Airside Optimization

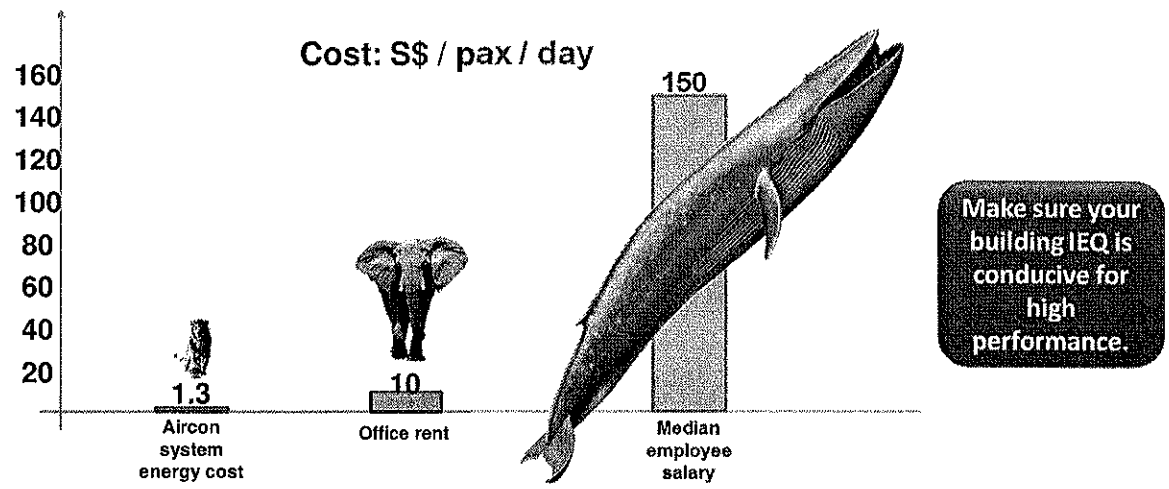
Steven Kang
Steven.kang@mnv.com.sg

Agenda

1. Airside system optimization & IAQ
2. Comparison of AHU and FCU
3. Optimization of AHU system
4. Optimization of FCU
5. CO2 demand ventilation

Airside System Optimization & IEQ

Where does it really count for a building?



Make sure your building IEQ is conducive for high performance.

Some energy cost saving strategies at the expense of IEQ

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- Raise room temperature
- Reduce airflow
- Use low rating filters
- Reduce outside air
- Minimize maintenance services
- Squeeze all M&E equipment above ceiling

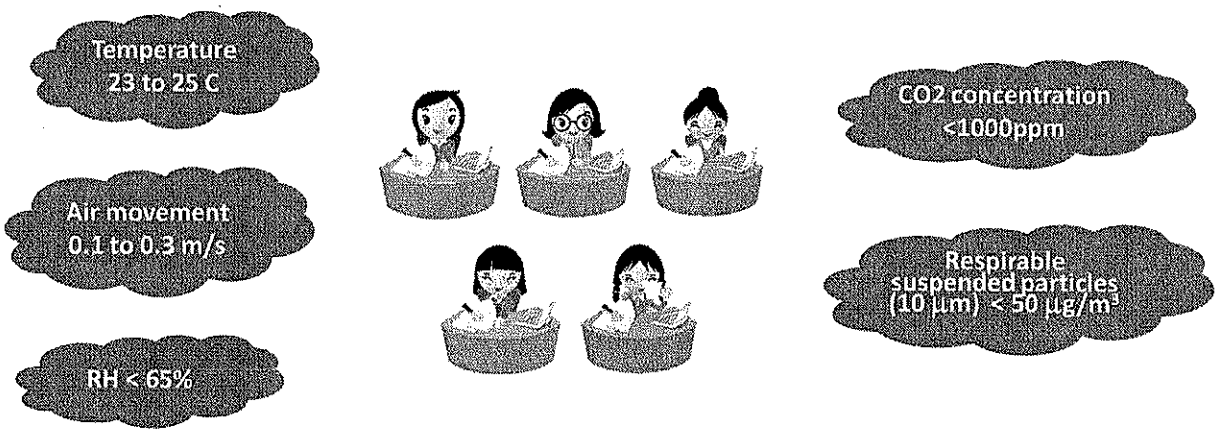




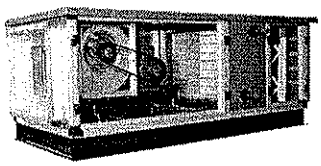


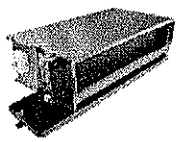
Goals for Good Air Quality (IAQ)

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Goals for good airside efficiency



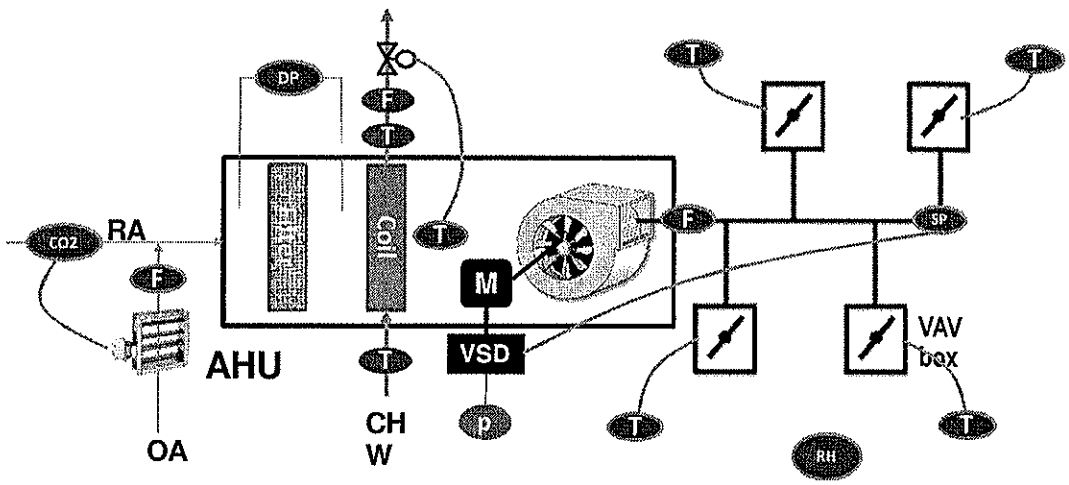


$$\frac{W}{CMH} = \frac{\text{Total Pressure}}{3600 \times \eta_{fan} \times \eta_{motor}}$$

