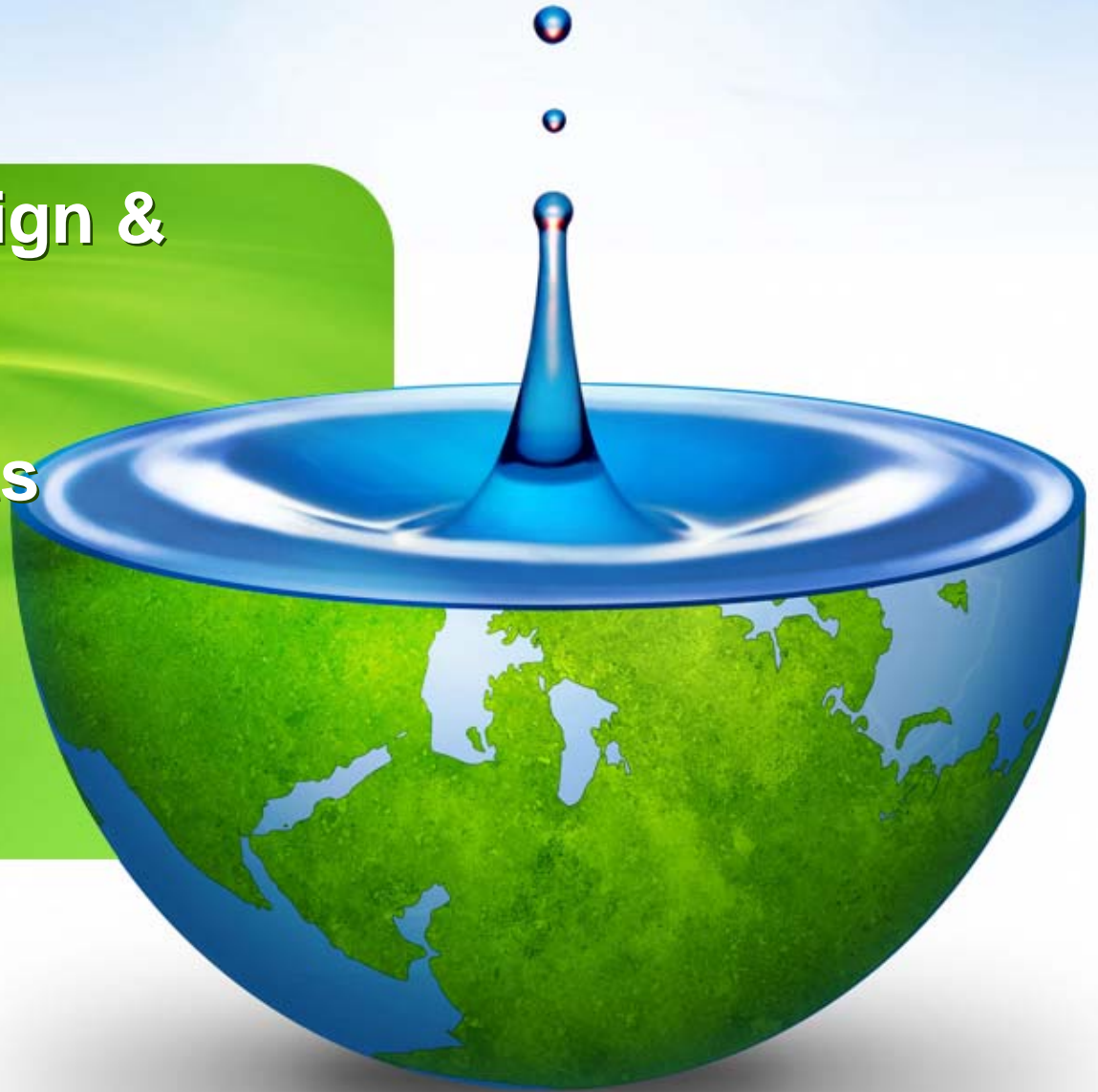


VRF Systems Design & Applications And Fan System Effects

By: Greg Drensky



What is VRF?



What is VRF?

- The ability to control the amount of refrigerant flowing to a series of evaporators in a common system
- Many evaporators of differing capacities and configurations
- Individualized comfort control
- Heating & Cooling system (Heat Pump)
- Potential to heat and cool simultaneously within the same system
- First Simultaneous Heat & Cool 1989



System Components



System Components

- Outdoor Unit
 - Variable Speed Fan
 - Inverter Driven Compressor
 - R-410a
- Indoor Unit
 - Multi-Speed Fan
 - Electronic Expansion Valve
- System Communications



Indoor Units

Type		Model	Size (K btu)						
			07	09	12	18	24	36	48
1 Way Cassette		**AHX52	✓	✓	✓				
4 Way Cassette		**XHX52			✓	✓	✓	✓	
Concealed Duct		UHX**52	✓		✓	✓	✓	✓	
Concealed Duct Medium Press.		DXH**52						✓	✓
Ceiling Suspended		THX**52			✓	✓	✓		
Wall Mounted		KHX**52	✓	✓	✓	✓	✓		



