MALAYSIAN STANDARD

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CODE OF PRACTICE ON ENERGY EFFICIENCY AND USE OF RENEWABLE ENERGY FOR NON-RESIDENTIAL BUILDINGS

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Committee representation

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Association of Consulting Engineers Malaysia
Department of Occupational Safety and Health
Department of Standards Malaysia
Malaysian Industrial Development Authority
Malaysian Motor Vehicle Assemblers Association
Ministry of Defence
Ministry of Works and Utilities (Public Works Department)
The Institution of Engineers, Malaysia
Universiti Malaya
Universiti Teknologi Malaysia

The development of this Malaysian Standard is under the supervision of the representatives from the following organisations of the Technical Committee on Energy Efficiency and Renewal Energy in Building

Alam Sekitar Malaysia Sdn Bhd
Association of Consulting Engineers Malaysia
Construction Industry Development Board Malaysia
Department of Standards Malaysia
Gading Kencana Sdn. Bhd.
Housing Developers Association
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The Institution of Engineers, Malaysia
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Universiti Teknologi MARA
Universiti Teknologi Malaysia
Universiti Kebangsaan Malaysia

The Working Group which developed this Malaysian Standard consists of representatives from the following organisations:

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Department of Standards Malaysia
Gading Kencana Sdn. Bhd.
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Jabatan Bekalan Elektrik dan Gas
Pertubuhan Akitek Malaysia
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Committee representation ***(continued)***

The Sub-Working Group which assisted in developing this Malaysian Standard consists of representatives from the following organisations:

Universiti Islam Antarabangsa
Universiti Malaya
Universiti Pertanian Malaysia
Universiti Teknologi Malaysia
Universiti Teknologi MARA

FOREWORD

This Malaysian Standard was developed by the Technical Committee on Energy Efficiency and Renewal Energy in Building under the authority of the Mechanical Engineering Industry Standards Committee.

This Code of Practice (COP) was developed to update and replace the Guidelines for Energy Efficiency in Buildings which was published by the Min istry of Energy, Telecommunications and Posts Malaysia in December 1989. The data adopted in this COP were gathered from the industry practice and cross referred with data from the region.

Compliance with a Malaysian Standard does not of itself confer im munity from legal obligations.

CODE OF PRACTICE ON ENERGY EFFICIENCY AND USE OF RENEWABLE ENERGY FOR NON-RESIDENTIAL BUILDINGS

0. Introduction

0.1 The purposes of this Malaysian Standard are to:

a) encourage the design of new and existing buildings so that they may be constructed, operated and maintained in a manner that reduces the use of energy without constraining the creativity, building function, nor the comfort or productivity of the occupants and with appropriate regard for cost consideration;

b) provide the criteria and minimum standards for energy efficiency in the design of new buildings, retrofit of existing buildings and methods for determining compliance with these criteria and minimum standards;

c) provide guidance for energy efficiency designs that demonstrate good professional judgement and exceeds minimum standards criteria; and

d) encourage the application of renewable energy in new and existing buildings to minimise non-renewable energy sources, pollution and energy consumption whilst maintaining comfort, health and safety of the occupants.

0.2 As the standard sets out only the minimum standards, designers are encouraged to design and select equipment above those stipulated in this standard.

0.3 The recommendations for renewable energy applications are classified under the following areas:

a) maximising the availability of renewable energy resources such as solar heating, solar electricity, solar lighting and solar assisted technologies;

b) optimising passive cooling strategies;

c) optimising environmental cooling through natural means such as vegetation, site planning, landscaping and shading; and

d) maximising passive solar design.

0.4 The requirements for energy efficiency is classified under the following areas:

a) designing an efficient lighting system (Clause 6);

b) minimising losses in electrical power distribution equipment (Clause 7);

c) designing an efficient air-conditioning system (Clause 8); and

d) designing a good energy management system (Clause 9).

1. Scope

This code of practice gives guidance on the effective use of energy including the application of renewable energy in new and existing non -residential buildings.

Buildings or portions thereof whose peak design ra te of electrical energy usage is less than 10 W/m^2 (installed) of gross floor area for all purposes are excluded from this standard. Where specifically noted in this standard, certain other buildings or elements thereof may be exempted when design data are not available or applicable.

2. Referenced documents

The following referenced documents contain provisions which, through references in this text, constitute provisions of this Malaysian Standard. For dated references, where there are subsequent amendm ents to, or revisions of, any of these publications the Malaysian Standard shall be amended or revised accordingly. For undated references, the latest edition of the publication referred to applies.

ASHRAE Handbook: 2000 - HVAC systems and equipment.

HVAC Duct Construction Standards Metal and Flexible, SMACNA, second edition, 1995

HVAC Air Duct Leakage Test Manual, SMACNA, first edition,1985

MS IEC 60929 : 1995, Specification for a.c. supplied electronic ballasts for tubular fluorescent lamps – Performance requirements.

Uniform Building By Laws, 1984.

3. Definitions

For the purpose of this standard, the followi ng shall apply.

3.1 Building envelope

The exterior portions of a building through which thermal energy is transferred.

NOTE. This thermal transfer is the major factor affecting interior comfort level and the air-conditioning load.

3.2 Coefficient of Performance

This is the ratio of the rate of net heat removal to the rate of total energy input, expressed in consistent unit s and under designed rating conditions.

3.3 Fenestration

A glazed opening in building wall to control solar radiant heat and daylighting.

NOTES:

1. Most common forms include windows and clerestories.
2. Sometimes a fenestration may include its associated interior and exterior elements such as shades and blinds.

3.4 Kilowatt refrigerant (kWr)

The unit used to denote refrigeration capacity in kW.

NOTE. 1 kWr = 3412 Btuh

3.5 Overall Thermal Transfer Value (OTTV)

The design parameter that indicates the solar thermal load transmitted through the building envelope excluding the roof.

3.6 Radiant Barrier

Radiant barrier is material that either reflects radiant heat or inhibits the emission of radiant heat.

3.7 Roof Thermal Transfer Value (RTTV)

The design parameter that indicates the solar thermal load transmitted through the roof.

3.8 Shading Coefficient

The shading coefficient of the fenestration system is the ratio of solar heat gain through the fenestration system to the solar heat gain through an unshad ed 3 mm clear glass under the same condition.

3.9 Skylight

A glazed opening, horizontal or inclined, which is set into roof of a building to provide daylighting.

4. Architectural and passive design strategy

4.1 Sustainable design approach

A combined architectural, engineering, site planning and landscape (multidisciplinary) approach to designing an energy conscious building should optimize the energy efficiency of a building especially in employing combined passive and active devices. In some cases mixed mode systems in maximizing daylight and thermal comfort whilst minimizing solar gain. Designing within contextual climate and site is the first criteria in the reduction of the overall energy consumption resulting in operational cost savings.

4.2 Passive design strategy

The design and construction of a building which takes optimal advantage of its environment need not impose any significant extra cost as compared to a more highly serviced building. All buildings have a primary function to provide an internal environment suitable for the purpose of the building. The architectural consideration in designing a building is influenced by its responsiveness to the immediate environment. The important factors that should be considered include the following:

a) building orientation;

b) building configuration;

c) floor depth;

d) floor to floor height;

e) location of cores;

f) building façade selection;

g) arrangement of spaces; and

h) landscaping.

These factors are just as important as the selection of systems or devices to control lighting and thermal comfort (cooling) within the building.

4.3 Site planning and orientation

For climatic zones nearer to the equator, generally the best orientation for buildings are with the long directional axis of buildings facing North-South, minimising the East-West orientation (refer to Figure 1). Technically the buildings' main longitudinal orientation should be on an axis 5° Northeast. On narrow sites this may not be possible. For circular, square and octagonal buildings, the shading devices should be addressed on the eastern and western facades. The microclimate information, wind direction and precipitation should be analysed for the locality in making design tradeoffs with regards to maintaining the design concept.

