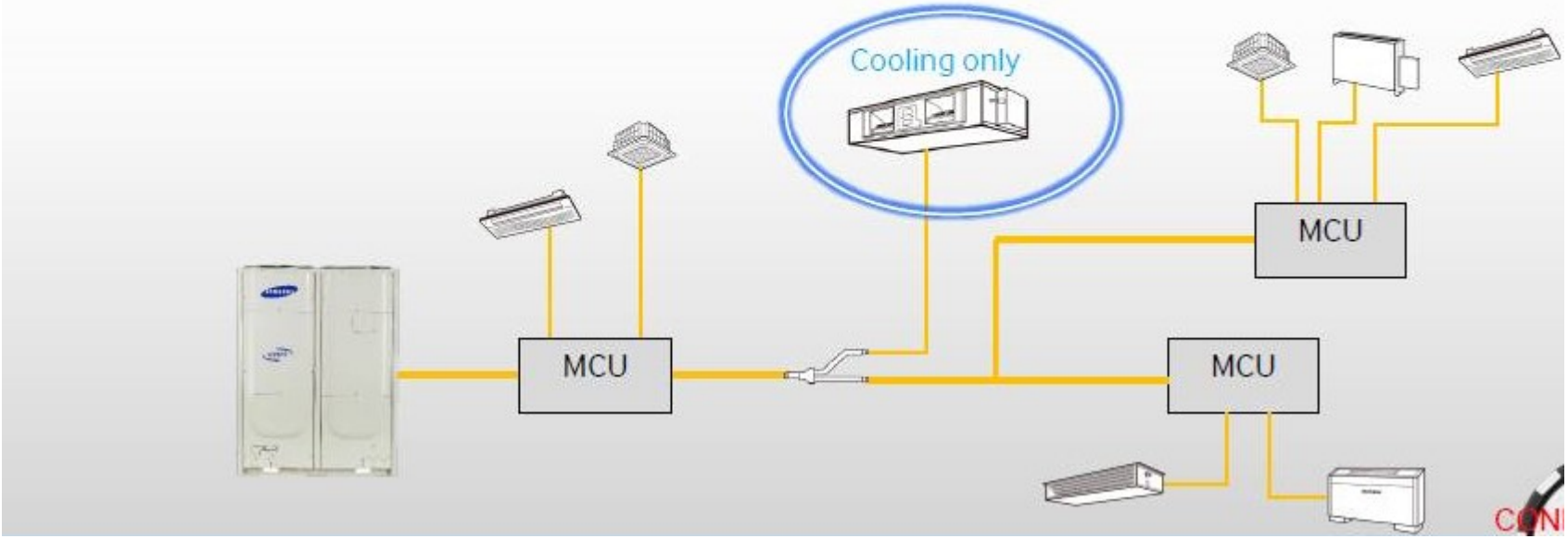


Serial connection – An MCU will have 3 inlet pipes and 3 outlet pipes to supply refrigerant to additional MCU's downstream (in addition to ports serving indoor units)

VRF

Cooling Only Indoor Units on Heat Recovery Systems

- Indoor units that are connected to heat recovery systems but are used for cooling only can be connected direct to the liquid and suction lines without connecting to an MCU



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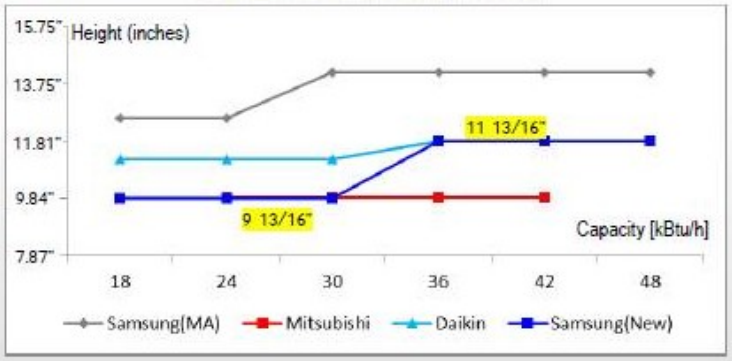
DVM S and CAC Indoor Units

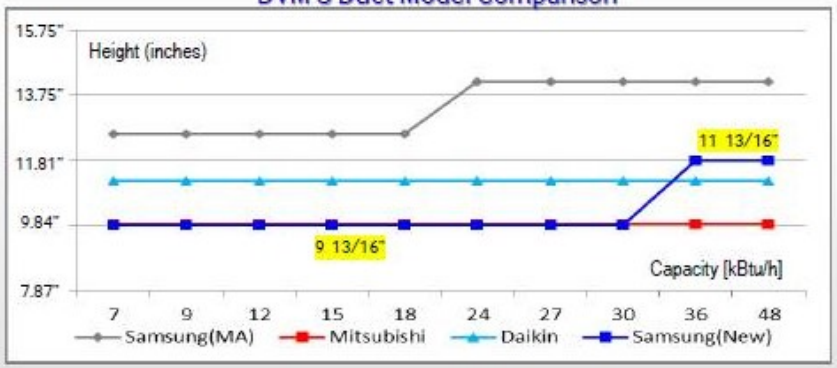
DVM S and CAC Duct Unit (continued)

- Competitors: 11.81" and shorter. Current Samsung models: 12.59" – 14.17"
- Installation is difficult or impossible in some applications due to limited ceiling space.

CAC Duct Model Comparison



DVM S Duct Model Comparison

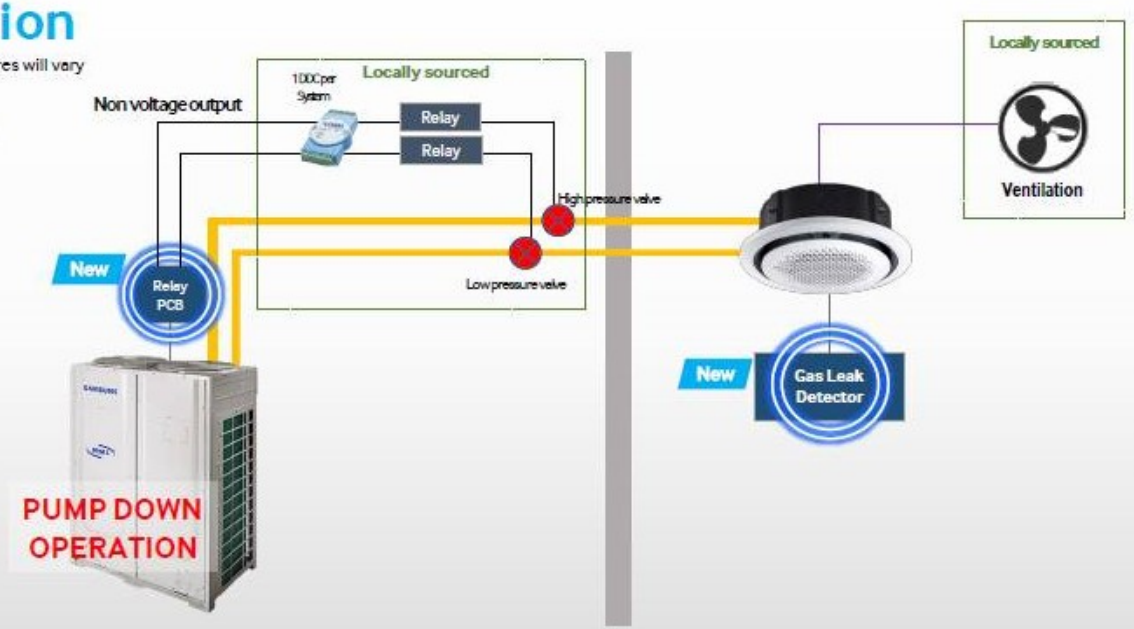


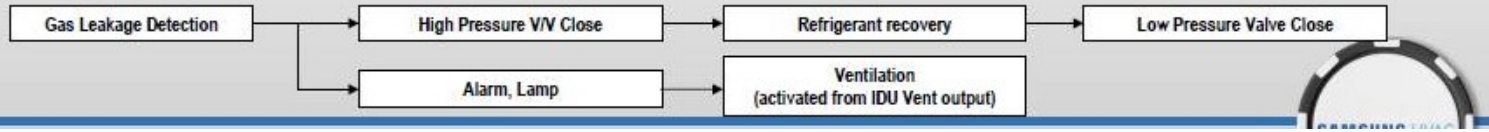
VRF

Gas Leakage Detection

NOTE: For general reference only, actual sequence and features will vary

- Pump down operation via external signal that will work along with refrigerant detection systems to secure system refrigerant in the outdoor unit
- DDC system, external solenoid valves, and relays will need to be sourced locally
- Subject to change





The Basics - Sequence of Operations

Jerry Cohen
President
Jacco & Assoc.

