AHU & FCU TECHNOLOGIES

Steven Kang
Steven.kang@mnv.com.sg

Agenda

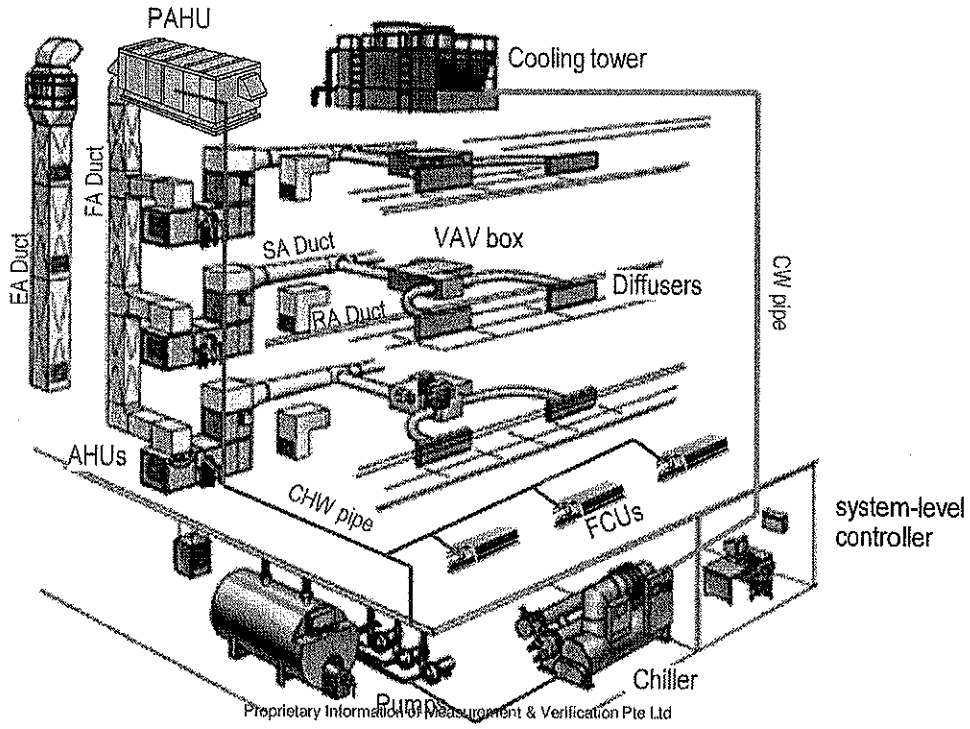
1. Overview of Air Side System
2. Air handling unit
3. Fan coil unit
4. Variable volume box

OVERVIEW OF AIR SIDE SYSTEM

Types of airside equipment

- **Air Handling Unit (AHU)**
  - Cool, dehumidify & filter recirculating air
  - Usually floor mounted in AHU room. However, increasingly are suspended from ceiling slab to save space.
  - Airflow: 2,000 to 90,000 CMH
  - External static pressure: Up to 1000pa
  - Supply air temperature: 12 to 15C
- **Pre-cooled Air Handling Unit (PAHU)** = MAU = DOA
  - Pre cool, dehumidify and filter outside air.
  - Unusually located at rooftop
- **Fan Coil Unit (FCU)**
  - Cool, dehumidify & filter recirculating air
  - Many types: Ducted, ceiling cassette, suspended, wall mounted
  - Airflow: 400 to 10,000 CMH
- **Variable Air Volume Box (VAV)**
  - Modulates the amount of cool air into the space to maintain comfort
- **Diffuser**
  - Distribute cool air evenly into space

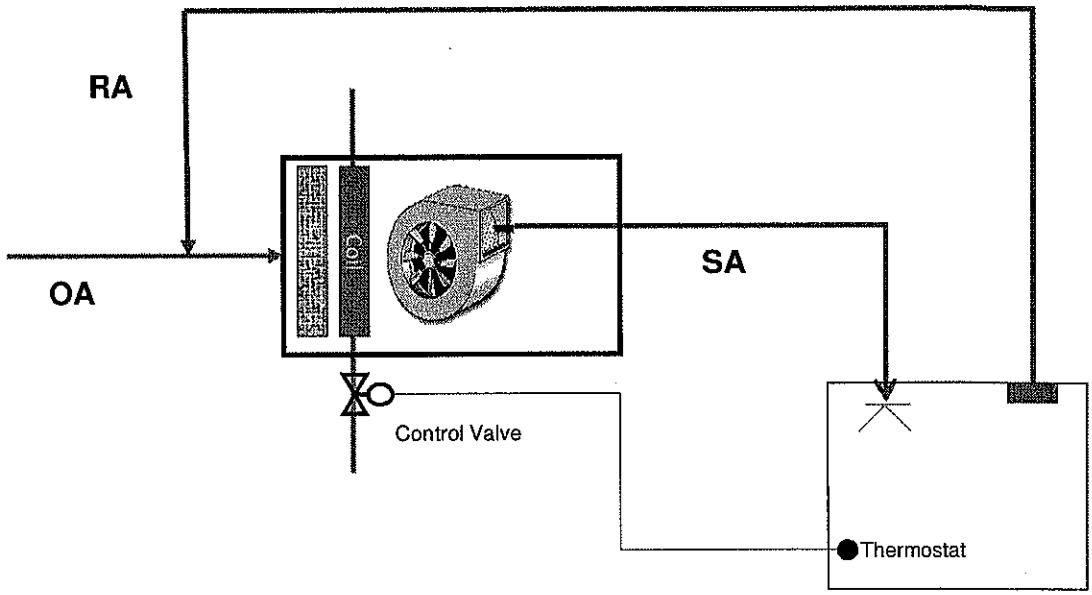
Chilled water system components



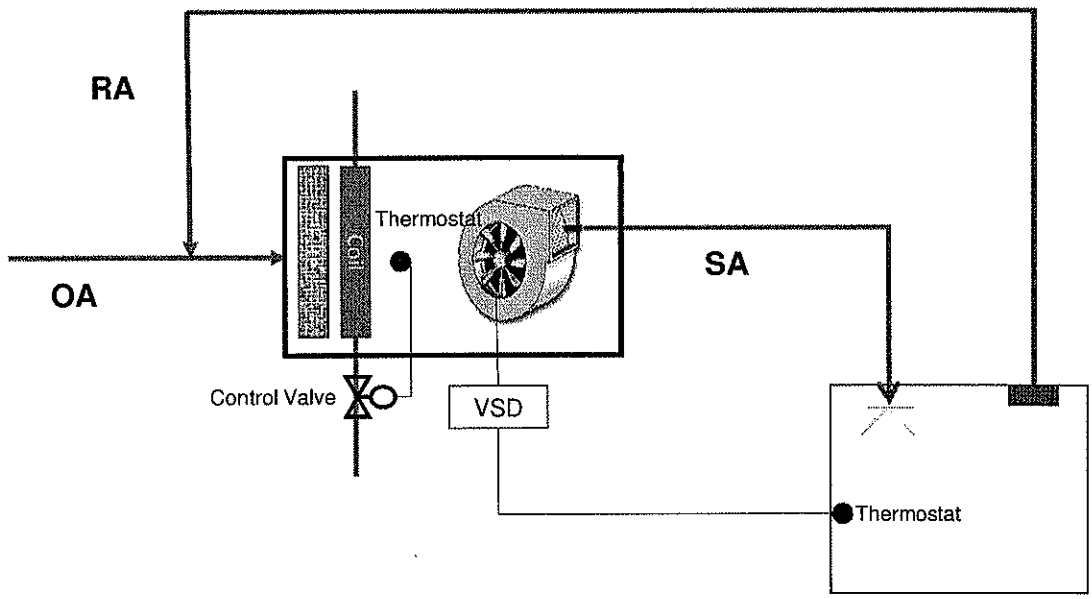
Types of airside systems

zones served by supply fan \ air volume delivered by supply fan		
	single zone constant volume	single zone variable volume
	multiple zone constant volume	multiple zone variable volume