4.4 Daylighting

Designing with emphasis on natural daylighting should begin at the preliminary design stage.

A good daylighting system must study the following building elements in relation to the sunlight:

a) the orientation and space organisation;

b) shape and size of glazing through which daylight will pass;

c) internal ceiling wall, partition and floor surface properties;

d) minimising the colour contrast between windows and internal adjoining walls and ceilings;

e) protection from solar gain or glare by external and internal shading or light shelf; and

f) the material characteristics of the glazing unit.

Conventional and innovative daylighting systems that collect, transport and distribute light deep into buildings that reduce the need for artificial lighting are reco mmended.

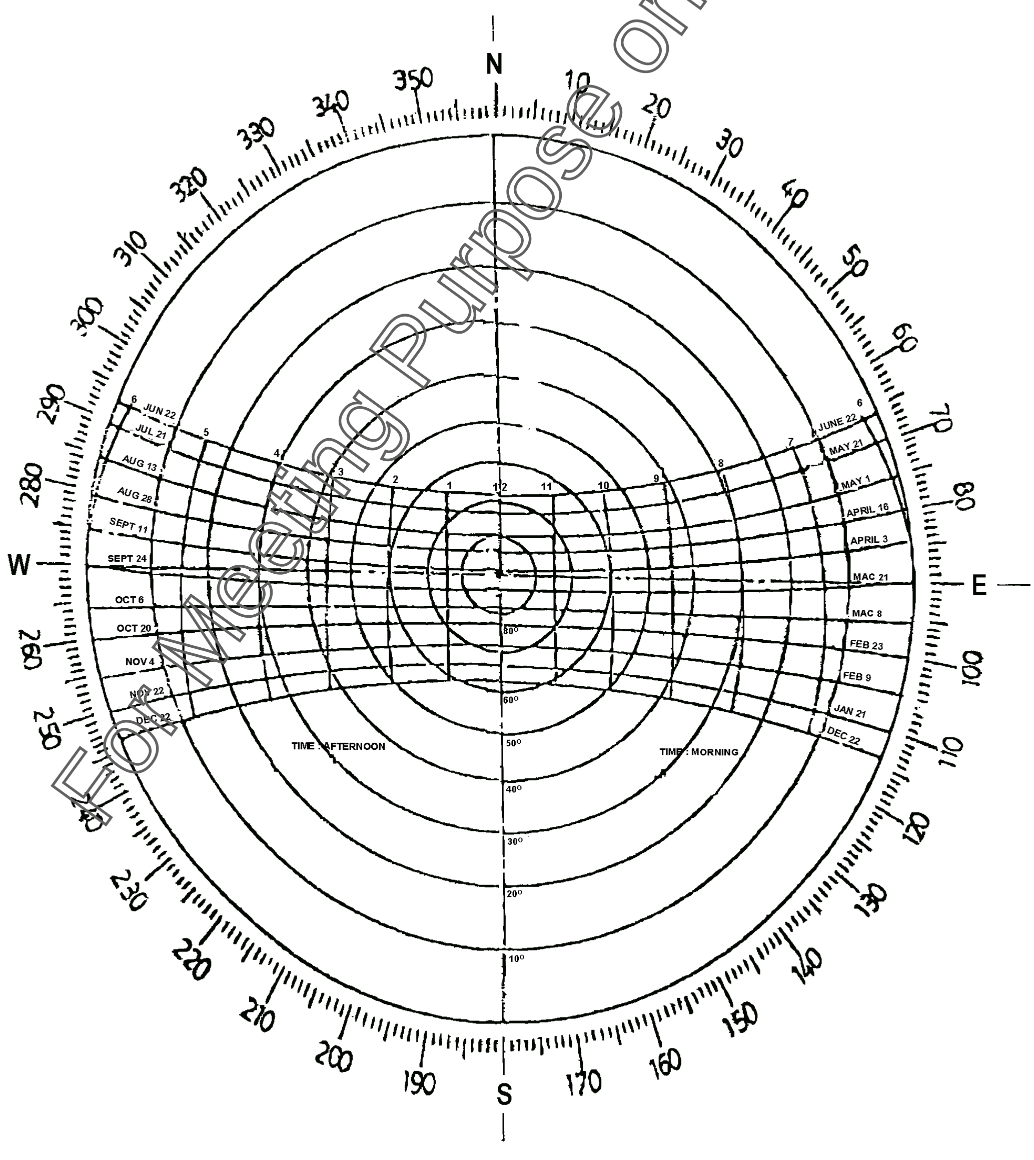

Figure 1. Sunpath diagram

4.5 Facade design

To achieve good daylighting, the glazing shall be designed to optimise light entering to the building whilst minimising solar heat gain. It is encouraged to model daylight performance by using scale models or computer simulations for buildings having greater than 4 000 m^2 of air-conditioned space.

4.6 Natural ventilation

Natural ventilation is the use of fresh air of sufficient volume and air change to ventilate enclosed spaces without active temperature controls or mechanical means. Provisions for naturally ventilated lobby areas, corridors, lift cores, staircases should be encouraged with compliance to the requirements from the fire authorities for smoke venting of the spaces in the event of a fire. In some of these cases, spill air from adjacent spaces is sufficient for air change to ventilate the space and provide thermal comfort with reduced energy.

The following criteria should be considered to optimise natural ventilation:

a) orientation of openings;

b) vertical positioning of openings;

c) size of openings;

d) allowance for cross ventilation; and

e) control and modification of openings to channel wind into the building.

The low incidence of significant wind force or wind speeds to achieve sensible air movement for thermal comfort may require additional air movement with the aid of mechanical systems.

4.7 Strategic landscaping

Strategic landscaping can influence less heat gain through several processes, including shading from the sun, shielding from infiltration at higher levels and the creation of a cooler microclimate around the building. Proper shading of the air-conditioner unit especially the exterior condenser, can lower energy use.

4.8 Future considerations for sustainable design

In addition to energy efficient and passive design considerations, the applications of renewable energy relevant to buildings that should be incorporated are as follows:

a) solar energy for heating, cooling, ventilation and lighting (daylighting);

b) photovoltaics for electricity;

c) other renewable energy resources for power generation such as biofuels, wind, municipal waste; and

d) fuel cells.

5. Building envelope

5.1 General requirement

Roof and ceiling systems should be designed to allow cooling by natur al ventilation through the space between roof and ceiling.

Radiant barrier should be installed on the under side of the roof. To be effective the radiant barrier should have an air space next to a reflective side. The emissivity of the radiant barrier should be no greater than 0.10. Only one side of the barrier needs to meet this requirement. Test data or manufacturer's data should be available to show that the material meets this requirement.

5.2 Concept of OTTV

The solar heat gain through building envelope constitutes a substantial share of cooling load in an air-conditioned building. In non air-conditioned buildings, the solar heat gain causes thermal discomfort. To minimise solar heat gain into a building is, therefore, the first and foremost consideration in the design of an energy efficient building.

A design criterion for building envelope known as the overall thermal transfer value (OTTV) has been adopted. The OTTV requirement, which applies only to air -conditioned buildings is aimed at achieving the design of building envelope so as to cut down external heat gain and hence reduce the cooling load of the air-conditioning system.

The OTTV of building envelope for a building, having a total air -conditioned area exceeding 4000 m^2 and above, shall not exceed 45 W/m^2.

