PAM CPD 2009 Seminar

GREEN BUILDING INDEX MALAYSIA

MS 1525 : 2007

ACMV System

Energy Management System

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8. Air-conditioning and mechanical ventilation (ACMV) system

- 8.1 Load calculations
- 8.2 System and equipment sizing
- 8.3 Separate air distribution systems
- 8.4 Controls
- 8.5 Piping insulation
- 8.6 Air handling duct system insulation
- 8.7 Duct construction
- 8.8 Balancing
- 8.9 ACMV systems
- 8.10 ACMV system equipment
- 8.11 ACMV system components
- 8.12 ACMV system equipment/component – heat operated (absorption), cooling mode
- 8.13 System testing and commissioning
- 8.14 Operation and maintenance (O&M) manual and as-built drawings
- 8.15 Preventive maintenance

"Air Conditioning is the control of the humidity of air by either increasing or decreasing its moisture content. Added to the control of the humidity is the control of temperature by either heating or cooling the air, the purification of the air by washing or filtering the air and the control of the air motion and ventilation."

- Willis H. Carrier

Without the need for thermal comfort, there will be no need for buildings

8.1 Load calculations

8.1.1 Calculation procedures

Cooling design loads should be determined in accordance with the procedures described in ASHRAE Handbooks, or other equivalent publications.

8.1.2 Indoor design conditions

Comfort condition depends on various factors including air temperature, mean radiant temperature, humidity, clothing, metabolic rate and air movement preference of the occupant.

The 3 main factors considered are:

- **DRY BULB TEMPERATURE;**
- **RELATIVE HUMIDITY; AND**
- **AIR MOVEMENT (AIR VELOCITY)**

8.1.3 Outdoor design conditions

a) dry bulb temperature **33.3 °C**

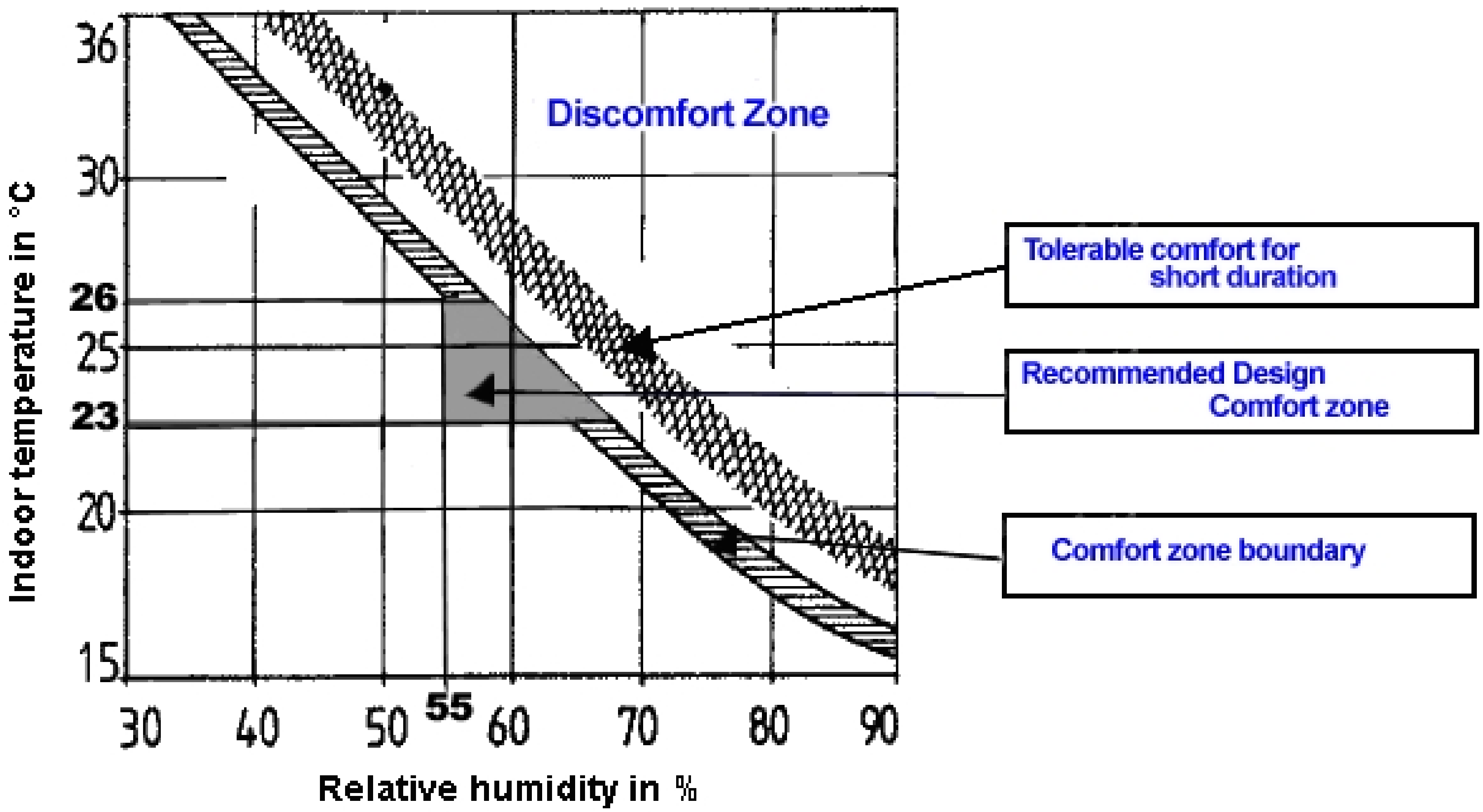
b) wet bulb temperature **27.2 °C**.

- You feel comfortable when metabolic heat is dissipated at the same rate it is produced.
- The human body needs to be maintained at a 37 ± 0.5 °C regardless of prevailing ambient condition.
- The higher the space RH, the lower the amount of heat the human body will be able to transfer by means of perspiration/evaporation.
- If indoor air temperature is high and RH is high (above 11.5 g vapour per kg dry air), the human body will feel uncomfortable.
- Generally, RH for indoor comfort condition **SHOULD NOT EXCEED 70 %.**

- Air movement is essential for comfort as it enhances heat transfer between air and the human body and accelerates cooling of the human body
- Air movement gives a feeling of freshness by lowering skin temperature, and the more varied the air currents in velocity and direction, the better the effect.
- A draught is created when temperature of moving air is too low and/or the velocity is too high.
- At comfort room temperature (23 to 26 °C), acceptable air velocity range is **0.15 to 0.50 m/s**.

