MALAYSIAN STANDARD

MS 1525:2014

Energy efficiency and use of renewable energy for non-residential buildings - Code of practice
(Second revision)

ICS: 91.040.01

Descriptors: energy efficiency, renewable energy, non-residential, buildings, code of practice, energy

DEPARTMENT OF STANDARDS MALAYSIA

DEVELOPMENT OF MALAYSIAN STANDARDS

The **Department of Standards Malaysia (STANDARDS MALAYSIA)** is the national standards and accreditation body of Malaysia.

The main function of STANDARDS MALAYSIA is to foster and promote standards, standardisation and accreditation as a means of advancing the national economy, promoting industrial efficiency and development, benefiting the health and safety of the public, protecting the consumers, facilitating domestic and international trade and furthering international cooperation in relation to standards and standardisation.

Malaysian Standards (MS) are developed through consensus by committees which comprise balanced representation of producers, users, consumers and others with relevant interests, as may be appropriate to the subject at hand. To the greatest extent possible, Malaysian Standards are aligned to or are adoption of international standards. Approval of a standard as a Malaysian Standard is governed by the Standards of Malaysia Act 1996 [Act 549]. Malaysian Standards are reviewed periodically. The use of Malaysian Standards is voluntary except in so far as they are made mandatory by regulatory authorities by means of regulations, local by-laws or any other similar ways.

For the purposes of Malaysian Standards, the following definitions apply:

Revision: A process where existing Malaysian Standard is reviewed and updated which resulted in the publication of a new edition of the Malaysian Standard.

Confirmed MS: A Malaysian Standard that has been reviewed by the responsible committee and confirmed that its contents are current.

Amendment: A process where a provision(s) of existing Malaysian Standard is altered. The changes are indicated in an amendment page which is incorporated into the existing Malaysian Standard. Amendments can be of technical and/or editorial nature.

Technical corrigendum: A corrected reprint of the current edition which is issued to correct either a technical error or ambiguity in a Malaysian Standard inadvertently introduced either in drafting or in printing and which could lead to incorrect or unsafe application of the publication.

NOTE: Technical corrigenda are not to correct errors which can be assumed to have no consequences in the application of the MS, for example minor printing errors.

STANDARDS MALAYSIA has appointed **SIRIM Berhad** as the agent to develop, distribute and sell Malaysian Standards.

For further information on Malaysian Standards, please contact:

Department of Standards Malaysia
Ministry of Science, Technology and Innovation
Level 1 & 2, Block 2300, Century Square
Jalan Usahawan
63000 Cyberjaya
Selangor Darul Ehsan
MALAYSIA

Tel: 60 3 8318 0002
Fax: 60 3 8319 3131
http://www.jsm.gov.my
E-mail: central@jsm.gov.my

OR

SIRIM Berhad
(Company No. 367474 - V)
1, Persiaran Dato' Menteri
Section 2, P. O. Box 7035
40700 Shah Alam
Selangor Darul Ehsan
MALAYSIA

Tel: 60 3 5544 6000
Fax: 60 3 5510 8095
http://www.sirim.my
E-mail: msonline@sirim.my

Contents

Committee representation

The Industry Standards Committee on Building, Construction and Civil Engineering (ISC D) under whose authority this Malaysian Standard was developed, comprises representatives from the following organisations:

Association of Consulting Engineers Malaysia
Construction Industry Development Board Malaysia
Department of Irrigation and Drainage Malaysia
Department of Standards Malaysia
Dewan Bandaraya Kuala Lumpur
Federation of Malaysian Manufacturers
Jabatan Bomba dan Penyelamat Malaysia
Jabatan Kerajaan Tempatan
Jabatan Kerja Raya Malaysia
Malaysian Timber Council
Malaysian Timber Industry Board
Master Builders Association Malaysia
Pertubuhan Akitek Malaysia
Projek Lebuhraya Utara-Selatan Berhad
Real Estate and Housing Developers' Association Malaysia
SIRIM Berhad (Secretariat)
Suruhanjaya Perkhidmatan Air Negara
The Cement and Concrete Association of Malaysia
The Institution of Engineers, Malaysia
Universiti Sains Malaysia
Universiti Teknologi Malaysia

The Technical Committee on Energy Efficiency in Buildings (Passive) which supervised the development of this Malaysian Standard consists of representatives from the following organisations:

Association of Consulting Engineers Malaysia
Federation of Malaysian Manufacturers
International Islamic University of Malaysia
Jabatan Kerja Raya Malaysia
Pertubuhan Akitek Malaysia
SIRIM Berhad (Secretariat)
SIRIM QAS International Sdn Bhd
Suruhanjaya Tenaga
Universiti Islam Antarabangsa Malaysia
Universiti Teknologi Malaysia
Universiti Teknologi MARA

The following working groups developed this Malaysian Standard:

The Working Group on Architecture and Passive Design Strategy which consists of representatives from the following organisations:

Malaysia Green Building Confederation
SIRIM Berhad (Secretariat)
Suruhanjaya Tenaga
Universiti Islam Antarabangsa Malaysia
Universiti Putra Malaysia
Universiti Teknologi MARA

Committee representation *(continued*)

The Working Group on Air-conditioning and Mechanical Ventilation (ACMV) System & Energy Management Control System which consists of representatives from the following organisations:

Acson Malaysia Sales & Service Sdn Bhd
Association of Consulting Engineers Malaysia
Carrier (Malaysia) Sdn Bhd
Daikin Air Conditioning (Malaysia) Sdn Bhd
Dunham-Bush (Malaysia) Bhd
Federation of Malaysian Manufacturers
Group Associated (C&L) Sdn Bhd
Jabatan Kerja Raya Malaysia
Malaysia Chapter of American Society of Heating, Refrigerating and Air-Conditioning Engineers (MASHRAE)
Malaysian Air Conditioning and Refrigeration Association (MACRA)
O.Y.L Industries Sdn Bhd
SIRIM Berhad (Secretariat)
Superior Make Aircon Refrigeration Tech Sdn Bhd
The Institution of Engineers, Malaysia
Trane Malaysia TM Sales and Services Sdn Bhd
York (Malaysia) Sales & Service Sdn Bhd