Types of air system	Green Mark (W/CMH)	Green Mark (KW/RT)	Excellent class (W/CMH)	Excellent class (KW/RT)
Constant Volume AHU Motor ≥ 4KW	0.42	0.29	0.20	0.14
Variable Volume AHU Motor ≥ 4KW	0.58	0.39	0.20	0.14
AHU/FCU Motor < 4KW	0.17	0.12	0.10	0.07

KW/RT = W/CMH * 680 CMH/RT /1000

Accurate measurement is the essential to "drive towards our goals"



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Comparison of AHU and FCU

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AHU versus FCU

Factors	Sub-factors	AHU	FCU
Energy efficiency	Fan ESP	High due to long ducts (ESP: 300 to 500pa)	Low due to short ducts (ESP: 50 to 100a)
	Fan efficiency	High (60 to 75%)	Low: (40 to 50%)
	Motor eff	High (85 to 93%)	Low: (35 to 50%)
	Overall efficiency	**0.20 to 0.70 W/CMH**	**0.15 to 0.30 W/CMH**
Cost	Initial cost	Generally high as custom built & require lots of ducts	Generally lower as standard product
	Life span	More durable (10 to 15 years lifespan)	Less durable (7 to 10 years lifespan)
Comfort	Temp	Generally better due to better temp, RH control	Generally lower
		VAV needed for zone temp control	Zone temp control is std
	IAQ	Better IAQ due to better filters. UV possible.	Flat filter
	Noise	Quieter as AHU confined and duct can attenuate noise	More prone to noise problem
Space requirement	Room	Generally need AHU room	Ceiling mounted
	Ceiling	Larger ducts, so more ceiling depth required	Smaller duct, so less ceiling depth required
Maintenance	-	Easier since less qty and floor mounted	More challenging due to large qty and ceiling mounted
Cooling coil	-	Can be customized for different temperatures. High DT &/or low DP possible.	Std conditions only
Fan	-	Can be customized for different CMH, static and fan types	Usually std FC fans only
Filters	-	Can be customized for various filtration efficiency	Usually std low efficiency filters only
Applications	-	High grade offices Large open areas such as function rooms Factories	Low grade offices Hotel room Retail shops Class rooms

Proprietary Information of Measurement & Verification Pte Ltd

Microsoft Excel Worksheet

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Optimization of AHU systems

Optimization of AHUs

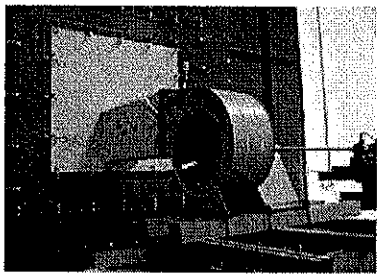
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1. Minimize fan system effect losses
2. "Fat short ducts with gradual bends" instead of "long skinny ducts with sharp bends".
3. Select high efficiency fans and motors.
4. Variable Air Volume (VAV) system using VSD instead of Constant Air Volume (CAV) system.
5. At the least, Adjustable Air Volume system using VSD.
6. Select low pressure drop filters
7. Low face velocity when space permits
8. Select high efficiency fans
9. Select high efficiency motors
10. High CHW DT, especially for PAHU.
11. Heat recovery for PAHUs

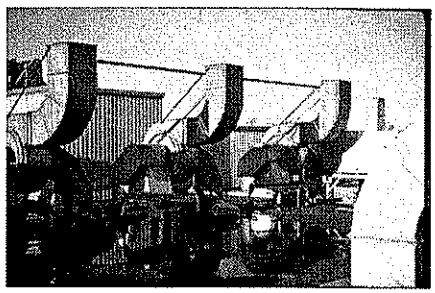
Fan System Effect Losses

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- A factor used to correct for system induced installation effects.
- The difference in performance between a fan tested in the laboratory and one tested in a real installation.



AMCA Rate Fan Condition



Real Installation

Minimize Fan System Effect Losses

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Rules of thumbs to minimize fan system effect losses

- Minimum of 2.5 Duct Diameters of straight duct on Outlet
- Minimum 3 to 5 Duct Diameters of straight duct on Inlet
- Avoid inlet swirl or turbulences