5.2.1 The OTTV of building envelope is given by the formula below:

$$OTTV = \frac{A_{o1} \ x \ OTTV_1 + A_{o2} \ x \ OTTV_2 ...... \ x \ A_{on} \ x \ OTTV_n}{A_{o1} + A_{o2} ...... + A_{on}} \qquad .....(1)$$

where,

A_{oi} is the gross exterior wall area for orientation *i*; and

$0TTV_i$ is the *OTTV* value for orientation *i* from equation (2).

5.2.2 For a fenestration at a given orientation

$$OTTV_i = 19.1 \ \alpha \ (1 - WWR) \ U_w + (194 \times CF \times WWR \times SC) \qquad .....(2)$$

Where,

WWR is the window-to-gross exterior wall area ratio for the orientation under consideration;

α is the solar absorptivity of opaque wall;

U_w is the thermal transmittance of opaque wall (W/m^2 K);

CF is the solar correction factor; as in Table 1; and

SC is the shading coefficient of the fenestratio n system.

Table 1. Solar correction factors

Orientation	CF
North	0.83
Northeast	1.01
East	1.15
Southeast	1.02
South	0.85
Southwest	1.02
West	1.14
Northwest	0.99

NOTES:

1. Table 1 specifies CF for the various orientation of the fenestration. For the calculation of CF, it is recommended to use the nearest predominant orientation.

2. A fenestration system may consist of a glazing material such as glass, a shading device and a combination of both.

5.3 Shading coefficient

5.3.1 The shading coefficient of a shading system is the product of the shading coefficients of its sub-systems, for example

$$SC = SC_1 \times SC_2 \qquad \text{..... (3)}$$

where,

SC is the effective shading coefficient of the fenestration system;

SC_1 is the shading coefficient of sub-system 1 (e.g. glass); and

SC_2 is the shading coefficient of sub-system 2 (e.g. external shading devices)

5.3.2 The shading coefficient for glass is the value assessed at an incident angle of 45 ° to the normal.

5.3.3 The shading coefficient of external shading devices can be obtained from Table 2, Table 3 and Table 4.

Table 2. Shading coefficient of horizontal projections

Ratio	Orientation			
R1	**North/South**	**East/West**	**Northeast/ Northwest**	**Southeast/ Southwest**
0.30 - 0.40	0.80	0.80	0.80	0.80
0.50 - 0.70	0.70	0.70	0.70	0.65
0.80 - 1.20	0.70	0.60	0.60	0.58
1.30 - 2.00	0.66	0.50	0.54	0.50

NOTE.
R1 is the $\frac{\text{Width of horizontal projection}}{\text{Height of fenestration}}$

Table 3. Shading coefficient of vertical projections

Ratio	Orientation			
R2	**North/South**	**East/West**	**Northeast/ Northwest**	**Southeast/ Southwest**
0.30 - 0.40	0.80	0.80	0.85	0.85
0.50 - 0.70	0.75	0.90	0.75	0.75
0.80 - 1.20	0.70	0.80	0.65	0.65
1.30 - 2.00	0.70	0.75	0.60	0.60

NOTE.
R2 is the $\frac{\text{Width of vertical projection}}{\text{Length of fenestration}}$

Table 4. Shading coefficient of egg -crate louvres

Ratios		Orientation			
R1	**R2**	**North/South**	**East/West**	**Northeast/ Northwest**	**Southeast/ Southwest**
0.20	0.20 0.40 – 0.60 0.60 – 1.80	0.80 0.75 0.70	0.80 0.80 0.70	0.80 0.70 0.60	0.80 0.70 0.60
0.40	0.20 – 0.40 0.60 – 1.20 1.40 – 1.80	0.70 0.66 0.66	0.75 0.70 0.60	0.70 0.60 0.50	0.70 0.60 0.50
0.60	0.20 – 0.60 0.80 – 1.80	0.66 0.66	0.66 0.60	0.60 0.50	0.60 0.50
0.80	0.20 – 0.60 0.80 – 1.80	0.66 0.66	0.60 0.55	0.60 0.50	0.60 0.50
1.00	0.20 – 0.40 0.60 – 1.20 1.40 – 1.80	0.66 0.66 0.66	0.55 0.55 0.50	0.60 0.50 0.50	0.50 0.50 0.50
1.20 - 1.80	0.20 – 1.80	0.66	0.50	0.50	0.50

NOTES:

R1 is the $\frac{\text{Width of horizontal projection}}{\text{Height of fenestration}}$

R2 is the $\frac{\text{Width of vertical projection}}{\text{Length of fenestration}}$

5.4 Daylighting

5.4.1 Lighting energy consumption savings due to daylighting technique can be greater than cooling energy penalties from additional glazed surface provided that the building envelope is carefully designed for daylighting. The transparent p ortions of the building envelope should, therefore, be designed to prevent solar radiant gain above that necessary for effective daylighting. Sidelit atria is recommended to be used in this country rather than toplit.

5.4.2 In order to take advantage of daylighting, the visible transmittance of the fenestration system should not be less than 0.25.

5.4.3 Daylighting controls used for interior lighting in the perimeter zon e within 5 m of each exterior wall, if provided, may be traded -off with increased OTTV of the envelope as specified in Table 5.

Table 5. Trade-off for daylighting controls

Type of control	Percentage increase in OTTV (%)
On-off control Dimming control	10 20

5.4.4 The total unshaded glazing area should not be more tha n 30% of the total floor area.

5.5 Roofs

5.5.1 The roof of a conditioned space shall not have a thermal transmittance (U -value) greater than that tabulated in Table 6.

Table 6. Maximum U -value for roof (W/m ²K)

Roof Weight Group	Light colour	Dark colour
Light (Under 50 kg/m²)	0.7	0.5
Medium (50 – 230 kg/m²)	1.0	0.8
Heavy (Over 230 kg/m²)	1.6	1.2

5.5.2 If more than one type of roof is used, the average thermal transmittance for the gross area of the roof shall be determined from:

$$U_r = \frac{(A_{r1} U_{r1})\ x\ (A_{r2}\ x\ U_{r2})......+(A_m\ x\ U_m)}{A_{r1}+A_{r2}......+A_m} \qquad ...... (4)$$

where,

U_r is the average thermal transmittance of the gross area (W/m ^{2} K);

U_{r1} is the respective thermal transmittance of different roof sections (W/m ^{2} K); and

A_{ri} is the respective area of different roof sections (m²).

The average weight of the roof is calculated as follows:

$$W_r = \frac{A_{r1} \times W_{r1} + A_{r2} \times W_{r2} ..... + A_m \times W_m}{A_{rt} + A_{r2} ..... + A_m} \quad .....(5)$$

where,

W_r is the average weight of roof (kg/m ^{2});

A_{ri} is the respective area of different roof sections (m²); and

W_{ra} is the respective weight of different roof sections (kg/m ^{2}).

5.5.3 If the roof area is shaded from direct solar radiation by ventilated external shading devices such as a double ventilated roof, the U -value may be increased by 50 %.

5.5.4 If external roof surface reflective treatments are used where the solar reflectivity is equal to or greater than 0.7 and the treatment is free from algae growth, the U -value may be increased by 50 %.

5.6 Roofs with skylights

5.6.1 Concept of roof thermal transfer value (RTTV)

In the case of an air-conditioned building, the concept of Roof Thermal Transfer Value (RTTV) is applied if the roof is provided with skylight and the entire enclosure below is fully air-conditioned.