The Working Group on Lighting which consists of representatives from the following organisations:

Association of Consulting Engineers Malaysia
Federation of Malaysian Manufacturers
Jabatan Kerja Raya Malaysia
Phillips (M) Sdn Bhd
SIRIM Berhad (Secretariat)
SIRIM QAS International Sdn Bhd
Tenaga Nasional Berhad
The Electrical and Electronics Association of Malaysia
The Institution of Engineers, Malaysia

The Working Group on Electric Power and Distribution which consists of representatives from the following organisations:

Association of Consulting Engineers Malaysia
Federation of Malaysian Manufacturers
Jabatan Kerja Raya Malaysia
SIRIM Berhad (Secretariat)
Suruhanjaya Tenaga

The Working Group on Energy Management System (EMS) which consists of representatives from the following organisations:

Association of Consulting Engineers Malaysia
BICT Engineering Sdn Bhd
Federation of Malaysian Manufacturers
George Kent (M) Bhd
Honeywell Sdn Bhd
Jabatan Kerja Raya Malaysia
Johnson Controls (M) Sdn Bhd
M&C Engineering and Trading Sdn Bhd
Malaysia Chapter of American Society of Heating, Refrigerating and Air-Conditioning Engineers (MASHRAE)
Malaysian Air Conditioning and Refrigeration Association (MACRA)
Metronic Engineering Sdn Bhd
SIRIM Berhad (Secretariat)
Solar District Cooling Sdn Bhd
The Institution of Engineers, Malaysia

Committee representation *(concluded)*

The Working Group on Overall Transfer Thermal Value (OTTV) which consists of representatives from the following organisations:

Building Sector Energy Efficiency Project
Federation of Malaysian Manufacturers
Malaysia Green Building Confederation
Malaysian Sheet Glass Sdn Bhd
Pertubuhan Akitek Malaysia
SIRIM Berhad (Secretariat)
The Institution of Engineers, Malaysia
Universiti Putra Malaysia

Foreword

This Malaysian Standard was developed by the Technical Committee on Energy Efficiency in Buildings (Passive) under the authority of the Industry Standards Committee on Building, Construction and Civil Engineering.

Major modifications of this revision are as follows:

a) improvement to description on passive design strategies especially daylighting and facade design;

b) diagrammatic representation of shading coefficients;

c) improved power intensities and inclusion of Colour Rendering Index (CRI);

d) efficiency classification for motors according to IEC;

e) introduction of MPLV (Malaysia Part Load Value); and

f) prerequisites for optimizing EMS operation.

This Malaysian Standard cancels and replaces MS 1525:2007, *Code of practice on energy efficiency and use of renewable energy for non-residential buildings (First revision).*

This Malaysian Standard has been republished to incorporate editorial amendment AMD 1:2014.

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

Introduction

The purposes of this Malaysian Standard are to:

a) encourage the design, construction, operation and maintenance of new and existing buildings in a manner that reduces the use of energy without constraining creativity in design, building function and the comfort or productivity of the occupants; and appropriately dealing with cost considerations;

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 judgment to comply with minimum standards; and

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

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

The recommendations for good practice in renewable energy applications are classified under the following areas:

a) maximising passive solar design;

b) optimising passive cooling strategies;

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

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

The requirements for energy efficiency are 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 and mechanical ventilation system (Clause 8); and

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

Energy efficiency and use of renewable energy for non-residential buildings - Code of practice

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 rate of electrical energy usage for all purposes is less than 10 W/m^2 (installed) of gross floor area 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 Normative references

The following normative references are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the normative references (including any amendments) applies.

MS 825, *Code of practice for the design of road lighting* (all parts)

MS 2449, *Performance rating of water-chilling packages using the vapor compression cycle*

MS IEC 8995, *Lighting of indoor work places (ISO 8995:2002, IDT)*

MS IEC 60287-3-2, *Electric cables - Calculation of the current rating - Part 3: Sections on operating conditions - Section 2: Economic optimization of power cable size (IEC 60287-3-2:1995, and its Amendment 1:1996, IDT)*

MS IEC 60364, *Electrical installations of buildings*

MS IEC 60364-5-52, *Electrical installations of buildings - Part 5-52: Selection and erection of electrical equipment - Wiring systems (IEC 60364-5-52:2001, IDT)*

MS IEC 60929, *Specification for a.c. supplied electronic ballasts for tubular fluorescent lamps - Performance requirements*

ASHRAE Handbook - *HVAC systems and equipment*

ANSI/SMACNA 006, *HVAC Duct Construction Standards Metal and Flexible, SMACNA*

AHRI 210-240, *Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment*

ANSI/AHRI 340/360, *Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment*

AHRI 550/590, *Performance Rating of Water Chilling Packages Using the Vapor Compression Cycle*

ARI 480, *Refrigerant-Cooled Liquid Coolers, Remote Type*

ANSI/ASHRAE 140, *Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs*

Uniform Building By Laws, 1984

HVAC Air Duct Leakage Test Manual, SMACNA

3 Terms and definitions

For the purpose of this standard, the following 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 units and under designed rating conditions.

3.3 cross ventilation

Cross ventilation is the flow of air through a building due to a wind-generated pressure drop across it.

3.4 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.

3.5 kilowatt refrigeration (kWr)

The unit used to denote refrigeration capacity in kW.

NOTE. 1 kWr = 3412 Btuh

3.6 Overall Thermal Transfer Value (OTTV)

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

3.7 radiant barrier

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

3.8 Roof Thermal Transfer Value (RTTV)

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

3.9 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 unshaded 3 mm clear glass under the same condition.

3.10 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

Designing within the contextual climate and site are the first steps to optimise the benefits provided by the specific environment. Design solutions shall strive to achieve energy efficiency and to use environmentally friendly materials of high quality and durability in order to decrease waste.