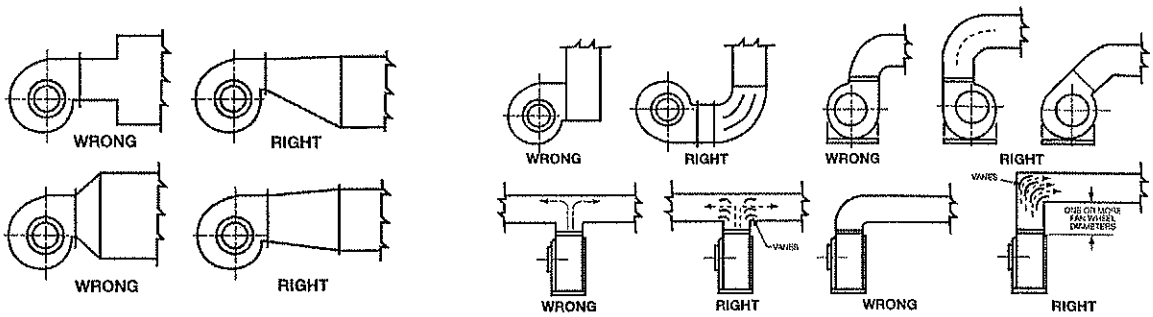
Minimize Fan System Effect Losses

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Inlet

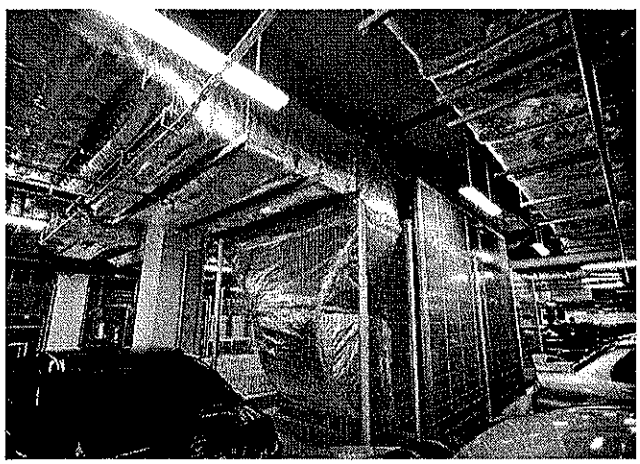


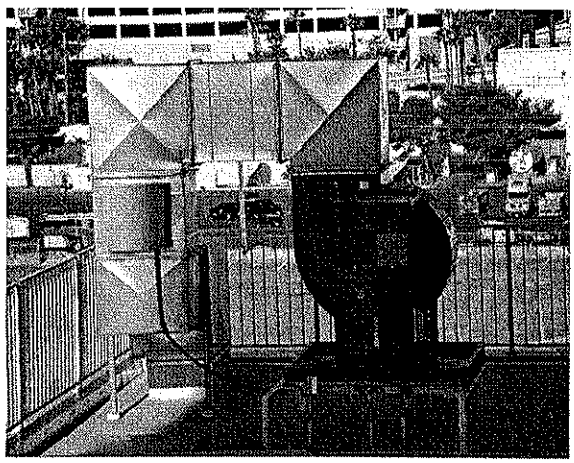
Outlet



Example of inefficiencies

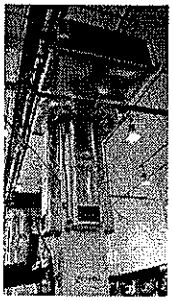
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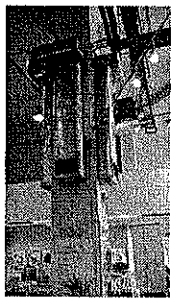




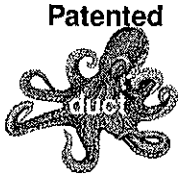
Example of inefficiencies

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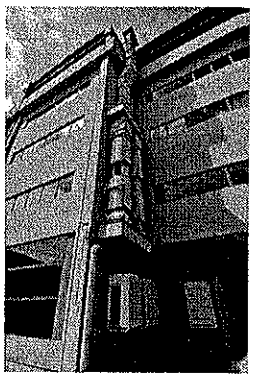




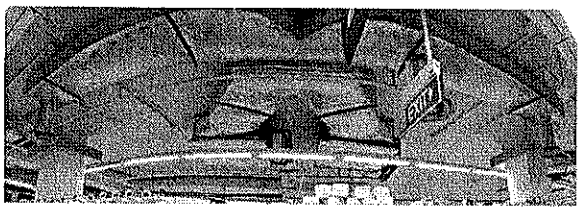
Patented



$$\frac{W}{CMH} = \frac{\text{Total Pressure}}{3600 \times \eta_{fan} \times \eta_{motor}}$$



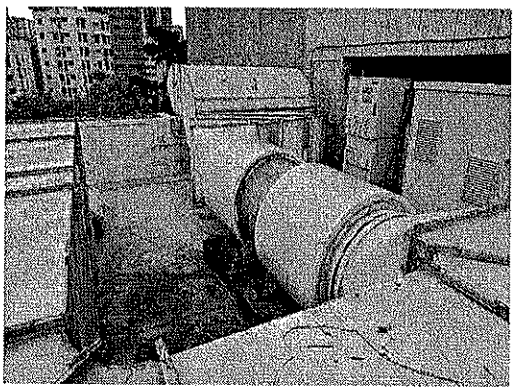
Rocket launcher



Traffic lights needed

Example of inefficiencies

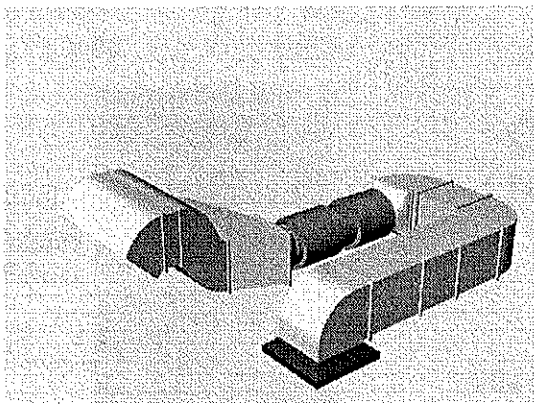
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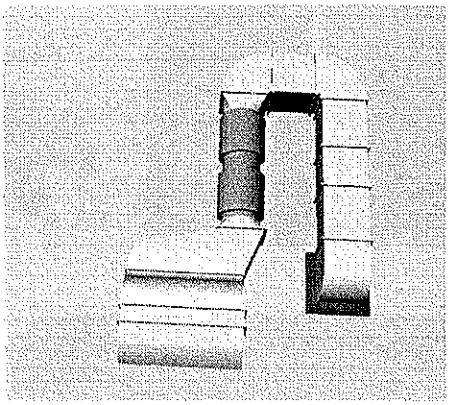




Example of inefficiencies

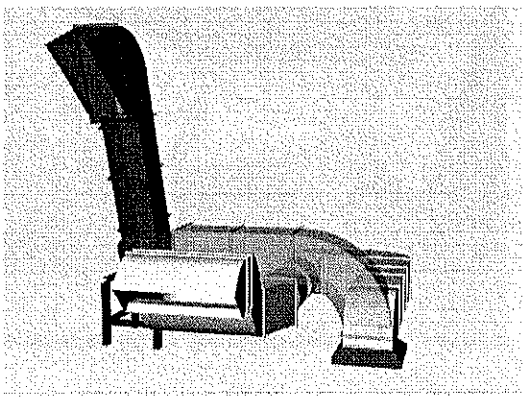
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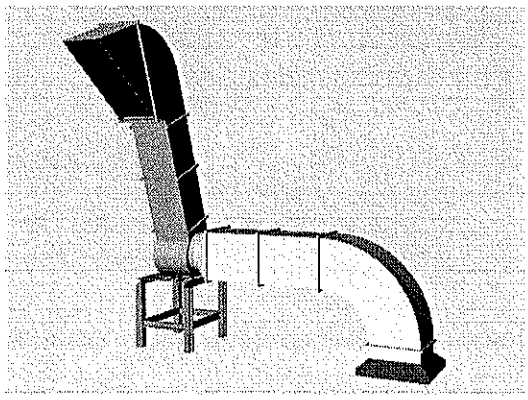




Ideas to improve

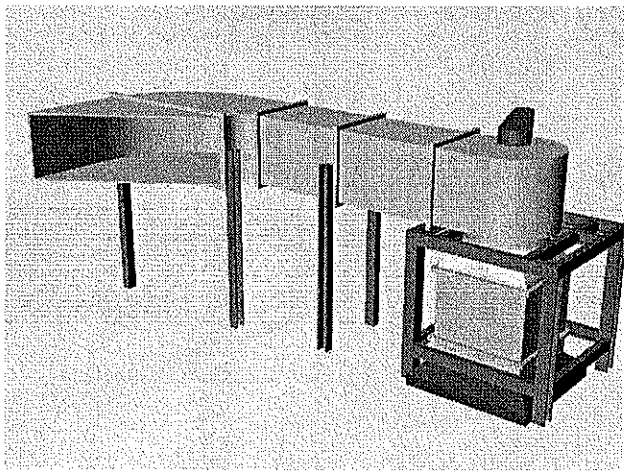
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Ideas to improve