Indoor conditions of ac space for comfort cooling:

Design dry bulb temperature	**23 º C – 26 °C**
Min dry bulb temperature	**22 ° C**
Design relative humidity	**55 % – 70 %**
Air movement	**0.15m/s–0.50m/s**
Max air movement	**0.7 m/s**



Discomfort Zone
Tolerable comfort for short duration
Recommended Design Comfort zone
Comfort zone boundary
Indoor temperature in °C
36
30
26
25
23
20
15
30
40
50
55
60
70
80
90
Relative humidity in %

8.1.4 Ventilation

Outdoor air-ventilation rates should comply with the 3rd Schedule (By Law 41) Article 12(1) of Uniform Building By Laws, 1984.

Exception:

Special occupancy or process requirements or source control of air contamination **or Indoor Air Quality consideration.**

MS1525 Design Application

Example:

Project consists of 3 distinct elements;

1. *Podium – Retail*
2. *Block A – Residential Apartments*
3. *Block B – Office Tower*

Step 1 – Estimate Cooling Loads for each in terms of;

- *Connected Load*
- *Diversified Load – Diversity Factors*
- *Peak Load*
- *Daily Load Profile – max and minimum*

Connected load Vs Peak load

	Area Ft2	Connected RT	Peak RT	
Podium	92,632	618	556	90%
Block A	324,000	1,350	675	50%
Block B	347,360	1,447	1,230	85%
TOTAL	763,992	**3,415**	**2,461**	**72%**

Need to watch out for Minimum loads

	Connected RT	Peak RT	Min RT	
Podium	618	556	250	45%
Block A	1,350	675	250	37%
Block B	1,447	1,230	250	20%
TOTAL	**3,415**	**2,461**	**750**	**30%**

8.2 System and Equipment Sizing

8.2.2 Where chillers are used and when the design load is greater than 1,000 kWr (280RT) , **a minimum of either two chillers or a single multi-compressor chiller** should be provided to meet the required load.

Other than chillers ....

8.2.4 Individual air cooled or water cooled direct expansion (DX) units > 35 kWr (reciprocating compressor) or 65 kWr (scroll compressor) should consist of either **multi compressors or single compressor with step/variable unloaders**

Ensure energy efficiency is optimised during partial load operation of ac plant

Combined Operating Peak Load is always smaller

	Area Ft2	Connected RT	Peak RT	Min RT
Podium	92,632	618	556	250
Block A	324,000	1,350	675	250
Block B	347,360	1,447	1,230	250
TOTAL	763,992	3,415	**2,461**	750
Combined Operating Peak Total			**2,300** **93%**	600 80%

Standalone Plants are always accumulatively larger

	Peak RT	Min RT	Standalone Plant	Total Plant RT
Podium	556	250	3 x 280RT	840
Block A	675	250	3 x 340RT	1020
Block B	1,230	250	2 x 620RT, 2 x 310RT	1860
TOTAL	2,461	750		3720 150%

Advantages of a Common Plant

	Peak RT	Min RT	Standalone Plant	Total Plant RT	Common Plant
Podium	556	250	3 x 280RT	840	
Block A	675	250	3 x 340RT	1020	
Block B	1,230	250	2 x 620RT, 2 x 310RT	1860	
TOTAL	2,461	750		**3720**	
Operating Peak Total	2,300	600	**10 chillers**	**3000** **80%**	5 x 600RT

8.9 ACMV systems

3 basic types discussed:

a) Central air-distribution systems

b) Central circulating water systems

c) Multiple units systems

Types of Airconditioning Systems:

Apartment Block

a) Refrigeration side

1) Part of centralised/district cooling chw system

2) DX Split units

3) VRV system

4) Air-cooled mini chw system

5) Other cutting edge systems viz LNG fired mini absorption chiller with fuel cell

b) Airside

- *FCUs: Free-throw and/or ducted*

Retail Block

a) Refrigeration Side

1) Standalone chw system

2) Part of centralised/district cooling chw system

3) DX Water-cooled Packaged Units

4) DX Air-cooled Packaged Units

b) Airside

1) AHUs only

2) AHUs and/or FCUs

Retail Block *cont'd*

c) Other Strategies

1) VAV and/or CAV distribution

2) VAV diffusers

3) Low Level Displacement

4) Heat Recovery Wheels, Heat Pipes

Office Tower

a) Refrigeration Side

1) Standalone chw system

2) Part of centralised/district cooling chw system

3) DX Water-cooled Packaged Units

4) VRV System + other combinations

5) DX Air-cooled Packaged Units

6) DX WCPUs and mini WCPUs

b) Airside Side

- *AHUs only*
- *AHUs and FCUs*

Office Tower *cont'd*

c) Other Strategies

1) VAV terminals

2) VAV diffusers

3) UFAD

4) Chilled Slabs/Beams

5) Chilled Ceilings

6) Heat Recovery Wheels, Heat pipes

8.3 Separate air distribution system

8.3.1 Zones which are expected to **operate non-simultaneously** for more than **750 hours per year** should be served by **separate air distribution** systems.

Podium Retail

- *Normally operate simultaneously*
- *Due to acoustic and duct size limits, normally multiple AHUs are used*
- *What about outlets not tenanted?*
- *Separate AHUs for cinemas, bowling alleys and the like due to different operating hours*
- *AHU/FCUs for back of the house facilities*

Block A - Apartments

- *Fan coil units per room – independent zoning*

Block B – Office Tower

- *Normally operate simultaneously on floor basis*
- *3 AHUs per floor offers excellent flexibility*
- *What about server rooms operating 24/7?*

8.3.3 Separate air distribution systems should be considered for areas of the building having substantially different cooling characteristics, such as perimeter zones **(3 m room depth**) in contrast to interior zones.