A combined architectural, engineering, site planning and landscaping (holistic) approach to designing an energy efficient building would optimise the energy efficiency of a building especially when employing combined passive and active devices. For example, adopting mixed mode systems, i.e. optimising daylighting and thermal comfort while reducing solar heat gain would be a strategy to achieve energy efficiency.

4.2 Passive design strategy

The basic approach towards good passive design is to orientate, to shade, to insulate, to ventilate and to daylight buildings.

Buildings have a primary function to provide an internal environment suitable for the purpose of the building. The architectural passive design consideration in designing a building is primarily influenced by its responsiveness to its site context. The important factors that should be considered include the following:

a) site planning and orientation;

b) daylighting;

c) facade design;

d) natural ventilation;

e) thermal insulation;

f) strategic landscaping; and

g) renewable energy.

These factors are just as important as the selection of active systems or devices to control visual and thermal comfort within the building, and need not impose any significant cost as compared to a more highly serviced building.

4.3 Site planning and orientation

Site planning and orientation is an important consideration in architectural and passive design strategy. The basic principle of good orientation in equatorial region is to avoid exposure of openings to the intense solar radiation from East and West.

The general rule for best orientation of buildings is to avoid facades with most openings facing East or West. Technically for buildings with rectangular plans the buildings' main longitudinal orientation should be on an axis 5° Northeast (see Figure 1 and 2). On narrow sites where the East-West longitudinal orientation may not be possible, the solutions may require other building geometries. In this case, the shading devices recommended may differ according to orientation (refer to shading coefficient values for external shading devices, in 5.3.3).

The orientation of buildings may also contribute to the immediate microclimate of open spaces through the provision of shading and shadowing to the immediate surroundings that will in turn benefit the indoor areas adjacent to it. The microclimate information (air temperature, radiant temperature, relative humidity, air velocity and precipitation, etc) should be analysed for the specific locality.

4.4 Daylighting

Designing with emphasis on day lighting should begin at the preliminary design stage.

A good day lighting system should consider the following:

a) space orientation and organisation;

b) physical (shape and size) and optical properties of glazing through which daylight will transmit or penetrate;

c) internal floor, wall and ceiling surface properties (colour and reflectivity);

d) visual contrast between adjacent surfaces (e.g between walls and ceilings); and

e) protection from visual discomfort (e.g glare and silhouette) caused by external and internal building elements.

Conventional and innovative day lighting strategies that collect transport and distribute light into buildings with deep plans and systems that reduce the need for artificial lighting without increasing solar heat gain, are recommended.

4.4.1 Daylight distribution

The simplest form of description of the daylight distribution, penetration and intensity is the Daylight Factor (DF), expressed as a percentage. This is the ratio of the internal illuminance (E_{internal}) at a point in a room to the instantaneous external illuminance (E_{external}) on a horizontal surface:

$$DF = \frac{E_{\text{internal}}}{E_{\text{external}}} \times 100\ \%$$

As a guide, the brightness inside a building and the associated distribution can be classified by the daylight factors as shown in Tables 1a, 1b and 1c.

Table 1a. Daylight factors and impact

DF (%)	Lighting	Glare	Thermal comfort
> 6.0	Intolerable	Intolerable	Uncomfortable
3.5 - 6.0	Tolerable	Uncomfortable	Tolerable
1.0 - 3.5	Acceptable	Acceptable	Acceptable
< 1.0	Perceptible	Imperceptible	Acceptable

Table 1b. Internal illuminance

DF / Ext (lux)	1	2	3	4	5	6
5 000	50	100	150	200	250	300
10 000	100	200	300	400	500	600
20 000	200	400	600	800	1 000	1 200
30 000	300	600	900	1 200	1 500	1 800
40 000	400	800	1 200	1 600	2 000	2 400
50 000	500	1 000	1 500	2 000	2 500	3 000
60 000	600	1 200	1 800	2 400	3 000	3 600
70 000	700	1 400	2 100	2 800	3 500	4 200
80 000	800	1 600	2 400	3 200	4 000	4 800

Table 1c. Sky conditions

Sky conditions			
Sky type	**Description**	**Cloud cover (%)**	**Sky Illuminance (lux)**
Standard overcast	Sun not visible;sky covered with thick, milky white cloud	100	5 000 - 20 000
Cloudy	Sky partially covered by cloud	> 70	20 000 - 100 000
Intermediate	Sky mostly covered with 30 % to 70 % cloud	30 - 70	30 000 - 100 000
Clear blue sky	Sky with almost no cloud	< 30	50 000 - 100 000

NOTE. In general the sky type in Malaysia can be classified as Intermediate.

The designed DF may be obtained by simulation or architectural modeling of the building design. It is encouraged to model daylight performance by using scaled models or computer simulations, and the selected model conditions should be as close as possible to actual room conditions.

4.5 Facade design

The facade of building is the external face of the building that encompasses the fenestration and other elements that describes the building form and aesthetics, enables indoor climatic control and provides security to occupants from weathering.

A good facade design can help optimise daylighting and thermal comfort. The exterior wall and cladding systems should be designed to provide an integrated solution for the provision of view, daylight control, passive and active solar energy collection (e.g. building integrated photovoltaic, solar water heaters, ventilation systems, etc), and moisture management systems (e.g. dehumidifiers) while minimising heat gain.

One of the most important aspects of façade design is sun-shading. The basic requirement is an understanding of the sun movement in relation to the site by studying the relevant sun path diagrams. The understanding of sun path diagram is also crucial for site planning and orientation as well as daylighting (refer 4.3 and 4.4).

4.5.1 Sun path diagram

Sun path diagrams show the apparent path of the sun across the sky. The position of the sun in sky is defined by two angles: solar azimuth (φ) and solar altitude (β) as shown in Figure 1. Solar azimuth is the clockwise angle between the North reference and the perpendicular projection of the sun down onto the horizontal plane. Solar altitude or also referred to as solar elevation angle is angle of the sun's position and the horizontal plane.