Agenda Control Options

System Controller

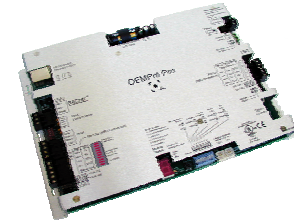


SHA-KCE6AG

Intelligent Controller



OEM Protocol



Wired Controller



Wireless Controller



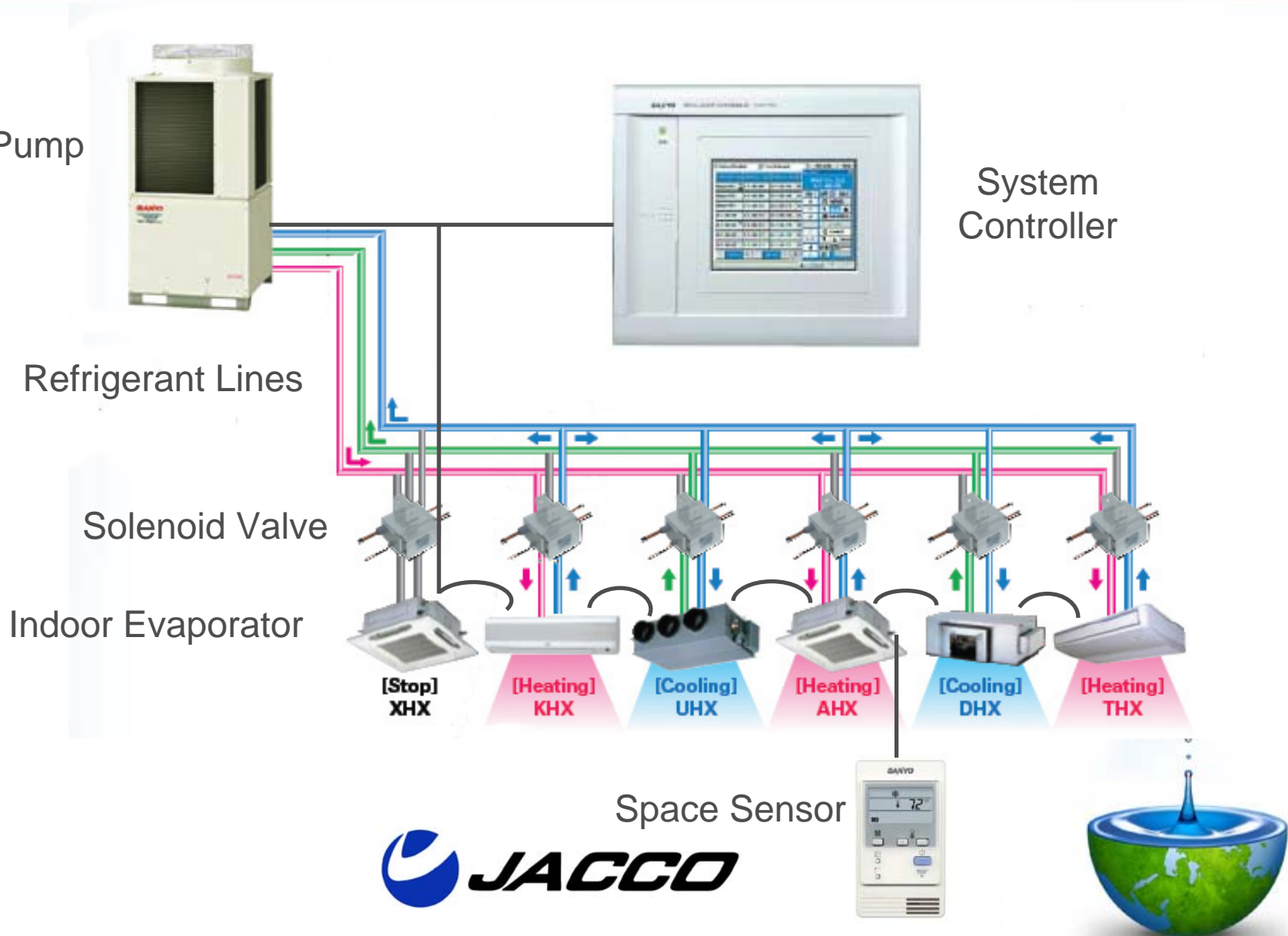
Simple Controller



System Operation

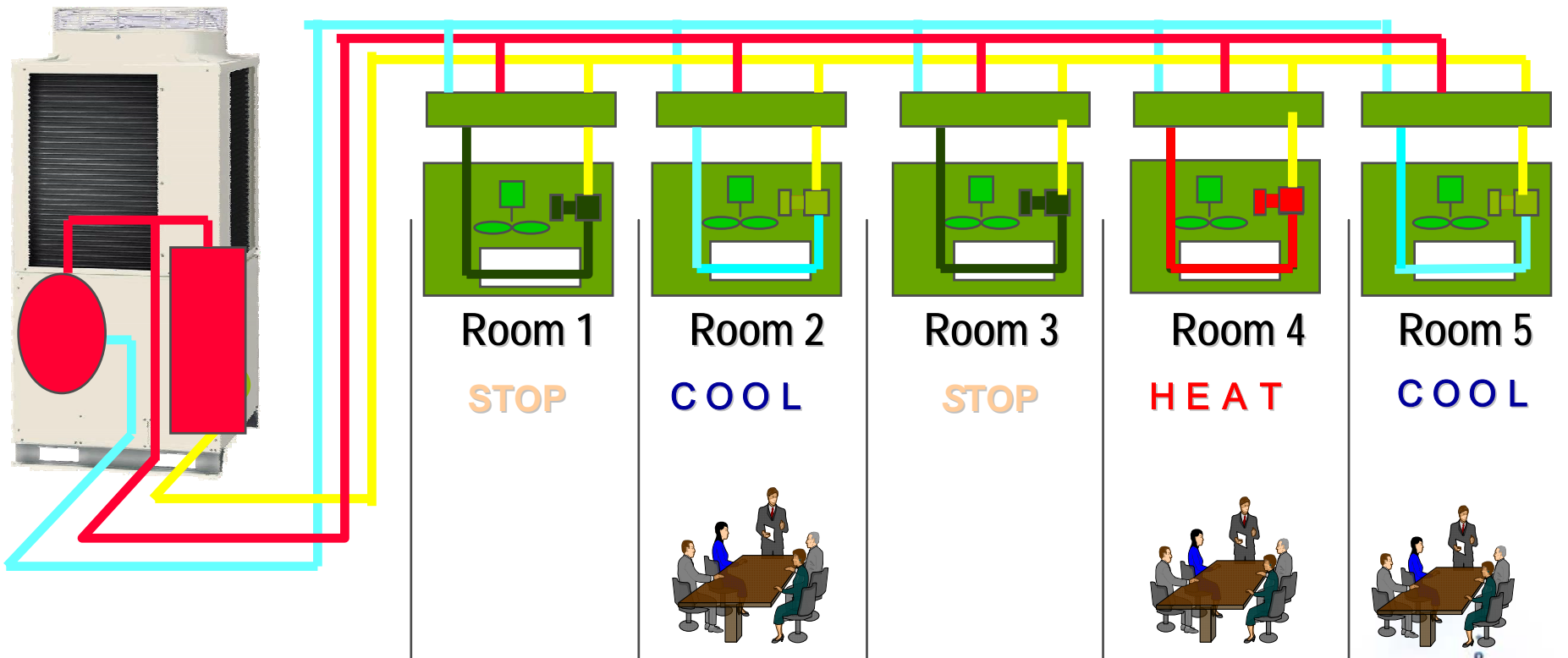


System Operation



System Operation: Simultaneous Heat & Cool

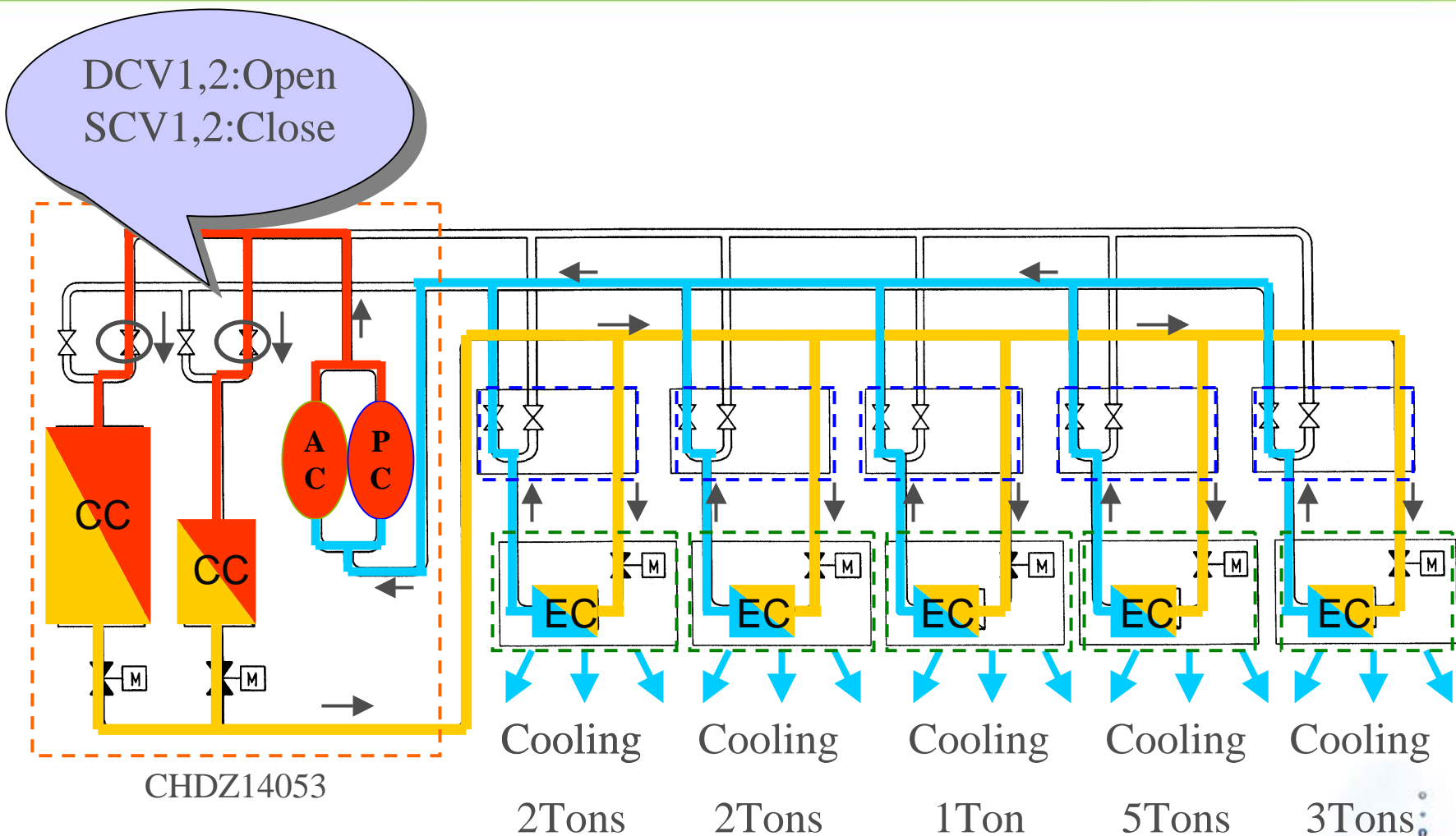
OUTDOOR UNIT



 **JACCO**

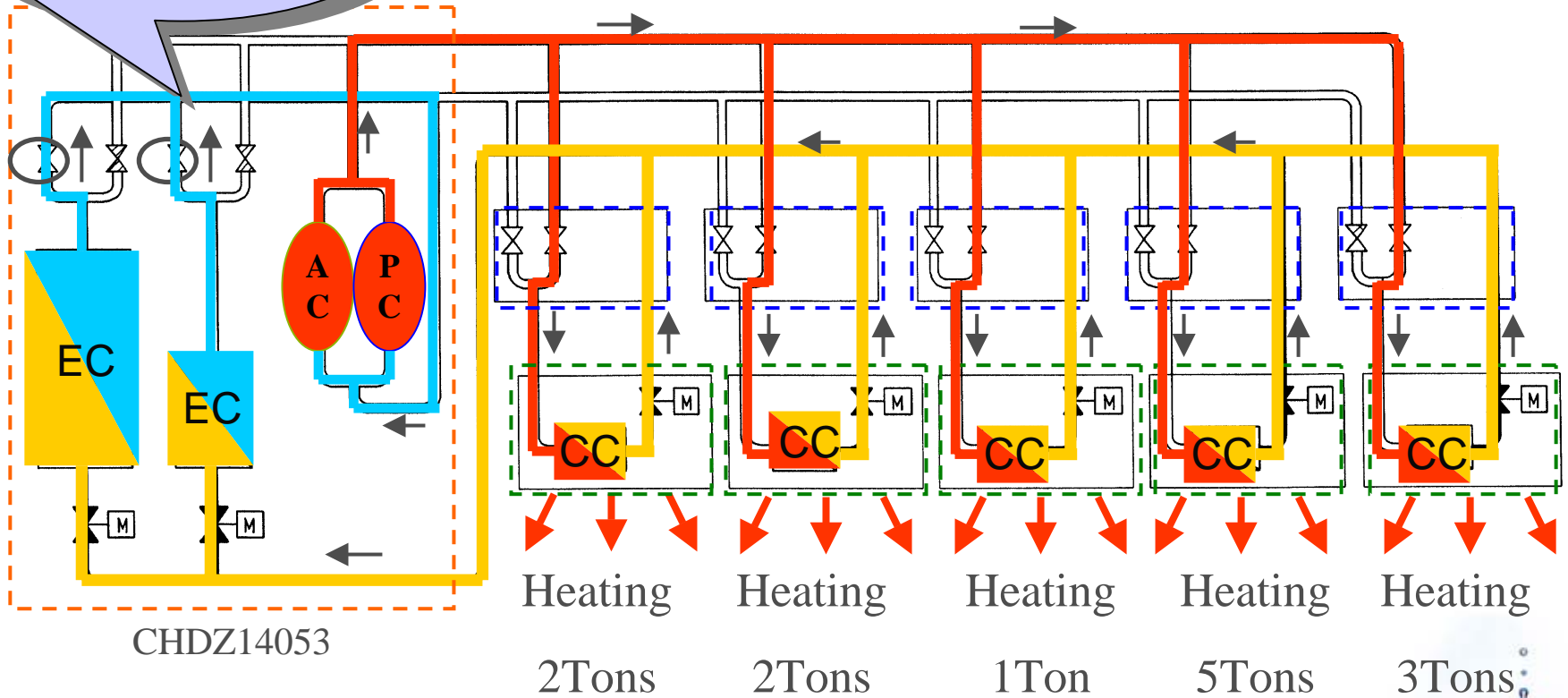


System Operation: Simultaneous Heat & Cool



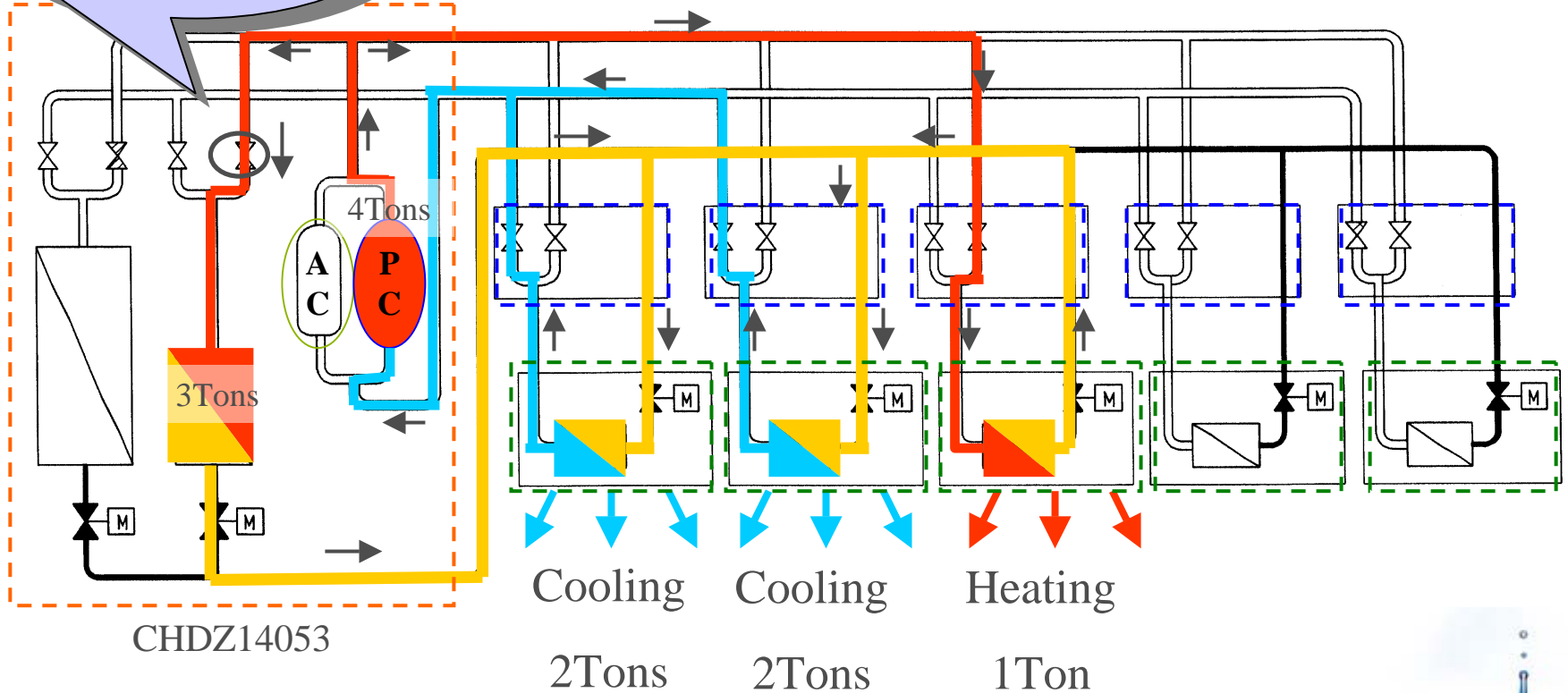
System Operation: Simultaneous Heat & Cool