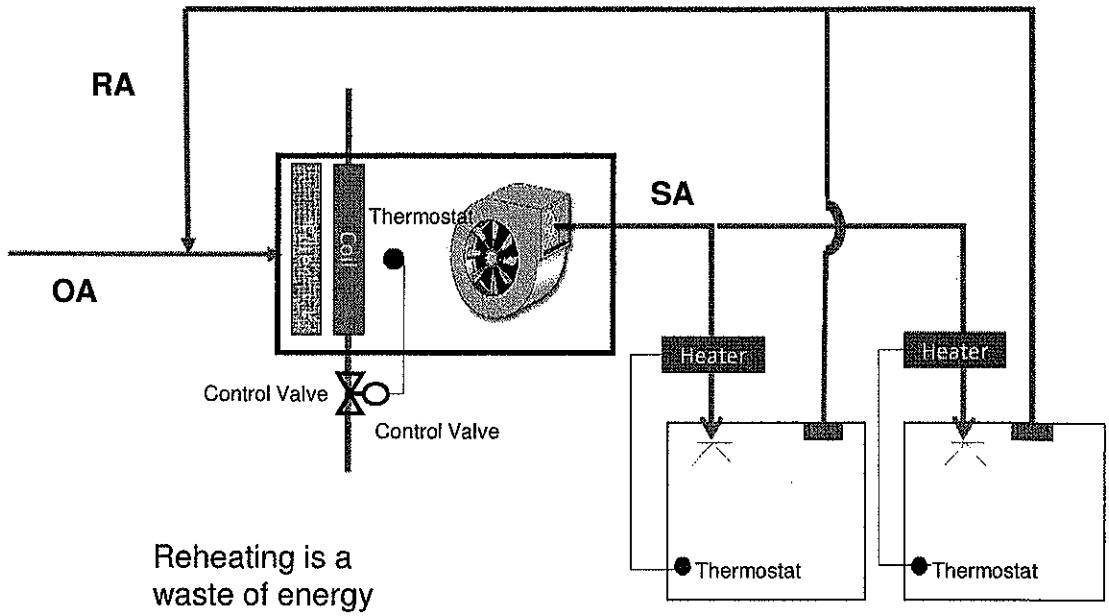
Single Zone, Constant Volume



Single Zone, Variable Volume

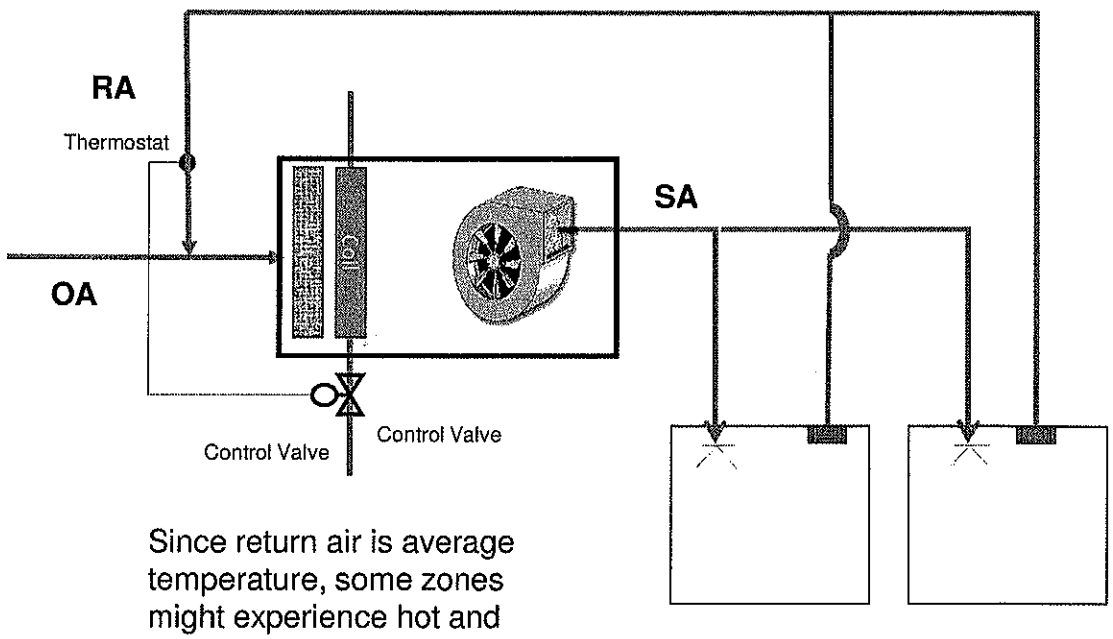


Multiple Zone, Constant Volume (With reheat)



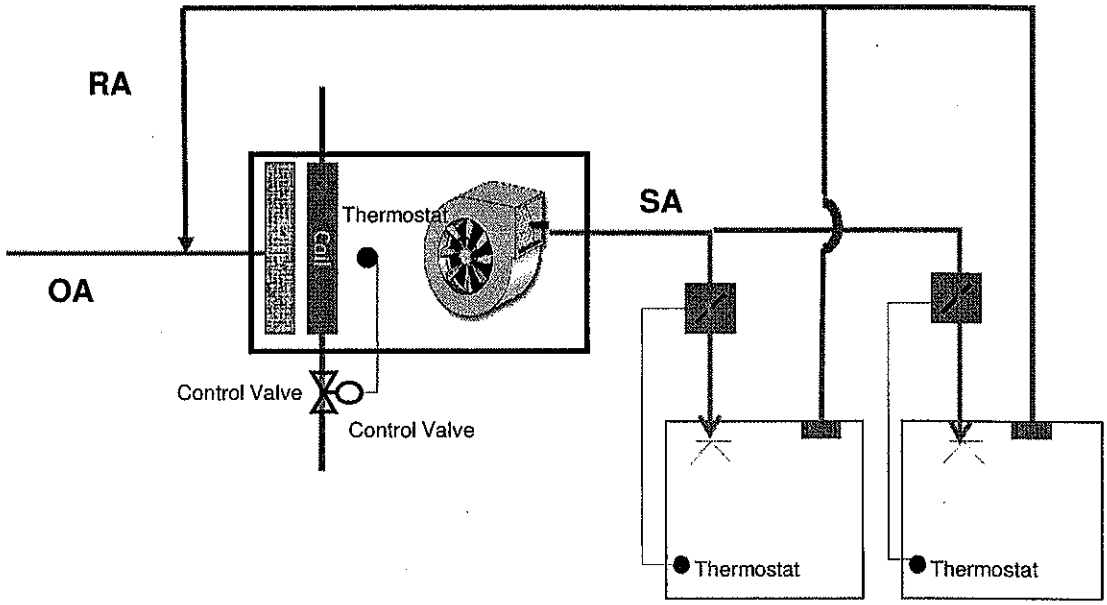
Reheating is a waste of energy

Multiple Zone, Constant Volume (Without reheat)



Since return air is average temperature, some zones might experience hot and cold spots.