Problem Job Project Action Levels

Level 1

Description: Problems are found during startup and Service Technician is able to repair them onsite.

Costs: Covered under startup pricing.

Lead: Service department.

Support: None required.

Action: Repair item, check to make sure everything works properly. Service Technician looks at project/application to foresee and eliminate any potential Level 3 problems.

Level 2

Description: Problems are found during startup or during the first 30 days of operation. Parts and/or labor will require manufacturer warranty authorization and/or have to be ordered for installation at a later date.

Costs: Costs not covered by warranty parts/labor authorization are to be covered by the Systems Sales department and charged to the project.

Lead: Service department.

Support: None required.

Action: Contact factory for warranty labor/parts authorization. Notification of problem to Systems Sales Engineer and installing Mechanical Contractor within 24 hours to include tentative repair timeframe based upon parts availability.

Level 3

Description: Level 2 resolution does not work. Problems occur outside of first 30 days after startup. Mechanical Contractor and/or End User are involved. Problem may be re-occurring. Level 3 can be initiated by anyone at Jacco & Associates.

Costs: Costs not covered by warranty parts/labor authorization are to be covered by the Systems Sales department and charged to the project. Service will take the lead on costs incurred that should be covered by the manufacturer.

Lead: Whoever designates the project a Level 3.

Support: Collective intelligence to include Systems Sales & Service.

Action: Lead person sends email to JKC, GAD and SML announcing project is Level 3. Collective intelligence gathering to correctly diagnose problem. Contact factory for warranty labor/parts authorization, potential factory Service Technician site visit. Include in Problem Job List

Closing: After completion have an action/project review internally to include costs, responsibility, improvement of processes to avoid similar instances in future. Follow up with Architect/Engineer and End User to insure customer satisfaction with the operation of the unit.

Level 4

Description: Problems occur outside of first 30 days after startup. Mechanical Contractor and/or End User are involved. Problem is re-occurring after multiple site visits by Service Technicians. Jacco ownership is involved. Manufacturer is involved.

Costs: Cost is not the issue, purpose drives the completion.

Lead: Whoever designates the project a Level 4.

Support: Collective Intelligence to include Systems Sales and Service.

Action: Lead person sends email to JKC, GAD & SML announcing project is Level 4. Perform any and all actions that can resolve the problem and keep the owner operating in the interim. Collective intelligence gathering to correctly diagnose problem. Include in Problem Job List

Closing: After completion have an action/project review internally to include costs, responsibility, improvement of processes to avoid similar instances in future. Personal Customer Review with Architect/Engineer and End User to insure customer satisfaction with the operation of the unit. Project does not come off of Problem List until the Personal Customer Review is complete and costs are delegated.

Special Note:

Everyone can offer to send a service technician to any project at any time. If it is Jacco/Manufacturer problem then there is no charge, if it is a project problem then Jacco will invoice customer.

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Recommendations

- Move the sequence of operations up to the schematic design phase!
- Keep it simple!
- Let the commissioning agent and TCC do their job!

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Process Elements

- List Systems To Be Controlled
- List Modes, Components & Sub-Components
- Write Simple Sequence
- Cartoon
- Add Points To Cartoon
- Final Points List

List Modes & Components

- Modes:
  - Occupied / Unoccupied
  - Cooling
  - Heating
  - Economizer
  - CO2
  - Building Pressure
  - Humidification
  - Dehumidification
- Components:
  - Cooling
  - Supply Fan
  - Return/Exhaust Fan
  - Economizer
    - Dampers
  - Heating
  - Reheat

List Sub-Components

- Cooling
  - DX, Chilled Water
  - Staged, Modulating
- Supply Fan
  - Constant, Variable
- Return/Exhaust Fans
  - Constant, Variable
  - Building Pressure
- Control Dampers
- Heating
  - Gas, Electric, Hot Water, Steam, Heat Pump
  - Staged, Modulating
  - Reheat

Your Home

- Who here has a home or apartment?

Your Home

- Fan on with call for heating or cooling
  - Auto/On
- Heating on with call from space thermostat
  - Stage as required to maintain 70F adj.
- Cooling on with call from space thermostat
  - Stage as required to maintain 75F adj.
- Humidification on with call from space/return air humidistat
  - Cycle as required to maintain 30% RH adj.
- Unoccupied mode to maintain 55 heating or 85 cooling adj.

Constant Volume

- Fan on with call for heating or cooling
- Outside air at minimum position 20% adj.
- Heating on with call from space thermostat
  - Stage as required to maintain 70F adj.
- Cooling on with call from space thermostat
  - Stage as required to maintain 75F adj.
- First stage of cooling shall be outside air if available through enthalpy/dry bulb economizer
- Humidification on with call from space/return air humidistat
  - Cycle as required to maintain 30% RH adj.
- Unoccupied mode to maintain 55 heating or 85 cooling adj.

CAV p1

Constant Air Volume (CAV)

Mode Enable Sensor Options

The temperature of this sensor will determine if the unit is in heating, cooling or vent mode during occupied operation. The following options are available:

- Space Air Temperature Sensor (CAV,)
- Return Air Temperature Sensor (CAV)

Occupied Operation

There are several ways to initiate the Occupied mode of operation for the VCM-X:

- Internal week schedule
- Remote Forced Occupied contact closure
- Pushbutton Override button on a Space Sensor (Override length is user adjustable)
- Monitoring an external Orion scheduling device

Scheduling

- Has an internal clock that provides 7 day scheduling with 2 start/stops per day.
- Allows scheduling of up to 14 holiday periods per year.

Unoccupied Operation

- The space sensor uses Night Setback Setpoints for heating and cooling calls. If Night Setback Setpoints are left at the default 30°, no Night Setback operation will occur and the unit will be off.
- Uses normal dehumidification setpoint for unoccupied dehumidification calls if Night Humidity Control is configured.
- Outdoor air damper will be closed except if unit is in unoccupied economizer free cooling mode.
- If there is no call for heating, cooling or dehumidification the unit will be in the Off Mode
- If this is a MUA unit that also has return air function, the unit can be configured to operate as a CAV unit in the Unoccupied Mode using space temperature night setbacks and/or a space dehumidification setpoint (See MUA Unoccupied Night Setback Operation section). The outside air damper remains closed. Otherwise the MUA unit will remain off in the Unoccupied Mode.

HVAC Modes of Operation

There are 6 possible HVAC Modes of Operation:

*Cooling
*Heating
*Ventilation *Off

Cooling Mode with Digital Scroll Compressor and Optional Fixed Capacity Scroll Compressors

- Cooling is enabled when the temperature at the Mode Enable Sensor rises one deadband above the Cooling Setpoint. Cooling is disabled when the Mode Enable temperature falls one deadband below the Cooling Setpoint. The setpoint and deadband are user adjustable.
- Under normal VAV operation (Supply Air Control), the unit is in Cooling Mode anytime it is in the Occupied Mode.
- In the cooling mode, as the Supply Air Temperature (SAT) rises above the Active Supply Air Cooling Setpoint (see Supply Air Temperature Setpoint Reset section for explanation), the Digital Compressor will stage on and modulate to control to the Active Supply Air Cooling Setpoint.
- If additional cooling is required, fixed compressor stages can be staged on while the Digital Compressor continues to modulate.
- To stage up the extra compressor(s), the SAT needs to be above the Active Supply Air Cooling Setpoint and the Digital Compressor needs to be at 100% for a period of time equal to the Stage Up Delay. Once a fixed compressor is enabled the digital compressor signal will go to 10% and modulate up as needed. This will repeat as additional fixed compressors are staged up.