5.6.2 For roofs with skylight, in addition to the requirement of 5.5.1 the maximum permissible RTTV is 25 W/m ^{2}.

5.6.3 The RTTV of roof is given by the following equation.

$$RTTV = \frac{(A_r \times U_r + TD_{eq}) + (A_s \times U_s \times \Delta T) + (A_s \times SC \times SF)}{A_o} \quad ..... (6)$$

where,

$RTTV$ is the roof thermal transfer value (W/m ^{2});

A_r is the opaque roof area (m ^{2});

U_r is the thermal transmittance of opaque roof area (W/m ^{2} *K);*

TD_{eq} is the equivalent temperature difference *(K),* as from Table 7;

A_s is the skylight area (m ^{2});

U_s is the thermal transmittance of skylight area (W/m ^{2});

ΔT is the temperature difference between exterior and interior design conditions (5 K);

SC is the shading coefficient of skylight;

SF is the solar factor (W/m^2), see 5.6.5; and

A_o is the gross roof area (m^2) where $A_o = Ar + A_s$.

5.6.4 Equivalent temperature difference

For the purpose of simplicity in RTTV calculation, the equivalent temperature difference (TD_{eq}) of different types of roof constructions have been standardised as follows:

Table 7. Equivalent temperature difference for roof

Roof construction (kg/m^2)	Equivalent temperature difference *(K)*
Under 50	24
50 – 230	20
Over 230	16

5.6.5 Solar factor

For a given orientation and angle of slope, the solar factor is given by the following equation.

$$SF = 323 \times CF \qquad \text{.....(7)}$$

where,

SF is the solar factor (W/m^2); and

CF *is* the correction factor with reference to the orientation of the roof and the pitch angle of its skylight and is given as in Table 8.

Table 8. Solar correction factor for roof

Slope angle (°)	Orientation			
	North/South	East/West	Northeast/ Southeast	Northwest/ Southwest
5 - 30	1.00	1.05	1.03	1.02
35 – 45	0.90	1.01	0.96	0.96
50 – 55	0.80	0.95	0.90	0.90
60 – 65	0.70	0.80	0.80	0.80
NOTE. The correction factors for other orientations and other pitch angles may be found by interpolation.				

If the roof consists of different sections facing different orientations or pitched at different angles, the RTTV for the whole roof shall be calculated as follows:

$$RTTV = \frac{A_{o1} \, x \, RTTV_1 + A_{o2} \, x \, RTTV_2 + ...A_{on} \, x \, RTTV_n}{A_{o1} + A_{02} + ...A_{on}} \qquad .....(8)$$

where,

$RTTV$ is the overall roof thermal transfer value (W/m ^{2});

A_{oi} is the respective area of different roof sections (m ^{2}), and

$RTTV_i$ is the respective roof thermal t ransfer value of different roof sections (W/m ^{2}).

5.6.6 The gross roof area shall include all opaque roof areas and skylight areas, when such surfaces are exposed to outdoor air and enclose an air conditioned space.

5.7 Daylight credit

5.7.1 Skylights for which daylight credit is taken may be excluded both from the U -value calculation and the calculation of the RTTV, provided the following conditions are met:

a) All electric lighting fixtures within the skylight areas shall be controlled by automatic daylighting controls.

b) The skylight area for which daylight credit can be taken, is the area under each skylight whose dimension in each direction (centred on the skylight) is equal to the skylight dimension in that direction plus the floor or ceiling hei ght.

c) The skylight areas, including framing, as a percentage of roof areas do not exceed the values in Table 9 where visible transmittance (VT) is the transmittance of a particular glazing material over the visible portion of the solar spectrum. (The sk ylight area shall only be interpolated between VT values of 0.75 and 0.5).

5.7.2 The skylight areas in Table 9 may be increased by 50 % if an external shading device is used that blocks over 50 % of the solar gain during the peak design period.

Table 9. Maximum percent skylight area

Visible Transmittable	**Illuminance (*Lux*)**	**Lighting power density (W/m^2)**			
		Less than 10	**15**	**20**	**More than 25**
0.75	300	2.2	2.8	3.4	4.0
	500	2.3	3.1	3.9	4.7
	700	2.9	4.1	5.3	6.5
0.50	300	3.3	4.3	5.1	6.0
	500	3.6	4.8	6.0	7.2
	700	4.2	6.0	7.8	9.6

5.8 Submission procedure

The following information shall be provided by a Professional Engineer or Registered Architect:

a) a drawing showing the cross-sections of typical parts of the roof construction, giving details of the type and thickness of basic construction materials, insulation and air space;

b) the U-value of the roof assembly;

c) the OTTV calculation; and

d) the RTTV of the roof assembly, if provided with skylights.

6. Lighting

6.1 Applications excluded from this clause include:

a) outdoor activities such as manufacturing, storage, commercial greenhouse and processing facilities;

b) lighting power for theatrical productions, television broadcasting, audio-visual presentations and those portions of entertainment facilities such as stage areas in hotel ballrooms, night-clubs, discos and casinos where lighting is an essential technical element for the function performed;

c) specialised luminaires for medical and dental purposes;

d) outdoor recreational facilities;

e) display lighting required for art exhibition or display in galleries, museums and monuments;

f) exterior lighting for public monuments;

g) special lighting needs for research laboratories;

h) lighting to be used solely for lighting indoor and outdoor plant growth during the hours of 10.00 pm and 6.00 am;

i) emergency lighting that is automatically 'off' during normal operations;

j) high risk security areas identified by local ordinances or regulations or by security or safety personnel requiring additional lighting;

k) lighting for signs; and

l) store-front display windows in retail facilities.

6.2 General principles of efficient lighting practice

6.2.1 Lighting must provide a suitable visual environment within a particular space i.e. sufficient and suitable lighting for the performance of a range of tasks and provision of a desired appearance.

6.2.2 The maintained illuminance levels for general building areas are as given in Table 10.

Table 10. Recommended average illuminance level s

Task	Illuminance (Lux)	Example of Applications
Lighting for infrequently used area	20	Minimum service illuminance
	50	Interior walkway and car-park
	100	Hotel bedroom
	100	Lift interior
	100	Corridor, passageways, stairs
	150	Escalator, travellator
	100	Entrance and exit
	100	Staff changing room, locker and cleaner room, cloak room, lavatories, stores.
	100	Entrance hall, lobbies, waiting room
	300	Inquiry desk
	200	Gate house
Lighting for working interiors	200	Infrequent reading and writing
	300 – 400	General offices, shops and stores, reading and writing
	300 – 400	Drawing office
	150	Restroom
	200	Restaurant, Canteen, Cafeteria
	150 – 300	Kitchen
	150	Lounge
	150	Bathroom
	100	Toilet
	100	Bedroom
	300 – 500	Class room, Library
	200 – 750	Shop / Supermarket/Department store
	300	Museum and gallery
Localised lighting for exacting task	500	Proof reading
	1000	Exacting drawing
	2000	Detailed and precise work

6.2.3 Installed power and energy consumption should be minimised by the use of more efficient lamp/ballast systems and luminaires.

6.2.4 The fluorescent ball ast loss shall not exceed 6.0 W (see MS IEC 60929 : 1995)

6.2.5 Luminaires shall be selected for efficient distribution of light without producing discomfort glare.

6.3 Maximum allowable power for illumination systems

Lighting load shall not exceed the corresponding maximum value as specified in Table 11.

Table 11. Unit lighting power allowance

Buildings Type/space	Max. lighting power W/m^2
Food Service	14
Cafeteria	14
Leisure Dining / Bar	14
Fast food	20
Office	20
Supermarket / Department Store	30
Retailed shop	20
Main Concourse at multi-store shopping centre	15
Basement Car park	5
Hotel / Motel;	
Guest room & Corridor	17
Public Area	20
Banquet & Exhibit	20
Store / Stairs/ Lavatory	10
Classroom	18
Lecture Theatre / Auditorium	25

6.4 Exterior building lighting power requirements

6.4.1 The same lighting systems criteria specified in 6.3 should apply.

6.4.2 The lighting power load for external car parks, drive -ways, pedestrian malls, landscape areas, shall not exceed 1.5 W/m^2. The area shall be the net site area excluding the built-up area.