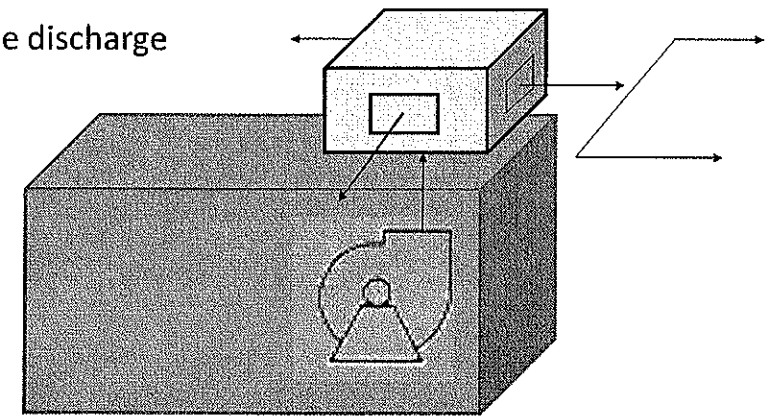
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Example of inefficiencies

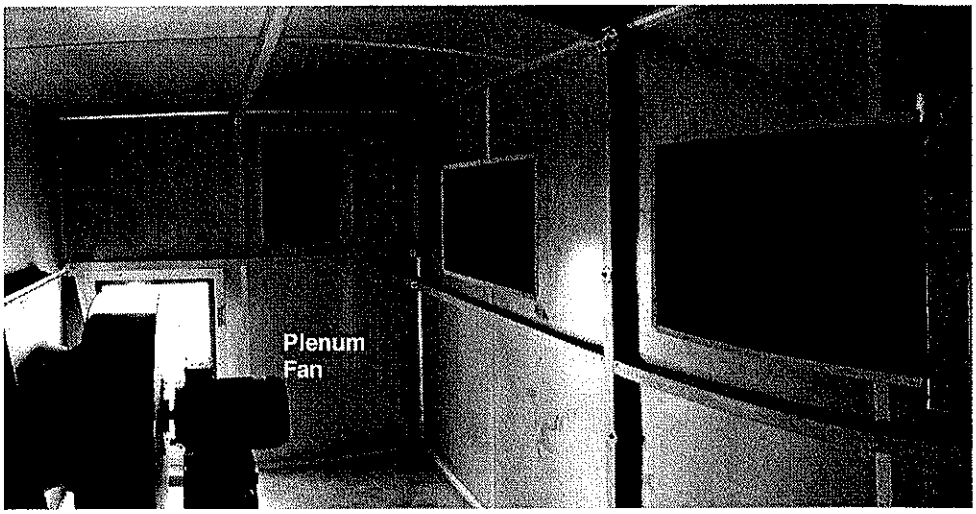
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AHU with multiple discharge



Ideas to improve

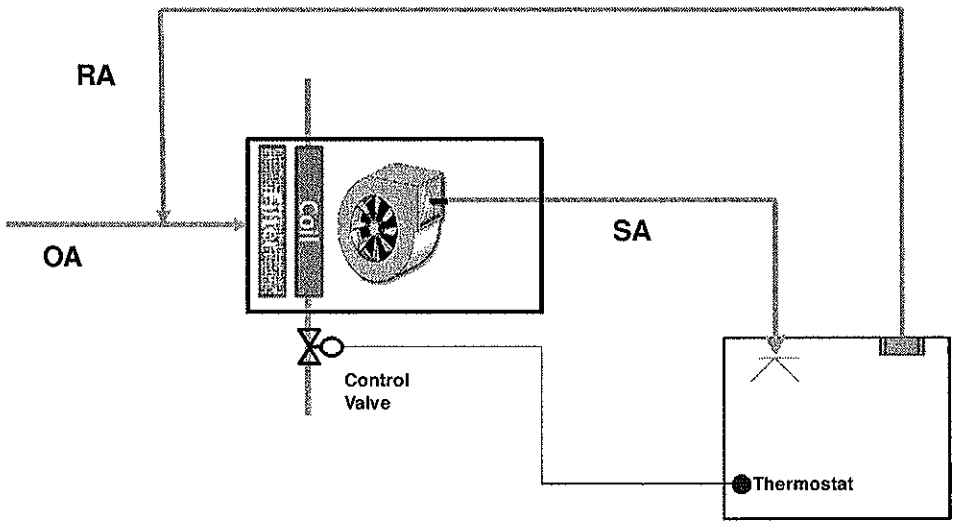
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CONSTANT Vs. VARIABLE AIR VOLUME SYSTEM

Constant Air Volume (CAV) System



CAV Full Load

With these design conditions ...

space sensible heat gain = 11.72Kw

space dry-bulb temperature = 23.9C

supply air dry-bulb temperature = 12.8C

SI units

$$\text{Supply Airflow CMH} = \frac{2960 \times \text{Sensible Heat Gain (KW)}}{(\text{Space DB (C)} - \text{Supply DB (C)})}$$

$$\text{Supply Airflow CMH} = \frac{2,960 \times 11.72\text{KW}}{(23.9^{\circ}\text{C} - 12.8^{\circ}\text{C})} = 3,125 \text{ CMH}$$