- ***Podium Application?***
- ***Office Block Application:***

Separate CAV AHU

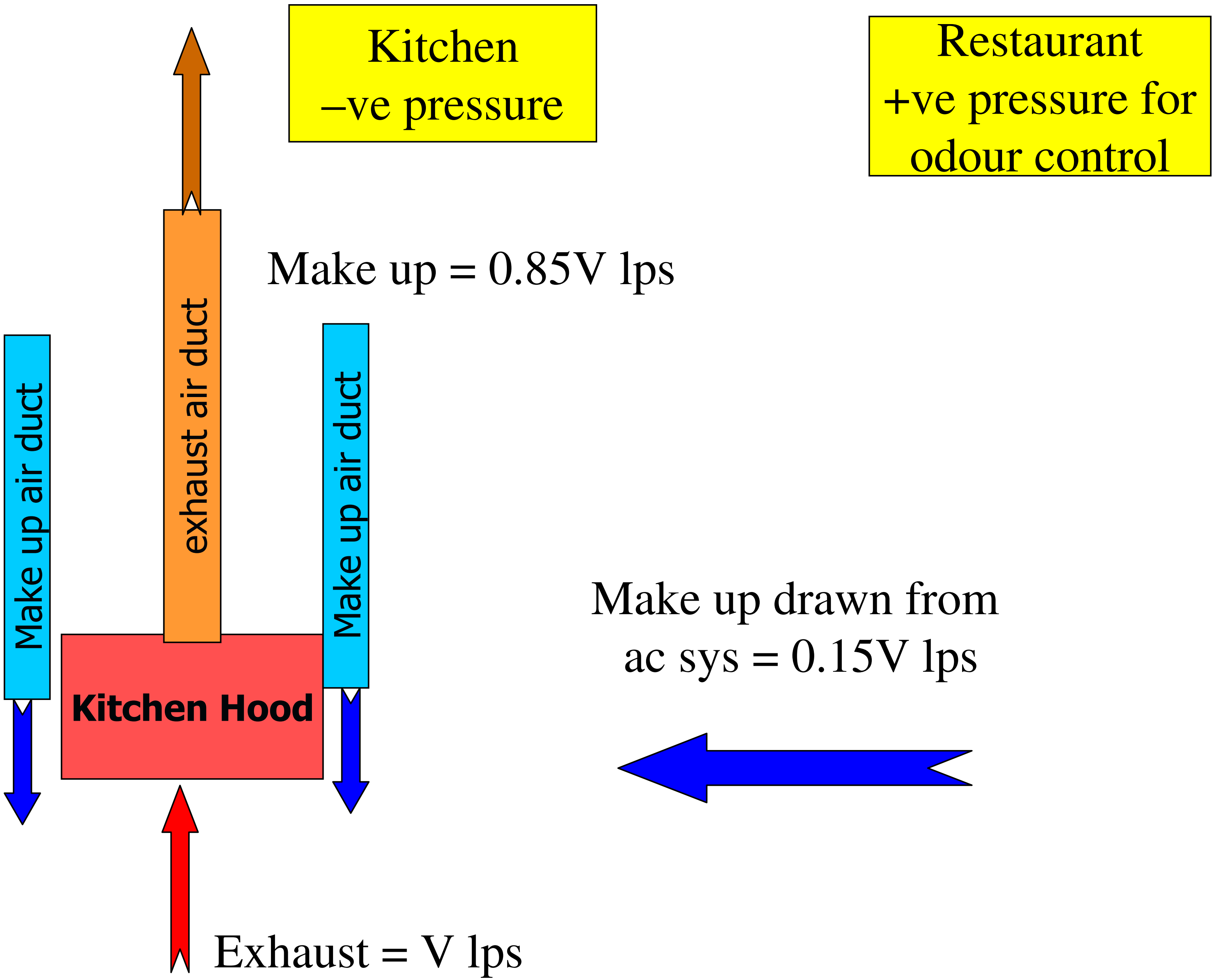
Separate VAV units

VAV diffusers

8.3.4 For air conditioned space requiring exhaust air volume in excess of 3,400 m3/h (2000cfm), not less than 85 % of non conditioned make up air should be introduced directly into the space concerned unless the exhausted conditioned air is utilised for secondary cooling purposes.

Alternatively, heat recovery devices should be provided.

Especially applicable for Kitchen hoods in Retail and Office Tower.


Kitchen
–ve pressure
Restaurant
+ve pressure for
odour control
Make up = 0.85V lps
Make up air duct
exhaust air duct
Make up air duct
Kitchen Hood
Make up drawn from
ac sys = 0.15V lps
Exhaust = V lps

8.4 Controls

8.4.1.1 Zoning for temperature control

At least one thermostat for regulation of space temperature should be provided for:

a) each separate system; and

b) each separate zone

As a minimum each floor of a building should be considered as a separate zone.

On a multi-storey building where the perimeter system offsets only the transmission gains of the exterior wall, an entire side of uniform exposure may be zoned separately.

8.4.3 Energy Recovery

It is recommended that consideration be given to the use of recovery systems which will conserve energy (provided the amount expended is less than the amount recovered) when the energy transfer potential and the operating hours are considered.

Recovered energy in excess of the new source of energy expended in the recovery process may be used for control of temperature and humidity.

Examples include the use of condenser water for reheat, desuperheater heat reclaim, heat recovery wheel, heat pipe **or any other energy recovery technology.**

At most, likely to be applicable to areas with high occupancy density such as auditorium and large function rooms in Office Tower, and cinemas in Podium.

8.4.4 Off-hour control

8.4.4.1 ACMV system shall be equipped with automatic controls capable of accomplishing a reduction of energy use for example through equipment shutdown during periods of non-use or alternative use of the spaces served by the system.

Exceptions:

a) systems serving areas which are expected to operate continuously; and

b) equipment with a connected load of 2 kWe or less may be controlled by readily accessible manual off-hour controls.

8.4.4.2 Outdoor air supply and exhaust systems should be provided with motorised or gravity dampers or other means of automatic volume shut-off or reduction during period of non-use or alternate use of the spaces served by the system.