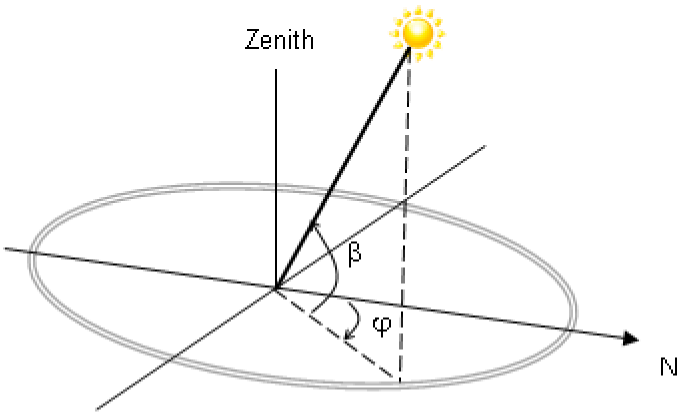


Figure 1. Solar angles

Figure 2 is sun path diagram of Kuala Lumpur. The paths of the sun are represented by elliptical curves. The top elliptical curve represents the path of the sun for summer solstice (approximately Jun 21-22). The middle elliptical curve represents the path of the sun for March Equinox (approximately March 20-21) and September Equinox (approximately September 22-23.) The bottom elliptical curve represents the path of the sun for winter solstice (approximately December 21-22). The vertical curves indicate the location of the sun along the path at a particular time of the day in solar time.

The location of the sun on the diagram at a particular time is defined by two lines namely the concentric lines representing solar altitude (β) with the outermost concentric line representing the horizon and the radial lines representing solar azimuth (φ). Solar angles are required for shading and shadowing analysis.

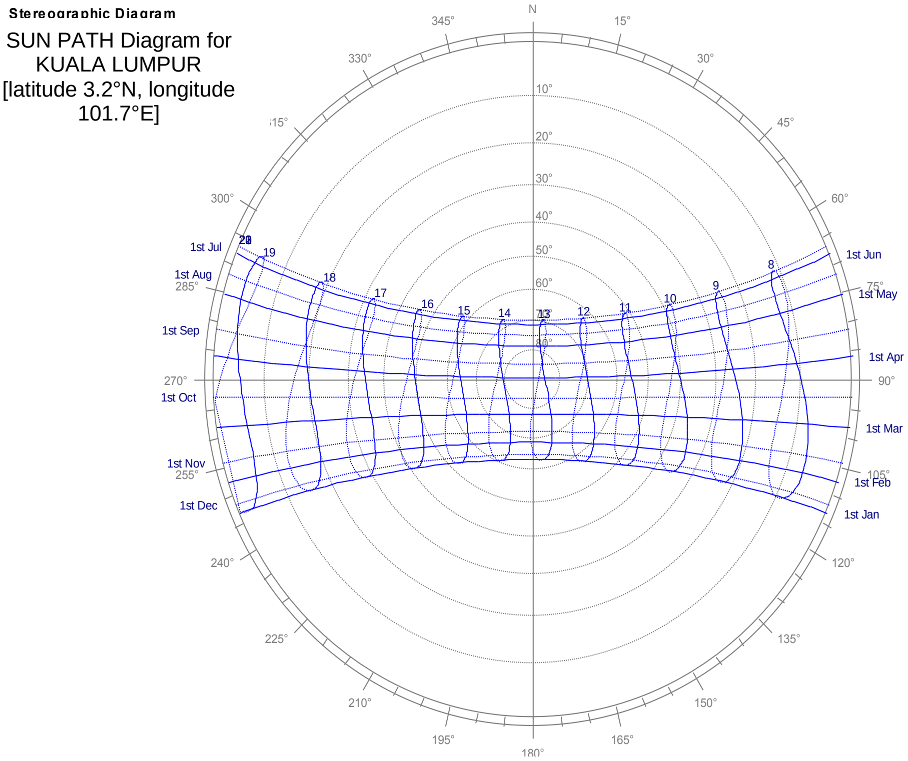


Figure 2. Sunpath diagram

4.5.2 Sun-shading

In determining the best sun-shading design, Shadow Angle Protractor can be superimposed on the sun path diagram to determine the Vertical Shadow Angle (VSA) and the Horizontal Shadow Angle (HSA). Figure 3 shows the superimposed Shadow Angle Protractor on the sun path diagram for Kuala Lumpur to determine VSA and HSA for North-East (NE) façade. For each façade the critical VSA and HSA need to be determined to design the appropriate sun-shading projections. Figure 4 illustrates the various solar angles (solar altitude and solar azimuth) and shadow angles (VSA and HSA) in relation to vertical and horizontal sun-shading