CAV p2

- For compressors to stage on, Minimum Off Times (adj.) must be satisfied as well as Stage Up Delays (adj.).
- To stage down the extra compressor(s), the SAT needs to be below the Active Supply Air Cooling Setpoint minus the Cooling Stage Control Window and the Digital Compressor needs to be at 0% for a period of time equal to the Stage Down Delay. Once a fixed compressor stages off the digital compressor will go to 100% and modulate down as needed. This will repeat as additional fixed compressors stage off.
- For compressors to stage down, Minimum Run Times (adj.) must be satisfied as well as Stage Down Delays (adj.). The digital compressor is always the last compressor to be deactivated.
- Mechanical cooling is disabled if the outdoor air temperature (OAT) falls 1° below the Cooling Lockout Setpoint and will remain disabled until the OAT rises 1° above the Cooling Lockout Setpoint. If the OAT disables mechanical cooling while it is currently operating, mechanical cooling will stage off as minimum run times and stage down delays are satisfied.
- If the economizer is enabled it will function as the first stage of cooling (see Economizer section).
- If this is a DPAC unit, the Return Air Bypass Damper remains closed during the cooling mode.

Heating Mode:

- Available heating option is Modulating Gas Heat.
- Heating is enabled when the temperature at the Mode Enable Sensor falls one deadband below the Heating Setpoint. Heating is disabled when the Mode Enable temperature rises one deadband above the Heating Setpoint.
- Once in the Heating Mode the unit will stage or modulate heating to maintain the Supply Air Temperature at the **Active Supply Air Heating Setpoint** (See Supply Air Temperature Setpoint Reset section for explanation).
- Multiple stages of heating can be configured subject to user adjustable minimum run times, minimum off times, staging up and staging down delays.
- Mechanical heating is disabled if the outdoor air temperature (OAT) rises 1° above the Heating Lockout Setpoint and will remain disabled until the OAT falls 1° below the Heating Lockout Setpoint. If the OAT disables mechanical heating while it is currently operating, mechanical heating will stage off as minimum run times and stage down delays are satisfied.

Ventilation Mode:

- This is only available in the Occupied Mode of operation on units configured for continuous fan operation and is generated anytime there is no demand for heating or cooling.

Off Mode:

- Occurs in the Unoccupied Mode when there is no heating, cooling or dehumidification demand.
- Can only occur in the Occupied Mode if the fan is configured to cycle with heating and cooling and there is no call for heating, cooling or dehumidification.
- Supply fan is off and the outside air damper is closed.

Economizer Operation

- Enabled when Outdoor Air (OA) drybulb or wetbulb temperature falls below the Economizer Enable Setpoint by 1° and the OA temperature is at least 5° below the return air temperature (if a return air temperature sensor is being used).
- Economizer operation is disabled when the OA temperature rises 1° above the Economizer Enable Setpoint.
- Wetbulb operation requires an Outdoor Humidity Sensor.
- Economizer acts as 1st stage of cooling and controls to the Active Supply Air Cooling Setpoint. If the economizer reaches 100% and the supply air temperature is still above setpoint, mechanical cooling is allowed to stage up while the economizer is held at the full open position.
- An Economizer Minimum Position can be programmed into the controller.
- A Economizer Damper is closed during Unoccupied Mode, except when unoccupied free cooling is used during night setback operation.

CAV p3

Space Sensor Operation

- Available as a Plain Sensor, Sensor with Override, Sensor with Setpoint Slide Adjust, and Sensor with Override and Setpoint Slide Adjust.
- Sensors with Setpoint Slide Adjust can be programmed to allow space setpoint adjustment of up to ± 10° F.
- The Setpoint Slide Adjust will adjust the setpoints of whichever sensor is the mode controlling sensor, even if that sensor is not installed Space Temperature Sensor.
- If Space Temperature is being used to reset the Supply Air Temperature Setpoint, then the Slide Adjust will adjust the HVAC Mode Enable setpoints and the SAT/Reset Source setpoints simultaneously.
- For MUA applications the Space Sensor can be used as a reset sensor to reset the Supply Air Setpoint based on space conditions.
- During Unoccupied hours the Override Button can be used to force the unit back into the Occupied Mode (by pressing the button for less than 3 seconds) for a user-defined override duration of up to 8.0 hours. Pressing the button between 3 and 10 seconds cancels the override.

Supply Fan Operation

- Occupied Mode – Supply fan can be configured to run continuously (default) or to cycle with heating, cooling or dehumidification.
- Unoccupied Mode – Supply fan will cycle on a call for heating, cooling or dehumidification.
- Anytime the Supply Fan is requested to start, a 1 minute minimum off timer must be satisfied. If the timer is satisfied the Supply Fan relay is activated while all other outputs are held off for a period of 1-2 minutes to purge stagnate air from the ductwork before heating or cooling occurs.
- In fan cycle mode or when going unoccupied the supply fan is held on for 2 minutes after the last stage of heating or cooling stages off.

Dirty Filter Status

This input in uses a 24 VAC wet contact closure for Filter Status Indication. A differential pressure switch (by others) is required.

Duct Static Pressure Control for Filter Loading

- In order to maintain a constant CFM through the supply air ducts on MUA Unit or a mixed air CAV, PAC or DPAC Unit, a duct static pressure sensor can be used to monitor the discharge pressure.
- If the filters are getting dirty, the VCM-X will ramp up the VFD to compensate for the decrease in airflow.
- To utilize this feature the unit must be configured to use VFD fan control.
- This feature cannot be used if this is a VAV Unit with typical duct static pressure control.

Remote Forced Heating and Cooling

- These inputs (24 VAC wet contacts) allow another control system or a thermostat to force the unit into heating or cooling.
- To utilize these inputs, the heating and cooling setpoints in the VCM-X must be set to zero.
- Once in this force mode the unit will stage heating/cooling to maintain the appropriate heating/cooling leaving air setpoint until the force is removed.

Emergency Shutdown

- A 24 VAC wet contact input is available to be used with a N.C. Smoke Detector, Firestat, or other shutdown condition (all by others).
- If this contact opens it will initiate shutdown of the VCM-X and will generate an alarm condition. This contact closure does not produce an instantaneous shutdown.

CAV p4

Temperature Protection:

- Activated when the Supply Air Temperature (SAT) rises above the High Cutoff Temperature (immediate) or drops below the Low Cutoff Temperature (for 10 minutes) both of which are user adjustable. This mode shuts off the unit (with a 3 minute fan off delay) until the mode is cancelled.
- This mode is cancelled when the SAT drops 5 degrees below the High Cutoff Temperature Setpoint or rises 5 degrees above the Low Temp Cutoff Temperature Setpoint, or when the unit changes back into Occupied Operation.

Outdoor Air Lockouts

- Mechanical cooling is disabled when the Outdoor Air Temperature is below the Cooling Lockout Setpoint.
- Mechanical heating is disabled when the Outdoor Air Temperature is above the Heating Lockout Setpoint.
- For Air to Air Heat Pumps the Cooling Lockout also applies to Compressor Heating, so it will usually be a lower setting that on Cooling units that are not Air to Air Heat Pumps.

VCM-X Controller and Expansion Boards I/O Map

I/O Map

VCM-X Controller			
	Analog Inputs	Analog Outputs	Relays
1	Space temperature	Economizer	Supply Fan
2	Supply Temperature	Supply Fan VFD	Configurable
3	Return Temperature		Configurable
4	Outdoor Temperature		Configurable
5	Coil Temperature		Configurable
6	Static Pressure		
7	Space Sensor Slide Offset or Remote BAS Reset of SAT Setpoint		
VCM-X Expansion Module			
	Analog Inputs	Analog Outputs	Binary Inputs
1	Outdoor Humidity	Building Pressure VFD	Emergency Shutdown
2	Space/RA Humidity	Modulating Heating	Dirty Filter
3	Not Used	Modulating Cooling	Proof of Flow
4	Building Pressure	Return Air Damper	Remote Forced Occupied
5		Return Air Bypass Damper	Remote Forced Heating
6			Remote Forced Cooling
7			Exhaust Hood On
8			Remote Forced Dehum.
4 Binary Input Expansion Module			
	Binary Inputs		
1	Emergency Shutdown		
2	Dirty Filter		
3	Proof of Flow		
4	Remote Forced Occupied		
12 Relay Output Expansion Module			
	Relay Outputs		
1-12	Configurable		

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Economizer Operation

- Enabled when Outdoor Air (OA) drybulb (enthalpy) temperature falls below the setpoint less offset
- Economizer operation is disabled when the OA temperature rises above the setpoint plus offset.
- Economizer acts as 1st stage of cooling and controls to the Cooling Setpoint. If the economizer reaches 100% and the temperature is still above setpoint, mechanical cooling is allowed to stage up while the economizer is held at the full open position.
- Comparative economizer requires RA sensors and compares OA to RA to use the most advantageous airstream to cool.
- Economizer Minimum Position can be controlled with an AFMS.
- Economizer Damper is closed during Unoccupied Mode, except when unoccupied free cooling is used during night setback operation.