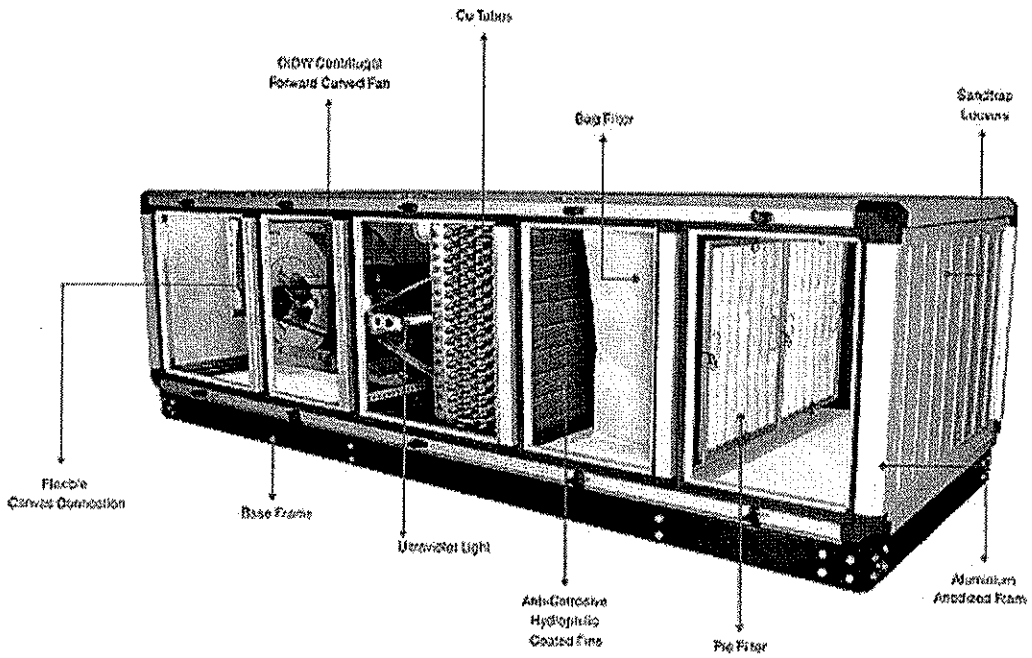
Multiple Zone, Variable Volume



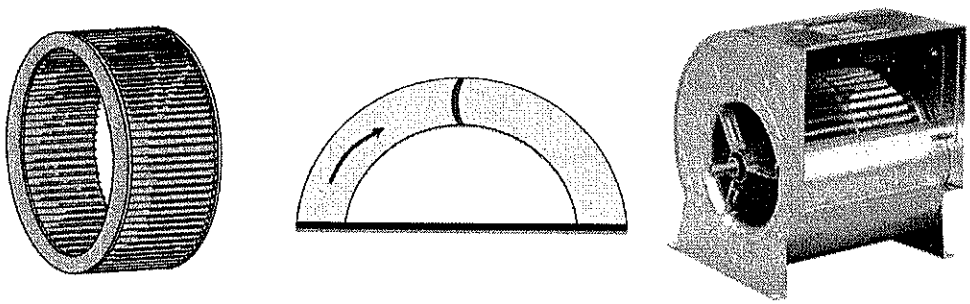
VAV - non energy benefits.
- diff temp set pt for diff zone
- better dehumidification due to SA control.

Air Handling Unit (AHU)

AHU



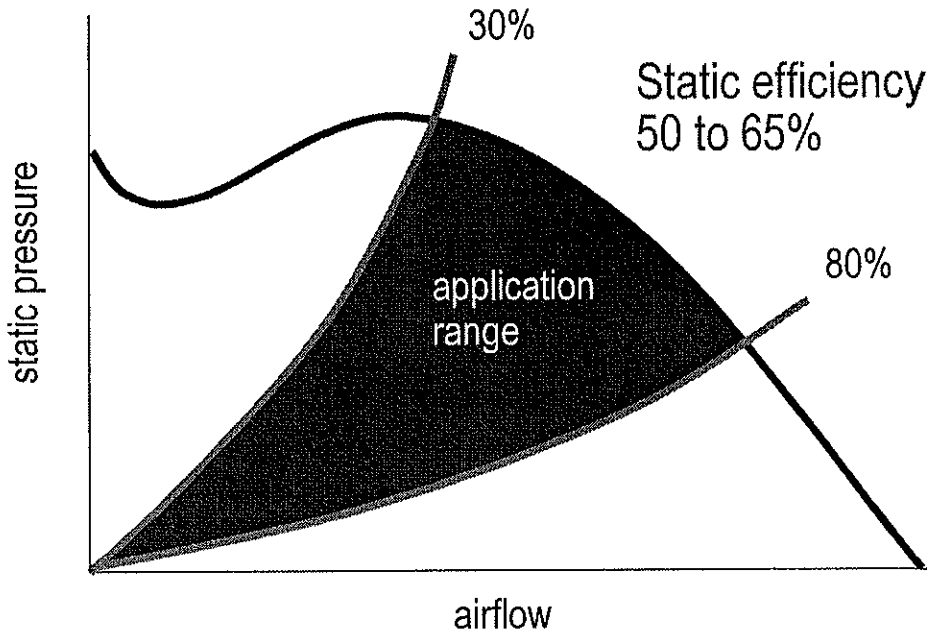
AHU centrifugal fan (FC fan)



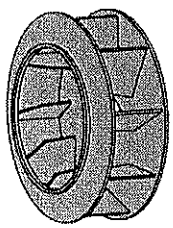
- Forward curved (FC) centrifugal fan has blades that are curved in the direction of wheel rotation.
- FC fans are operated at relatively low speeds and are used to deliver large volumes of air against relatively low static pressures.
- The inherently light construction of the forward curved fan wheel does not permit this wheel to be operated at the speeds needed to generate high static pressures.

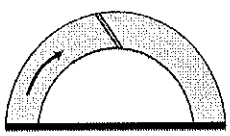
for FCUs.

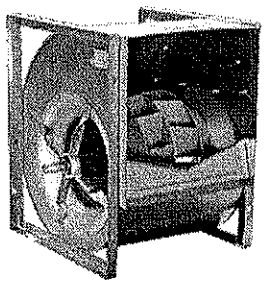
AHU centrifugal fan (FC fan)



AHU centrifugal fan (BC fan)