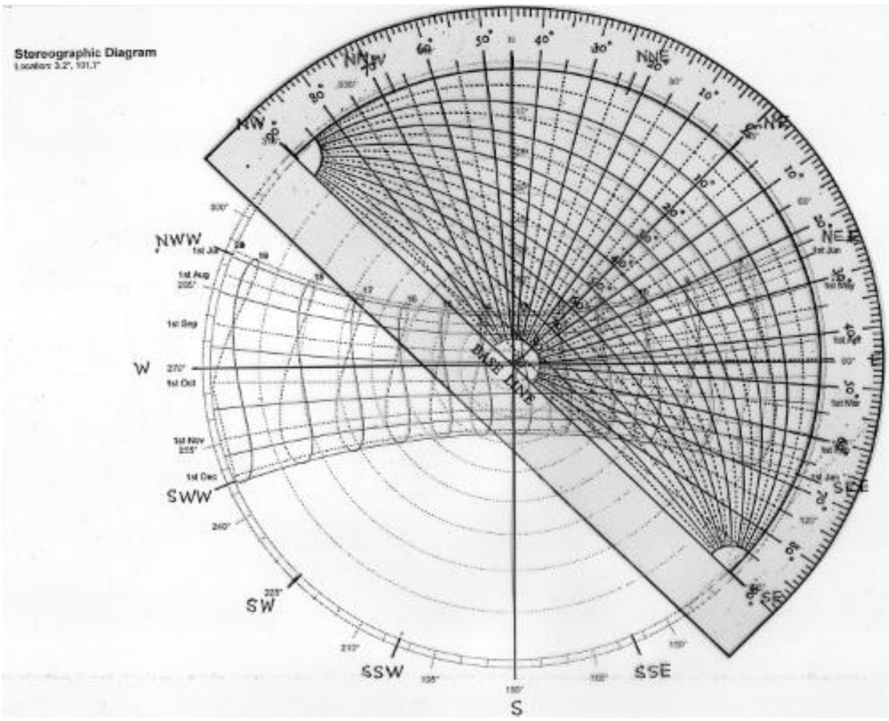
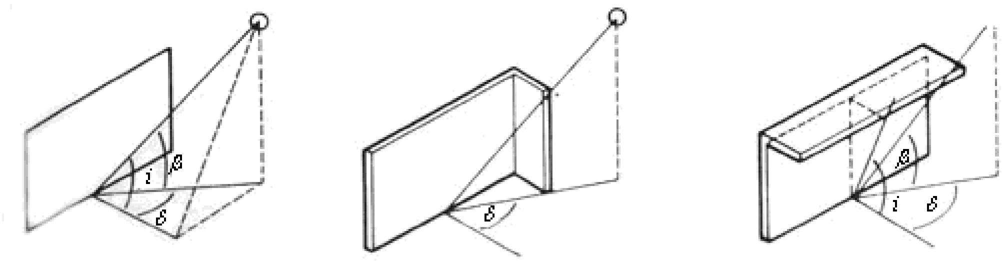


Figure 3. Superimposed shadow angle protractor on sun path diagram



a) Solar azimuth and Solar altitude

b) Altitude and HSA

c) Solar altitude, HSA and VSA

Figure 4. Solar angles and shadow angles

Table 2 presents shadow angle guidelines for preliminary design work. Various tools and softwares are now available to work out detailed sun-shading and overshadowing geometries.

Table 2. Shadow angle guidelines for Kuala Lumpur

Orientation	VSA	HSA		Remarks
		(-)	(+)	
N	65°	60°	60°	Full shading
NE	35°	-	20°	Shading from 09:30 hr
E	35°	-	-	Shading from 09:00 hr
SE	30°	18°	-	Shading from 09:30 hr
S	60°	55°	55°	Full shading
SW	30°	-	15°	Shading until 17:00 hr
W	35°	-	-	Shading until 17:00 hr
NW	45°	15°	-	Full shading

4.6 Natural ventilation

Natural ventilation uses natural forces of wind and buoyancy to deliver sufficient fresh air and air change to ventilate enclosed spaces without active temperature controls or mechanical means. Fresh air is required in buildings to alleviate odours and improve indoor environmental quality. Provisions for naturally ventilated lobby areas, corridors, lift cores, staircases should be encouraged. This could aid 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, spilled air from adjacent spaces is sufficient to provide for the required air change to ventilate the space and provide thermal comfort with reduced energy. Natural ventilation strategies rely on the movement of air through space to equalise pressure.

There are basically two methods for providing natural ventilation:

a) cross ventilation (wind-driven); and

b) stack ventilation (buoyancy-driven).

4.6.1 Cross ventilation

Good cross ventilation design should consider the following:

a) orientate the building to maximise surface exposure to prevailing winds;

b) provide inlets on the windward side (pressure zone) and outlets on the leeward side (suction zone);

c) use architectural features like wing walls and parapets to create positive and negative pressure areas to induce cross ventilation;

d) provide openings on opposite walls for optimum cross ventilation effectiveness. However, if this is not possible, openings can be placed on adjacent walls;

e) design openings to be easily accessible and operable by the occupants;

f) avoid obstructions between inlets and outlets;

g) have equal inlet and outlet areas to maximise airflow;

h) design outlet openings to be slightly larger than inlet openings to produce higher air velocities;

i) locate outlet openings on the windward side at the occupied level; and

j) use good site planning, landscaping and planting strategies to cool incoming air.

4.6.2 Stack ventilation

A good stack ventilation should consider the following:

a) provide at least two ventilation openings, one closer to the floor (inlet) and the other, higher in the space (outlet);

b) maximise the vertical distance between these two sets of openings. Increasing the differential height will produce better airflow;

c) provide equal inlet and outlet areas to maximise airflow;

d) provide adequate openings in stairwells or other continuous vertical elements so that they can work as stack wells. Such spaces may be used to ventilate adjacent spaces because their stack height allows them to displace large volumes of air;

e) use louvers on inlets to channel air intake; and

f) use architectural features like solar chimneys to effectively exhaust the hot indoor air.

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

4.6.3 Air movement

Air movement affects thermal comfort. The presence of air movement enhances evaporative and convective cooling from the skin and can further increase our thermal comfort. Table 3 provides a guide on the impact of air speed on occupants' sensation.

Table 3. Impact of air speed on occupants

Air speed (m/s)	Mechanical effect	Occupant sensation
≤ 0.25	Smoke (from cigarette) indicates movement	Unnoticed, except at low air temperatures
0.25 - 0.5	Flame from a candle flickers	Feels fresh at comfortable temperatures, but draughty at cool temperatures
0.5 - 1.0	Loose papers may be moved. Equivalent to walking speed	Generally pleasant when comfortable or warm, but causing constant awareness of air movement
1.0 - 1.5	Too fast for deskwork with loose papers	Acceptable in warm conditions but can be from slightly to annoyingly draughty
> 1.5	Equivalent to a fast walking speed	Acceptable only in very hot and humid conditions when no other relief is available. Requires corrective measures if comfort and productivity are to be maintained

4.6.4 Window design for daylighting and natural ventilation

Windows form a fundamental component in a building's facade. They provide a relationship between the exterior and interior in the form of light, sound, air and view of the exterior. The size, shape, position and orientation of windows are designed based on intended purposes and prioritised requirements. Table 4 is a guide for the design of windows.