CAV Part Load

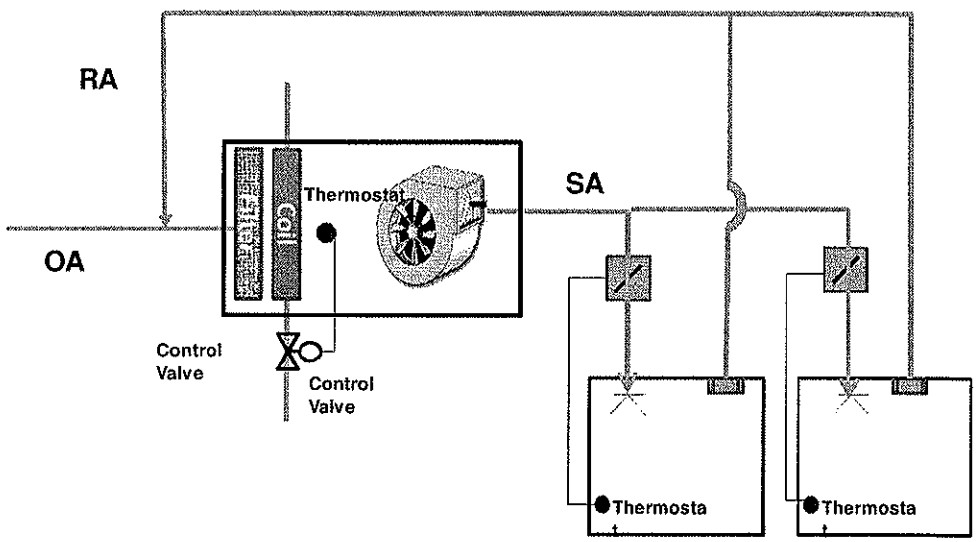
With these part load conditions ...
space sensible heat gain = 5.86KW
space dry-bulb temperature = 23.9
supply airflow = 3,125 CMH

SI units

$$\text{Supply DB (C)} = \text{Space DB (C)} - \frac{\text{2,960 x Sensible Heat Gain (KW)}}{\text{Supply Airflow (CMH)}}$$

$$\text{Supply DB (C)} = 23.9^{\circ}\text{C} - \frac{\text{2,960 x 5.86KW}}{\text{3,125 CMH}} = 18.3^{\circ}\text{C}$$

Variable Air Volume (VAV) System



VAV Full Load

With these design conditions ...

space sensible heat gain = 11.72Kw

space dry-bulb temperature = 23.9C

supply air dry-bulb temperature = 12.8C

SI units Supply Airflow CMH $= \frac{2{,}960 \times 11.72\text{KW}}{(23.9^\circ\text{C} - 12.8^\circ\text{C})} =$ 3,125 CMH

VAV Part Load

With these part load conditions ...

space sensible heat gain = 5.86KW

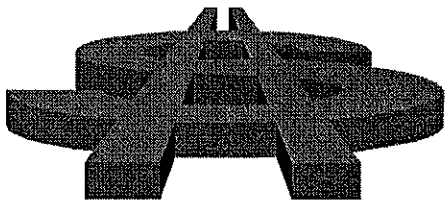
space dry-bulb temperature = 23.9C

supply air dry-bulb temperature = 12.8C

SI units Supply Airflow CMH $= \frac{2{,}960 \times 5.86\text{KW}}{(23.9^\circ\text{C} - 12.8^\circ\text{C})} =$ 1,563 CMH

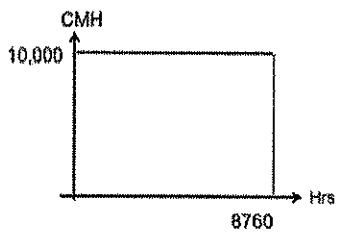
VAV Part-Load Energy Savings

- Reduced fan energy
- Reduced refrigeration energy



Constant Air Volume System

KWH = CMH x W/CMH x Hrs
= 10,000 x 0.47 x 8760/1000
= 41,172 KWH



Fan operating cost = 41,172KWH *0.24/KWH
= S$9,881

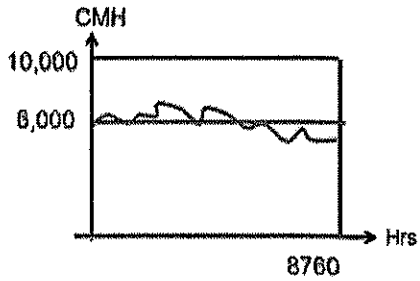
Fan C02 emission = 41,172KWH * 0.59 kg CO2/KWH
=24,291kg CO2 emission

Variable Air Volume System

KWH = CMH x W/CMH x Hrs
= 6,000 x [(0.60) ^{2} x 0.47] x 8760/1000
= 8,893 KWH

Fan operating cost = 8,893KWH *0.24/KWH
= S$2,134

Fan C02 emission = 8,893KWH * 0.59 kg CO2/KWH
=5,247kg CO2 emission



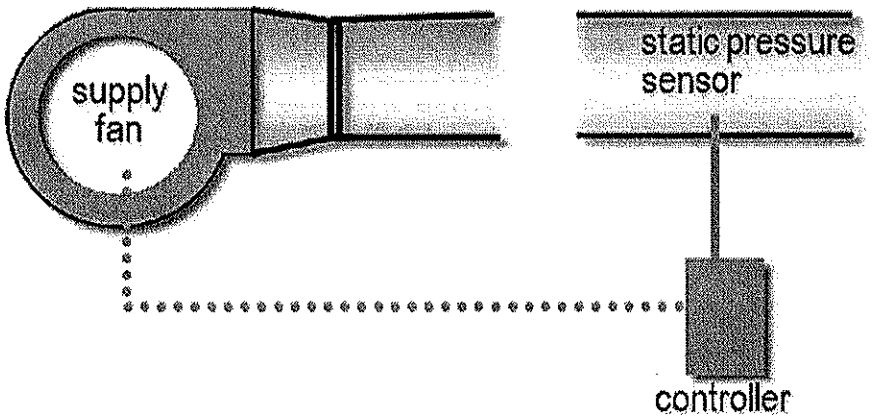
$W \propto Q^3$

$W/Q \propto Q^2$

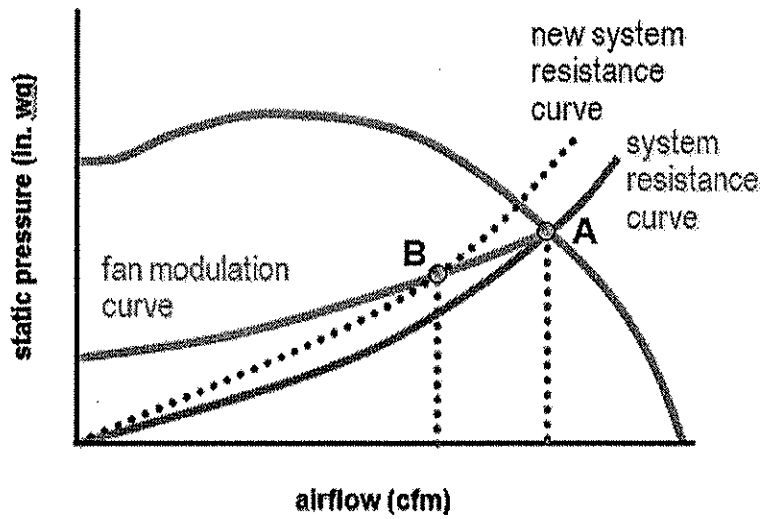
Impact of CAV Vs. VAV system

- Operating cost savings/year= S$7,747
- C02 emission reduction = 19,044kg
- A car CO2 emission/year ~ 5,000kg
- Emission reduction is equivalent to about removing 4 cars