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Unoccupied

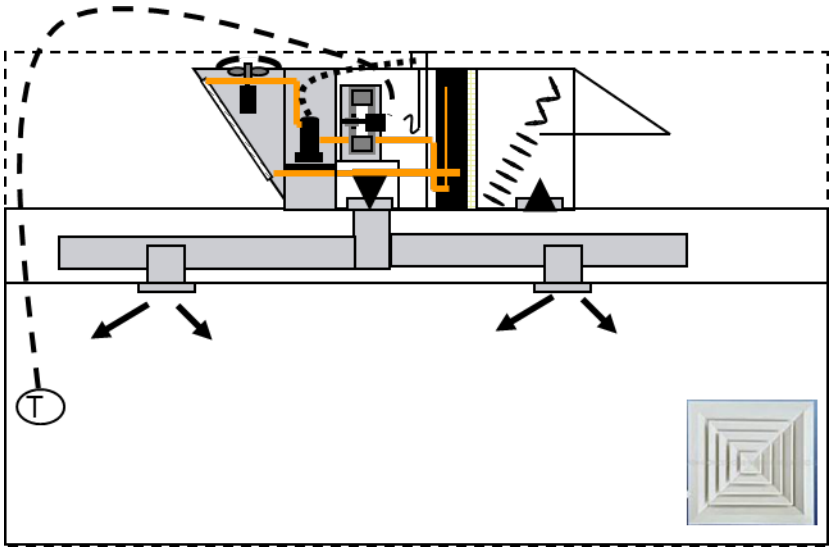
- During the unoccupied mode the fan shall be disabled and the economizer dampers shall be in the full return position. The unit shall remain in the unoccupied mode until commanded to the warm-up, cool-down, or occupied mode. (EMS, Thermostat, VAV)
- During the unoccupied heating mode the supply fan shall be enabled. The economizer dampers shall remain in the full return position. The unit shall cycle the gas heat on to achieve the unoccupied heating setpoint.
- During the unoccupied cooling mode the supply fan shall be enabled. The economizer dampers shall remain in the full return position, unless outdoor air temperature conditions allow for free cooling. The unit shall cycle the cooling on to achieve the unoccupied cooling setpoint.

SZVAV

- Heating on with call from space thermostat
  - Stage as required to maintain 70F adj.
- Fan at 100%
- Outside air at minimum position 20% adj.
- Cooling on with call from space thermostat
  - Cooling to maintain constant discharge air temperature of 55F adj.
  - Compressor to modulate
- Fan to modulate to maintain space temperature of 75F adj.
- First stage of cooling shall be outside air if available through enthalpy/dry bulb economizer
- Unoccupied mode to maintain space at 55 heating or 85 cooling adj.

Single Zone VAV Systems

- Single Zone VAV systems serve one zone.
- Airflow changes based on space load
- Unit capacity changes to maintain supply air temperature
- SAT set point can be reset to maintain humidity control (if reheat available)
- VAV boxes not required



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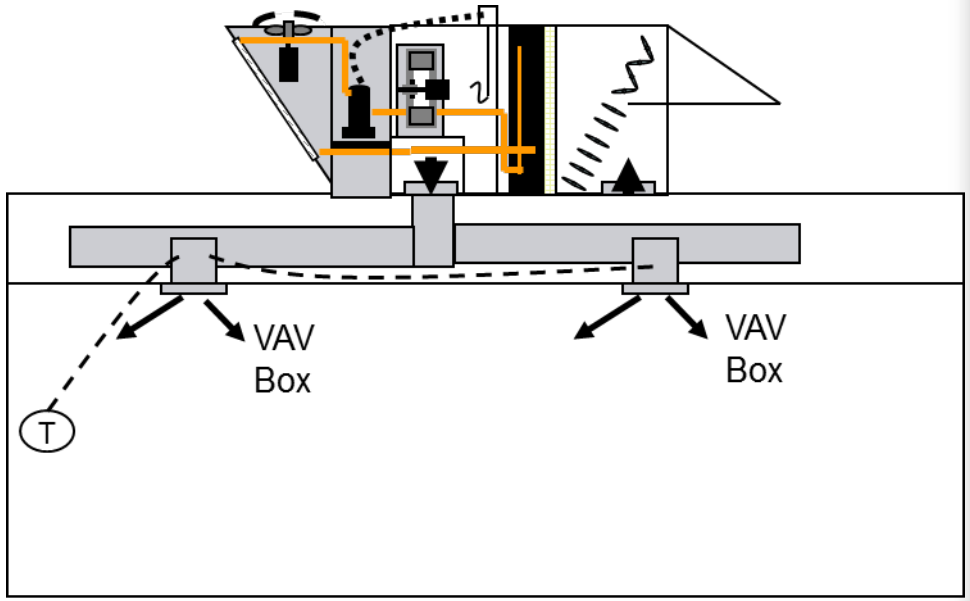
VAV

- Outside air at minimum position 20% adj.
- Cooling on year round during occupied mode
  - Cooling to maintain constant discharge air temperature of 55F adj.
- Compressors to modulate
- First stage of cooling shall be outside air if available through enthalpy/dry bulb economizer
- Fan to modulate to maintain duct static pressure of .75" adj.
- Unoccupied mode to maintain space at 55 heating or 85 cooling adj.

Traditional VAV Systems

- Traditional VAV systems feed multiple zones from one unit
- Supply airflow changes to maintain supply duct pressure
- Unit capacity changes to maintain supply air temperature



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VAV Temperature Reset

- The discharge air temperature setpoint shall be reset based on OA temperature. The setpoint shall adjust on a linear scale.
  - The DAT SP shall be fifty-five degrees Fahrenheit when the outdoor air temperature is at or above seventy-five degrees Fahrenheit.
  - The DAT SP shall be sixty-five degrees Fahrenheit when the outdoor air temperature is at or below forty-five degrees Fahrenheit.

VAV CFM Reset

- The discharge air temperature setpoint shall be reset based on CFM. The setpoint shall adjust on a linear scale.
  - The DAT SP shall be fifty-five degrees Fahrenheit when the CFM is at or above 75% volume.
  - The DAT SP shall be sixty-five degrees Fahrenheit when the CFM is at or below 50% volume.

VAV Morning Warm Up

- Upon a call (BAS or RA Thermostat) for morning warm-up the supply fan shall be enabled to 100%.
- Economizer dampers shall remain in the full return position.
- The heat wheel shall remain off and the bypass dampers open.
- The unit shall cycle the gas heat stages on and off to achieve the return air setpoint.

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VAV Morning Cool Down

- Upon a call (BAS or RA Thermostat) for morning cool-down the supply fan shall be enabled to 100%.
- The economizer dampers shall remain in the full return position, unless outdoor air temperature conditions allow for free cooling.
- The heat wheel shall remain off and the bypass dampers open.
- The unit shall cycle the mechanical cooling stages on and off or modulate the economizer dampers to achieve the return air setpoint.

jZone VVT

- Heating on with call from space thermostat (polling or largest offset or designated thermostat)
  - Modulate/stage heat to maintain 85F discharge air adj.
    - 4 stage to 10:1 modulation with gas heat
- Cooling on with call from space thermostat (polling or largest offset or designated thermostat)
  - Cooling to maintain constant discharge air temperature of 55F adj.
  - Compressor to modulate
- Fan to modulate to maintain duct static pressure of .75" adj.
- Outside air at minimum position 20% adj.
- First stage of cooling shall be outside air if available through enthalpy/dry bulb economizer
- No call from space, cooling and heating off, fan to modulate return air to maintain duct static pressure of .75" adj.

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DOAS

- Heating on with call from outdoor air thermostat at 65F adj.
- Modulate heat to maintain 70F adj.
- OA & RA dampers at 100%
- Supply and exhaust fan at 100%
- Cooling on with call from outdoor air thermostat at 75F adj. or DP of 50F adj.
- Cooling to maintain constant discharge air dewpoint of 50F adj.
  - Compressor to modulate
  - Hot gas reheat to maintain discharge air at 75F adj.
- Heat wheel shall be on during heating and cooling modes

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Heat Wheel

- Wheel shall be on during heating and cooling modes
- Wheel shall be protected from defrost by preheat, VFD or OA bypass
- The heat wheel shall act as first stage heating or cooling.
- The heat wheel shall be locked out when the outdoor air temperature is between fifty-five and seventy-five degrees Fahrenheit.
  - Two bypass dampers, one for outdoor air and one for exhaust air, shall open when the heat wheel is locked out.
  - The exhaust fan shall be enabled when the heat wheel is enabled.