DCV1,2:Close
SCV1,2:Open



System Operation: Simultaneous Heat & Cool

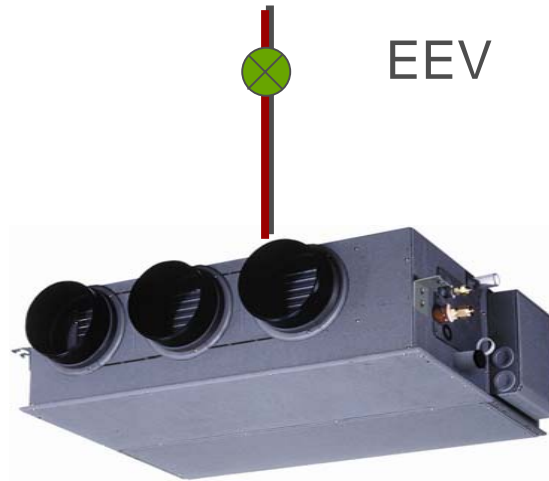
DCV1:Open
DCV2,SCV1,2
:Close



Heating Operation

$$dT = \frac{\text{Cap}}{\text{CFM}} \downarrow$$

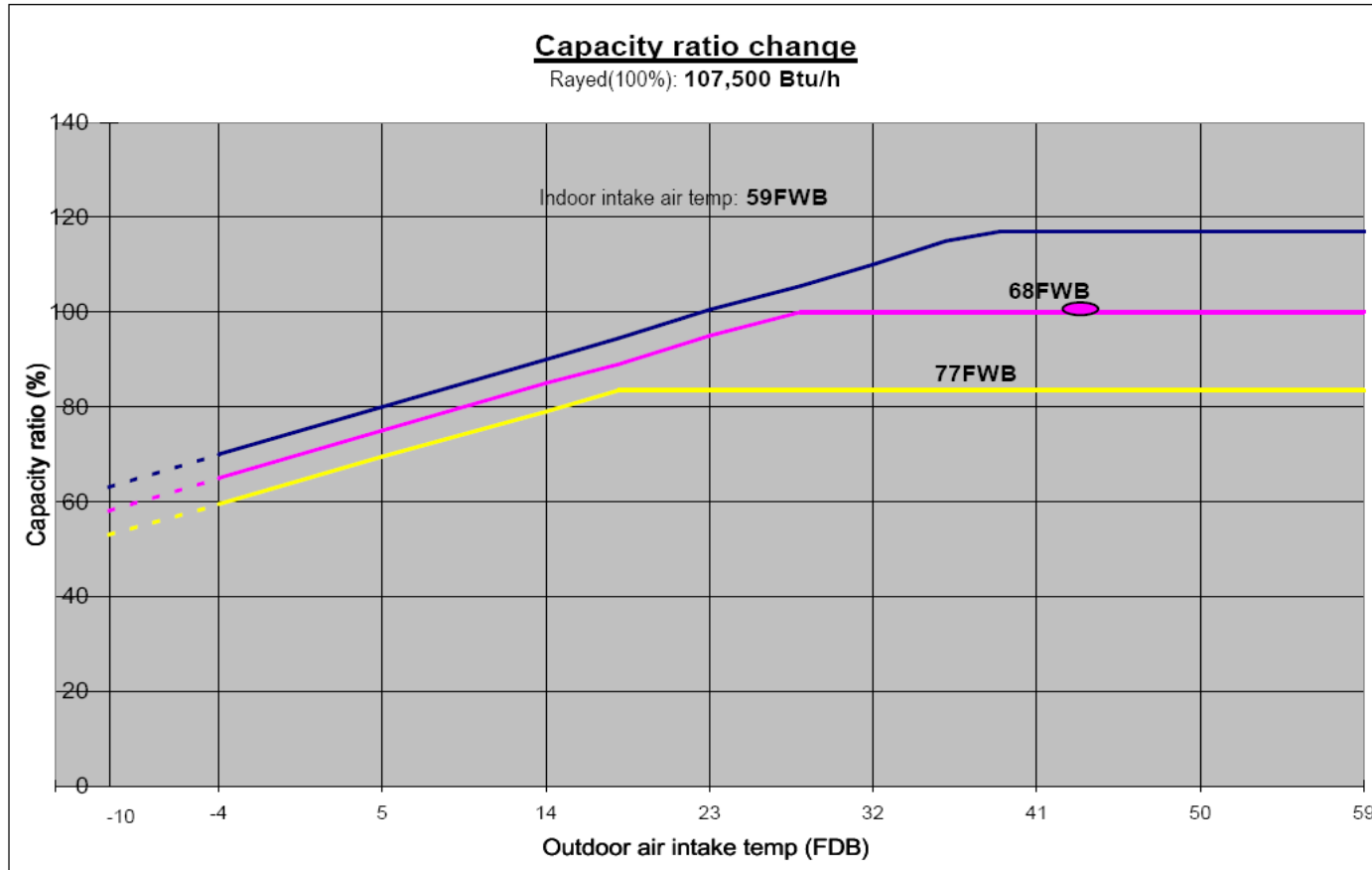
104 deg F
Discharge



Muti speed Fan



Heating Operation



- Indoor Heat Pump Option



Acoustics



Acoustics

- Low Noise Levels
 - Heat Pumps – 55dBa
 - Fan Coils – 22-47dBa

Sound Level Decibel Loudness Comparison Chart

Environmental Noise	
Weakest sound heard	0dB
Whisper Quiet Library	30dB
Normal conversation (3-5')	60-70dB
Telephone dial tone	80dB
City Traffic (inside car)	85dB
Train whistle at 500', Truck Traffic	90dB
Subway train at 200'	95dB



Economic Performance



Economic Performance: COP's

- Coefficient of Performance
 - Ratio of energy output compared to energy input
- VRF Cooling COP: 6.3
 - Air Cooled CU: 2.8
 - Air Cooled Chiller: 2.8
 - Packaged RTU: 3.2
 - Packaged RTU with Energy Wheel: 3.8
 - Geothermal Heat Pumps: 4.5
- VRF Heating COP: 4 @ 25F (1.5 @ -10F)
 - Electric Heat: 1.0
 - Gas Heat: 0.92
 - Hot Water: 0.85
- System Modeling Programs Available (www.energysoft.com)



Preventative Maintenance



Preventive Maintenance

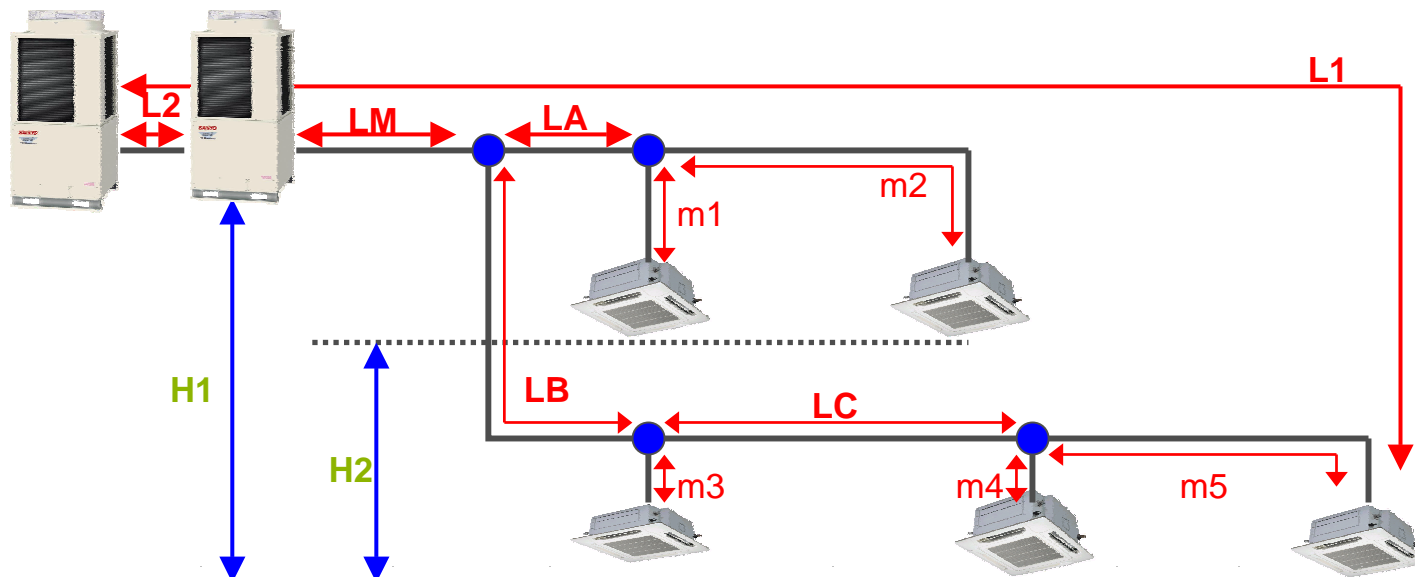
- Clean/Replace Filters
- Check Electrical Connections
- Clean Condensate Pan
- Blow Out Drain Lines
- Clean Condenser Coils
- Inspect Cabinets and Refrigerant Lines
- Check Motors
- Check Communication
- Check Operation
 - On-board Diagnostics



Selection Software



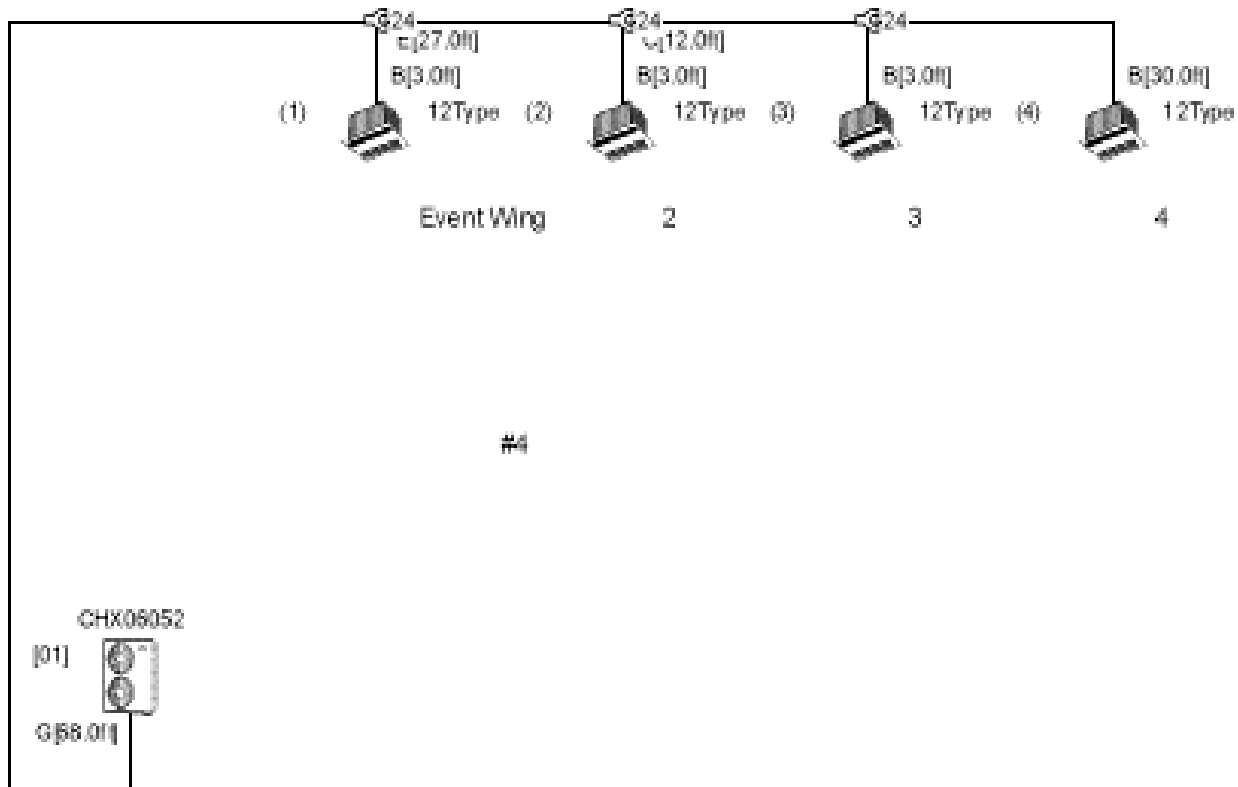
Selection Software



Items	Reference	Contents		Length (feet)	
				Mini Eco-i	W-Multi
Allowable tubing length	L1	Max tubing length	Actual length Equivalent length	≤ 492 ≤ 574	≤ 492 ≤ 574
	m1 ~ m5	Max. length of each distribution joint		≤ 98	≤ 98
	LM	Max. main piping length		≤ 262	≤ 262
	LM+LA+ ~ LC +m1+ ~ m5	Total max. tubing length including length of each distribution joint		≤ 656	≤ 984
Allowable elevation difference	H1	When outdoor unit installed higher		≤ 164	≤ 164
		When outdoor unit installed lower		≤ 131	≤ 131
	H2	Max. difference between indoor units		≤ 50	≤ 50