Exceptions:

a) systems serving areas which are expected to operate continuously;

b) systems which have a design air flowrate of 1,800 m3/h (1,000cfm) or less;

c) gravity and other non-electrical ventilation systems may be controlled by readily accessible manual damper controls; and

d) where restricted by process requirements such as combustion air intakes.

Likely to be applicable to systems installed for auditorium and large function areas which are not frequently used.

The exceptions on exhaust quantity will apply to small domestic type kitchens and pantries.

8.4.4.4 For buildings where occupancy patterns are not known at time of system design, such as speculative buildings, isolation areas may should be pre-designed.

- *Very applicable for retail podium where demarcated retail lots are best determined*
- *Also applicable for office floor and in this instance, 3 zones per floor are already projected.*

8.4.4.5 Zones may be grouped into a single isolation area provided the total conditioned floor area does not exceed 250 m2 per group nor include more than one floor unless variable air volume or equivalent devices are incorporated. Use of outside economy air cycle design where feasible should be considered.

8.4.5 Mechanical ventilation control

Each mechanical ventilation system (supply and/or exhaust) should be equipped with a readily accessible switch or other means for shut-off or volume reduction when ventilation is not required. Examples of such devices would include timer switch control, thermostat control, duty cycle programming and CO/CO_2 sensor control.

- *Applicable to the basement car park level.*

Floor to Floor Heights

- *Apartment Block*

  9F – 27F = 3050 : OK
- *Retail Podium*

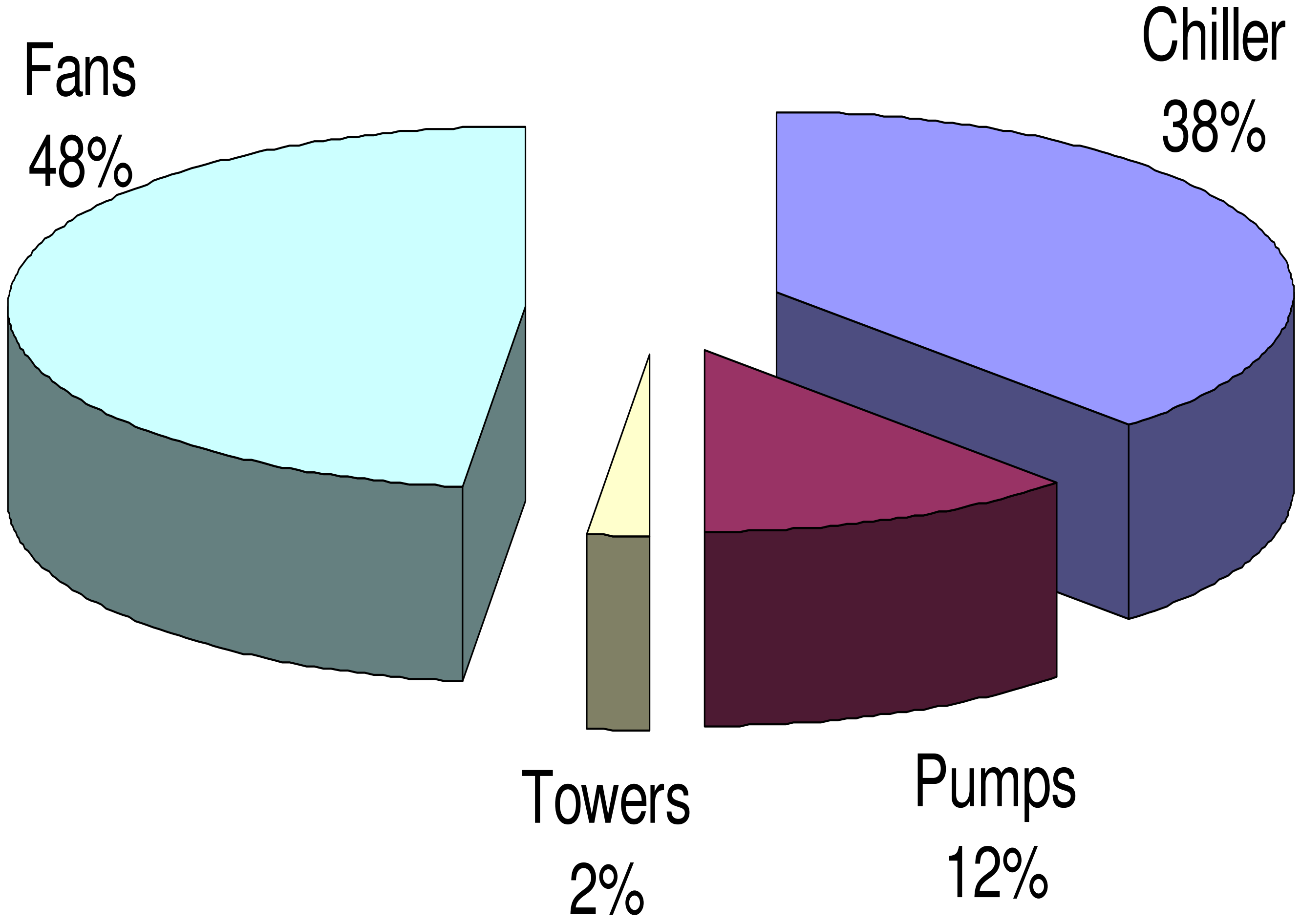
  GF = 6600, 1F – 2F = 4500 : OK
- *Carpark Floors*

  B3 – B1 & 3F – 7F = 3050 : OK
- *Office Tower*

  9F – 35F = 3050 : limitation to ducted system?

8.4.6 Fan System Efficiency

For fan system with air flowrate >17000 m3/h and operating for more than 750 hours a year, the power required by the motor for the entire fan system at design conditions should not exceed **0.45 W per m3/h** of air flowrate.