MAU w/o Humidity Control

- Heating on with call from outdoor air thermostat at 65F adj.
  - Modulate heat to maintain 85F adj.
- Outside air at 100%
- Supply fan at 100%
- Cooling on with call from outdoor air thermostat at 75F adj.
- Cooling to maintain constant discharge air temperature of 55F adj.
  - Compressor to modulate
- Room thermostat to reset discharge air temperature as required to maintain space temperature

MAU w/ Humidity Control

- Heating on with call from outdoor air thermostat at 65F adj.
  - Modulate heat to maintain 85F adj.
- Outside air at 100%
- Supply fan at 100%
- Cooling on with call from outdoor air thermostat at 75F adj.
- Cooling to maintain constant dewpoint temperature of 55F adj.
  - Compressor to modulate
  - Room thermostat to activate modulating hot gas reheat to maintain space temperature
  - Room thermostat to reset discharge air temperature as required to maintain space temperature

Process Dehumidification

- At low loads simultaneous heat maybe required to maintain set point
- Return air bypass damper controlled by room thermostat?

Coil Suction Temperature Setpoint Reset

- During dehumidification automatically reset the Coil Suction Temperature Setpoint based on the space or return air humidity sensor condition.

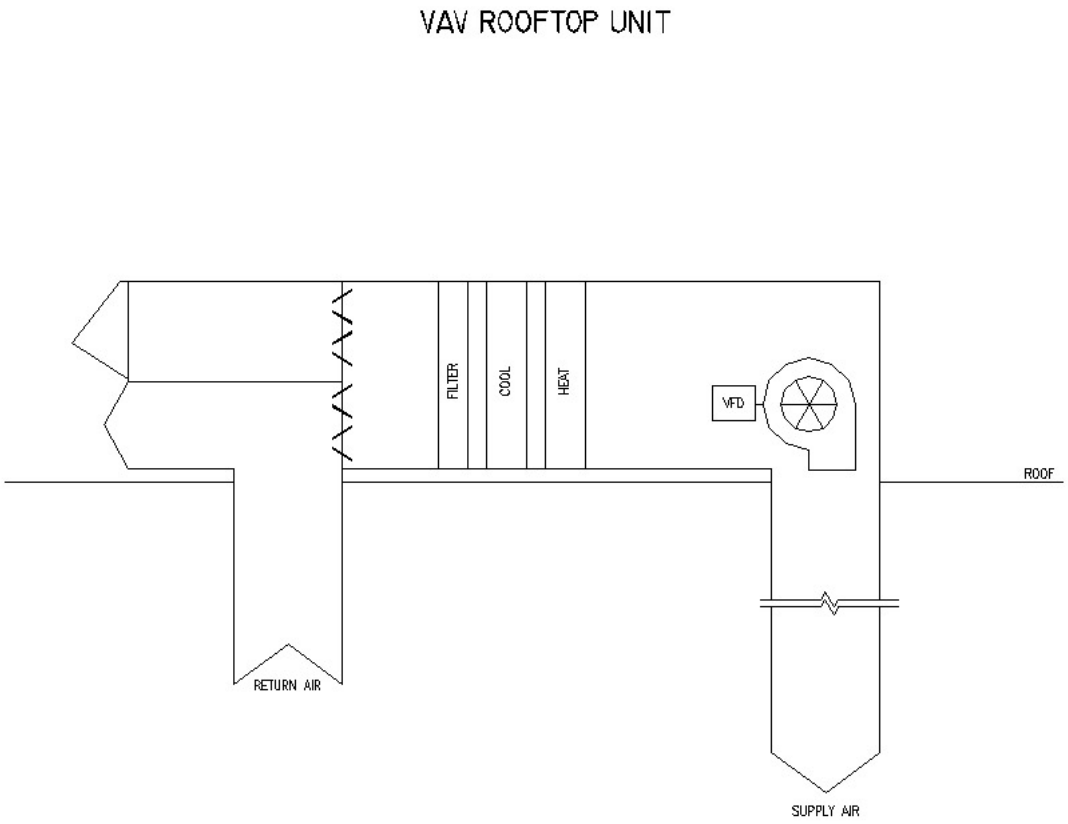
Discharge Air Temperature Setpoint Reset

- During dehumidification automatically reset the Cooling Discharge Air Temperature Setpoint based on the space or return air humidity sensor condition.

Low Limit

- The unit shall be shutdown if the discharge air temperature falls below the low limit set point of 45F adj.
- Low Limit or Freezestat?

Cartoon


VAV ROOFTOP UNIT
FILTER
COOL
HEAT
VFD
ROOF
RETURN AIR
SUPPLY AIR

Points List

Unit Type:	VAV Rooftop									
	Hardware Points				Software Points					Show On
Point Name	BI	AI	BO	AO	AV	BV	Schedule	Trend	Alarm	Graphics
Outside Air Temp		X								X
Outside Air Humidity		X								X
Return Air Temp		X								X
Return Air Humidity		X								X
Mixed Air Temperature		X								X
Discharge Air Temperature		X						X	X	X
Duct Static Pressure Sensor		X							X	X
Economizer Dampers				X						X
1st Stage Cooling			X					X		X
2nd Stage Cooling			X					X		X
1st Stage Heating			X							X
2nd Stage Heating			X							X
Supply Fan Status (speed)		X							X	X
Supply Fan Speed				X						X
Supply Fan Start/Stop			X							

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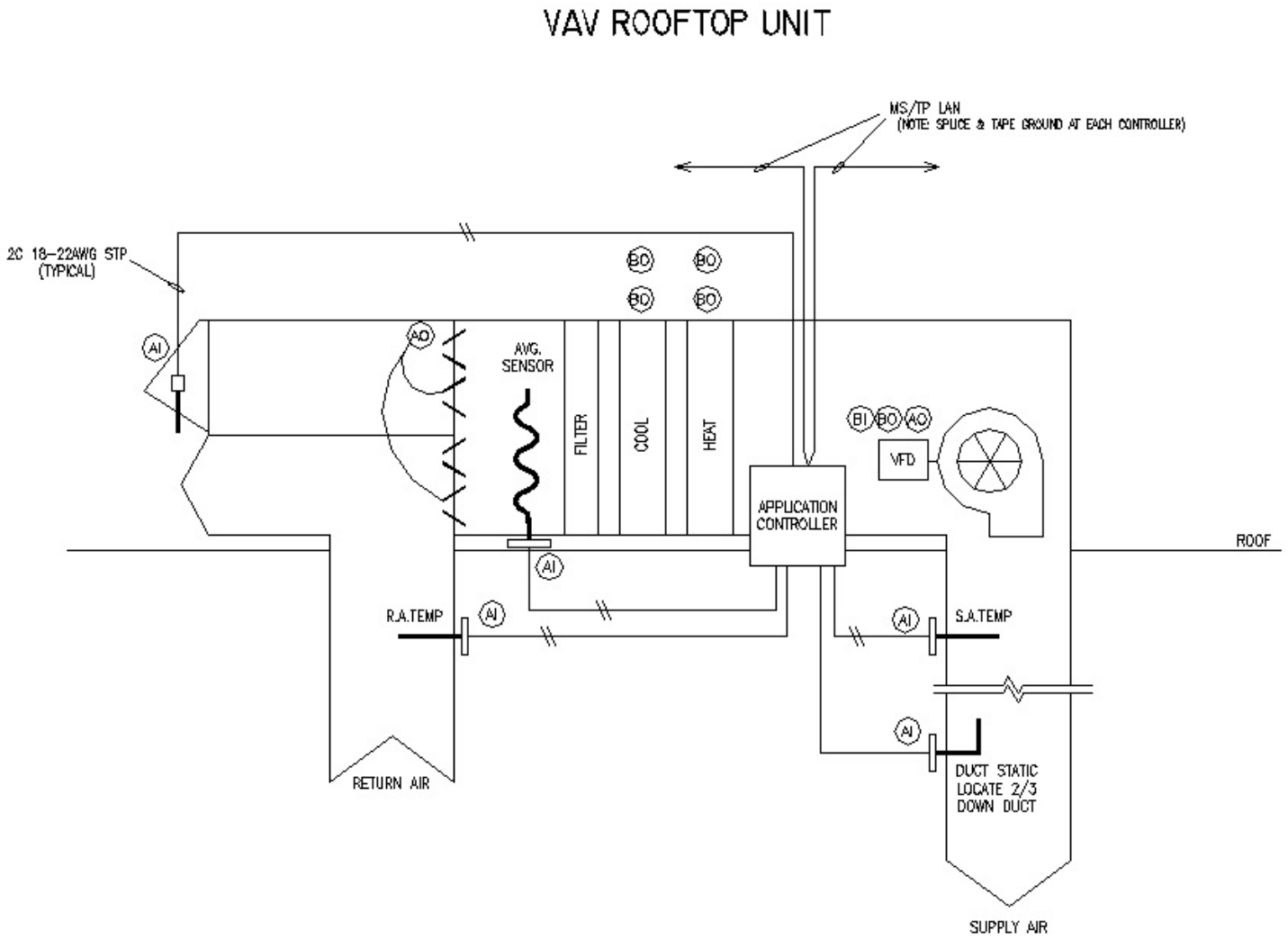
Cartoon