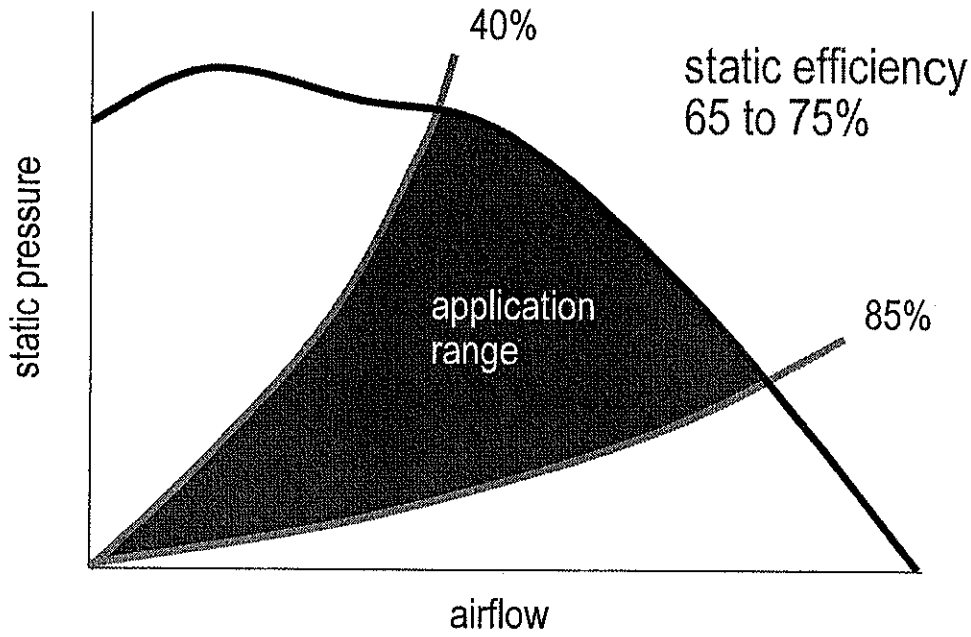




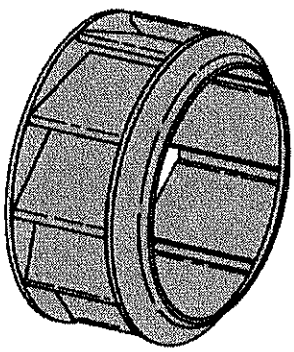


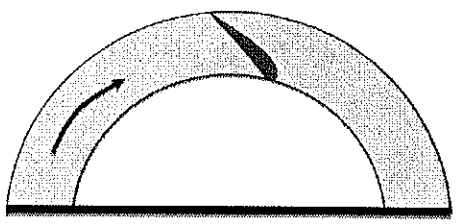
- Backward curved (BC) centrifugal fan design has blades that are slanted away from the direction of wheel rotation.
- BC fan operate at higher speeds than FC fans.
- Their rugged construction makes them suitable for moving large volumes of air in higher static-pressure applications.

AHU centrifugal fan (BC fan)



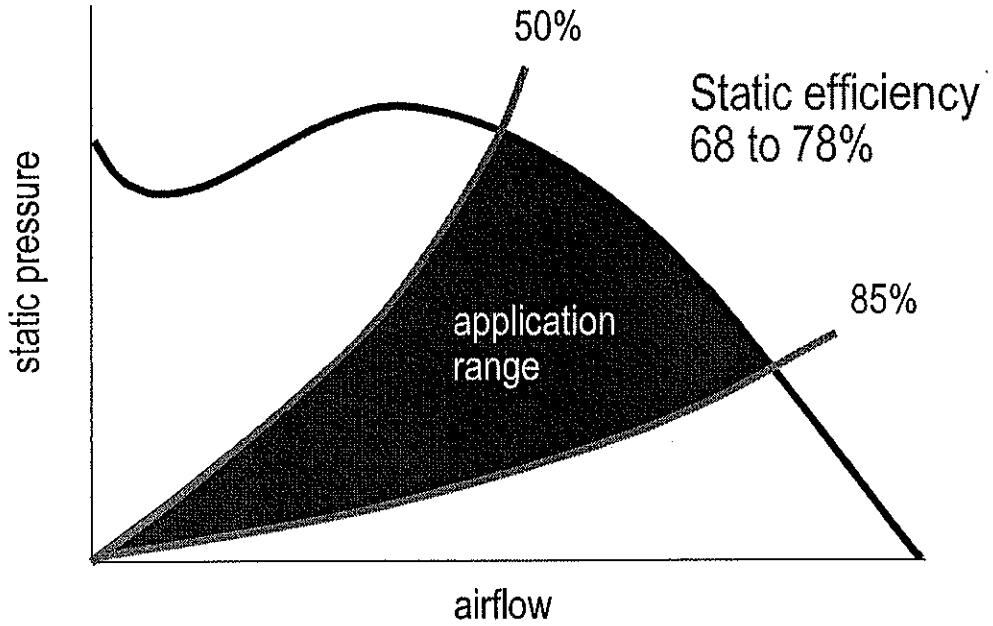
AHU centrifugal fan (Airfoil fan)



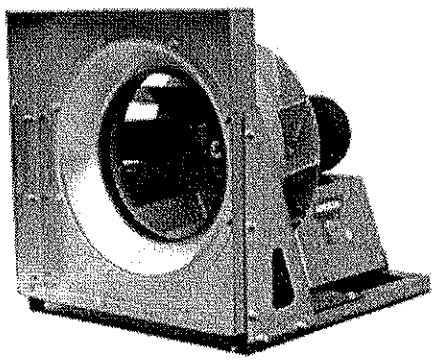


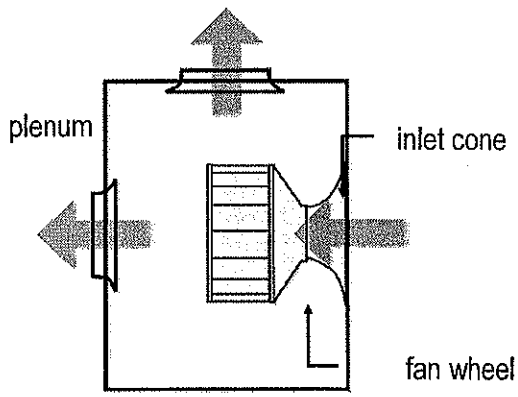
- A refinement of the BC fan changes the shape of the blade from a flat plate to that of an airfoil, similar to an airplane wing.
- The airfoil blade induces a smooth airflow across the blade surface, reducing turbulence and noise within the wheel. This results in increased static efficiency and reduced overall sound levels.

AHU centrifugal fan (Airfoil fan)



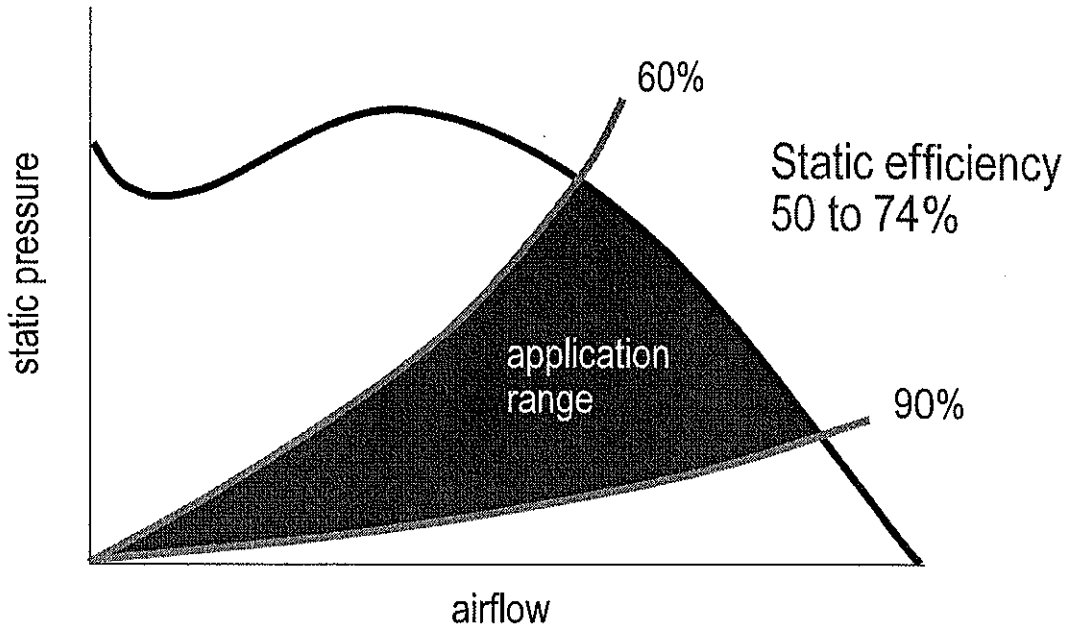
AHU Plenum fan





- Plenum fan consists of an unhoused fan wheel with airfoil fan blades and an inlet cone.
- The fan wheel pressurizes the plenum surrounding the fan, allowing the air to discharge in multiple directions. This fan can save space by eliminating turns in the ductwork and allowing multiple discharge ducts in different directions.
- Other advantages of plenum fan include being direct driven and being free of obstruction at suction and discharge.