Selection Software



Selection Software

Refrigerant Tubing System Diagram			
Project Name	Polomac winery and Cellars	230V	Page 1
System Name	[01] System 01 [02] System 02	Capacity Ratio of Indoor and Outdoor Units 91% 91%	

Limit Density	
[01] The room dimensions have not been entered.	Refrigerant Amount (12.408lb) Room Area (0.013)
[02] The room dimensions have not been entered.	Refrigerant Amount (11.016lb) Room Area (0.013)

Since Tees for narrow tube is exclusive design for Sanyo multi system, be sure to use optional joint kit. In case of "Tees+Adaptor", 3/4 to 5/8 or 3/4 to 1/2 adaptor to be needed. In 3Way system, connect liquid and suction tube to COOL ONLY indoor unit.

Code	Tubing Size (#)	Quantity (#) / Additional Refrigerant Charge Amount (oz/lb)							
		[01]		[02]					
B	1/2 x 1/4	39.0	0.280	39.0	0.280				
C	1/2 x 3/8	12.0	0.602	12.0	0.602				
E	5/8 x 3/8	27.0	0.602	28.0	0.602				
G	3/4 x 3/8	68.0	0.602	30.0	0.602				
Additional Charge Amount (oz)		75.334		53.080					

Code	Joint Type	Model Name	Quantity (Units)			
			[01]	[02]		
024	Distri. Joint Kit	APR-P160BA	3	3		



Selection Software

Code	Tubing Size (in)	Quantity (ft) / Additional Refrigerant Charge Amount (oz/ft)							
		[D1]							
B	1/2 x 1/4	58.0	0.279						
C	1/2 x 3/8	27.0	0.602						
E	5/8 x 3/8	34.0	0.602						
G	3/4 x 3/8	20.0	0.602						
J	7/8 x 3/8	16.0	0.602						
M	1-1/8 x 1/2	23.0	1.390						
W	1-1/8 x 5/8	18.0	1.990						
Initial Charge Amount Additional Charge Amount (oz)		142.136							

Code	Joint Type	Model Name	Quantity (Units)			
			[D1]			
21	Distrib. Joint Kit	APR-CHP680BA	1			
23	Ditto	APR-P160BA	3			
24	Ditto	APR-P680BA	4			
13	Ball Valve Kit	BV-3B	2			
14	Ditto	Field Supply	10			



Dedicated Outdoor Air Systems (DOAS)



DOAS

- Operable windows
- Aeon Dedicated Outdoor Air System



DOAS

- Common to following systems:
 - VRF
 - Geothermal
 - Chilled Beams
 - Radiant Cooling
- Provide neutral air to space
 - Supply 70°F @ 50-55% RH
 - Maintain RH per ASHRAE 62.1-2004
- Utilize VCC's & energy recovery wheels
- Single source filtration (VRF no zone to zone air mixing)



System Applications



System Applications

01 April 2007 edition of ASHRAE Journal.

VRF systems, which were introduced in Japan more than **20 years** ago, has gradually expanded its market presence reaching European markets in 1987 and the US more recently. ***In Japan, VRF systems are used in approximately 50% of medium-sized commercial buildings (up to 70,000 sq.ft) and one-third of large commercial buildings (more than 70,000 sq.ft.)***

Several thousand systems likely will be sold in the U.S. this year, amounting to ***tens of thousands of tons*** of capacity.

The success of the VRF in other countries, and its historically limited market presence in the U.S., has several sources, including:

* The long history and large installed base of ducted direct exchange (DX) systems ...



System Applications

For Release:

August 8, 2007

ATLANTA-

- Just completed, Ashrae's renovated Headquarters building in Atlanta features two separate HVAC systems as part of its role as living lab.
- Level one of the building features air-cooled multi-split variable refrigerant flow fan coil units with zoned inverter-driven outdoor heat pumps.
- ASHRAE plans to apply for a LEED Gold certification under the U.S. Green Building Council's Leadership in Energy and Environmental Design rating system.



System Applications

- Schools
 - Churches
 - High Rise Condos
 - Multi Story Office Buildings
 - Research Facilities
 - Federal Buildings
 - Hospitals
 - Strip Malls
 - Shopping Malls
 - Residential - Townhouses
 - Hotels and Motels
 - Colleges
 - Manufacturing Plants
 - Apartments
- Shell & Core Projects: 50% total connected load



System Applications



Sample Projects



Sample Projects: Project B

12 Ton HP

5 Evaps

Total Pipe: 430'

Total Refrigerant: 42.3#

5. Piping

	Liquid / High (inch)	Gas / Low (inch)	Low Gas /Bypass/Oil (inch)	Total Length (feet)	Number of bent
First joint to Indoor unit	1/4	1/2	-	50	0
First joint to Indoor unit	3/8	5/8	-	125	0
Outdoor Unit to first joint	1/2	1 1/8	-	40	0

Summary totals

Pipe Size (inch)	Total Length (feet)	Number of bent
3/8	125	0
5/8	125	0
1/4	50	0
1/2	90	0
1 1/8	40	0

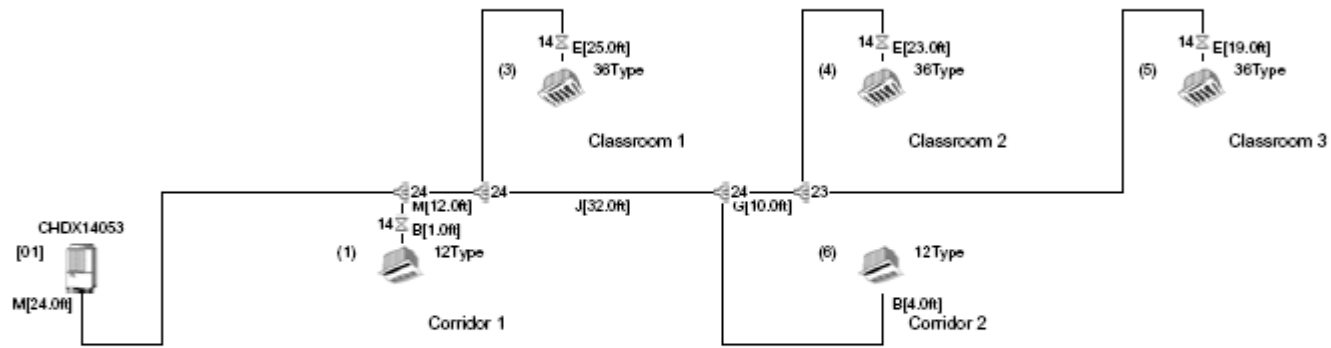
6. Water Flow Rate

Flow rate	Pressure drop

Additional refrigerant required:	R410A	x	13.7	lb
Total refrigerant amount:	R410A	x	42.3	lb



Sample Projects: Project B



Sample Projects: Project B

12 Ton HP

5 Evaps

Total Pipe: 150'

Total Refrigerant: 9.8#

Savings:

Pipe: 280'

Refrigerant: 32.5#

Refrigerant Tubing System Diagram			
Project Name	St Mary's	230V	Page 1
System Name	[01] System01	Capacity Ratio of Indoor and Outdoor Units 87%	

Limit Density	
[01] The room dimensions have not been entered.	Refrigerant Amount (35.918lb) Room Area (0.063)

Since Tees for narrow tube is exclusive design for Sanyo multi system, be sure to use optional joint kit. In case of "Tees+Adaptor", 3/4 to 5/8 or 3/4 to 1/2 adaptor to be needed. In 3Way system, connect liquid and suction tube to COOL ONLY indoor unit.

Code	Tubing Size (in)	Quantity (ft) / Additional Refrigerant Charge Amount (oz/ft)					
		[p1]					
B	1/2 x 1/4	5.0	0.279				
E	5/8 x 3/8	67.0	0.602				
G	3/4 x 3/8	10.0	0.602				
J	7/8 x 3/8	32.0	0.602				
M	1-1/8 x 1/2	36.0	1.380				
Initial Charge Amount		42					
Additional Charge Amount (oz)		116.693					

Code	Joint Type	Model Name	Quantity (Units)			
			[p1]			
23	Distri. Joint Kit	APR-P160BA	1			
24	Ditto	APR-P680BA	3			
14	Bell Valve Kit	Field Supply	4			



Sample Projects



Sample Projects



Sample Projects



Sample Projects



Sample Projects



Sample Projects



Fan System Effects: Creating High Performance Air Handling Systems

By: Greg Drensky



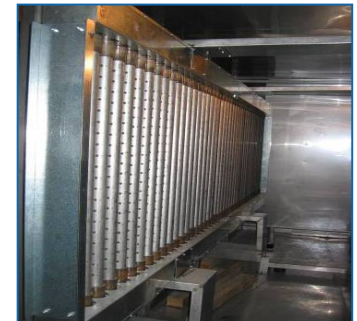
System Static Pressure



System Static Pressure

• Internal Pressure Drop

- Dampers (inlet, discharge, fan isolation)
- Air Mixers
- Coils
- Filters (Dirty)
- Sound Attenuators
- Energy Recovery Devices
- Diffusers
- Humidifiers
- Desiccant Wheels
- Airflow Measuring Stations



System Static Pressure

- External Static Pressure

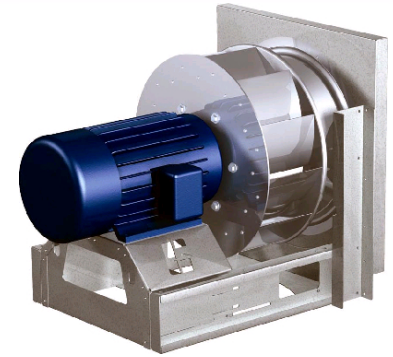
- Length Of Duct
- Duct Size
- # Turns, Types Of Turns (Turning Vanes?)
- Discharge Direction
- Diffusers
- VAV Boxes (Single, Parallel, Series)
- Reheat Coils



System Static Pressure

- Plenum fans max. about 10”
– 55-65% efficient
- Centrifugal fans max about 20”
– 65-75% efficient
- Axial fans max. about 13”
– 75-85% efficient

**Belt Losses Can Account For Approximately
10% Loss In Efficiency**



What Is Fan System Effect?