Fan Control Loop

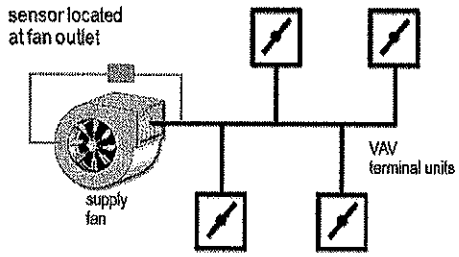


VAV Fan Modulation

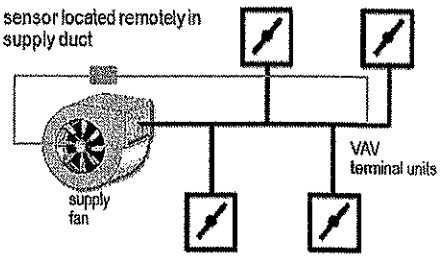


Static Pressure Control

1.Fan Outlet Static Pressure Control

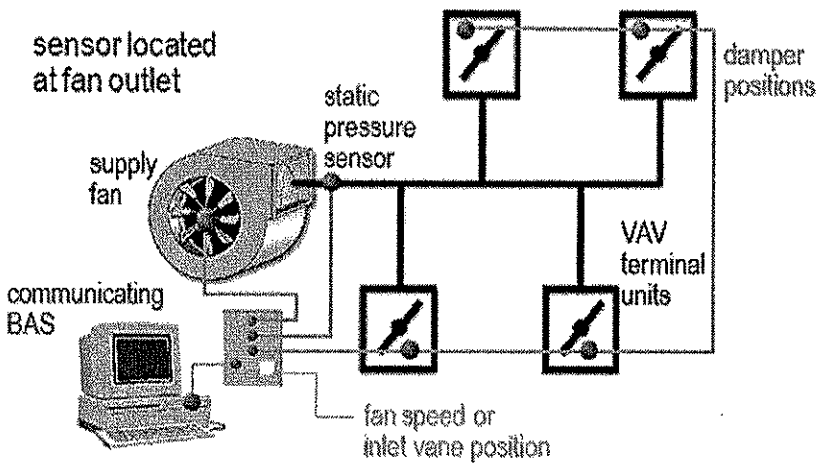


2.Supply Duct Static Pressure Control



Static Pressure Control

3.Optimized Static Pressure Control

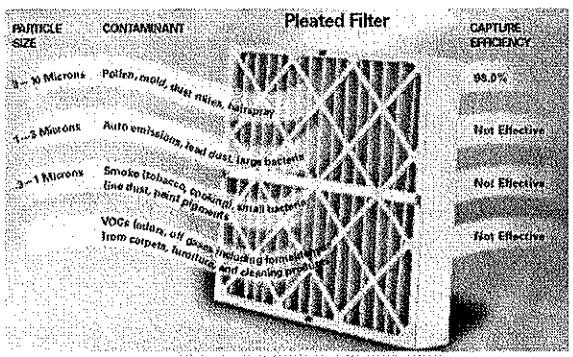


Part-Load Comparison

Control Method	Airflow (Cfm)	Fan SP (In. Wg.)	Brake Hp	% Full-load Power	Relation
Full Load	24,000	2.70	22	---	
Part Load ...					
Fan Outlet	18,000	2.13	13	60%	HP α $(cfm)^{1.8}$
Supply Duct	18,000	1.85	12	55%	HP α $(cfm)^{2.1}$
Optimized	18,000	1.52	9.5	43%	HP α $(cfm)^{2.9}$

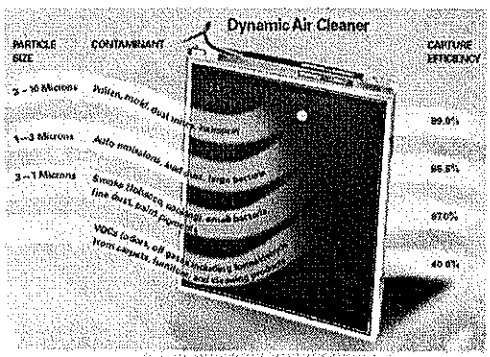
Ideas to improve: Electronic Air Filters

Traditional Passive Filters



Mid-life Pressure Drop: 100 – 200pa

Electronic Air Cleaners



Mid-life Pressure Drop: 30 – 70pa

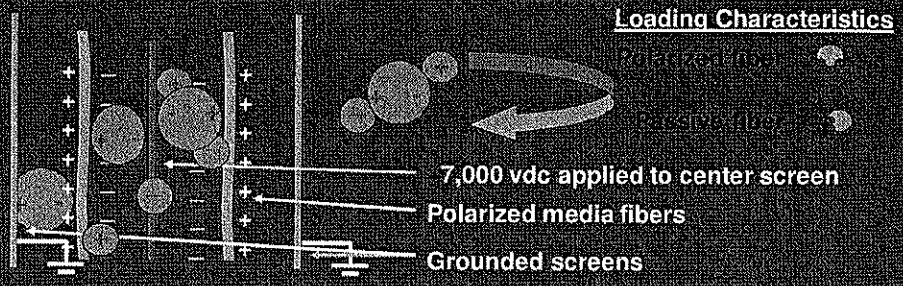
Electronic Air Cleaners

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Passive mechanisms:
- because there is a media, there is passive collection.

Polarization and electrostatic attraction:
- polarized fibers collect polarized and charged particles.
- charged center screen collects polarized and charged particles.