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GEO/WSHP

- Start pump or pump run continuously
- Proof of flow
- When loop temperature falls below 60F adj. allow heat injection
- When loop temperature rises above 90F allow heat rejection

Alarming

- The BAS shall generate alarms for the following items:
  - Low limit shutdown
  - Clogged filter alarm
  - Supply fan failure
  - Exhaust fan failure
  - High Temperature in Cooling
  - Low Temperature in Heating

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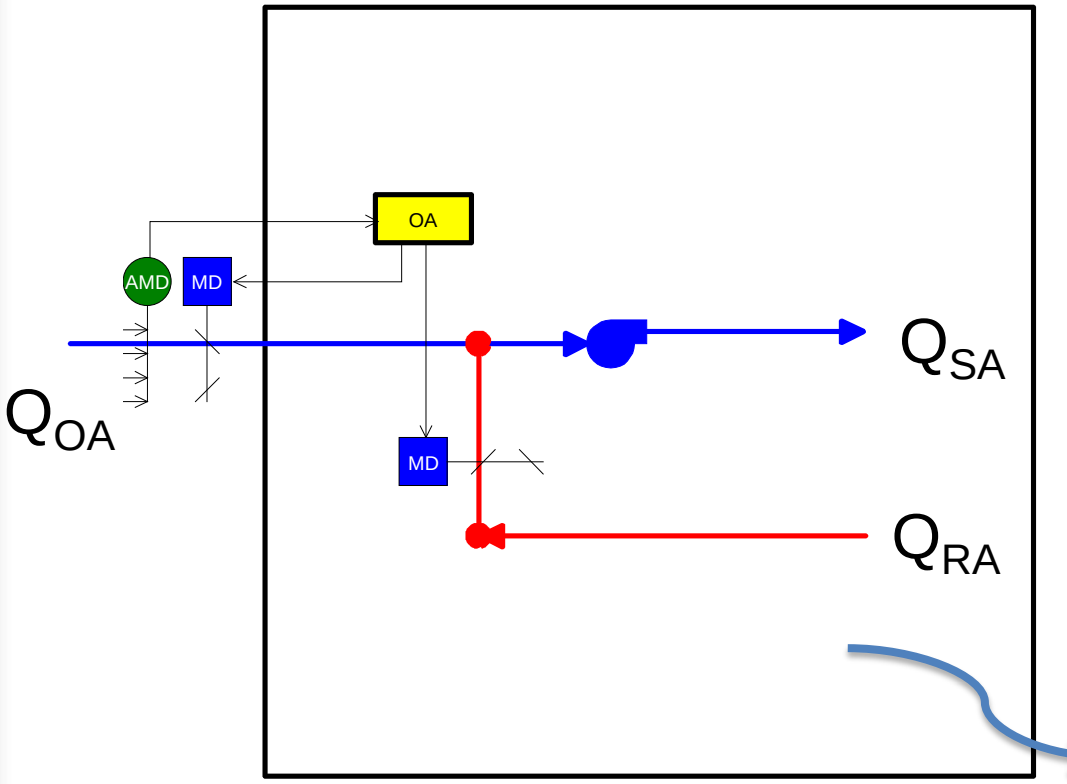
Airflow Measurement

Minimum OA



$Q_{OA\ set}=Q_{OA\ min}=Q_P$

Airflow Measurement

Minimum OA

Modulate OA and RA dampers in sequence to maintain OA setpoint

Or

Modulate OA dampers to maintain OA setpoint

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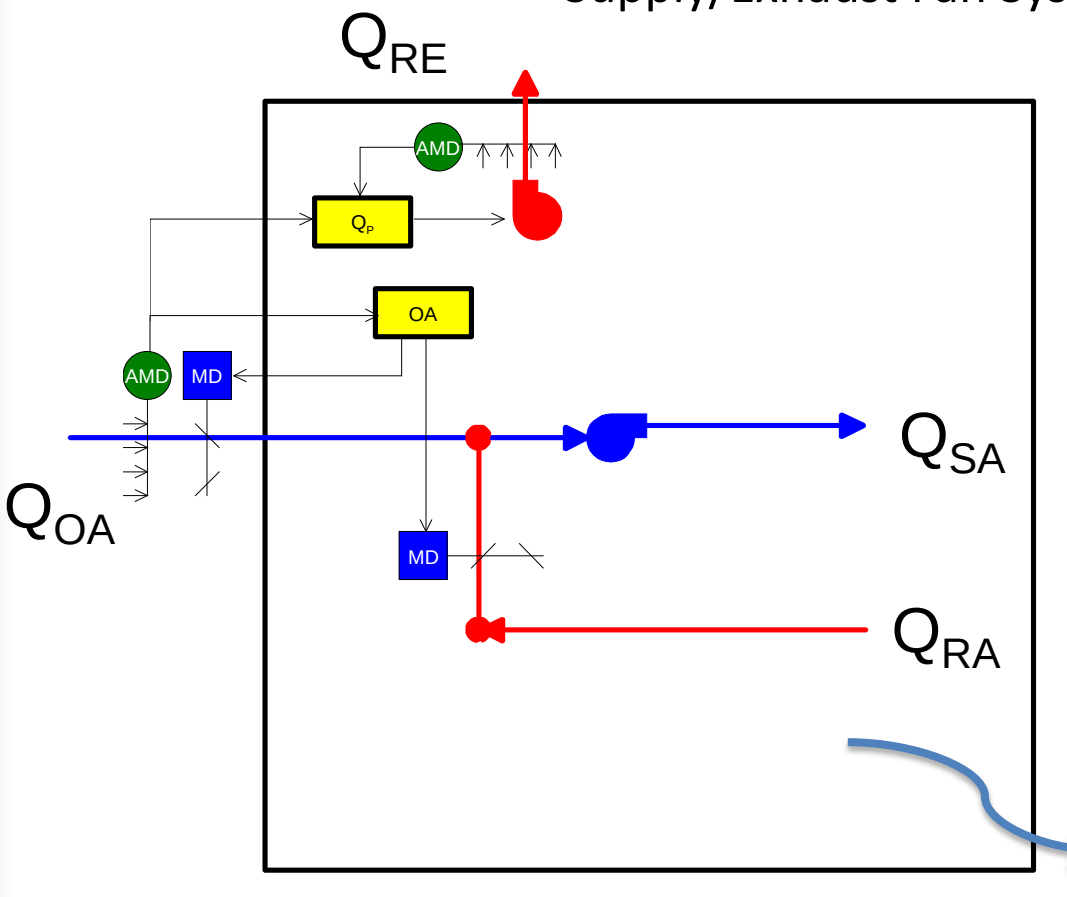
Airflow Measurement