Fans
48%
Chiller
38%
Towers
2%
Pumps
12%

Fan Laws

1. **Volume flow is directly proportional to fan speed**

   $$Q_1 / Q_2 = (N_1 / N_2)$$

2. **Pressure is directly proportional to square of fan speed**

   $$SP_1 / SP_2 = (N_1 / N_2)^2$$

3. **Fan power is directly proportional to cube of fan speed**

   $$P_1 / P_2 = (N_1 / N_2)^3$$

where

where	Q	= Air Volume Flowrate
	N	= Rotational Speed
	SP	= Static Pressure
	P	= Power

1. $Q_1 / Q_2 = (N_1 / N_2)$

   ie $Q = k N$

2. $SP_1 / SP_2 = (N_1 / N_2)^2$

   ie $SP = k' N^2 = k' Q^2$

   which means if fan speed is doubled, its static pressure is increased $2^2 = 4$ folds and similarly for the same duct, **if airflow is doubled, its friction loss is increased 4 folds**

3. $P_1 / P_2 = (N_1 / N_2)^3$

   ie $P = k'' N^3$

   which **means if fan speed is doubled, power is increased $2^3 = 8$ folds !!**

8.5 Piping Insulation

All piping should be adequately insulated to prevent excessive energy losses. Additional insulation with vapour barriers may be required to prevent condensation under some conditions.

Exceptions:

a) Piping installed within ACMV equipment.

b) Piping at fluid temperatures 23 to 49 °C

c) When the heat loss and/or heat gain of the piping, without insulation, does not increase the energy requirements of the building.

8.6 Air handling duct system insulation

All ducts, plenums and enclosures should be insulated to prevent excessive energy losses.

Exceptions:

a) Where the design temperature differential between the air in the duct and the surrounding air is ≤ 8 °C and the duct is within ac space

b) When the heat gain or loss of the ducts, without insulation, will not increase the energy requirements of the building.

c) Within ACMV equipment.

d) Exhaust air ducts.

8.7 Duct construction

All ductwork should be constructed in accordance with HVAC Duct Construction Standards Metal and Flexible published by **SMACNA** or any other equivalent duct construction standards.

8.7.1

High-pressure and medium-pressure ducts should be **leak tested** in accordance with HVAC Air Duct Leakage Test Manual published by SMACNA or any other equivalent standards, with the rate of leakage not to exceed the maximum rate specified.

8.7.2

When low pressure supply air ducts are located outside of the conditioned space (except return air plenums), all transverse joints should be sealed using mastic or mastic plus tape or equivalent material. For fibrous glass ductwork, pressure sensitive tape is acceptable.

8.7.3

Automatic or manual dampers installed for the purpose of shutting off outside air intake for ventilation air should be designed with **tight shut-off characteristics** to minimise air leakage.

8.8 Balancing

The system design should provide **means for balancing** the air and water system such as but not limited to dampers, temperature and pressure test connections and balancing valves.

Table 19. Unitary air conditioners, electrically driven:

Equipment	Size	Sub-category	Min. COP
Air cooled with condenser	<19kWr	Split system Single package	2.7 2.7
	≥ 19kWr < 35kWr	Split system & single package	2.6
	≥ 35kWr	Split system & single package	2.5
Water and evaporatively cooled	<19kWr	Split system & single package	3.0
	≥ 19kWr < 35kWr	Split system & single package	3.5
	≥ 35kWr	Split system & single package	3.6

Table 21. Water chilling packages, electrically driven:

Equipment	Size	Min COP or Min NPLV COP
Aircooled with condenser	<105kWr (30RT)	2.6 COP(1.36kWe/RT) or 2.8 NPLV
	≥ 105kWr <530kWr(150RT)	2.7 COP(1.3kWe/RT) or 2.8 NPLV
	≥ 530kWr <1060kWr(300)	2.8 COP(1.26kWe/RT) or 2.9 NPLV
	≥ 1060kWr	2.9 COP(1.21kWe/RT) or 3.0 NPLV
Watercooled Recip or scroll	All capacities	3.9 COP(0.9kWe/RT) or 4.0 NPLV
Watercooled Rotary	<530kWr(150RT)	4.0 COP or 4.2 NPLV
	≥ 530 < 1060kWr	4.4 COP(0.8kWe/RT) or 4.7 NPLV
	≥ 1060kWr	5.4 COP(0.65kWe/RT) or 5.8 NPLV
Watercooled Centrifugal	< 1060kWr	5.2 COP(0.68kWe/RT) or 4.7 NPLV
	≥ 1060kWr	5.7 COP(0.62kWe/RT) or 5.2 NPLV

8.13 System testing & commissioning

- Air system balancing should **minimise throttling losses** and fan speed adjusted to meet design flow conditions.
- Hydraulic system balancing should **minimise throttling losses** and pump impeller/s trimmed or pump speed adjusted to meet design flow conditions.
- ACMV control systems should be tested to assure that control elements are **calibrated, adjusted** and in proper working condition.

8.14 O&M and As-Builts

- An operation and maintenance (O & M) manual and as-built drawings should be provided to the owner. Manual should include basic data relating to the operation and maintenance of ACMV systems and equipment. Required routine maintenance action should be clearly identified. Where applicable, ACMV controls information such as diagrams, schematics, control sequence descriptions and maintenance and calibration information should be included.
- As-built drawings should contain information relating to rated capacities of all ac plants which includes, but not limited to AHUs and fans.

8.15 Preventive Maintenance

- The owner should implement preventive maintenance system and schedule periodic maintenance on all the critical items of air-conditioning systems such as compressors, cooling towers, pumps, condensers, air handlers, controls, filters and piping.

Some important EE Design Issues

- *Solar heat gain from building envelope and heat from light fittings can contribute up to 70% of total cooling capacity required*
- *Every Watt saved in lighting reduces building's power consumption by 1.2 to 1.3 Watts*
- *Daylight will effectively penetrate up to 1.5X the height of the window*

End of Presentation Chapter 8 - ACMV

9. Energy Management Control System

9.1 Energy Management System (EMS)
9.2 Control of equipment
9.3 Monitoring of equipment
9.4 Integration of equipment subsystems
9.5 Energy consuming areas
9.6 Application of EMS to the ACMV system
9.7 Application of EMS to the lighting system
9.8 Application of EMS to Energy Audit
9.9 Characteristics of EMS

9.1 Energy Management System (EMS)

The Energy Management System (EMS) is a subset of the Building Automation System function. It should be considered for buildings having area greater than **4,000 m2 of air-conditioned space**. Generally, the Building Automation System has 3 functions:

a) control of equipment;

b) monitoring of equipment; and

c) integration of equipment sub-systems.