6.4.3 For facilities with multiple buildings, the building e xterior lighting power requirements may be traded off among the buildings.

6.5 Lighting controls

6.5.1 All lighting systems except those required for emergency or exit lighting shall be provided with manual, automatic or programmable controls. For light ing loads exceeding 100 kW automatic control shall be provided.

6.5.2 Lighting zones control for daylight energy savings scheme

The minimum number of lighting control for daylight energy savings scheme shall take into consideration the following criteria:

a) all spaces enclosed by walls or ceiling height partitions shall be provided with at least one operated-on-off lighting control for each room;

b) one switch is provided for each task or group of tasks within an area of 30 m^2 or less;

c) the total number of switches shall be at least one switch for each 1 kW of connected load; and

d) lighting zones control for energy savings.

6.5.3 Switches provided for task areas, if readily accessible may be mounted as part of the task lighting fixtures. Switches controlling the same load from more than one location shall not be credited as increasing the number of controls to meet the requirements of this clause.

6.5.4 Lighting control requirements for spaces which are used as a whole (such as public lobbies of office buildings, hotels and hospitals, retail and department stores and service corridors under centralised supervision) shall be controlled in accordance with the work activities, and controls may be centralised in remote locations.

6.5.5 Control accessibility

All lighting controls shall be located at an accessible place with the following exceptions:

a) lighting control requirements for spaces which must be used as a whole, such as public lobbies of office buildings, hotels and hospital, retail and department stores and service corridors under centralised supervision shall be controlled in accordance with the work activities, and controls may be centralised in remote locations;

b) automatic controls;

c) programmable controls;

d) controls requiring trained operators; and

e) controls for safety hazards and security

6.5.6 Hotel and motel guest rooms shall have a master switch which automatically turns off all lighting, power outlets and reduce operating air-conditioning loads except for essential loads.

6.5.7 Exterior lighting not intended for 24 hour continuous use shall be automatically switched by timer and/or photocell.

6.5.8 Local manual controls or automatic controls such as photoelectric switches or automatic dimmers shall be provided in day lighted space. Controls should be provided so as to operate rows of light parallel to the facade/ exterior wall.

6.6 Operation and maintenance (O and M) manual and as built drawing

An operation and maintenance manual and as built drawing manual shall be provided to the owner. The manual shall include the following information:

a) the design standard service illuminance;

b) the number of each type of lighting device;

c) the total wattage of each type of lighting device, including nominal rating and gear losses;

d) the installed lighting load for interior and exterior; and

e) the gross built-up floor area of the installation.

7. Electric power and distribution

This clause applies to the energy efficiency requirements of electric motors, transformers and distribution systems of buildings except those required for emergency purposes.

All electrical power distribution equipment should be selected for their energy efficiency and the installation method should be to minimise energy losses as far as possible.

7.1 Alternative Current (A.C.) Electric motors

A.C electric motors should preferably be of the squirrel-cage type unless specified otherwise.

This clause shall apply to all permanently wired squirrel-cage induction type motors of 0.4 kW size and larger. It shall not apply to other types as regards efficiency requirements.

7.1.1 Output rating and duty

The continuous rated output (kW) of motors shall not exceed the excess percentage (service factor) in the calculation for the load as follows:

a) 30 % for motor output 1.5 kW to 3.75 kW;
b) 20 % for motor output 3.75 kW to 7.5 kW; and
c) 15 % for motor output above 7.5 kW.

7.1.2 Motor efficiencies

7.1.2.1 Motors expected to operate less than 750 hours per year shall have full load efficiencies not less than the values shown in Table 12.

Table 12. Minimum acceptable full load efficiency for motor operating less than 750 hours per year

Motor size kW (hp)	Min. efficiency (%)
0.4 kW (0.5 hp)	70.0
0.8 kW (1 hp)	77.0
4.0 kW (5 hp)	83.0
8.0 kW (10 hp)	86.0
40.0 kW (50 hp)	90.0
80.0 kW (100 hp)	92.0
100 kW up (150 hp)	93.0
NOTE. This table applies to single speed poly phase squirrel-cage induction motors with nominal speeds of 1,500 RPM (4-poles) at 50 Hz with open, drip-proof or totally enclosed fan-cooled enclosures.	

7.1.2.2 Motors operating more than 750 hours per year should be of the high efficiency type with efficiencies higher than those listed in Table 13.

Table 13. Minimum acceptable full load efficiency for motor operating more than 750 hours per year

Motor size (kW)	Minimum efficiency (%)
4.0	85.0
7.5	88.0
37.0	93.5
75.0	94.8
110.0	95.5

7.1.2.3 Motors with ratings different from those given in Tables 12 and 13 shall follow the figures in the efficiency table shown in manufacturer's catalogues.

7.2.1 Motor power factor

Power factor for motors shall be corrected to better than 0.85 when operating at duty point, to minimise losses due to reactive currents in the cables back to the main switchboard.

7.2.2 Motor drives

Where applicable, inverter controlled motor drives shall be used to control the speed of the motors to effect energy savings.

7.2.3 Cabling

The cross-section area of the cables and wires should be adequate to carry th e required current without raising their temperature above the appropriate limit. In addition, it shall not exceed the allowable voltage drop and fault current rating. Special attention shall be given to lay cables in such configuration to minimise losses due to eddy and harmonic current effects.

7.3 Transformer

7.3.1 All transformers in the building's electrical system shall have efficiencies not lower than 98 % for sizes below 1 000 kVA and not less than 99 % for sizes equal to or greater than 1 000 kVA at 75 % load conditions.

7.3.2 The average power factor of the loads being served by the transformer at any time should not be less than 85 %. In cases where load power factors fall below 85 %, capacitor or power factor improving devices shall be prov ided for automatic or manual correction.

7.3.3 Transformer load grouping schemes shall be designed to accommodate load not less than 40 % of the full load. Combination of no -load circuits and partial load circuits combination shall be minimised.

7.3.4 Location of distribution transformers and main low voltage switchboard should be as close as possible to the load centers.

7.4 Inverter

All inverters or devices with electronic switching gates shall be of at least the 12 pulses type. The 24 pulses type i s recommended to minimise harmonic currents.

7.5 Power factor correction capacitors

Power factor correction capacitors should be the low loss type with losses per kVAR not exceeding 0.35 W at upper temperature limit and without discharge resistors conne cted.

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

8.1 Load calculations

8.1.1 Calculation procedures

Cooling system design loads for the purpose of sizing systems and equipment shall be determined in accordance with the procedures des cribed in the latest edition of the ASHRAE Handbook, or other equivalent publications.

8.1.2 Indoor design conditions

The indoor conditions of an air-conditioned space for comfort cooling shall be designed and maintained as follows:

a)	Recommended design dry bulb temperature	23 °C – 26 °C
b)	Minimum dry bulb temperature	22 °C
c)	Recommended design relative humidity	60 % – 70 %
d)	Minimum relative humidity	55 %

8.1.3 Outdoor design conditions

The recommended outdoor design conditions shall be taken as follows:

a)	dry bulb temperature	33.3 °C
b)	wet bulb temperature	27.2 °C

8.1.4 Ventilation

Outdoor air-ventilation rates shall comply with Third Schedule (By Law 41) Article 12(1) of Uniform Building By Laws, 1984.

Exception:

Outdoor air quantities may exceed those shown, if required because of special occupancy or process requirements or source control of air contamination.

8.2 System and equipment sizing

8.2.1 Air conditioning systems and equipment shall be sized to provide no more than the space and system loads calculated in accordance with 8.1 above, consistent with available equipment capacity. Redundancy in capacity of equipment, if incorporated into the sizing of the duty equipment, shall include efficiency devices such as variable speed drive, multi compressors etc so as not to diminish the equipment/system efficiency when operating at varying loads.