AHU Plenum fan

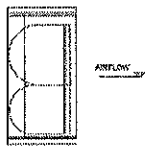
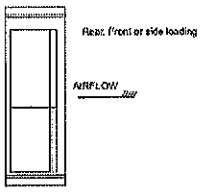


AHU filter rating

Ashrae 52.2 Filter rating: Minimum Efficiency Rating Value (MERV)

MERV VALUE	The filter will trap Average Particle Size Efficiency 0.3 - 1.0 Micron	The filter will trap Average Particle Size Efficiency 1.0 - 3.0 Micron	The filter will trap Average Particle Size Efficiency 3.0 - 10.0 Micron	Types of things these filters will trap
MERV 1	-	-	Less than 20%	Pollen, dust mites, standing dust, spray paint dust, carpet fibers
MERV 2	-	-	Less than 20%	
MERV 3	-	-	Less than 20%	
MERV 4	-	-	Less than 20%	
MERV 5	-	-	20% - 34%	Mold spores, hair spray, fabric protector, cement dust
MERV 6	-	-	35% - 49%	
MERV 7	-	-	50% - 69%	
MERV 8	-	-	70% - 85%	
MERV 9	-	Less than 50%	85% or better	Humidifier dust, lead dust, auto emissions, milled flour
MERV 10	-	50% - 64%	85% or better	
MERV 11	-	65% - 79%	85% or better	
MERV 12	-	80% - 89%	90% or better	
→ MERV 13	Less than 75%	90% or better	90% or better	Bacteria, most tobacco smoke, droplet Nuceli (sneeze)
→ MERV 14	75% - 84%	90% or better	90% or better	
MERV 15	85% - 94%	90% or better	90% or better	
MERV 16	95% or better	90% or better	90% or better	

AHU filter types

Filter Types		MERV rating & pressure drop
	Flat Filter, washable / low eff media 50mm depth	MERV 1 to 4 Mid-life DP: 75pa
	Bag or Rigid Box Filter, med eff media 500mm depth	MERV 9 to 12 Mid-life DP: 150pa
	Bag or Rigid Box Filter High eff media 500mm depth	MERV 13 to 16 Mid-life DP: 150pa

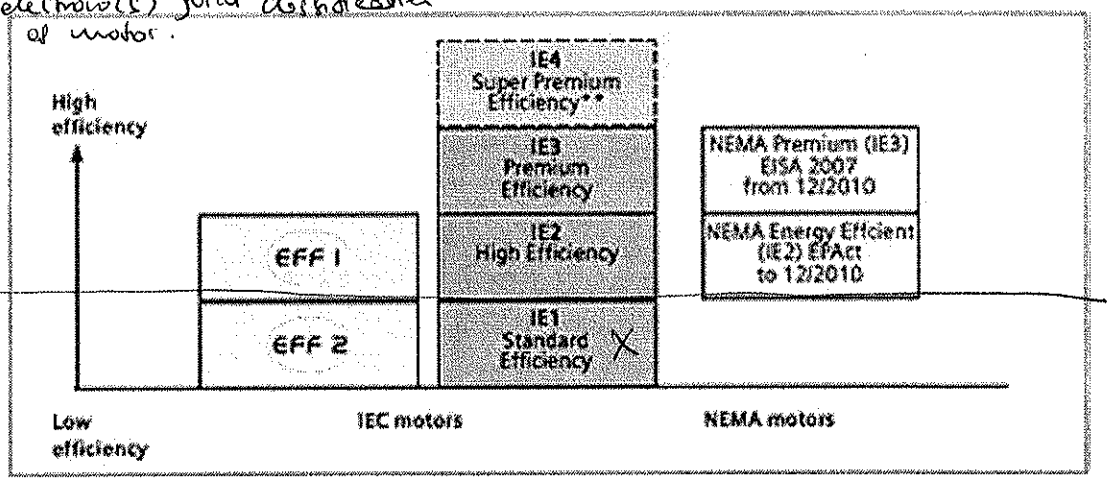
Motor Efficiency

EU and CEMEP (European Committee of manufacturers of Electrical Machine & Power electronics) joint classification of motor.

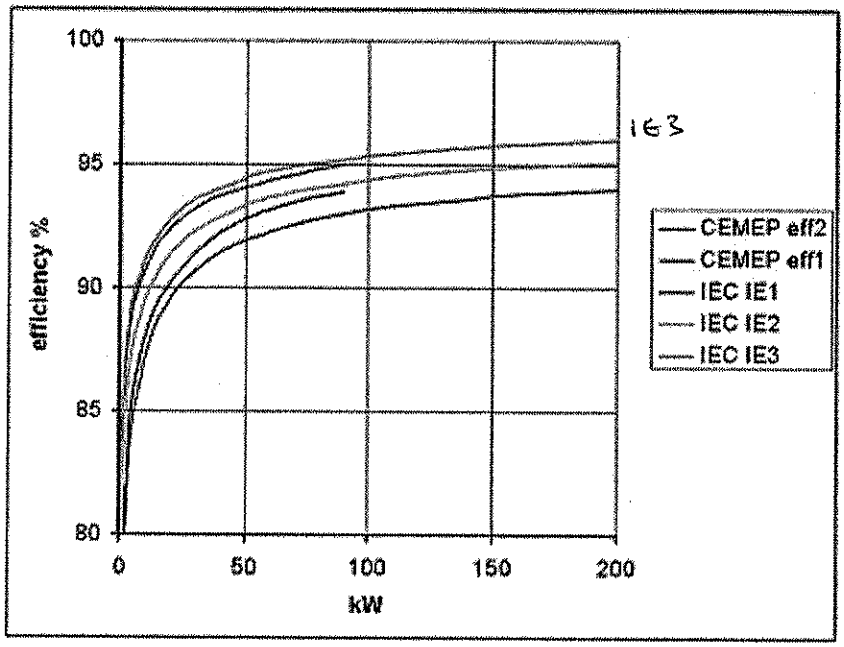
IEC 60034 specify EE classes for motors

US EPAct & NEMA classifications of motors.

current trends.