Supply/Exhaust Fan System



1. $Q_{OA\ set}=Q_{OA\ min}$
2. $Q_{RE\ set}= Q_{OA}-Q_P$

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Airflow Measurement

Supply/Exhaust Fan System

Modulate OA and RA dampers in sequence to maintain OA setpoint

Or

Modulate OA dampers to maintain OA setpoint

Modulate relief fan to maintain relief exhaust setpoint

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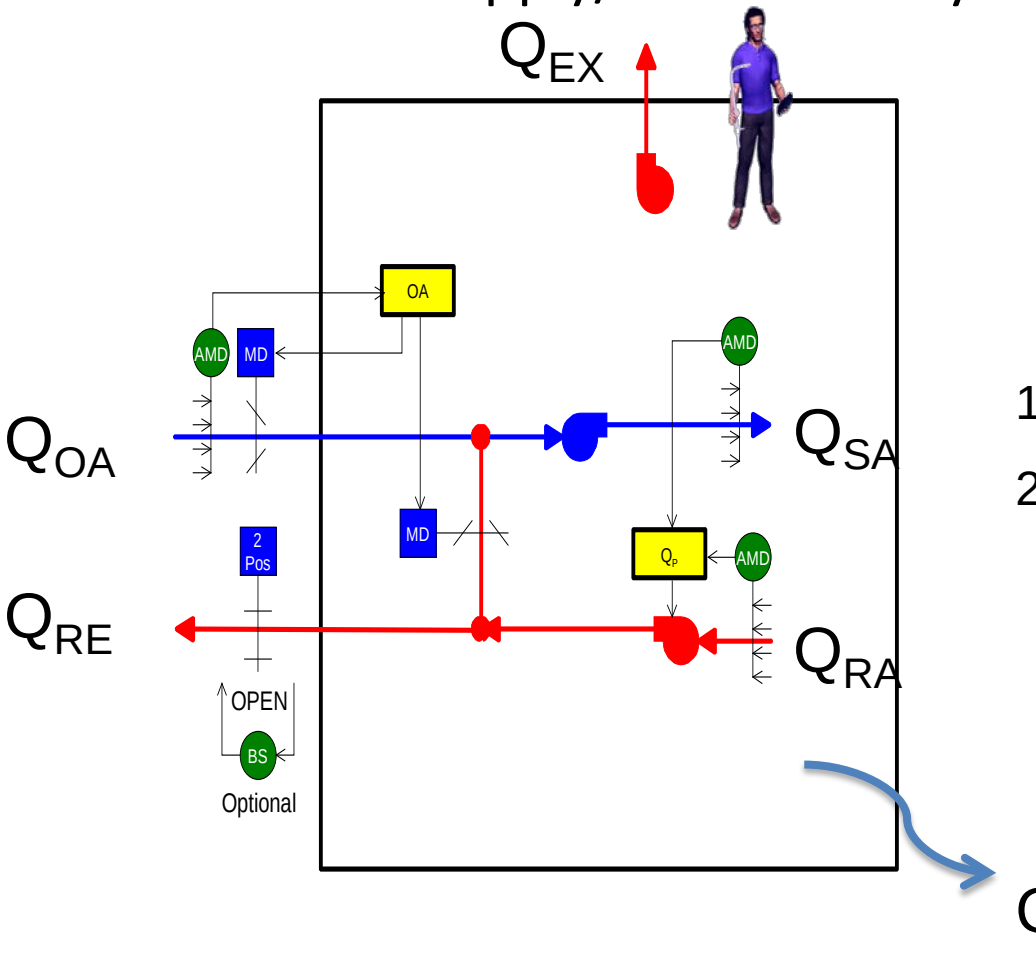
Airflow Measurement

Supply/Return Fan System



1. $Q_{OA\ set}=Q_{OA\ min}$
2. $Q_{RA\ set}=Q_{SA}-(Q_P+Q_{EX})$

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Airflow Measurement

Supply/Return Fan System

Modulate OA and RA dampers in sequence to maintain OA setpoint

Or

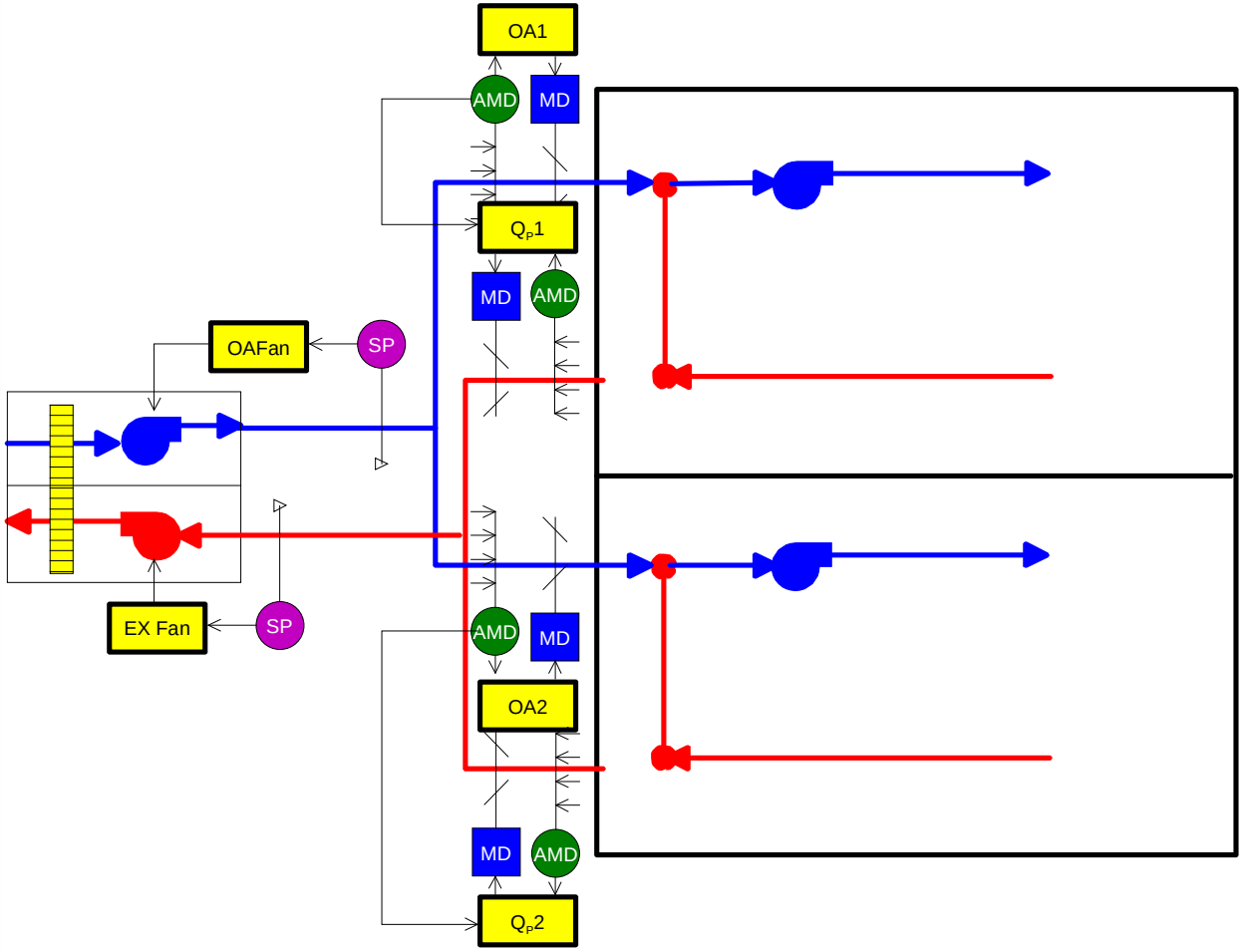
Modulate OA dampers to maintain OA setpoint

Use air balance measurement or AFMS to determine exhaust

Modulate return fan to maintain RA setpoint

Airflow Measurement

DOAS - Multiple AHU's



1. $Q_{OA1set}=Q_{OA1min}$
2. $Q_{EA1set}=Q_{OA1}-Q_{P1}$

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Airflow Measurement

DOAS - Multiple AHU's

1. Modulate SA and EA fans to maintain static pressure setpoint of outdoor air and exhaust air ducts
2. Modulate zone outdoor air damper to maintain OA setpoint
3. Modulate zone exhaust air damper to maintain Exhaust setpoint
4. Do for all floors or pressure zones served