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

8.2.3 Multiple units of the same equipment type, such as multiple chillers, with combined capacities exceeding the design load may be specified to operate concurrently only if controls are provided which sequence or otherwise optimally control the operation of each unit based on load.

8.2.4 Individual air cooled or water cooled direct expansion (DX) units greater than 35 kWr shall consist of either multi compressors or single compressor with minimum 2 -step capacity (cylinder) unloaders ((0-50-100) % capacity) or variable unloaders.

8.3 Separate air distribution systems

8.3.1 Zones which are expected to operate non-simultaneously for more than 750 hours per year shall be served by separate air distribution systems. As an alternative off -hour controls shall be provided in accordance with 8.4.8.

8.3.2 Zones with special process temperature and/or humidity requirements shall be served by separate air distribution systems from those serving zones requiring only comfort cooling, or shall include supplementary provisions so that the primary systems may be specifically controlled for comfort purposes only.

Exception:

Zones requiring comfort cooling only which are served by a system primarily used for process temperature and humidity control, need not be served by a separate system if the total supply air to these zones is no more than 25 % of the total system supply air, or the total conditioned floor area of the zones is less than 100 m^2.

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

8.3.4 For air conditioned space requiring exhaust air volume in excess of 3 400 m^3/h, not less than 85 % of non conditioned make up air shall be introduced directly into the space concerned unless the exhausted conditioned air is utilised for secondary cooling purposes. Alternatively, heat recovery devices shall be provided.

8.4 Controls

8.4.1 Temperature control

Each system shall be provided with at least one thermostat for the regulation of temperature. Each thermostat shall be capable of being set by adjustment or selection of sensors over a minimum range of between 22 °C to 27 °C. Multi-stage thermostat shall be provided for equipment exceeding 35 kWr in conjunction with 8.2.4.

8.4.2 Humidity control

In a system requiring moisture removal to maintain specific selected relative humidity in spaces or zones, no new energy shall be used to produce a space relative humidity below 75 % for comfort cooling purposes.

8.4.3 Zoning for temperature control

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

a) Each separate system, and

b) Each separate zone as defined in 8.3.

As a minimum each floor of a building shall 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. A readily accessible manual or automatic means shall be provided to partially restrict or shut off the cooling input (for the exposure side) to each floor.

8.4.4 Control setback and shutoff

Each system shall be equipped with a readily accessible means of shutting off or reducing the energy used during periods of non-use or alternate uses of the building spaces or zones served by the system. The following are examples that meet these requirements:

a) manually adjustable automatic timing devices;

b) manual devices for use by operating personnel; and

c) automatic control system.

8.4.5 Reheat systems

Systems employing reheat where permitted by 8.4.2 and serving multiple zones, other than those employing variable air volume for temperature control, shall be provided with controls that will automatically reset the system cold air supply to the highest temperature level that will satisfy the zone requiring the coolest air. Single zone reheat systems shall be controlled to sequence reheat and cooling.

8.4.6 Recovered energy in excess of the new 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 etc.

8.4.7 Multi zone systems

These systems, other than those employing variable air volume for temperature control shall be provided with controls that will automatically reset the off-coil air supply to the highest temperature that will satisfy the zone requiring the coolest air.

8.4.8 Off-hour control

8.4.8.1 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 kW or less may be controlled by readily accessible manual off-hour controls.

8.4.8.2 Outdoor air supply and exhaust systems shall be provided with motorised or gravity dampers or other means of a utomatic volume shutoff 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) system which have a design air flow of 1 800 m^3/h 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.

8.4.8.3 Systems that serve zones which can be expected to op erate non-simultaneously for more than 750 hours per year shall include isolation devices and controls to shut off the supply of cooling to each zone independently. Isolation is not required for zones expected to operate continuously.

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

8.4.8.5 Zones may be grouped into a single isolation area provided the total conditioned floor area does not exceed 250 m^2 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.

8.4.9 Cooling equipment auxiliary controls

Evaporator coil frosting and excessive compressor cycling at part-load conditions should be controlled by limited and controlled cycling of the refrigerant prime mover rather than by the use of either hot gas by-pass or evaporator pressure regulator control.

8.4.10 Mechanical ventilation control

Each mechanical ventilation system (supply and/or exhaust) shall 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 tim er switch control, thermostat control, duty cycle programming and CO sensor control.

8.5 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 t he amount recovered) when the energy transfer potential and the operating hours are considered.

8.6 Piping insulation

All piping installed to serve buildings and within buildings shall be adequately insulated to prevent excessive energy losses. Addition al insulation with vapour barriers may be required to prevent condensation under some conditions.

Exceptions:

Piping insulation is not required in any of the following cases:

a) Piping installed within ACMV equipment.

b) Piping at fluid temperatures between 23 °C and 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.

8.7 Air handling duct system insulation

All ducts, plenums and enclosures installed in or on buildings shall be adequately insulated to prevent excessive energy losses. Additional insulation with vapour barriers may be required to prevent condensation under some conditions.

Exceptions:

Duct insulation is not required in any of the following cases:

a) Where the design temperature differential between the air in the duct and the surrounding air is 8 °C or less provided that the duct is within the air-conditioned 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.

8.8 Duct construction

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

8.8.1 High-pressure and medium-pressure ducts shall 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.

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

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

8.9 Balancing

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

8.10 ACMV systems

For the purposes of this part, 'ACMV System' are considered to be of three basic types:

a) Central air-distribution systems

In this type, either ACMV System Equipment (see 8.11) or an engineered and field-assembled combination of ACMV System Components (see 8.12), receives recirculated room air (plus outside air as required) from a central duct system, performs the required ventilating or air-conditioning functions, and delivers the conditioned air to the central duct system, for final delivery to the conditioned space(s) of the building.

b) Central circulating water systems

In this type, a centrifugal, rotary or reciprocating, compression refrigeration or absorption refrigeration type water-chilling package provides chilled water to a central piping system; and the piping system supplies cooled water, as required, to water-air heat exchangers (terminal units) serving the conditioned space(s) of the building.

The water chilling package, including its heat-rejecting element, and the terminal units are considered to be ACMV System Components.

c) Multiple unit systems

In this type, a number of units of ACMV Equipment, each receiving a supply of electric energy, performs the functions of cooling air for distribution to a space or zone of the building.

8.11 ACMV system equipment

ACMV system equipment provides, in one (single package) or more (split system) factory assembled packages, means for air-circulation, air-cleaning, air-cooling with controlled temperature and dehumidification. The cooling function may be either electrically or heat operated, and the refrigerant condenser may be air, water or evaporatively-cooled.

Where the equipment is provided in more than one package, the separate packages should be designed by the manufacturer to be used together.

8.11.1 ACMV system equipment, electrically operated, cooling mode

8.11.1.1 ACMV system equipment as listed in 8.11.1.2 whose energy input in the cooling mode is entirely electric, shall show a coefficient of performance (COP) cooling as defined in 8.11.2 at the standard rating conditions specified in Table 14 and additional standard rating conditions specified in applicable standards for particular ACMV system equipment and not less than values shown in Table 15.

8.11.1.2 These requirements apply to but are not limited to unitary (central) cooling equipment (air-cooled, water-cooled and evaporatively-cooled) packaged terminal air-conditioners; and room air-conditioners.

8.11.2 Coefficient of performance (COP) - cooling

This is the ratio of the rate of net heat removal to the rate of total energy input, expressed in consistent units and under designed rating conditions (See Tables 14 and 15).