Fan System Effect

- Detrimental effect on fan air performance due to airflow disturbances in close proximity to the fan – either upstream or downstream



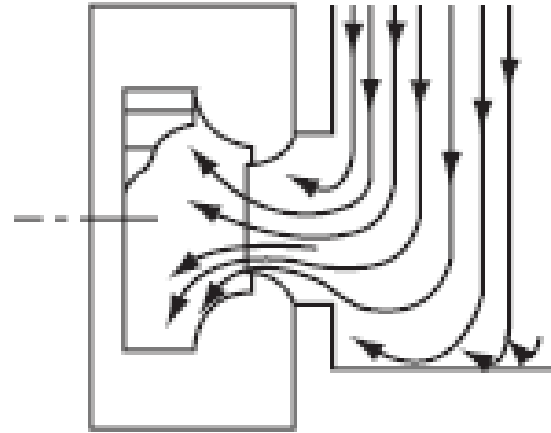
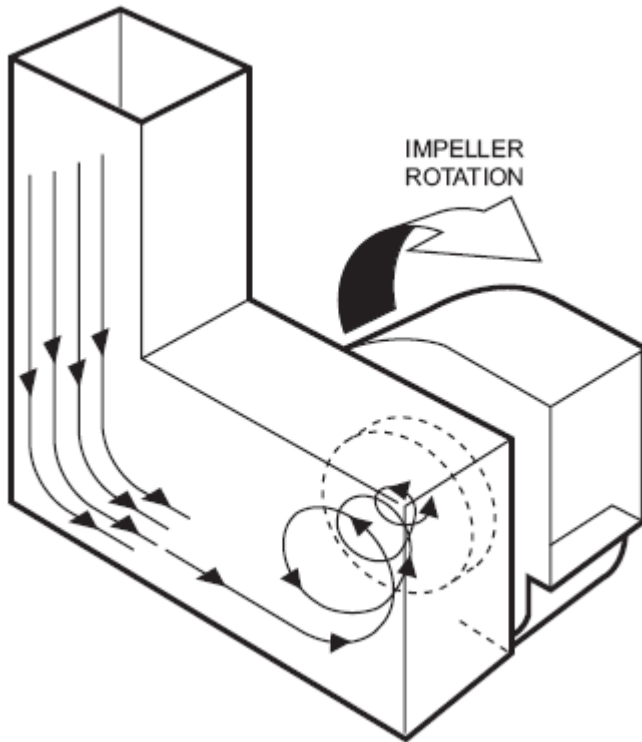
Fan Testing Criteria

- Air Movement & Control Assoc. (AMCA) Standard 201
- Proper Straight Duct Length (Effective Length) For Uniform Velocity Profile
- Inline & Centrifugal Fans
 - 2.5 duct diameters for 2,500fpm or less
 - Add 1 duct diameter for each additional 1,000fpm
- Axial Fans
 - 3 duct diameters
- Vane Axial Fans
 - 10 duct diameters



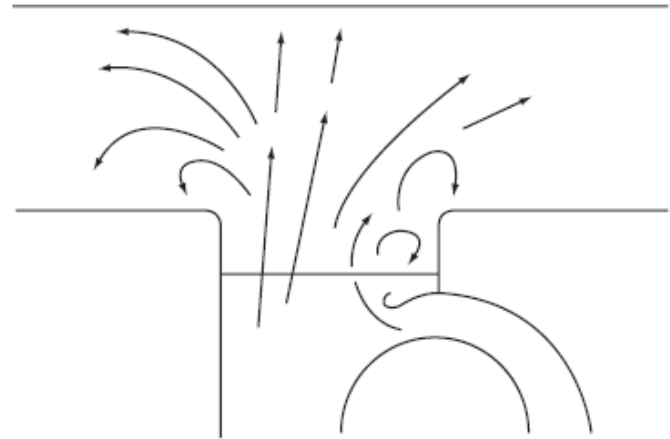
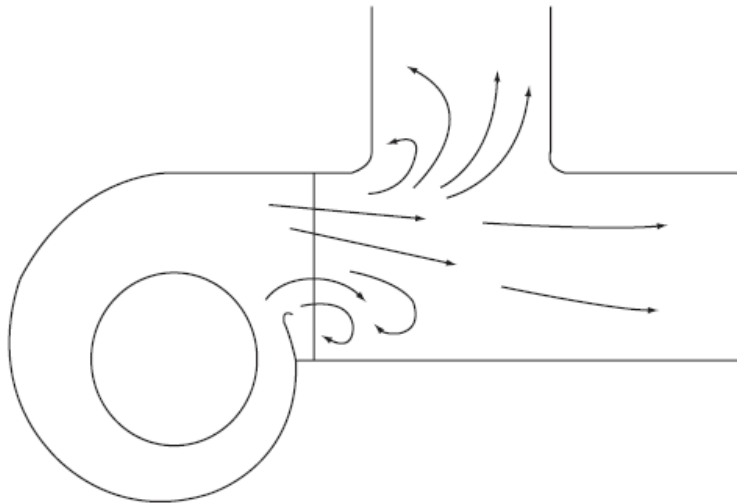
Fan System Effect Causes

- Inefficient Design Or Installed Duct Fittings At Inlet
- Insufficient Clearance Between Cabinet & Fan Inlet



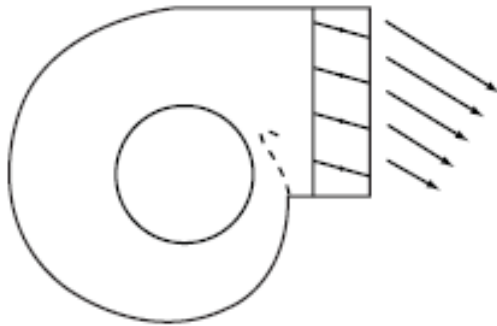
Fan System Effect Causes

- Inefficient Design Or Installed Duct Fittings At Outlet

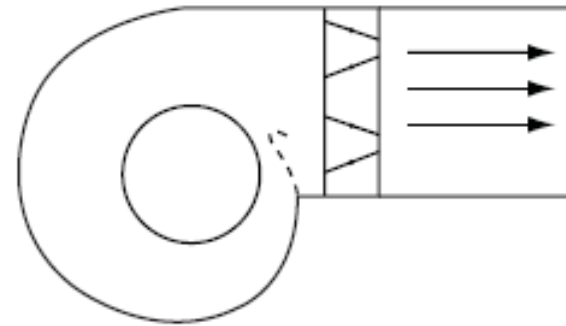


Fan System Effect Causes

- Inlet & Discharge Dampers



PARALLEL-BLADE DAMPER
ILLUSTRATING DIVERTED AIRFLOW

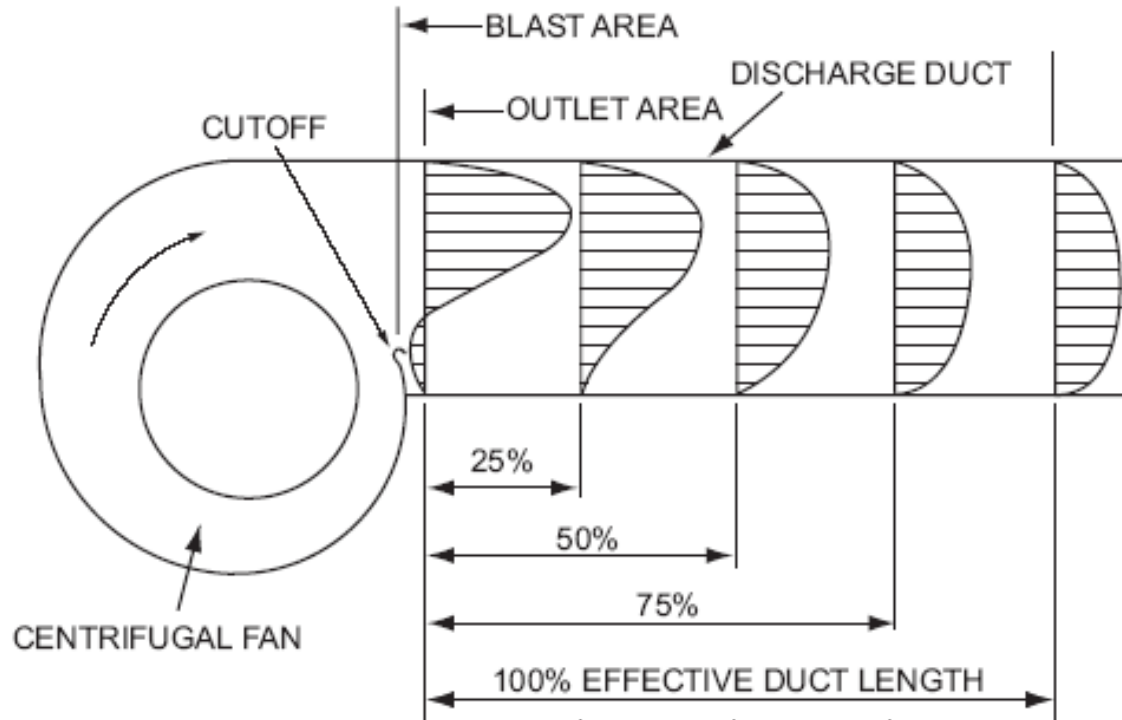


OPPOSED-BLADE DAMPER
ILLUSTRATING NON-DIVERTED
AIRFLOW

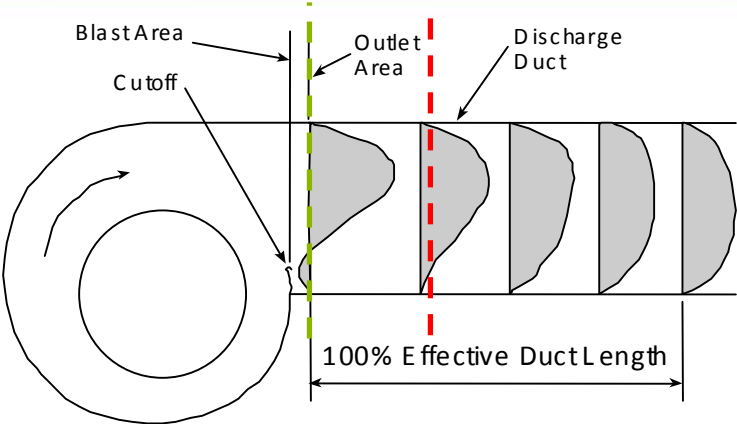


Fan System Effect Causes

- Blast Area Vs. Outlet Area



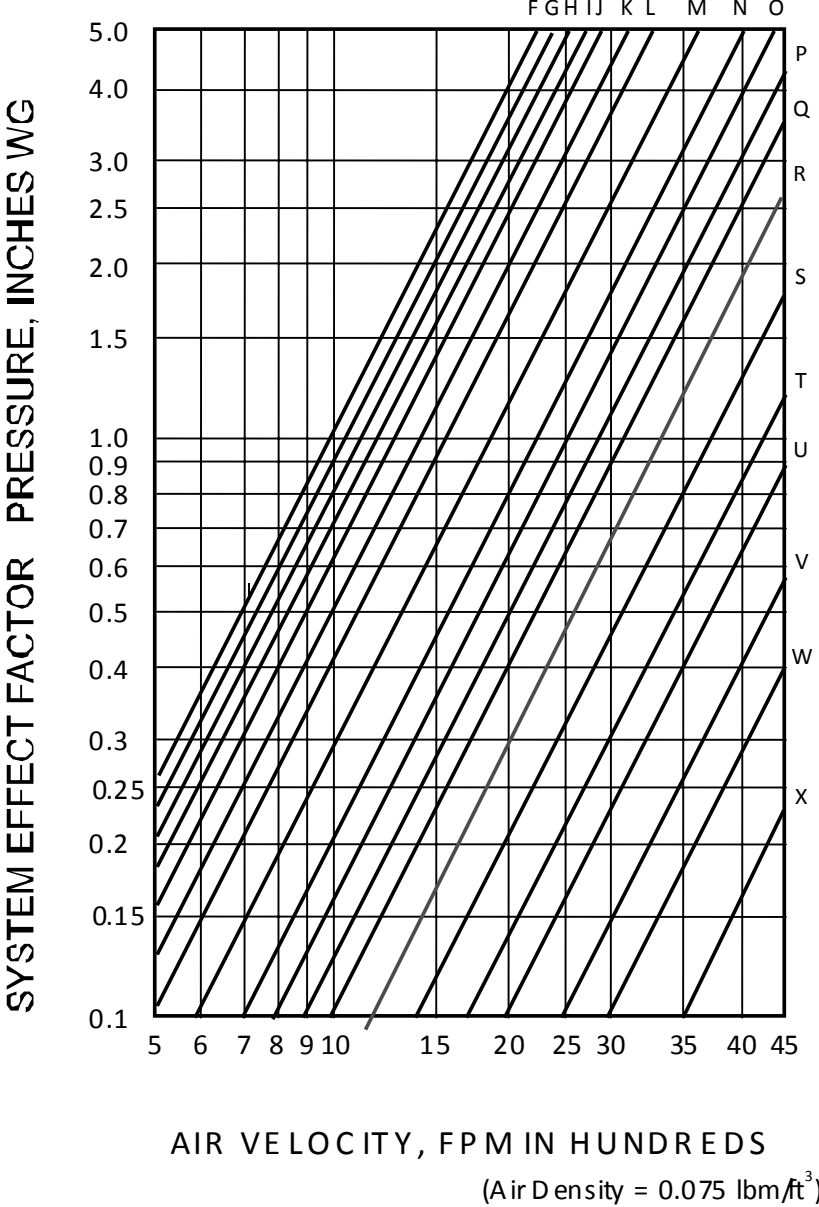
Fan System Effect



	No Duct	12% Effective Duct	25% Effective Duct	50% Effective Duct	100% Effective Duct
<u>Blast Area</u> <u>Outlet Area</u>	System Effect Curve				
0.4	P	R-S	U	W	--
0.5	P	R-S	U	W	--
0.6	R-S	S-T	U-V	W-X	--
0.7	S	U	W-X	--	--
0.8	T-U	VW	X	--	--
0.9	W-W	W-X	--	--	--
1.0	--	--	--	--	--