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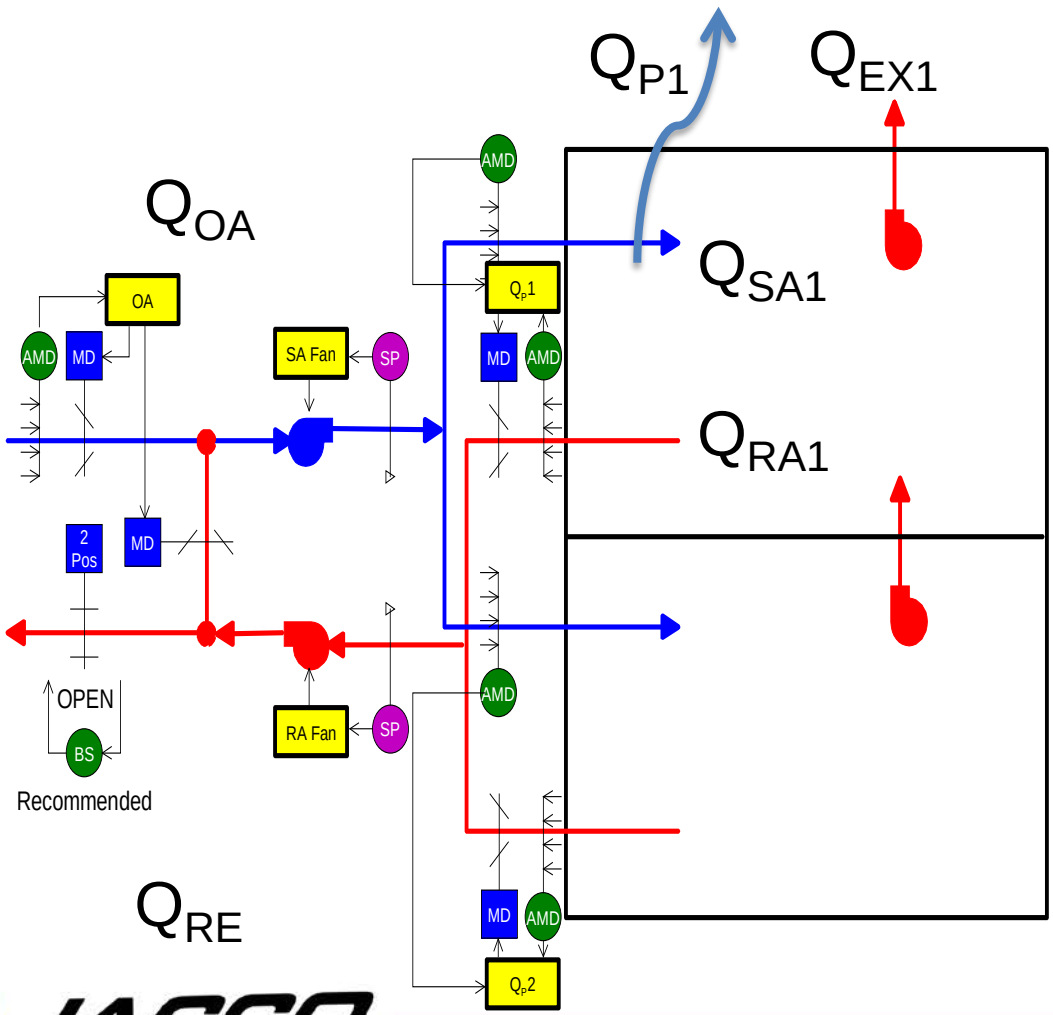
Airflow Measurement

Single Supply/Return/Exhaust - Multiple Floors



1. $Q_{OA\ set}=Q_{OA\ min}$
2. $Q_{RA1set}=Q_{SA1}-(Q_{P1}+Q_{EX1})$

JACCO

Airflow Measurement

Single Supply/Return/Exhaust - Multiple Floors

1. Modulate SA and RA fans to maintain duct static (w/reset)
2. Modulate OA and RA dampers in sequence to maintain OA setpoint
3. Modulate floor/zone return damper to maintain RA setpoint
4. Do for all floors or pressure zones served.

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Single Duct VAV Boxes

Single Duct Cooling Only

- With room temperature at setpoint, unit delivers minimum cfm. An increase in room temperature causes airflow to increase. Airflow and temperature setpoints can be different for Occupied, Unoccupied, and Night Setback states.

Cooling with Electric Reheat

- An increase in room temperature over cooling setpoint causes airflow to increase. Below cooling setpoint, airflow is at minimum or zero. A decrease in room temperature below heating setpoint causes airflow to increase to the second heating minimum, as stages of reheat are energized. Airflow and temperature setpoints can be different for Occupied, Unoccupied, and Night Setback states.

Cooling with Proportional Hot Water Reheat

- An increase in room temperature over cooling setpoint causes airflow to increase. Below cooling setpoint, airflow is at minimum or zero. A decrease in room temperature below heating setpoint causes airflow to increase to a fixed heating minimum, or modulate to match water valve action, as hot water valve modulates open. Airflow and temperature setpoints can be different for Occupied, Unoccupied, and Night Setback states.

Series Fan Powered VAV Boxes

Constant Fan VAV Terminal Cooling Only

- Fan operates continuously in Occupied mode, providing constant volume to the space. An increase in room temperature causes cooling airflow to increase. Airflow and temperature setpoints can be different for Occupied, Unoccupied, and Night Setback states for all Constant Fan VAV Terminal sequences.

Constant Fan VAV Terminal with Electric Heat

- Fan operates continuously in Occupied mode, providing constant volume to the space. An increase in room temperature triggers an increase in cooling airflow. Below cooling setpoint, cooling airflow is at minimum or zero. On a decrease in room temperature below heating setpoint, stages of heat are energized.

Constant Fan VAV Terminal with Proportional Water Heat

- Fan operates continuously in Occupied mode, providing constant volume to the space. An increase in room temperature causes cooling airflow to increase. Below cooling setpoint, cooling airflow is at minimum or zero. On a decrease in room temperature below heating setpoint hot water valve modulates open.

Parallel Fan Powered VAV Boxes

Variable Volume Fan VAV Terminal Cooling Only

- At cooling setpoint, unit delivers minimum cooling cfm. An increase in room temperature causes cooling airflow to increase. On a decrease in room temperature below heating setpoint or on a decrease in cooling cfm approaching cooling setpoint (software selectable), unit fan is energized to provide plenum air to the space. Airflow and temperature setpoints can be different for Occupied, Unoccupied, and Night Setback states, for all variable volume fan VAV terminal sequences.

Variable Volume Fan VAV Terminal with Electric Heat

- At cooling setpoint, unit delivers minimum cooling cfm. An increase in room temperature causes cooling airflow to increase. On a decrease in room temperature below heating setpoint or on a decrease in cooling cfm approaching cooling setpoint (software selectable), unit fan is energized to provide plenum air to the space, additional stages of heat are energized as required.

Variable Volume Fan VAV Terminal with Proportional Water Heat

- At cooling setpoint, unit delivers minimum cooling cfm. An increase in room temperature causes cooling airflow to increase. On a decrease in room temperature below heating setpoint or on a decrease in cooling cfm approaching cooling setpoint (software selectable), unit fan is energized to provide plenum air to the space, hot water valve modulates open as required.

VRF

- You Don’t Have a Choice, BUT…
- Things we like!
  - Alternating Defrost!!!
  - Snow Blow Function
  - Lead/Lag/Alternating Compressor!!!
  - Space or RA Sensor Selection
  - # of Fan Coils per Sensor
- Make Sure Manufacturer Software is Left on the Job!

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Problem Jobs

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Problem

- MAU with heat pump and heat recovery
- Unit set up for SZVAV.
- Building pressure was introduced and the exhaust fan was shut off and the supply fan was running at 100%.

Problem

- 100% OA kitchen make up air unit
- Heat pump with modulating gas heat. The heat pump operates down to 40 degrees and then it switches over to gas heat.
- Modulating gas heat being operated with on - off control. When heat comes on the burner fires off on high fire then modulates down to low fire, waiting for the modulating signal.
- On the cooling side there is one modulating compressor and one on/off compressor. The digital scroll is being treated as an on/off and not modulating.

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Problem

- DOAS unit
- TCC added compressor time delays on top of manufacturer compressor time delays.

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Problem

- Aaon controls
- TCC added controls to monitor but actually took control of the compressors.

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Problem

- Aaon controls
- Start up technician set up first stage heat as electric and second and third stage heat as LP Gas, in Montana!

Recommendations

- If controls by TCC…Always provide the sequence to the manufacturer's rep for review and approval.
- If controls by TCC…SLOW DOWN!!!
- Don't mix and match control systems on the same unit.
- Go with factory controls when possible, especially for DX systems, they have invested the time and money to get their sequence to work.

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Recommendation

- Move the sequence of operations up in the design process and keep it simple!
- Visit our website, we have posted detailed sequence of operations in the Engineering Tools tab.
- Visit our website, we have this presentation, with simple sequences, posted in the Seminars tab.

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Thank You!

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