Table 4. Window design

Purpose	Design recommendation
Daylighting	Optimum height and size for required daylight factor
Natural ventilation	Orientation towards prevailing wind direction
Daylighting and view	Size and sill height suited to occupant position and external features
Daylighting and natural ventilation	Size and location should be suited to all parameters

4.7 Thermal insulation

Thermal insulation and thermal mass can play an important role to reduce solar heat gain for passive cooling and decrease energy demand for active cooling of the building interior.

Thermal insulation in buildings can be categorised as 'bulk' or 'resistive insulation' and 'reflective insulation'. Bulk insulation (e.g. mineral wool) is normally used for thermal insulation in walls and roofs, as well as for noise-dampening under a metal roof. It works on the principle of retarding heat transfer due to the properties of low thermal conductivity (k-value) or high thermal resistance (R-value).

Reflective insulation (e.g. aluminium foil) is effective in reducing radiant heat flow into the building interior by creating reflective air spaces a within wall or roof constructions. It works on the principle of reflecting and re-emitting of radiant heat due to the properties of low emissivity (≤ 0.1) and high reflectivity (≥ 0.9).

Thermal mass is solid or liquid material that will absorb and store warmth and coolness until it is needed. It works on the principles of thermal energy storage due to the properties of high specific heat capacity and high density. Building envelope with appropriate thermal mass properties maybe used to advantage as a form of insulation and structural cooling element.

A combination of the two insulation types is a normal practice for buildings with extensive roof areas, such as industrial buildings. For low-rise buildings, thermal insulation is most critical for the roof, since it is the most exposed surface of the building to the sun. The downward heat flow from the roof/ceiling elements is mainly by radiation. For high-rise buildings walls facing east and west become important in terms of thermal insulation and thermal mass provision.

4.8 Strategic landscaping

Strategic landscaping can reduce heat gain through several processes such as shading from the sun, shielding from infiltration at higher levels and the creation of a cooler microclimate around the building. It helps to reduce Urban Heat Island Effect, where highly urbanised and built-up areas are found to be significantly warmer than the rural and less built-up areas surrounding it.

Creating a cooler microclimate around a building can reduce the temperature difference and maybe achieved through planning by maximising areas allocated for landscape (softscape and hardscape) and implementation of aquascape. Appropriate selection of plant types and the choice of materials for the hardscape will help reduce the solar heat gain and reflection at the surrounding spaces. It is also important to properly shade any air-conditioner unit i.e. external condenser, to maximise the efficiency of the condensers.

4.9 Renewable energy

Renewable Energy (RE) is energy which comes from natural resources such as sunlight, wind, tide, geothermal and biomass which are renewable.

In addition to passive design considerations, the applications of RE in buildings should be considered as follows:

a) solar energy;

   i) solar thermal e.g water heating and cooling; and

   ii) photovoltaic e.g electricity.

b) wind energy e.g electricity;

c) biomass and municipal waste e.g gas for electricity generation; and

d) other natural resources e.g rainwater harvesting.

The decision to apply RE systems in a building shall be made at the design and planning stage. The selection of the most suitable RE option should be based on the microclimatic conditions and the availability of the natural resources. Rain water harvesting should also be considered to be integrated into building and/or part of any befitting renewable energy systems. The design solutions for the selected option/s should ensure the effectiveness of the operation to optimise the efficiency of the system.

4.10 Other considerations

In addition to the above, the following aspects should be considered: overall site master planning, the building's internal design such as effective room depth, floor to ceiling height, location of cores, internal layout, building materials and roof design and colour.

5 Building envelope

5.1 General requirement

Fundamentally, the building envelope has to block out heat gain into buildings via conduction and solar radiation.

Simulation studies indicate that heat may be conducted both in and out of the building depending on the time of the day. This is especially so, for a typical office buildings that are air-conditioned during daytime only - heat would be conducted into the buildings during daytime and heat would be conducted out of the building during night time (especially during early morning hours when external temperatures are low). This phenomenon occurs in buildings that have high internal load at night. Internal loads are caused by lightings and equipments that are kept running during night time and these would generate heat within the building. It is therefore important that energy management is well conducted to ensure that night time internal load is kept to the minimum, to ensure that maximum benefit would be derived from the insulation of the building envelope.

An alternative to complying with this clause is available in Clause 10, Building Energy Simulation Method. The Building Energy Simulation Method, allows designer to prove compliance by the same method used to derive the OTTV constants. In addition, Clause 10 applies the whole-building energy efficiency concept, and credits are accepted for on-site renewable energy sources, improved ACMV and daylight use.

5.2 Concept of OTTV

The solar heat gain through the 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, a very important 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 is simple, and was developed for air-conditioned building. It is also a useful indicator for non air-conditioned buildings. The OTTV aims at achieving the design of building envelope to cut down external heat gain and hence reduce the cooling load of the air-conditioning system.

The OTTV of the building envelope for a building, having a total air-conditioned area exceeding 1000 m^2 should not exceed 50 W/m^2 and should meet the requirement specified in 5.4.2.

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

where

$$OTTV = \frac{(A_1 \times OTTV_1) + (A_2 \times OTTV_2) + ... + (A_n \times OTTV_n)}{A_1 + A_2 + ... + A_n} \quad (1)$$

A_1 is the gross exterior wall area for orientation 1; and

$OTTV_1$ is the *OTTV* value for orientation 1 from equation (2).

5.2.2 For a fenestration at a given orientation, the formula is given as below:

$$OTTV_i = 15\alpha(1 - WWR)U_w + 6(WWR)U_f + (194 \times OF \times WWR \times SC) \quad (2)$$

where

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

α is the solar absorptivity of the opaque wall, as in Table 6;

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

U_f is the thermal transmittance of fenestration system (W/m^2 K);

OF is the solar orientation factor; as in Table 5; and

SC is the shading coefficient of the fenestration system.