The rate of net heat removal shall be defined as the change in the total heat content of the air entering and leaving the equipment (without reheat).

Total energy input shall be determined by combining the energy inputs to all elements supplied with the package of the equipment, including but not limited to, compressor(s), compressor sump heater(s), pump(s), supply-air fan(s), return-air fan(s), condenser-air fan(s), cooling tower fan(s) and circulating water pumps(s) and the ACMV system equipment control circuit.

Table 14. ACMV system equipment, electrically driven[a]: Standard rating temperatures - cooling[b]

Item	Air-cooled		Water-cooled (water-source)	
	Dry-bulb	Wetbulb	Inlet	Outlet
Room air entering equipment (°C)	27	19	-	-
Condenser ambient (air-cooled) (°C)	35.0	24	-	-
Refrigerant-water heat exchanger (°C)	-	-	29.4	35.0

[a] Data in this table apply to the following types of equipment:
Central Air Conditioners Air Evaporatively and Water Cooled, ARI Std 210-1994
Commercial/Industrial Unitary Air- Conditioning Equipment, ARI Std 360-1986
Package Terminal Air Conditioners ARI Std 310-1990
Room Air Conditioners ANSI Z234, 1-1972

[b] Standard Ratings are also based on other standard rating conditions such as but not limited to electrical conditions; cooling coil air quantity; requirements for separated (split) assemblies; and minimum external static conditioned-air flow resistance, as provided in the applicable standards.

Table 15. ACMV system equipment [a], electrically driven: Minimum COP - cooling

Standard rating capacities			
Under 19 kWr		19 kWr and over	
Air cooled	Evaporatively or water-cooled	Air cooled	Evaporatively or water-cooled
2.6	2.9	2.7	2.9
[a] Applies to requirement as listed in Table 14. All performances at sea level. COP is defined in 8.11.2.			

8.12 ACMV system components

ACMV system components provide, in one or more factory -assembled packages, means for chilling water with controlled temperature, for delivery to terminal units serving the conditioned space of the building. The chiller may be of the centrifugal, rotary or reciprocating, electrically driven type, absorption (heat -operated) type or using other prime movers.

A second type of ACMV System Components involves the condensing unit, which receives its suction refrigerant vapour from a packaged or field assembled combination of cooling coil and fan (central station air handling unit) and delivers liquid refrigerant to the air handling unit.

8.12.1 ACMV system components, electrically operated, cooling mode

ACMV system components, as listed in Tables 18 and 19, whose energy input is entirely electric, shall, at the Standard Rati ng Conditions specified in Table 16 for water -chillers and Table 17 for condensing units, and at additional standard rating conditions specified in applicable standards for particular system components, show a Coefficient of Performance (COP) – cooling, as defined in 8.12.2 not less than the values shown in Tables 18 and 19.

8.12.2 Coefficient of performance (COP) – cooling

The definition in 8.11.2 applies together with the following supplementary qualifications.

In air-cooled packages, the fan motor(s) energy is included in determining the COP of the package.

In water-cooled or evaporatively-cooled types, if a cooling tower or evaporative condenser is included in the package the circulating pump motor(s) are also taken into account in determining the COP**.**

The COP of the reciprocating condensing unit is based on the energy input to the condensing unit and the change in enthalpy of the refrigerant entering and leaving the condensing unit.

Table 16. ACMV system components, electrically driven [a] for water chillers: Standard rating conditions – cooling[b]

Conditions		Centrifugal or self-contained reciprocating water-chilling package	Condenserless[d] reciprocating water-chilling package
Leaving chilled water temperature	°C	6.7	6.7
Entering chilled water temperature	°C	12.2	12.2
Leaving condenser water temperature	°C	35.0	-
Entering condenser water temperature	°C	29.0	-
Fouling factor, water[c]			
Non ferrous tubes	m^2 K/W	0.000044	0.000044
Steel tubes	m^2 K/W	0.00018	0.00018
Fouling factor, Refrigerant	m^2 K/W	0.00000	0.00000
Condenser, ambient Temperature			
Air-cooled	°C	35.0 DB	-
Evaporatively-cooled	°C	23.9 WB	-
Compressor, saturated discharge temperature			
Water-or-evaporatively cooled	°C	-	40.6
Air cooled	°C		48.9
Refrigerant, liquid temperature			
Water-or-evaporatively cooled	°C	-	35.0
Air cooled	°C	-	43.3

[a] Data in this Table apply to the following types of ACMV System Components:
Centrifugal or Rotary or Reciprocating water-chilling packages ARI Std 550 / 590 – 98.

[b] Standard Ratings are also based on other Standard Rating Conditions, such as but not limited to, electrical conditions, indoor or condenser air quantities : minimum external flow resistance etc. as provided in the applicable standards.

[c] For information on fouling factors, see the following standard.

Refrigerant condensers, remote type:
ARI standard 480-95 for refrigerant-cooled liquid coolers, remote type
ARI standard 550 / 590 – 98 also contain procedures for adjusting ratings for other than the standard rating fouling factor.

[d] The condenser is not within the package unit.

The energy consumed by the heat rejecting device (cooling tower or heat exchanger) is not included in the COP consideration for the condensing unit, unless the device (i.e air -cooled condenser) is integrally incorporated i nto the package by the manufacturer.

Chiller water pumps circulating chilled water through the piping system external to the package, and cooling tower pumps and fans circulating water or air through the condenser and cooling tower are not to be included in the consideration of the COP for the component.

Table 17. ACMV System components, electrically driven [a]: for condensing units: Standard rating conditions – cooling [b]

Group No.	Temperatures					
	Evaporator[b]		Condenser[c]			
			Air-cooled[d]	Water-cooled		Evaporatively-cooled
			Air entering	Water		Air entering
	Saturation (°C)	Return gas (°C)	Dry bulb (°C)	In (°C)°C	Out (°C)	Wetbulb (°C)
1	7.2	18.3	35.0	-	-	-
2	4.4	18.3	-	29.4	35.0	23.9

[a] Data in this table apply to ACMV Condensing Units. See ARI Std 520-90 for Positive Displacement Refrigerant Compressor, Compressor Units and Condensing Units. Data are from Table 3 of ARI 520-90 Groups 1 and 2.

[b] Not part of Condensing Unit; conditions to be maintained by separately furnished condenser.

[c] Refrigerant liquid sub-cooling, in °C shall be stated by the manufacturer as obtained under the conditions below as measured at the liquid line leaving the Condensing Unit.

[d] With 35°C dry bulb ambient air temperature surrounding unit.

Table 18. ACMV system components, electricall y driven[a]: Minimum COP - cooling[b]

Water-chilling packages				
Type	**Self-contained**		**Condenser**	
Condenser cooling means[c]	**Air**	**Water**	**Air**	**Water**
C	2.3	4.0	-	-
R	2.5	3.5	2.9	3.5

a. Applies to equipment as listed in Table 16.

b. Performance of water-chilling packages does not include energy to drive chilled-water and condenser-water pumps, or cooling-tower fans.

c. ***C* = Centrifugal or rotary type (ARI Standard 550 / 590 - 98).**
R = Reciprocating type (ARI Standard 550/590-98).

Table 19. ACMV system components, electrically driven for condensing units 19 kWr and over[a]: Minimum COP - cooling[b]

Positive displacement		
Condensing means		
Air	Evaporatively	Water
2.8	3.7	3.7

a Per ARI Standard 520 – 90 for Positive displacement refrigerant compressors, compressor units and condensing units.

b Based on Standard rating capacity at conditions in Table 17 and at sea level.

8.13 ACMV system equipment/component – heat-operated (absorption), cooling mode

8.13.1 Coefficient of performance (COP) - cooling

The definition in 8.11.2 applies together with the following supplementary.