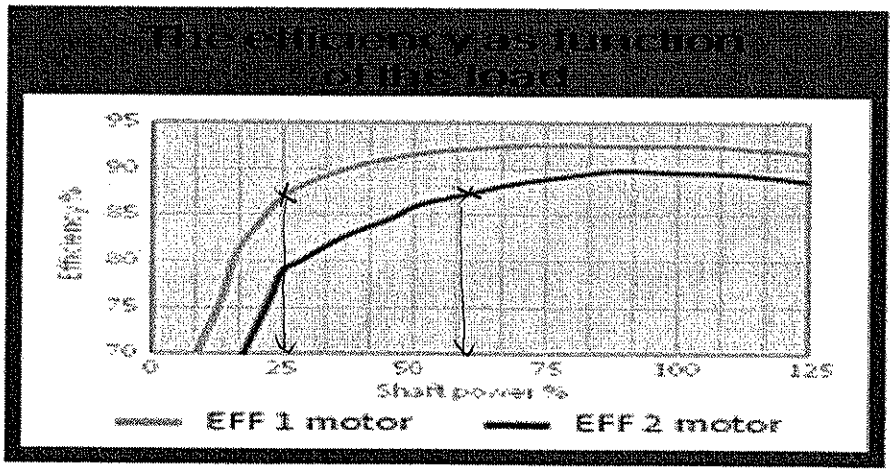


Motor Efficiency



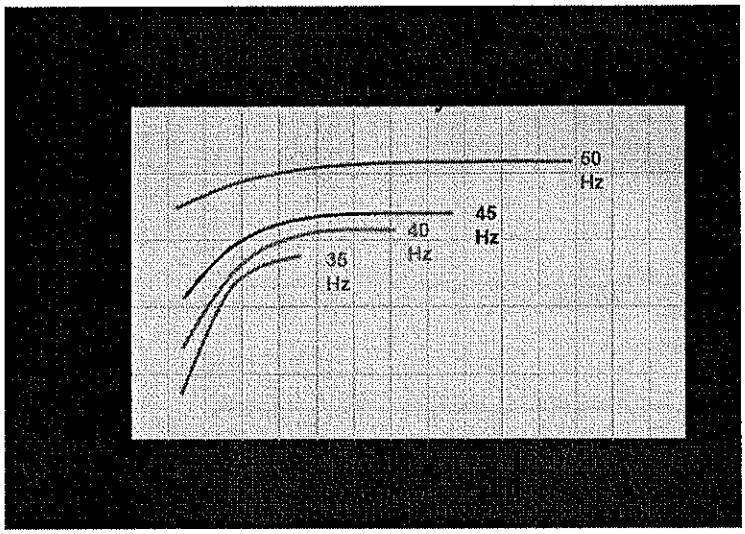
Motor efficiency

- The motor efficiency is dependent on the type of motor (EFF1 or EFF2) and the load of the motor (shaft power). A low load (below 25%) means a significant drop in efficiency.



Variable Speed Drive Efficiency

- The drive efficiency is dependent on the load of motor and the frequency output, but the efficiency down to 30% load is more or less constant.

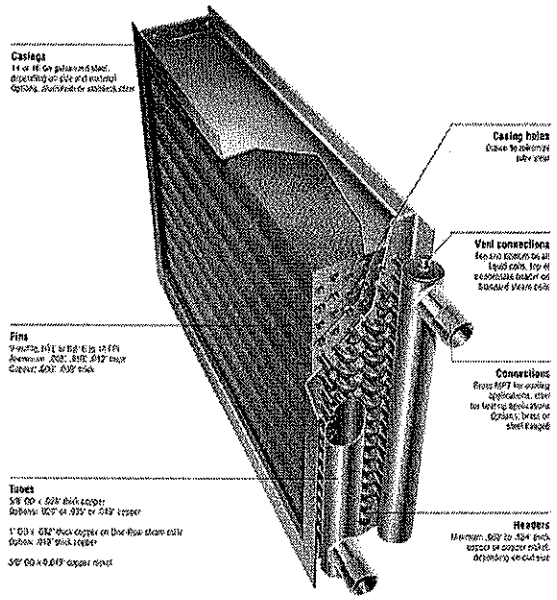


Fan Power

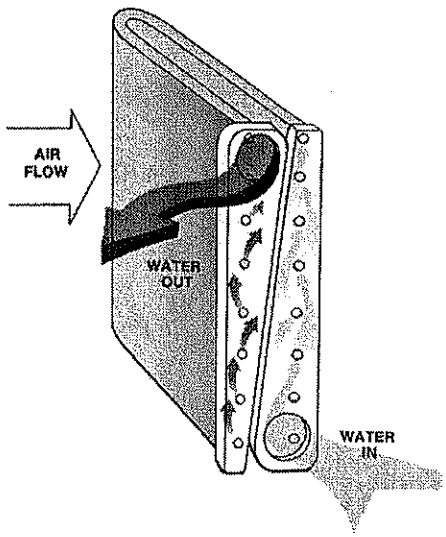
$$\text{Fan power} = \frac{\text{Flow rate x Total Pressure}}{3600 \times 1000 \times \eta\text{fan} \times \eta\text{motor}}$$

Where:
Fan power: KW
Flow rate: CMH
Total Pressure: Pa
ηfan: fan efficiency (%) ≈ 0.75
ηmotor: Motor efficiency (%) ≈ 0.90

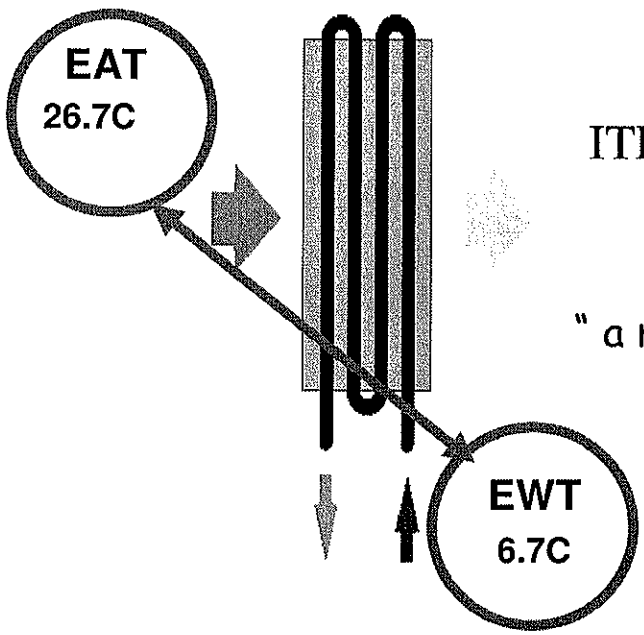
Cooling coils



Counter flow design



Coil initial temperature difference (ITD)

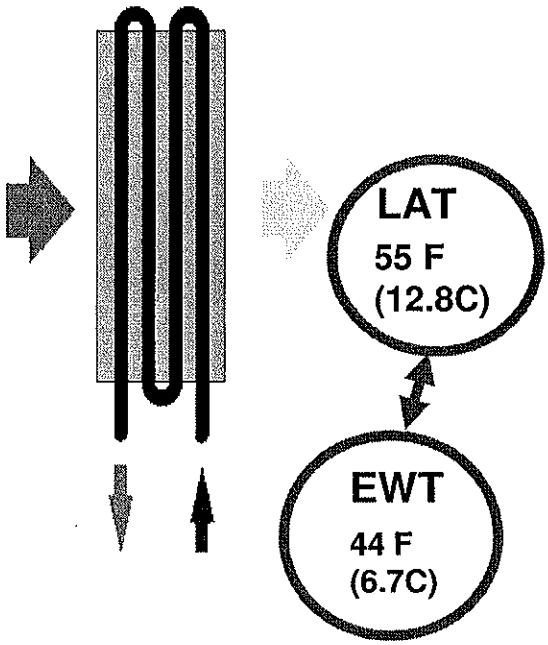


$$ITD = EAT - EWT$$

(hottest - coldest)