9.2 Control of equipment

The purpose of the **control** of equipment is to **save energy**.

This is performed by the EMS function of the Building Automation System.

9.3 Monitoring of equipment

The purpose of **monitoring** the equipment is to **improve** the **efficiency of operations** personnel by:

a) providing centralised information of current equipment conditions;

b) providing historical information of equipment conditions;

c) providing a “management by exception” function to alert the operator of any abnormal equipment conditions; and

d) providing analysis tools to aid in the study of equipment operations.

9.4 Integration of equipment sub-systems

Equipment subsystems are integrated for the purpose of improving:

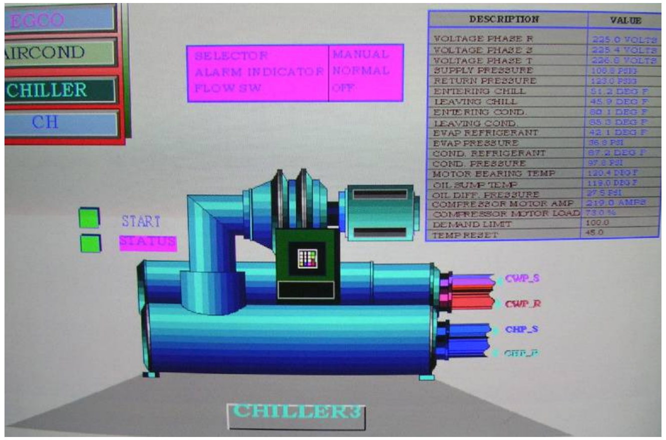
a) **safety/security**; for example, in the event of fire, AHUs can be used to create a sandwich system for smoke control;

b) **indoor air quality**; for example, by utilising the smoke purging system for periodic air purging to achieve good indoor air quality;

c) information management; by allowing information from multiple equipment subsystems to be stored and reported in a consistent format; and

d) overall system reliability;

BAS


EGCO
AIRCOND
CHILLER
CH
SELECTOR
ALARM INDICATOR
FLOW SW
MANUAL
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OFF
DESCRIPTION
VALUE
START
STATUS
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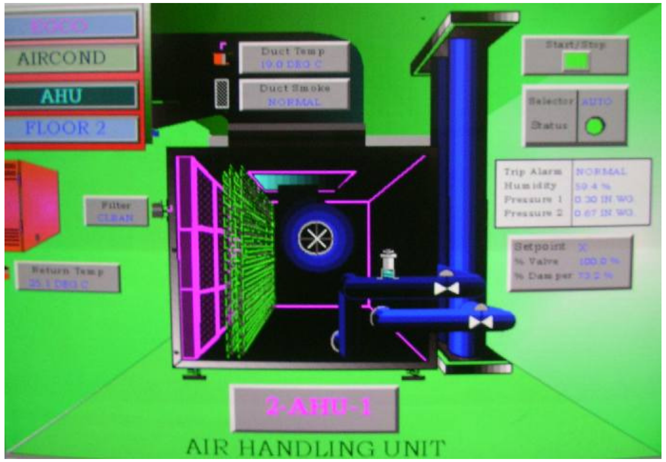
CHILLER3


EGCO
AIRCOND
AHU
FLOOR 2
Duct Temp
Duct Smoke
NORMAL
Start/Stop
Selector
AUTO
Status
Filter
CLEAN
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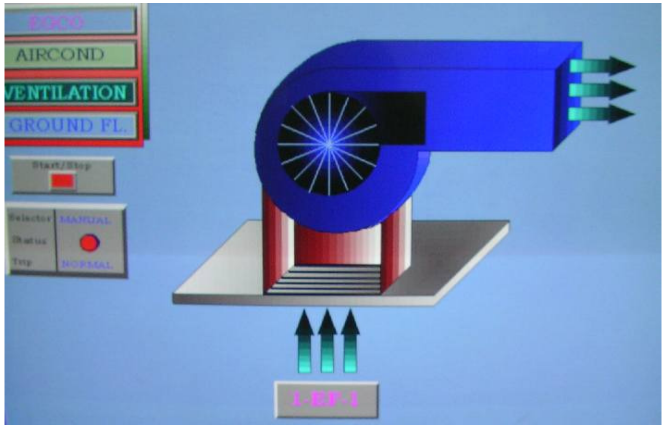
NORMAL
Humidity
Pressure 1
Pressure 2
Setpoint
% Valve
% Damper
2-AHU-1
AIR HANDLING UNIT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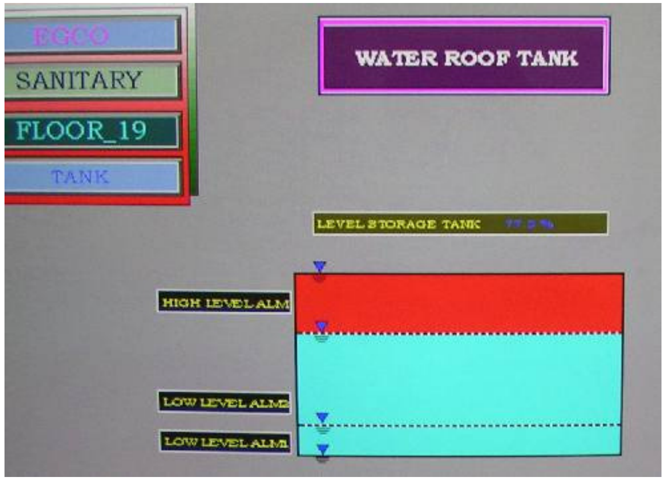
AIRCOND
VENTILATION
GROUND FL.
Start/Stop
Selector
MANUAL
Status
Trip
NORMAL
1-EF-1


EGCO
SANITARY
FLOOR_19
TANK
WATER ROOF TANK
LEVEL STORAGE TANK
HIGH LEVEL ALM
LOW LEVEL ALM2
LOW LEVEL ALM1

9.5 Energy consuming areas

9.5.1 ACMV system

This system is typically the **largest energy consumer** in the building and has the largest savings potential. The EMS must place special emphasis on the ACMV system

9.5.2 Lighting system

The lighting system is typically the **second largest energy consumer** in the building and should also be considered for inclusion in the EMS

9.5.3 Others

Any other large energy consuming equipment such as water pump sets, electric heaters and others should be included under the EMS programme. However, it is typically not appropriate to apply an EMS to control other equipment, such as computers etc.