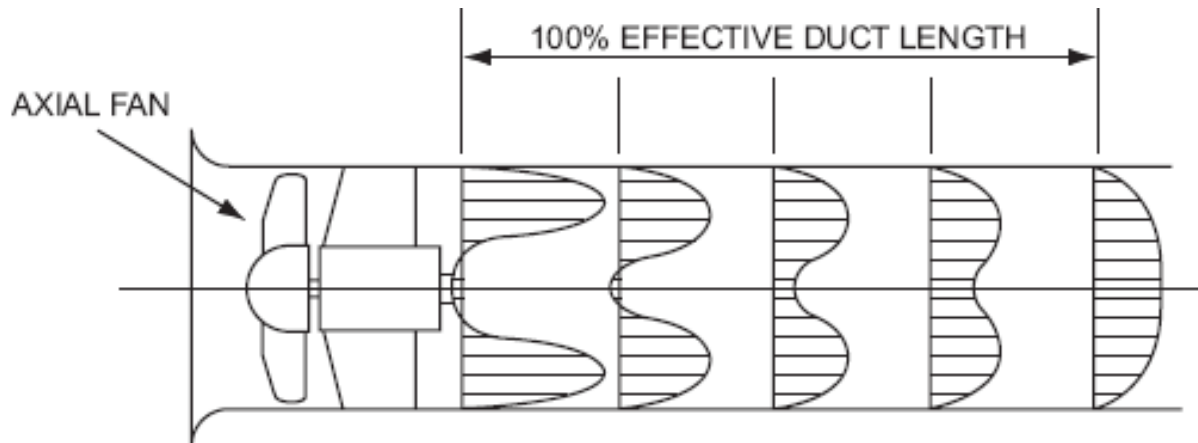
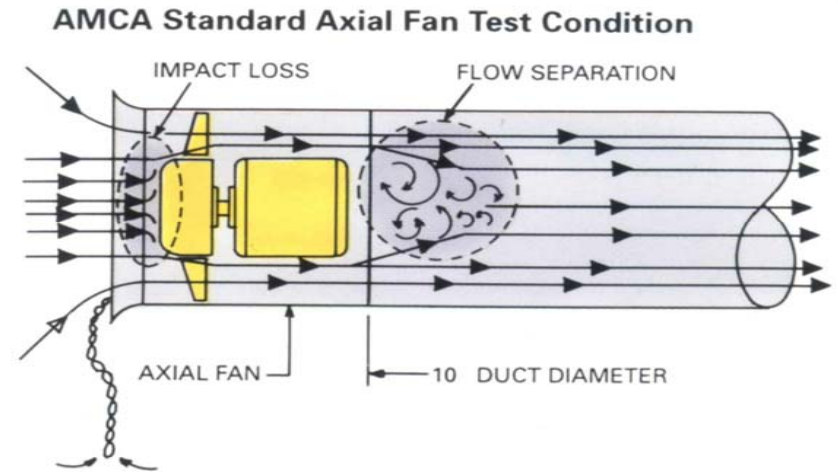


Typical System Effect Curve



Fan System Effect Causes

- Fan Motors & Hubs



Fan System Effect

- Testing, Adjusting & Balancing Reports (TAB)
- Point 1 – Design Point
- Point 2 – Design Volume On Corrected System Curve
- Point 3 – Deficient Volume On Original System Curve
- Point 4 – Deficient Volume On Corrected System Curve

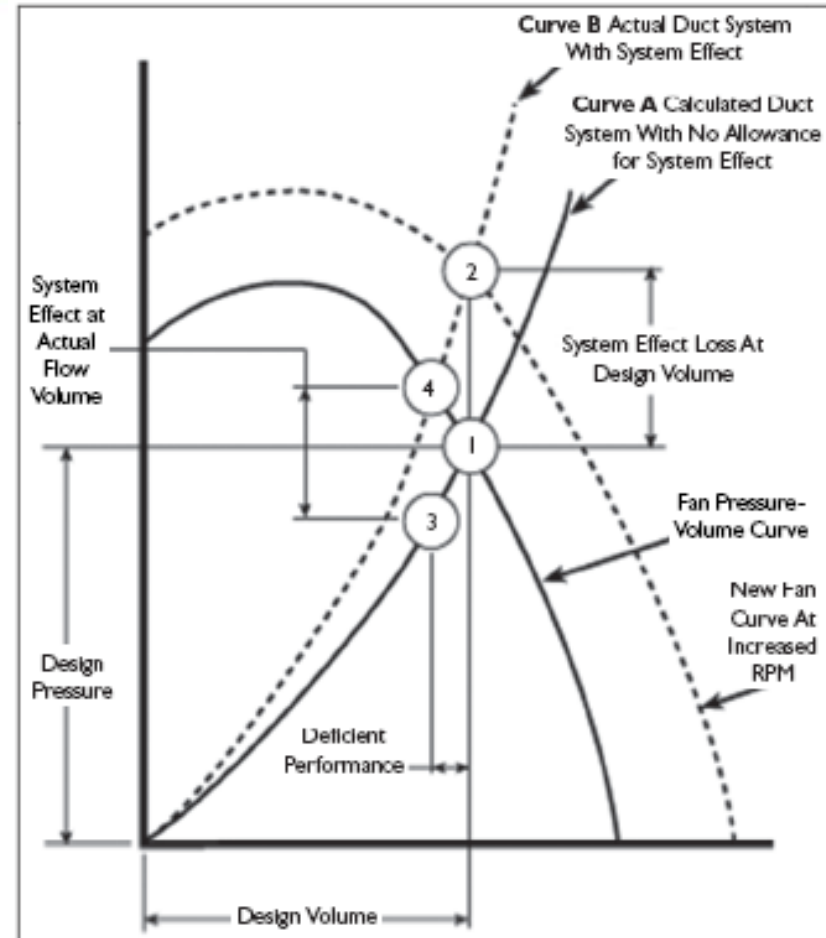


Figure 6: Deficient duct system performance—system effect ignored.



Fan System Effect Corrections At Design

- Take Care Designing Inlet & Outlet
 - Proper distances
 - Proper “swirl”
 - Laminar flow
 - Damper location & styles
 - Turning vanes, straighteners (still account for PD)
- Account For System Effect Factor (SEF)
 - Select fan to include additional SEF pressure drop
 - Must account for both inlet & outlet pressure drop
- Include SEF In Fan Schedule
 - Explicitly accounts for SEF for all SEF factors
 - Manufacturer to account for variations to meet performance



Fan System Effect Corrections In Field

- Increase RPM Of Fan
- Increase Motor Size
- Increase Fan Size
- Increase Electrical (Wiring, Fusing, Disconnect, etc.)
- Alter Ductwork
- Add Sound Attenuators???

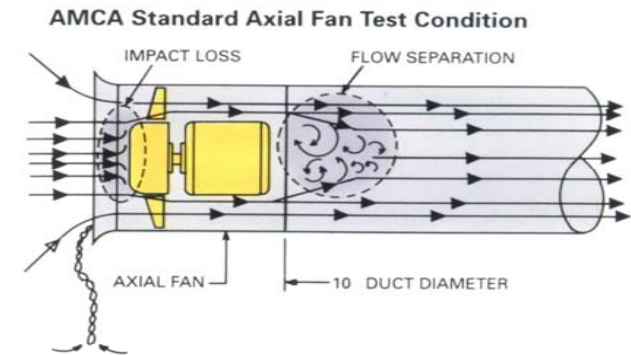
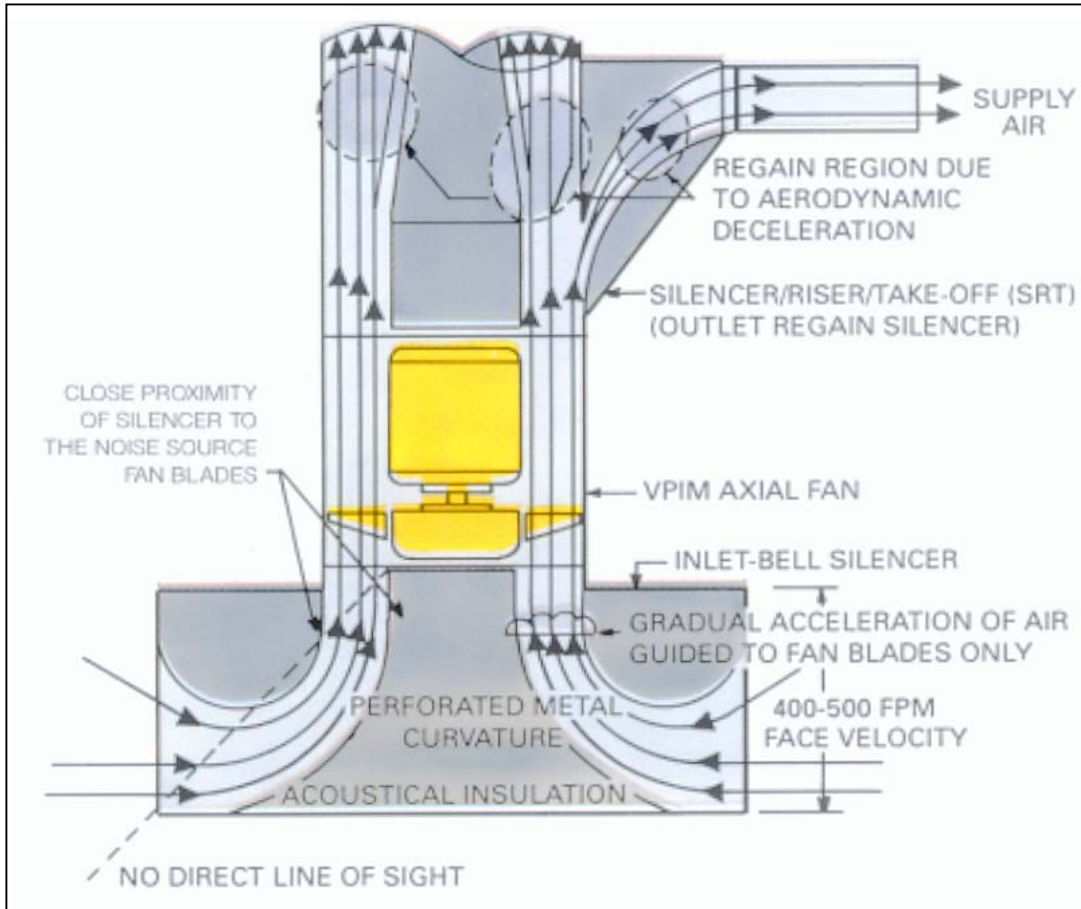