In the heat-operated (absorption) system equipment/components, pumps included in the package for circulating refrigerant and absorber fluids in the refrigeration cycle are included in determining the COP of the equipment/components.

Heat-operated cooling equipment/components shall show a COP-cooling not less than the values shown in Table 21 when tested at standard rating conditions shown in Table 20.

For heat-operated cooling equipment /component, the heat energy input should be limited to:

a) solar energy;

b) recovered energy from other processes, and

c) natural gas or others (non electric).

Table 20. ACMV system cooling equipment/component, heat-operated: Standard rating conditions – cooling

Standard rating conditions		Heat source	
		Direct fired (Gas, oil)	**Indirect fired (Steam, hot water)**
Airconditioners[a]	**Units**	**Temperatures**	**Temperatures**
Entering conditioned air	°C	26.7 DB, 19.4 WB	-
Entering condenser air	°C	35.0 DB, 23.9 WB	-
Water chillers[b]		-	
Leaving chilled water	°C	7.2	6.7
Fouling factor	m^2 K/W	-	0.00009
Entering chilled water	°C	Per mfg. Spec	12.2
Entering condenser	°C	23.9	29.4
Fouling factor	m^2 K/W	-	0.00018
Leaving condenser water	°C	35.0	-
Condenser water flow rate	l/min		Per mfg spec

[a] Per ANSI Standard Z21.40.1-1994 and Addenda for Gas-fired absorption summer air-conditioning appliances.
[b] Per ARI Standard 560-92 for Absorption water-chilling packages.

Table 21. ACMV system cooling equipment/components, heat -operated[b]: Minimum COP[c] – cooling

Heat Source			
Direct fired (Gas, Oil)		**Indirect fired (steam, hot water)**	
Type X[a]	Type Y[a]	Type X[a]	Type Y[a]
0.6	1.0	0.6	1.0

[a] Type X = Single effect absorption chillers
Type Y = Double effect absorption chillers

[b] As listed in Table 18 at sea level.

[c] $$\text{Minimum COP} = \frac{\text{Net cooling output}}{\text{Total heat input (electrical auxiliary inputs included)}}$$

8.14 System testing and commissioning

Air system balancing shall be accomplished in a manner to minimise throttling losses and then fan speed shall be adjusted to meet design flow conditions.

Hydraulic system balancing shall be accomplished in a manner to minimise throttling losses and then the pump impeller shall be trimm ed or pump speed shall be adjusted to meet design flow conditions.

ACMV control systems shall be tested to assure that control elements are calibrated, adjusted and in proper working condition.

8.15 Operation and maintenance (O & M) manual and as -built drawings

An operating and maintenance (O & M) manual and as -built drawings shall be provided to the owner. The manual shall include basic data relating to the operation and maintenance of ACMV systems and equipment. Required routine maintenance action sh all be clearly identified. Where applicable, ACMV controls information such as diagrams, schematics, control sequence descriptions and maintenance and calibration information shall be included.

As-built drawings shall contain information relating to rate d capacities of all air conditioning plants which includes, but not limited to air handling units and fans.

8.16 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.

9. Energy management control system

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 m^2 of air conditioned space. Generally, the building automation system has three 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 subsystems

Equipment subsystems are integrated for the purpose of improving:

a) safety/security; for example, in the event of a fire, air-handling units 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; the component of an equipment subsystem allows each of the personnel computer to act as a standby unit for other systems without incurring additional cost.

9.5 Energy consuming areas

9.5.1 Air conditioning and mechanical ventil ation (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 as specified in 9.6.

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 as specified in 9.7.

9.5.3 Others

Any other large energy consuming equipment such as water pump sets, electric heater 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 an EMS to the 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 o n:

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 micr oprocessor 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 the 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 ad just the set point ba sed 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 Air handling units (AHU)

Next to the chiller, the air handling units are typically the largest consumers o f energy in the building. The EMS should have the facility to start and stop the air handling units based on a time schedule. For further energy savings, the cooling coil valve of the air handling units should be controlled by a microprocessor based contr oller which integrates with the EMS. Where permitted by the mechanical design of the air handling units, the speed of the fan should be decreased and the set point of the cooling valve control loop should be increased to minimise energy.

9.6.3 Terminal Units

Terminal units include variable air volume (VAV) boxes, fan coil units (FCU) and split units should be started and stopped by the EMS. Some applications may require a number of fan coil units or split units to be grouped together as a common zone for start and stop control by the EMS.

9.6.4 Mechanical ventilation

Where appropriate the EMS should start and 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 and stop control by the EMS. Control should be based on, but not limited to:

a) time schedules;

b) carbon monoxide (CO) level in parking garages or carbon dioxide (CO_2) level in large rooms with highly variable occupancy; and

c) duty cycling algorithm.

9.7 Application of EMS to the 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 shall be provided to allow localised control. The status of these switches shall 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 Applications of EMS to Energy Audit

Buildings provided with EMS as specified in 9.1 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 shall be provided to all incoming power supply to a building and the subcircuits serving but not limited, to the following :

a) central air-conditioning system;

b) lift and escalator system; and

c) general power and lighting supply.

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 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.

Appendix A

Bibliography

ANSI/ARI 210 : 1994 Unitary air-conditioning and air-source heat pump equipment.

ANSI/ARI 590 : 1992 Reciprocating water chilling package

ANSI/ARI 310 : 1990 Packaged terminal air-conditions

ANSI/ARI 360 : 1986 Commercial and Industrial Unitary air conditioning equipment.

ANSI/ARI 480 : 1987 Refrigerant – Cooled liquid coolers, remote type.

ANSI/ARI 520 : 1990 Positive displacement refrigerant compressors, compressor units and IEC 555-2 : 1982 Disturbances in main supply network caused by household appliances and similar electrical

ANSI/ARI 550 : 1992 Centrifuged or rotary screw water chilling package.

ANSI Z21.40.1 : 1996 Gas fired, heat activated air conditioning and heat pump appliances.

ARI 560 : 1992 Absorption water-chilling package

ANSI Z234;1-1972 Room air conditioners

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Technical Committee

Dato' Mohd Annas Mohd Nor (Chairman), Ir. Guntor Tobeng/Puan Fakitah Mat Kasa (Secretary), Hajjah Ir. Azura Mahayudin, Encik Fu Wing Hoong, Ir. Fong Tian Y ong, Prof. Dr. Baharudin Yatim, Puan Maznah Abdul Majid, Encik Mohd Khalid Harun, Dato Abu Bakar Jaafar, Encik Teoh Chee Hai, Ir. Yim Hon Wa, Encik Asfaazam Kasbani, Encik Elias Ismail, Encik Asri Abd Halim, Encik Othman Abd Jalil, Ir. Ramli Mohd Yusoff, E ncik Mustafa Yusof, Puan Lee Bee Chew, Dr Mohd Johari Md Arif, Encik Abd Haris Abd Karim, Encik Hamzah Omar.

Working Group

Prof. Dr. Ir. K.S. Kannan (Chairman), Ir. Guntor Tobeng/Puan Fakitah Mat Kasa (Secretary), Ir. Abdul Aziz Abdul Rahman, Dr. Azni Zain-Ahmed, Ir. Chen Thiam Leong, Dr. Md. Najib Ibrahim, Dr. Samirah Abdul Rahman, Puan Serina Hijjas, Puan Siti Mariam Rahmat, Ir. Wong Shue Leong, Puan Hasnah Awang.

Sub-Working Group

Dr. Md. Najib Ibrahim, Prof. Peter Woods, Puan Sri Nila Inangda, Enc ik Ruslan Khalid, Puan Noor Hanita A Majid, Puan Nor Aziah Mohd Ariffin, Encik Malik Rahman.