9.6 Application of EMS to ACMV system

9.6.1 Central plant

In buildings where chillers are used, the EMS should be used to issue start/stop commands to the chiller control panel. The start /stop commands should be based on:

a) time schedules to match occupancy patterns; and

b) selection of the **most energy efficient combination** of chillers to satisfy building load; this is known as chiller sequencing **(chiller optimisation programming).**

Chillers are typically supplied with microprocessor based control panels. Where possible, a **high level data interface** between the chiller control panel and the EMS should be provided.

The chiller is typically the largest single energy consumer in the building. The energy consumed by a chiller decreases as the set point of the leaving chilled water is increased.

The EMS should automatically increase the set point of the leaving chilled water whenever possible to minimise energy consumption.

The EMS may adjust the set point based on (but not limited to):

a) time schedule;

b) outdoor air temperature/enthalpy;

c) maximum AHU valve position; and

d) indoor relative humidity condition

9.6.2 AHUs

Next to the chiller, AHUs are typically the largest consumers of energy in the building.

The EMS should have the facility to start and stop AHUs based on a time schedule.

For further energy savings, the cooling coil valve of AHUs should be controlled by a microprocessor based controller which integrates with the EMS.

Where permitted by design, the speed of the AHU fan should be decreased and the set point of the cooling valve control loop should be increased to minimise energy consumption.

9.6.3 Terminal Units

Terminal units include variable air volume (VAV) boxes, fan coil units (FCU) and split units should be start/stop by the EMS.

Some applications may require a number of FCUs or split units to be grouped together as a common zone for start/stop control by the EMS.

9.6.4 Mechanical ventilation

Where appropriate the EMS should start/stop mechanical ventilation equipment such as supply or exhaust fans.

Some applications may require a number of fans to be grouped together as a common zone for start/stop control by the EMS.

Control should be based on, but not limited to:

a) time schedules;

b) CO/CO2 level in parking garages or CO2 level in large rooms with highly variable occupancy;

c) duty cycling algorithm.

9.7 Application of EMS to Lighting system

9.7.1

Lighting systems shall be provided with manual, automatic or programmable controls except:

a) those required for emergency lighting;

b) those required for exit lighting; and

c) continuous lighting required for security purposes.

The minimum number of controls shall be not less than **one for every 1,000 W** of connected lighting power .

9.7.2 Common areas

Lighting for common areas include:

a) decorative lighting;

b) security lighting;

c) lobby lighting; and

d) corridor lighting.

Where appropriate, the lighting for common areas should be controlled by the EMS.

Control of lighting for common areas should typically be based on time of day schedules or occupancy schedules.

9.7.3 Work Areas

In cases where the EMS controls the lighting in the work areas, local override switches should be provided to allow localised control.

The status of these switches should be monitored by the EMS so that the EMS knows the command which has been sent to the lights.

Control of lighting for work areas should typically be based on occupancy schedules.

9.8 Application of EMS to Energy Audit

Buildings provided with EMS shall be equipped with data logging facilities for the **collation of data** for energy auditing.

Suitable means or facilities for the monitoring of energy consumption (sub-metering) should be provided to all incoming power supply to a building and the outgoing sub-circuits serving, but not limited, to the following :

a) central air-conditioning system;
b) lift and escalator system;
c) major water pumping system;
d) general power supply; and
e) lighting supply to tenancy areas and landlord areas.

9.9 Characteristics of EMS

The EMS should be supplied with a full complement of energy management features including but not limited to:

a) direct digital control algorithms;

b) starting and stopping of equipment based on a time schedule;

c) temporary override of the time schedules to accommodate changes in usage;

d) chilled water leaving and/or entering temperature reset algorithm;

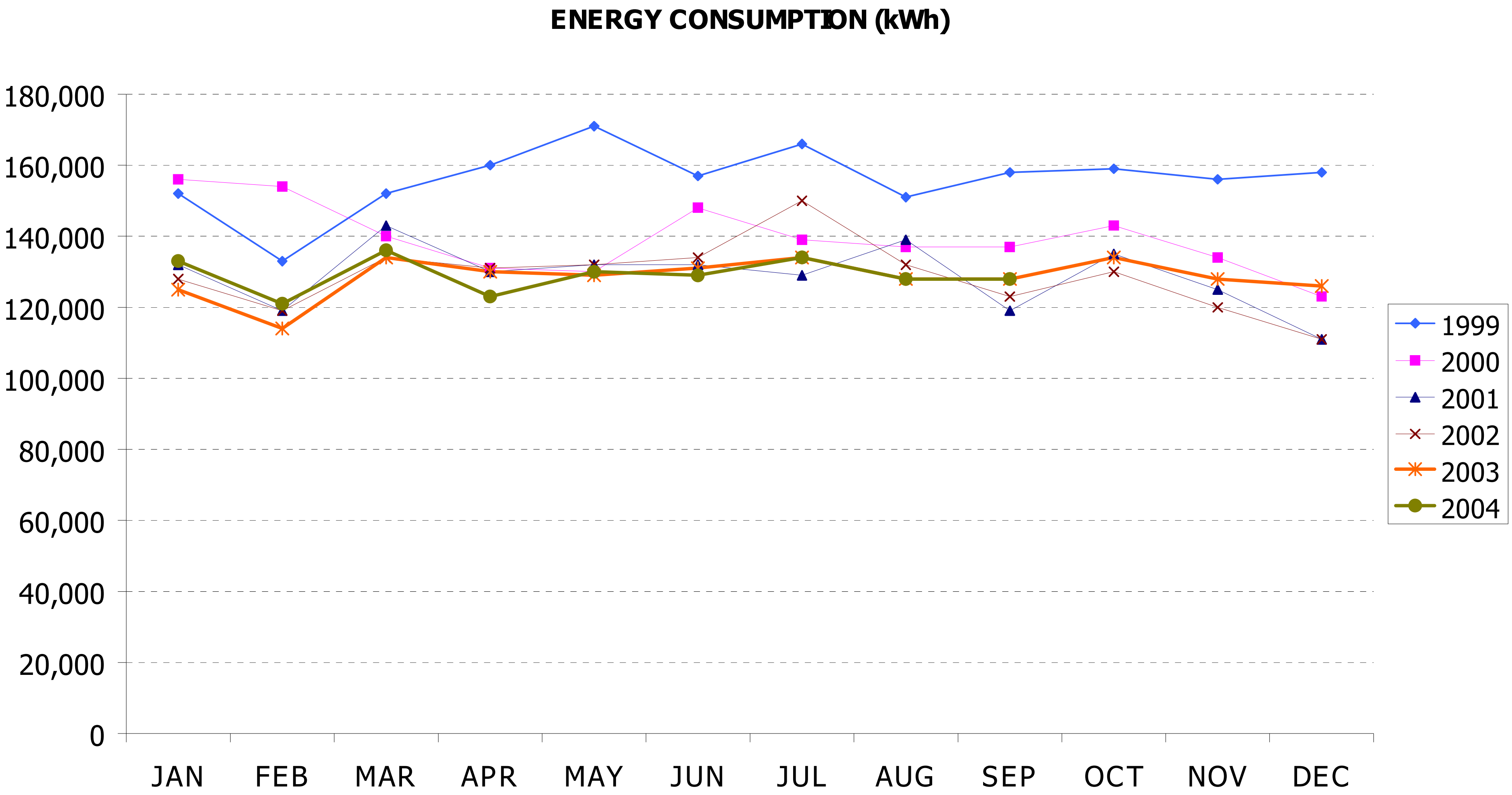
e) control loop set point reset algorithm;