" a measure of coil capacity "

Coil Approach

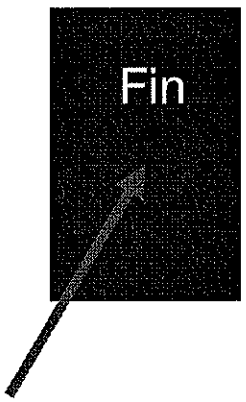


APR = LAT - EWT

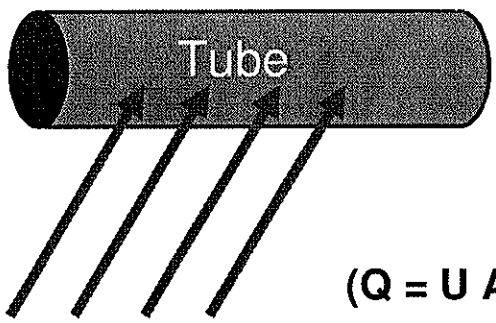
" a measure of coil efficiency "

(how close can you get?)

Coil heat transfer



$(Q = U\ A\ \Delta t)$



$(Q = U\ A\ \Delta t_{LM})$

log mean temp diff

Coil heat transfer

$$Q = UA \quad LMTD$$

Mostly hardware

Mostly application

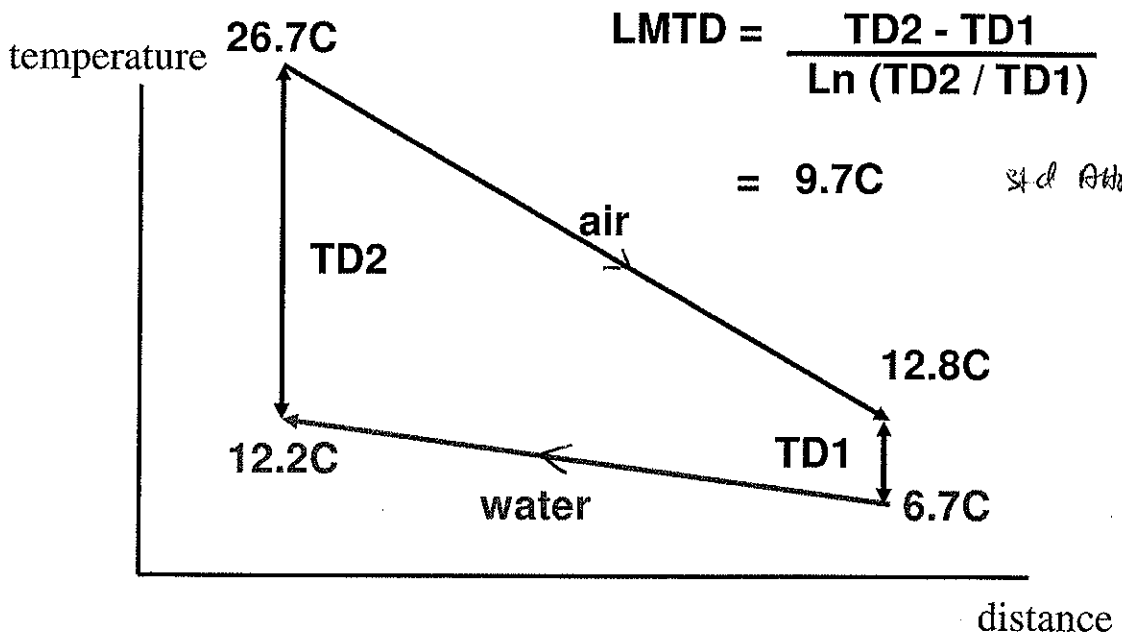
Q: Heat transfer, Btu/H (KW)

U: Heat transfer coeff , Btu/H.ft^2.F (W/m^2.K)

A: Surface area for heat transfer Ft^2 (m^2)

LMTD: Log-mean temperature diff, F (C)