$SHGC$ is solar heat gain coefficient where $SHGC = SC \times 0.87$.

Table 5. Solar orientation factors

Orientation	*OF*
North	0.90
Northeast	1.09
East	1.23
Southeast	1.13
South	0.92
Southwest	0.90
West	0.94
Northwest	0.90

NOTES:

1. Table 5 specifies *OF* for the various orientation of the fenestration. For the calculation of *OF*, it is recommended that the nearest predominant orientation be selected.
2. A fenestration system may consist of a glazing material such as glass, a shading device and a combination of both.

Table 6. Solar absorbtivity

Colour	Suggested value of α
Light	< 0.40
Medium	0.40 to 0.70
Dark	> 0.70

NOTE. Table 5 and Table 6 is based on updated (2006) data to match with the current test reference year (TRY) weather data for Kuala Lumpur. Data collected indicates that the average vertical East surface solar radiation is significantly higher than the vertical West surface. This trend is seen to be caused by the normally clear sky in the morning and cloudy sky in the afternoon.

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

$$SC = SC_1 \times SC_2 \quad (3)$$

where

SC is the effective shading coefficient of the fenestration system;

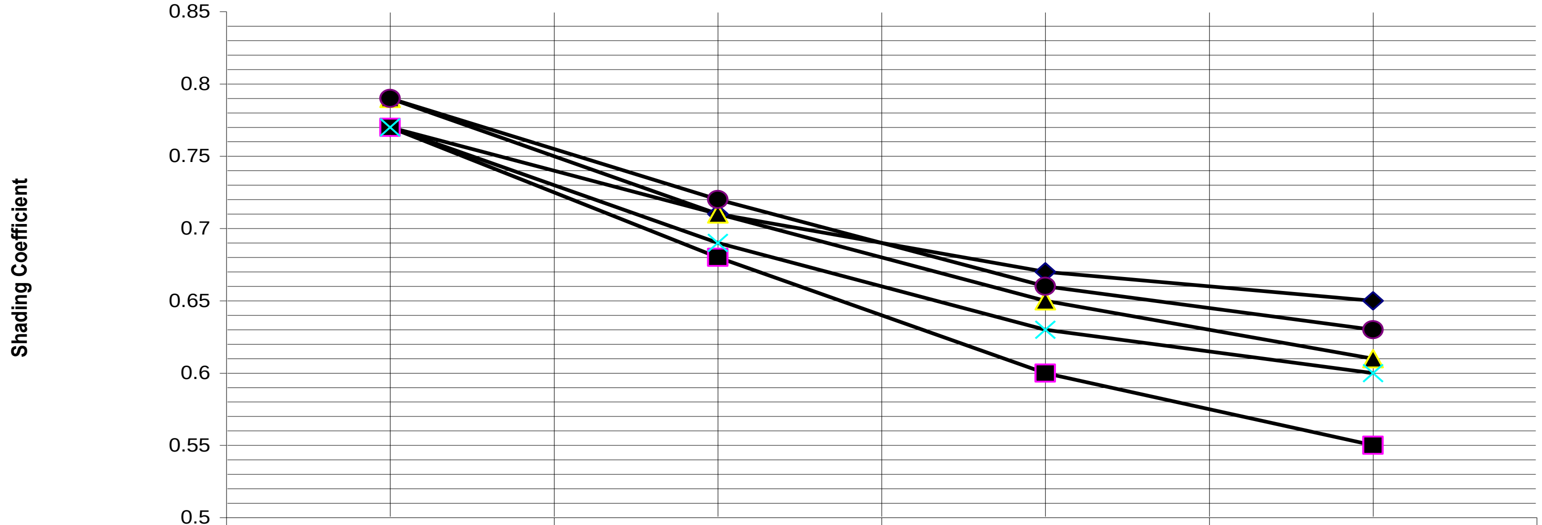
SC_1 is the shading coefficient of sub-system 1 (e.g. glass); and

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 normal incident angle.

5.3.3 The shading coefficient of external shading devices can be obtained from following Figures 5, 6, 7 and 8.

HORIZONTAL PROJECTION SHADING COFFICIENTS



	0,35	0.6	1	1.65
North/South	0.77	0.71	0.67	0.65
East	0.77	0.68	0.6	0.55
West	0.79	0.71	0.65	0.61
NE/SW	0.77	0.69	0.63	0.6
NW/SE	0.79	0.72	0.66	0.63

R1 (Projection / Window Height)

SHADING COFFICIENTS HORIZONTAL PROJECTIONS

R1	**0.3 to 0.4**	**0.5 to 0.7**	**0.8 to 1.2**	**1.3 to 2.0**
North/South	0.77	0.71	0.67	0.65
East	0.77	0.68	0.6	0.55
West	0.79	0.71	0.65	0.61
NE/SW	0.77	0.69	0.63	0.6
NW/SE	0.79	0.72	0.66	0.63