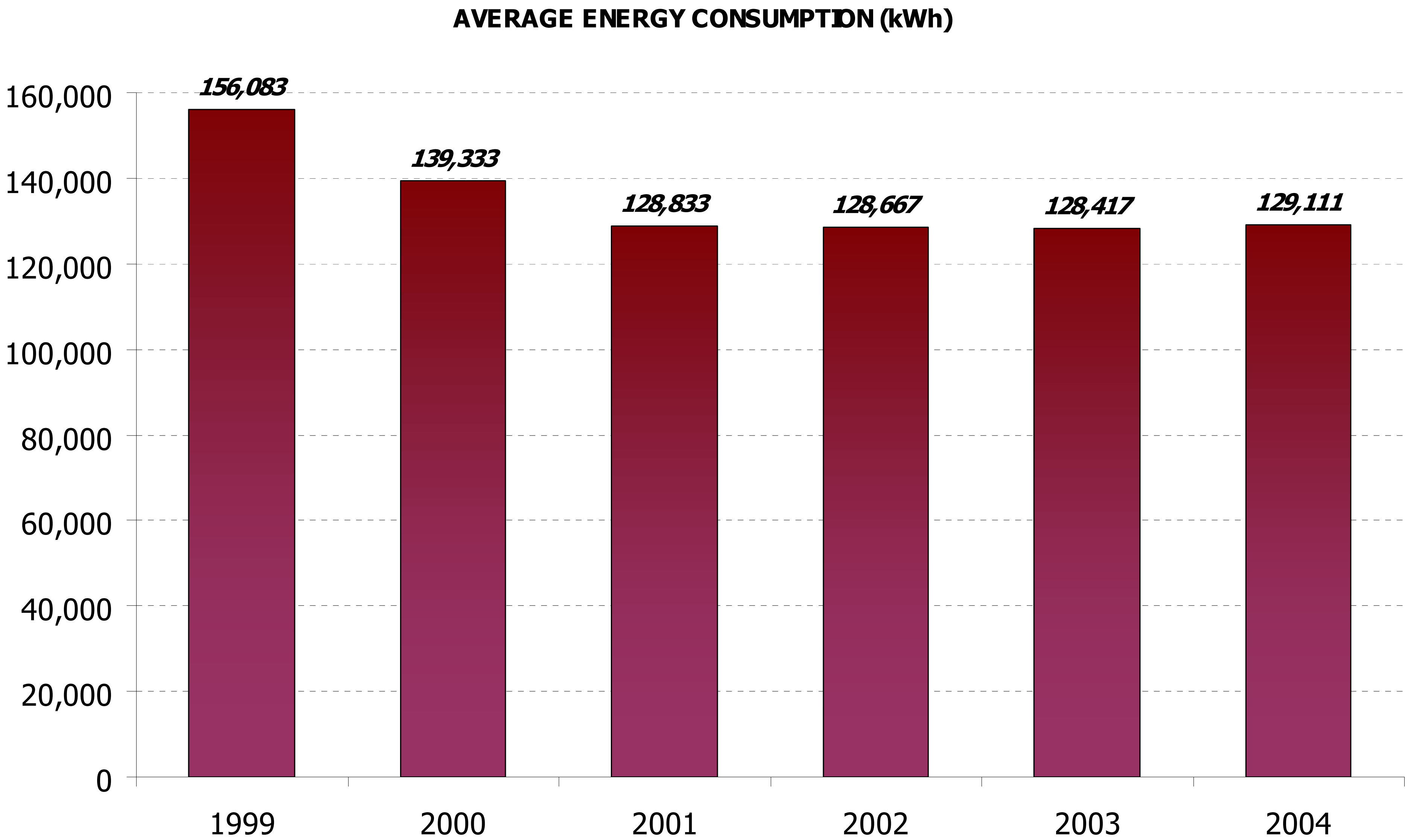
f) chiller sequencing and optimisation and sequencing algorithm;

g) demand limiting algorithm; and

h) duty cycling algorithm.

The EMS should come with an **energy tracking** and reporting system so that a historical record of energy usage is maintained for analysis and energy audit purposes.


ENERGY CONSUMPTION (kWh)
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1999
2000
2001
2002
2003
2004


AVERAGE ENERGY CONSUMPTION (kWh)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
156,083
139,333
128,833
128,667
128,417
129,111
1999
2000
2001
2002
2003
2004

End of Presentation