LMTD for standard CHW temp

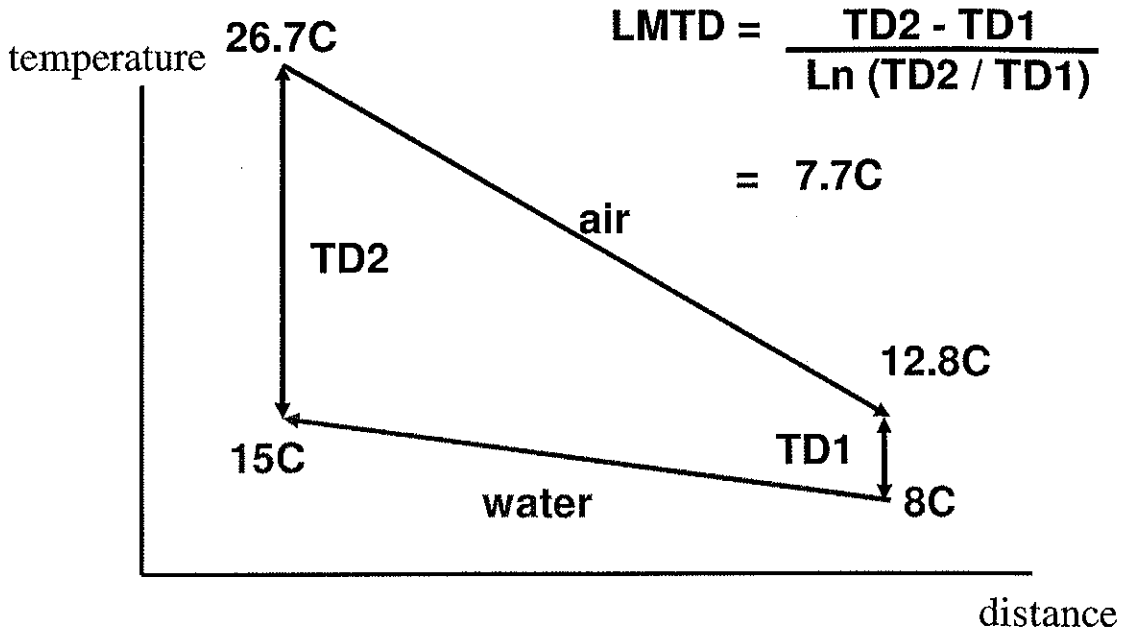


$$LMTD = \frac{TD2 - TD1}{Ln\ (TD2 / TD1)}$$

$$= 9.7C$$

Std Aircon condition

LMTD for high CHWS temp and high DT



LMTD for high CHWS temp and high DT

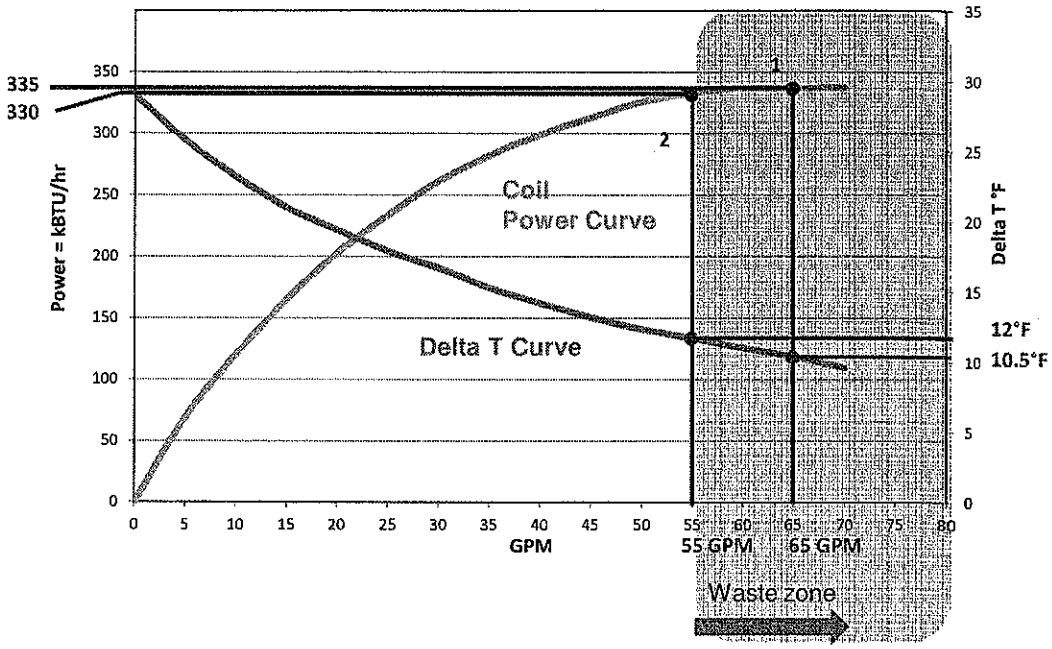
Q = UA LMTD



<u>To compensate for lower LMTD</u>
- Need for fins per feet (FPF)
- Need more rows

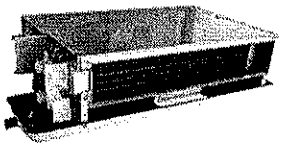
<u>Implications</u>
- Increase in cost
- Increase in air pressure drop
- Increase in water pressure drop

Cooling coil part load performance

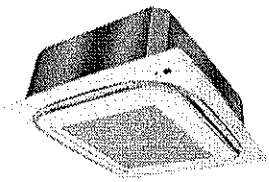


Fan Coil Unit (FCU)

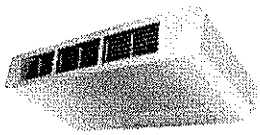
Fan Coil Unit (FCU)



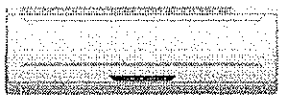
Ceiling concealed ducted Type



Cassette type

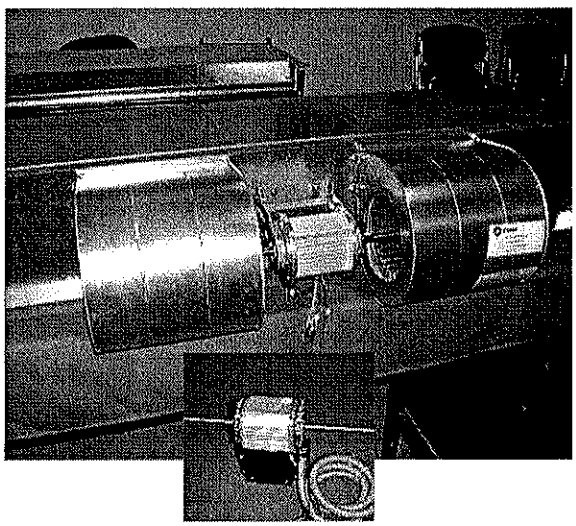


Ceiling suspended type



Wall type

VAV FCU with DC motor

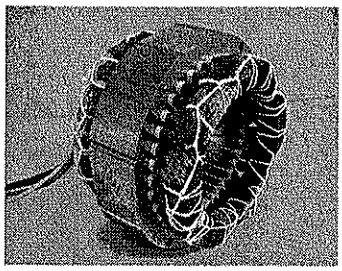


Integrated signal driver to the DC (brushless) fan motor

- *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**

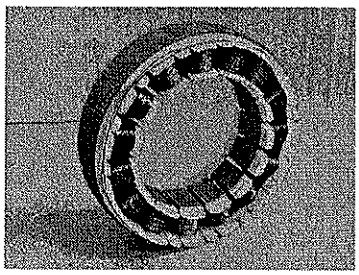
0.17 w/cmH

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 (aprrox 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.

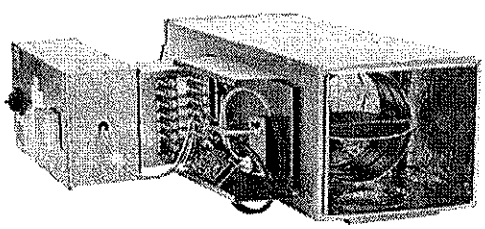
[b] Saving calculations are based on annual operation of 4,000 hours and an energy cost of $0.06/kWh.

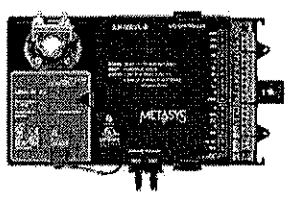
Extracted from Trane *Engineers Newsletter* volume 33–4 (Lit. no. ADM-APN013-EN)

Variable Air Volume Box (VAV Box)

VAV box

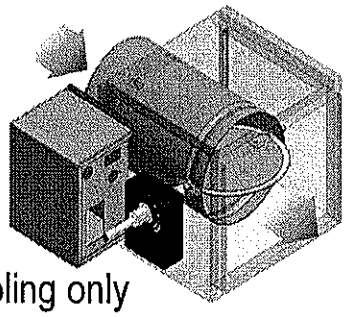
- VAV box provides a variable volume of air to match the cooling demand
- Designed to provide a constant supply air temperature to the space, whilst VAV box vary the amount of air (volume) to the space
- VAV boxes control the space temperature by modulating a damper
- The speed of the AHU fan/motor changes to match the system static pressure
  - Saves energy at reduced speeds



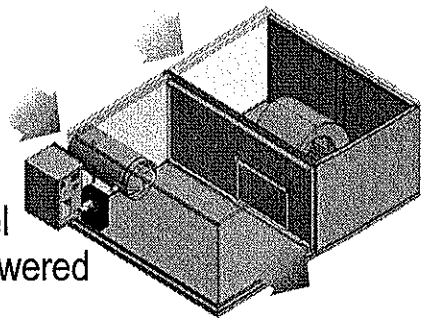


VAV controller

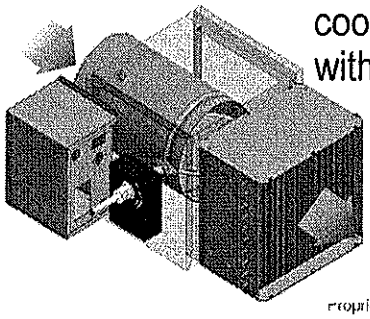
VAV box types



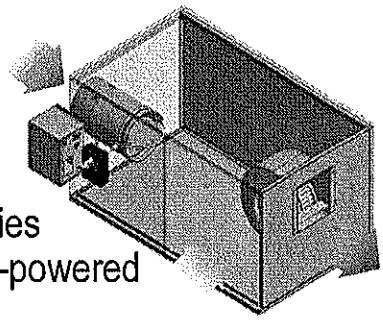
cooling only



parallel
fan-powered



cooling
with reheat



series
fan-powered

THANK YOU