Airflow Efficiency



Airflow Efficiency

- Begins With Engineering



Airflow Efficiency

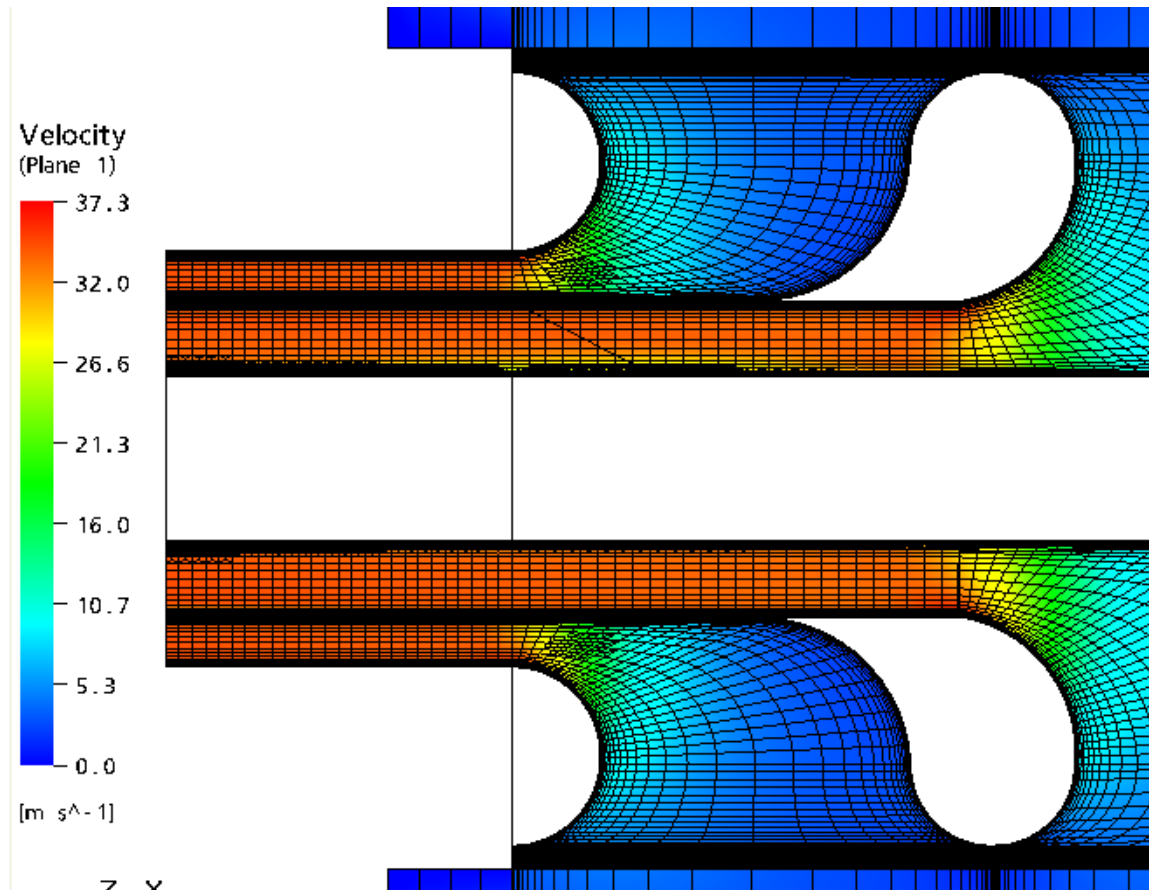
Total Pressure = Static Pressure + Velocity Pressure

- Velocity Regain
 - Conversion Velocity Pressure To Static Pressure Through Deceleration
- Created Through “Diffuser” or Evase
- Efficiency Of Conversion Based On:
 - Angle of expansion
 - Length
 - Blast/Outlet area ratio



Airflow Efficiency

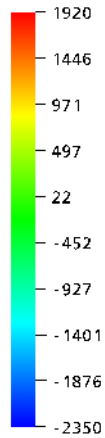
- Computational Fluid Dynamics (CFD)



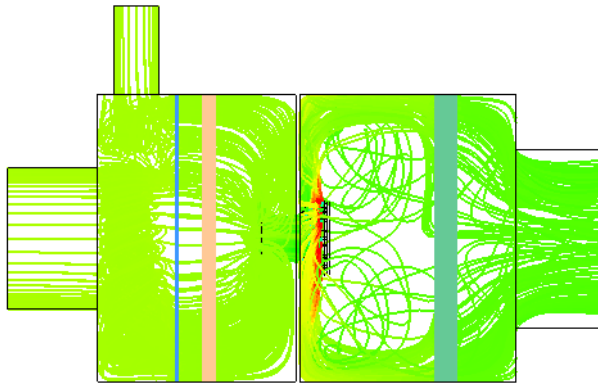
Airflow Efficiency

Total Pressure Distribution Across the Models

Total Pressure
(Streamline 1)

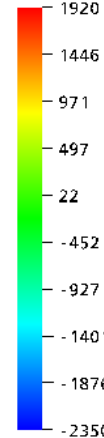


[Pa]

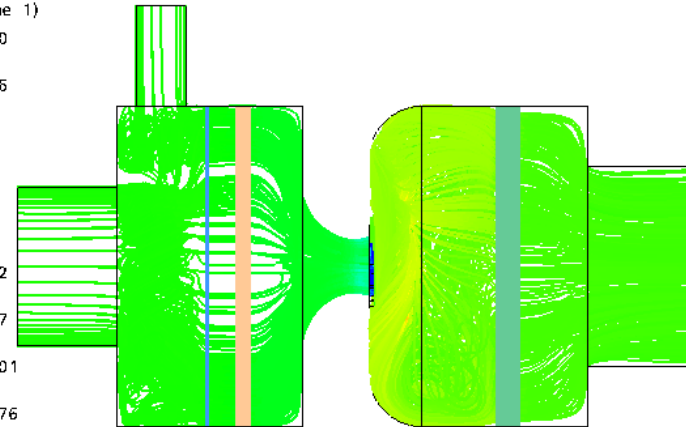


Conventional Design

Total Pressure
(Streamline 1)



[Pa]



M&I Solution

•Additional Benefits:

- Filter Loading
- Moisture Carryover

- Freezestat Trips
- Sound & Vibration



Airflow Efficiency Examples

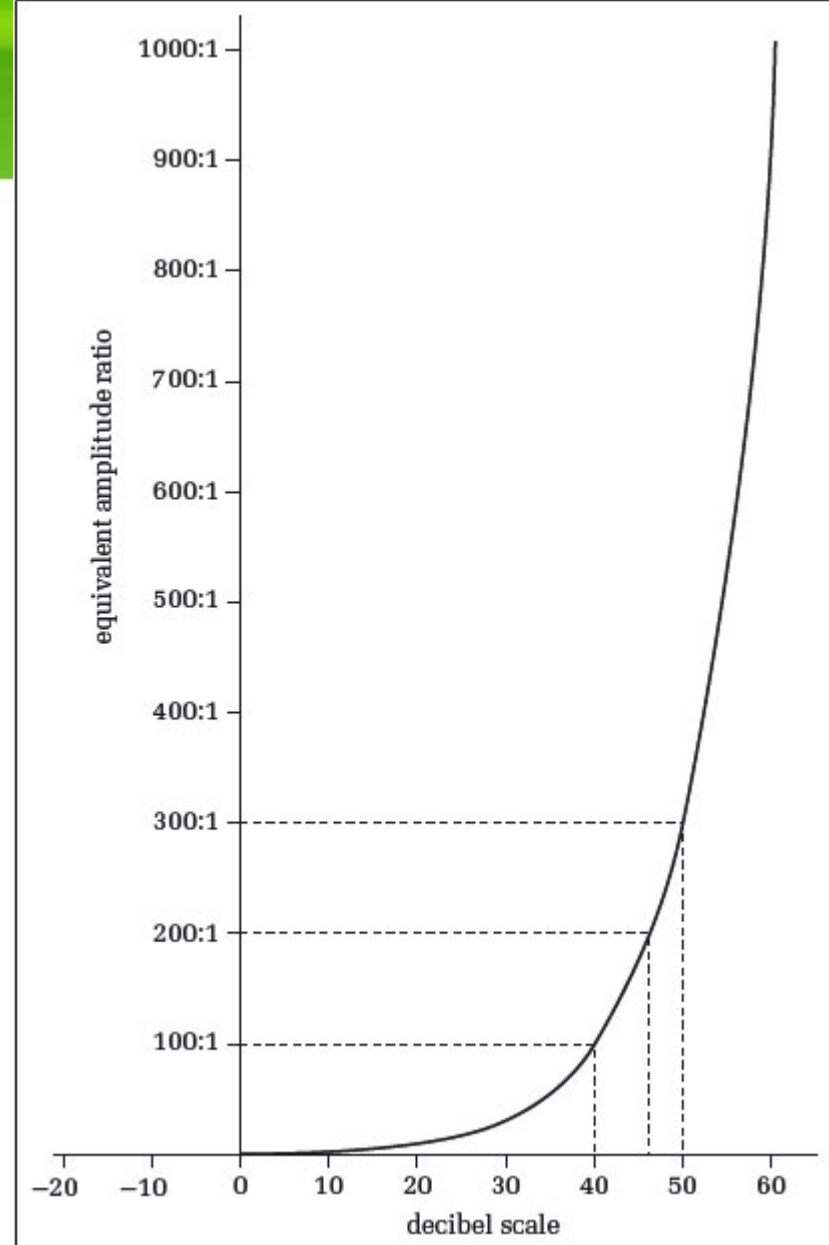


Sound Levels



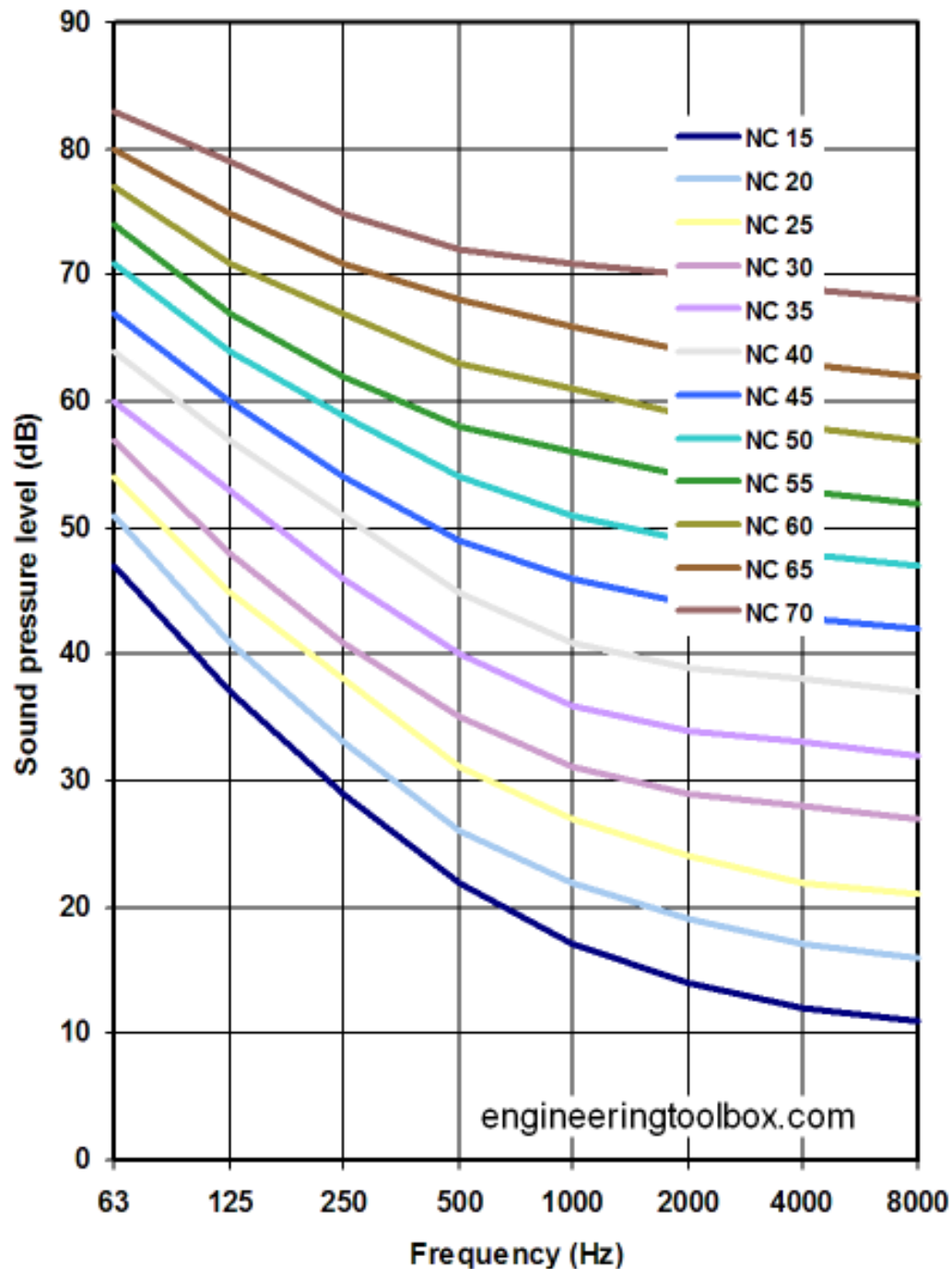
Sound Levels

- Decibels (dB)
 - Logarithmic Measurement
 - 0 dB Is Lowest Audible Sound To Human Ear (Near Total Silence)
 - 10 x Silence = 10dB
 - 100 x Silence = 20dB
 - 1,000 x Silence = 30dB



Sound Levels

- Used For Rating Indoor Noise
- NC-10 Virtually Impossible To Hear
- M&I Can Achieve NC-15
- Highest Single Value Over 8 Octave Bands
- Don't Know If Noise Will Be "Rumble" or "Hiss"



Sound Levels

- Acceptable / Comparable dB & NC levels

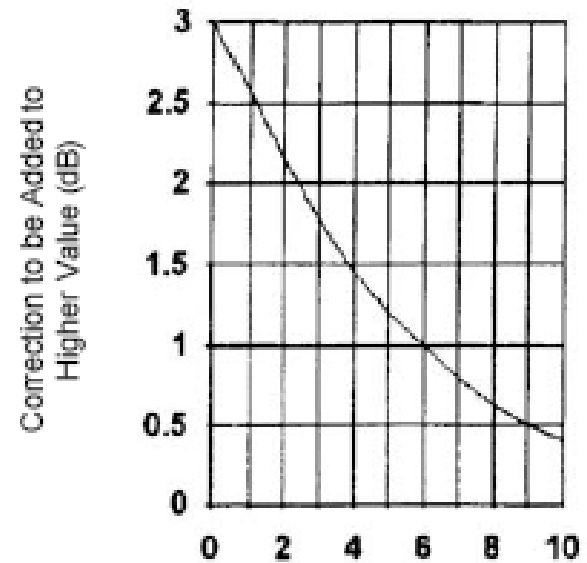
Type of Room - Occupancy		Noise Criterion - NC -	Noise Rating - NR -	db(A)
Very quiet	Concert and opera halls, recording studios, theaters, etc.	10 - 20	20	25 - 30
	Private bedrooms, live theaters, television and radio studios, conference and lecture rooms, cathedrals and large churches, libraries, etc.	20 - 25	25	25 - 30
	Private living rooms, board rooms, conference and lecture rooms, hotel bedrooms	30 - 40	30	30 - 35
Quiet	Public rooms in hotels, small offices classrooms, courtrooms	30 - 40	35	40 - 45
Moderate noisy	Drawing offices, toilets, bathrooms, reception areas, lobbies, corridors, department stores, etc.	35 - 45	40	45 - 55
Noisy	Kitchens in hospitals and hotels, laundry rooms, computer rooms, canteens, supermarkets, office landscape, etc.	40 - 50	45	45 - 55



Sound Levels

- Decibel Addition
- More Equal In dB Level, Greater Value
- 2 Fans At Equal dB = +3dB
- $10 \times \text{LOG}(\# \text{ Fans})$

ARI Standard 885-2008



Difference in Decibels Between Two Values Being Added (dB)

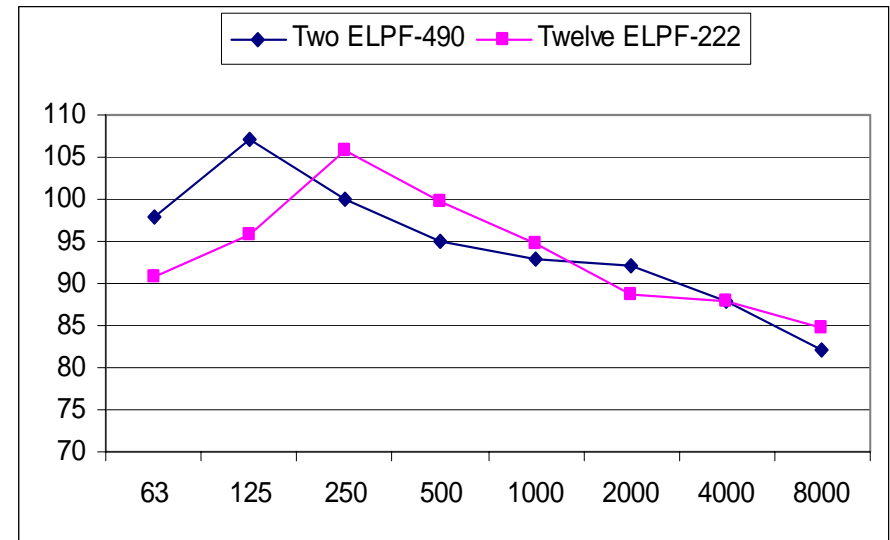
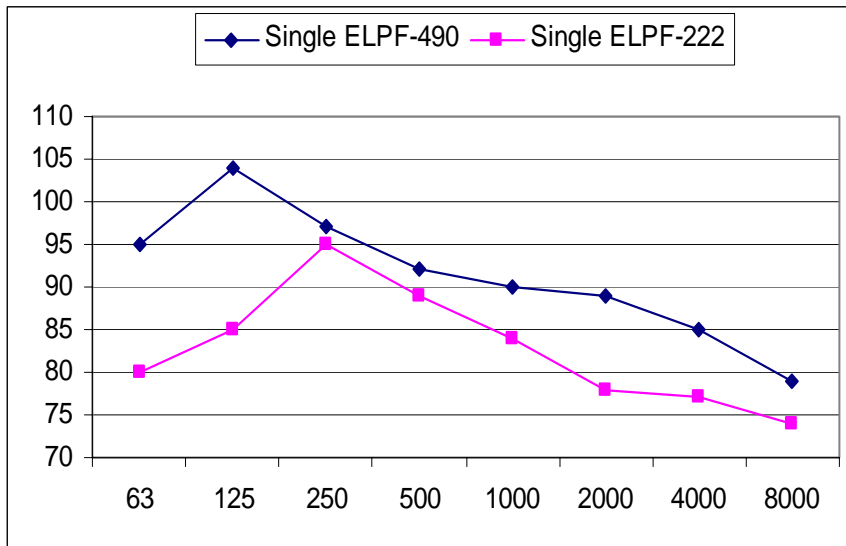


Sound Levels

But after you account for the total quantity of fans with the acoustical relationship for multiple identical sound sources, single-fan PWL + $10 \cdot \text{LOG}(N)$, there is no significant advantage.

Dual fan pair (2 x 490), $10 \cdot \text{LOG}(2) = +3\text{dB}$ per octave band

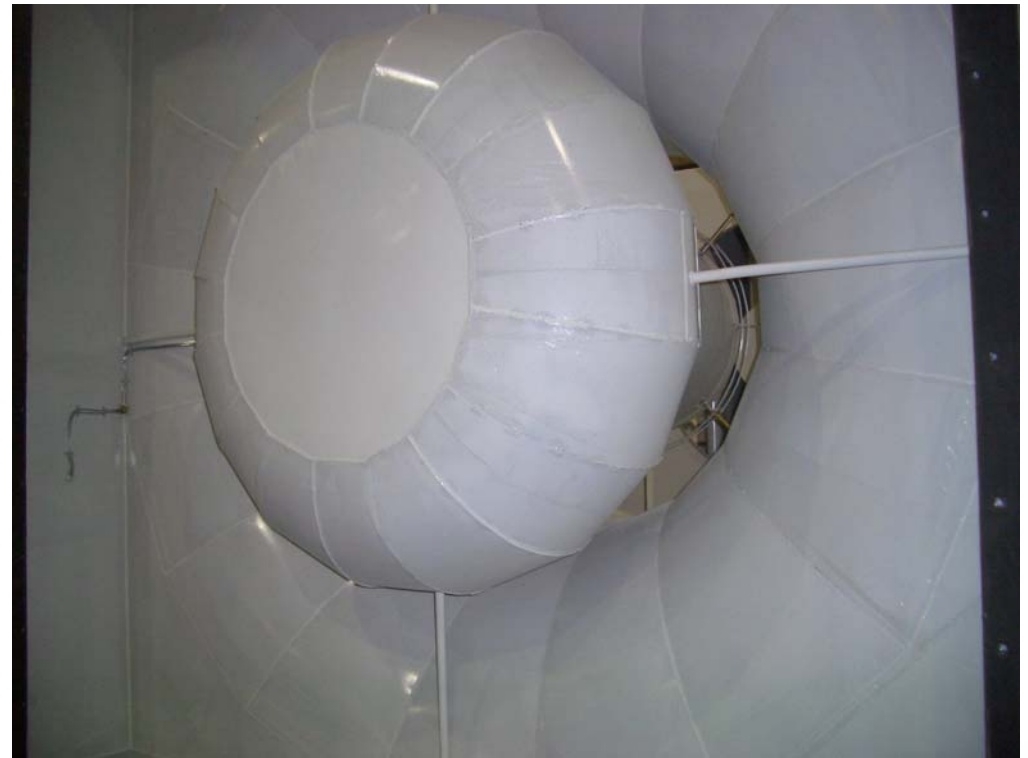
12-fan Array (10 x 222), $10 \cdot \text{LOG}(12) = +11\text{dB}$ per octave band



Delivering the same 72KCFM at 5" TSP, both the dual '490s and the array of twelve '222s have the *same* overall unweighted sound PWL: 108-109 dB.



Sound Levels



Sound Levels



**Creating High
Performance HVAC
Systems**



Creating High Performance HVAC Systems

- Air Handler Is Extremely Important, But Don't Forget Other Components:

- Chiller Size Reduction
- Pipe Size Reduction
- Pump Size Reduction
- VFD Size Reduction
- Generator Size Reduction



System Energy Savings



System Energy Savings

- Hospital Project in Akron, OH
- Base of Design Fan Array With 950 total hp
- Compac Vaneaxial Design 790 total hp
- Savings 160 hp
- Assuming 24/7/365 Operation at \$0.10
- Yearly Operational Savings: \$112,400
- Present Day Value Over 15 Years: \$1,450,000
- Does Not Include Demand Charge Savings, Chiller/Pump Reductions



Contact Information:

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Thank You