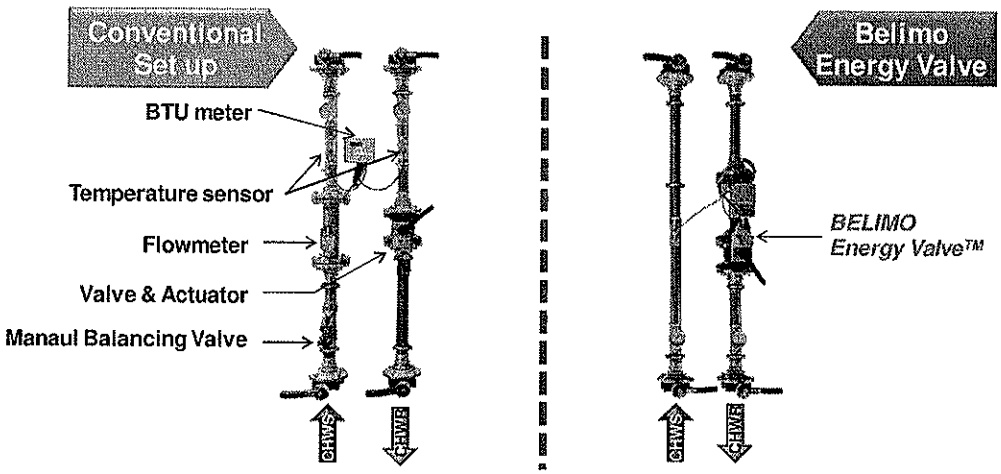
Agglomeration:
- natural process (Brownian Motion) greatly accelerated by the field inside the air cleaner. Polarized particles attract each other and charged particles to form clusters that are more easily captured.



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Ideas to improve: Intelligent Control Valve

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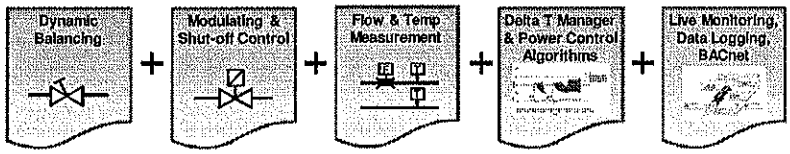
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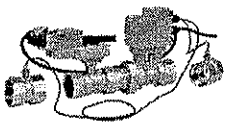
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Ideas to improve: Intelligent Control Valve

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Belimo Energy Valve - Five Functions in One Valve





DN15...50



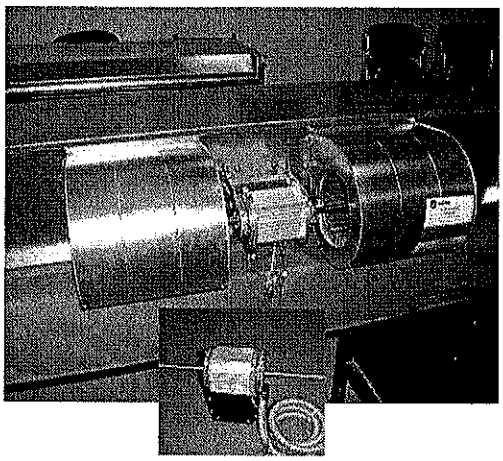
DN65...150

Key element for improvement

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Optimization of FCU

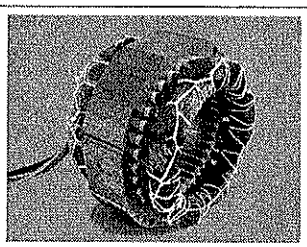
VAV FCU with DC motor



Integrated signal driver to the DC (brushless) fan motor

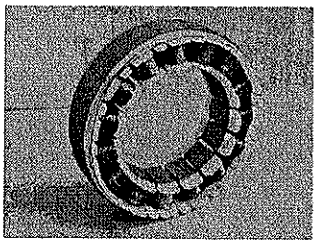
- *Substantial energy saving*
  - **Almost double efficiency than PSC motor**
- *Stepless control*
  - **Non-stage variable speed**
- *Quiet*
  - **Low electro-magnetic noise**
- *Comfortable*
  - **Constant temperature**
- *PI control*
  - **Fast response to the load changes**

VAV Fan Coil Unit -- Motor Coil



Traditional AC Motor

- **Less reliable**
- **Lower energy efficient (35-50% FL eff)**
- **Lower 1st cost**



DC brushless Motor

- **More reliable**
- **Higher efficiency (65-70% FL eff)**
- **Higher 1st cost (approx 2 x vs ac motor)**

Energy Efficiency comparison

Table 1. Simple payback for replacing three-speed permanent split-capacitor AC (PSC-AC) induction motors with brushless DC (BLDC) motors in fan–coils [a,b]

Nominal airflow, cfm	First cost (est), $ USD		Motor efficiency, %		Energy input, watts			Annual energy cost savings, $ USD	Simple payback, yr
	PSC-AC (std)	BLDC (opt)	PSC-AC	BLDC	PSC-AC	BLDC	Energy saved		
200			35	65	55.5	30.0	25.5	16.29	8.6
300			35	70	80.2	39.0	41.2	26.35	5.4
400	—	+70	35	70	96.4	49.1	47.3	30.29	4.6
600			50	70	115.2	79.1	36.1	23.12	6.0
800			50	70	124.3	93.2	31.2	19.95	7.0

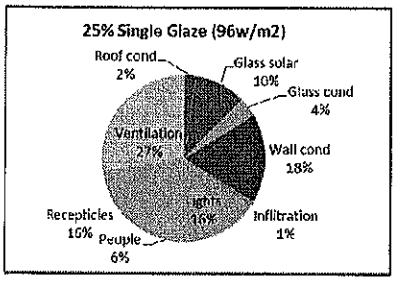
[a] This comparison isn't exactly "apples to apples": The PSC-AC motors varied in size, with the smallest fan–coil using a 1/20 hp motor; but in each case, the replacement was a 1/3 hp BLDC motor.

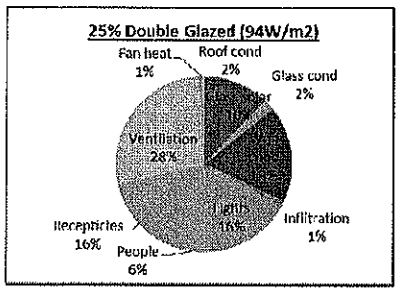
[b] Saving calculations are based on annual operation of 4,000 hours and an energy cost of $0.08/kWh.

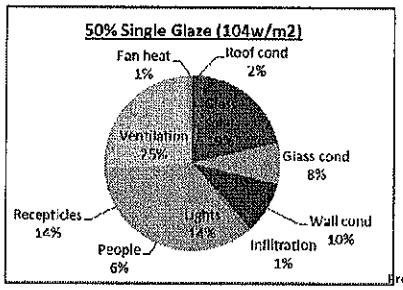
Extracted from Trane *Engineers Newsletter* volume 33–4 (Lit. no. ADM-APN013-EN)

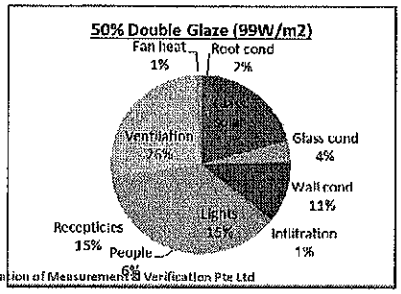
CO2 demand Ventilation

Cooling Load Component Breakdown









Ventilation load is a very large % of total building cooling load due to Singapore's hot & humid climate

Proprietary Information of Measurement & Verification Pte Ltd

Green Mark Rating

Non residential New Building, V4.0

Part I-G

(g) Sensors or similar automatic control devices are used to regulate outdoor air flow rate to maintain the concentration of carbon dioxide in accordance with Table 1 – Recommended IAQ Parameters of SS 554.

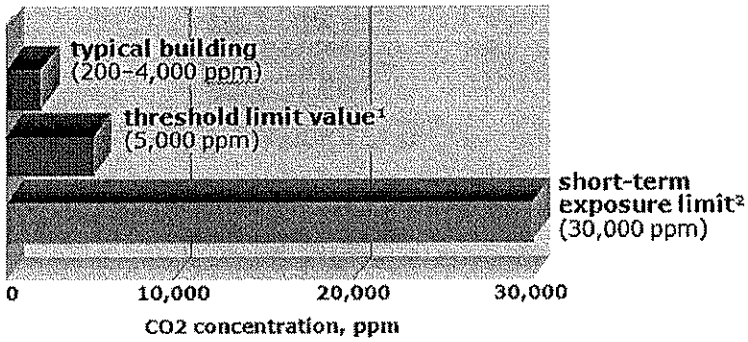
Carbon dioxide acceptable range: ≤ 700 ppm above outdoor.

BCA GREEN MARK

1 point

Is CO2 a Contaminant?

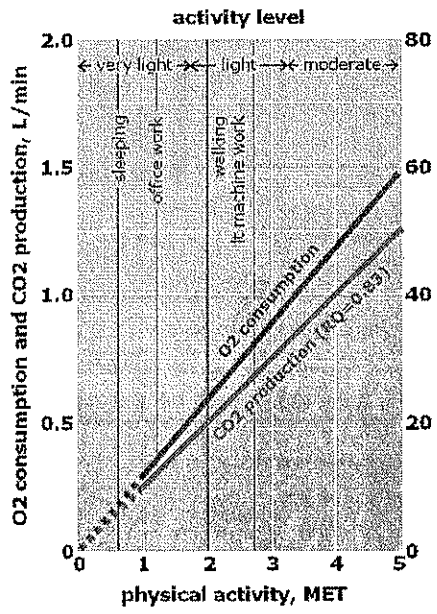
- Not at the concentrations commonly found in buildings



Notes:
[1]Time-weighted average overfive 8-hourworkdays
[2]Fifteen-minute exposure

Sources:
- Occupational Safety and Health Administration (OSHA)
- American Conference of Governmental Industrial Hygienists (ACGIH)

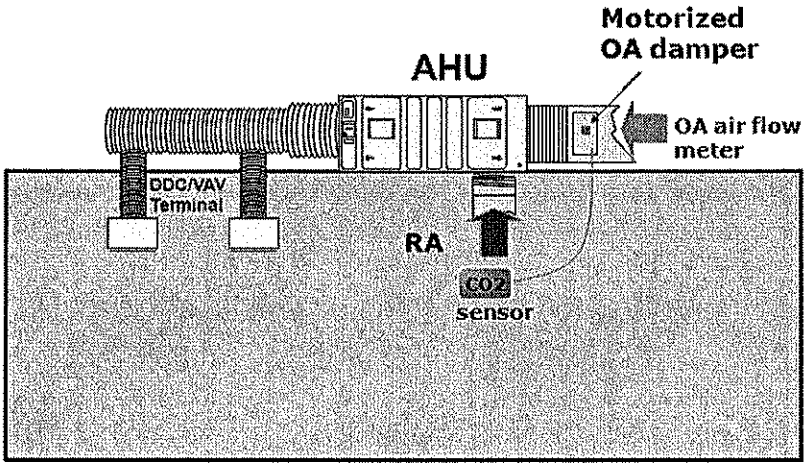
CO2 Consumption & Production



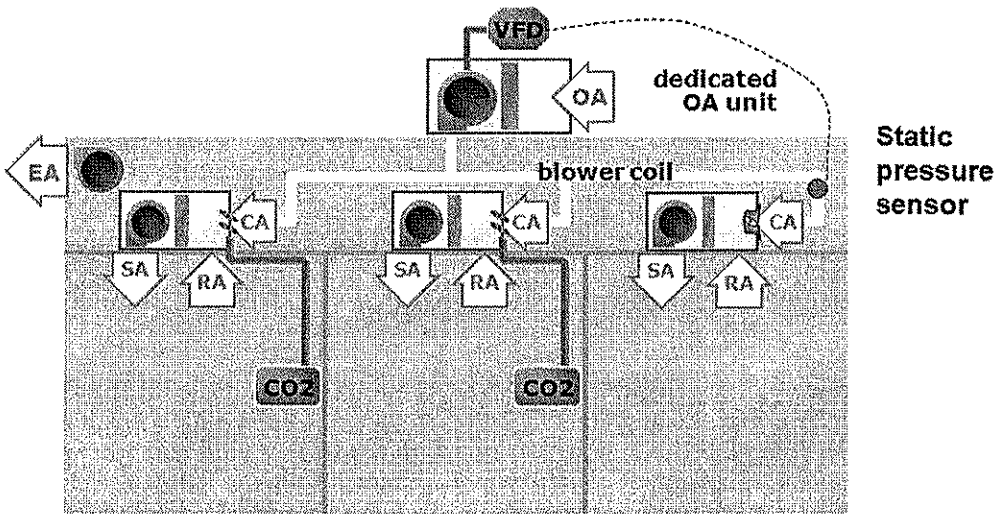
CO2 production is related to person's level of activity …

So CO2 can be used as a "tracer gas" for bioeffluents

Single Zone CO2 Controlled Ventilation



Multi zone CO2 Controlled Ventilation with PAHU



THANK YOU

Measurement & Verification Pte Ltd



Water Cgs.

$$kW = 4.19 \times L/s \times \Delta T$$

$$RT = 1.19 \times L/s \times \Delta T$$

$$kW_{pump} = \frac{l/s \times kPa}{1000 \times \eta_m \times \eta_p}$$

$$\text{Pump } kW/RT = \frac{\frac{l/s}{RT} \times kPa}{1000 \times \eta_m \times \eta_p}$$