Figure 5. Horizontal projection shading coefficients

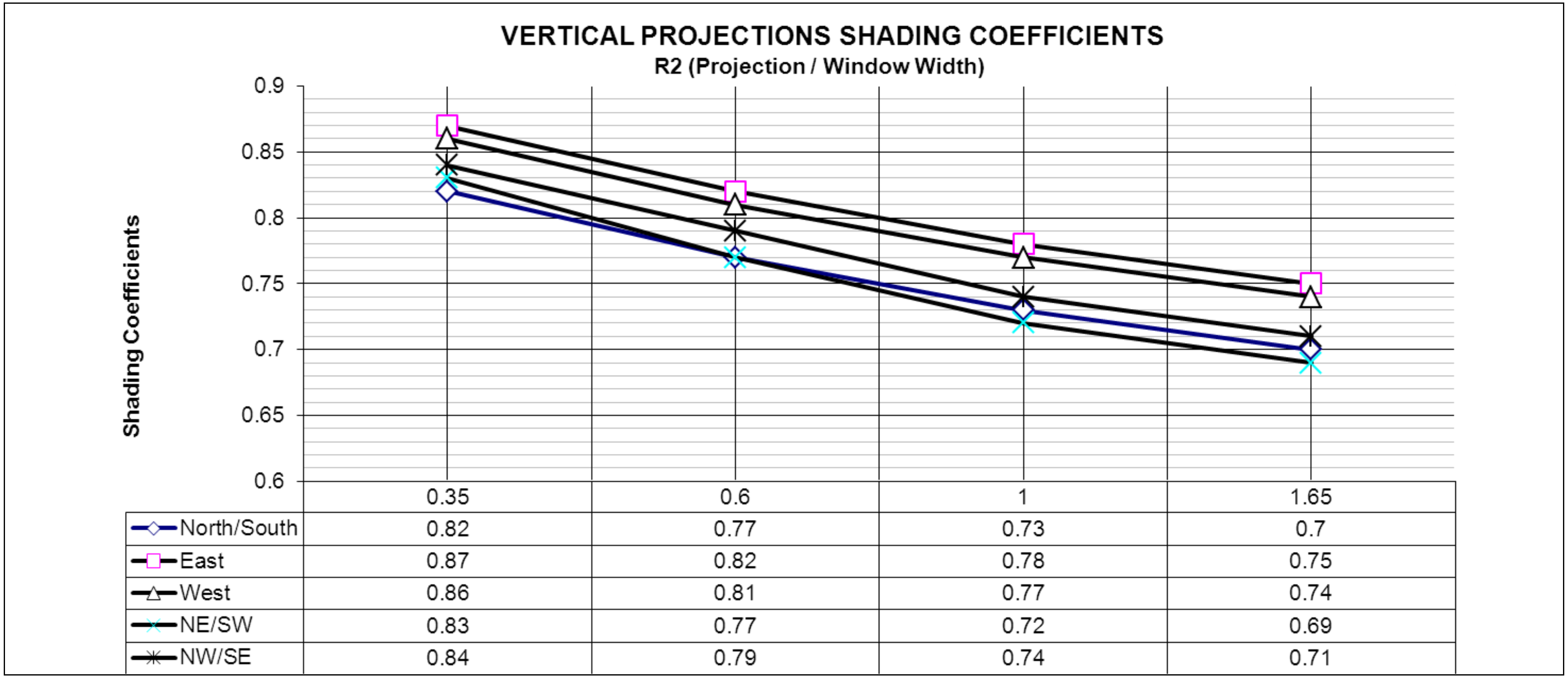
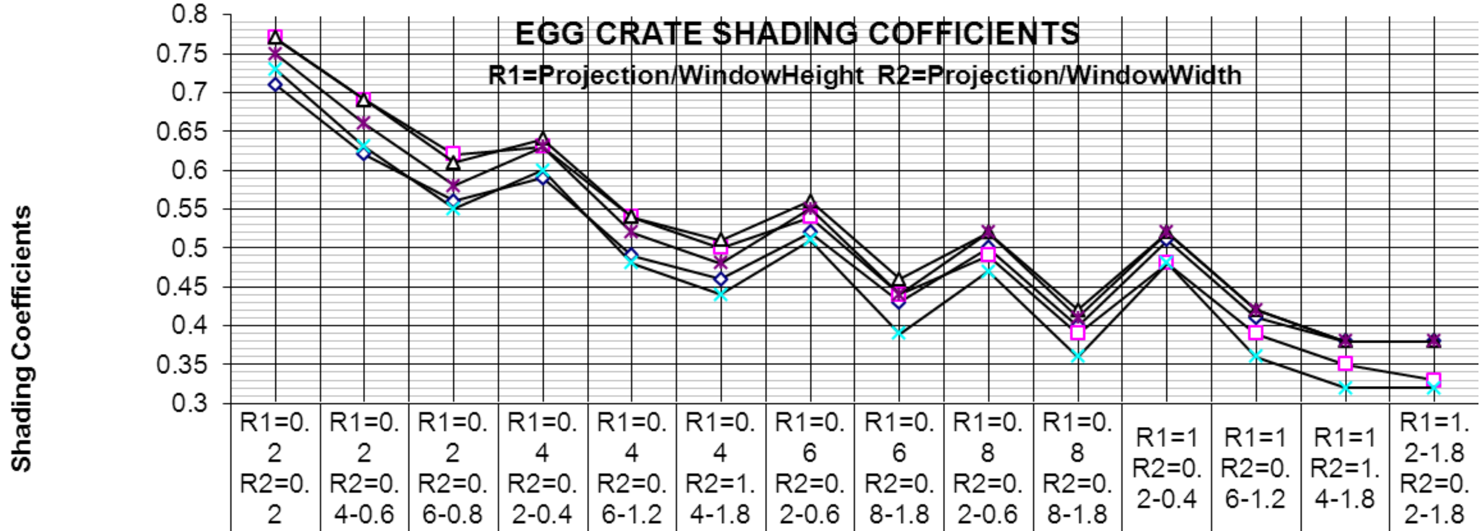


Figure 6. Vertical projection shading coefficients

VERTICAL PROJECTIONS SHADING COEFFICIENTS

R2	0.3 to 0.4	0.5 to 0.7	0.8 to 0.12	1.3 to 2.0
North/South	0.82	0.77	0.73	0.7
East	0.87	0.82	0.78	0.75
West	0.86	0.81	0.77	0.74
NE/SW	0.83	0.77	0.72	0.69
NW/SE	0.84	0.79	0.74	0.71



	R1=0.2 R2=0.2	R1=0.2 R2=0.4-0.6	R1=0.2 R2=0.6-0.8	R1=0.4 R2=0.2-0.4	R1=0.4 R2=0.6-1.2	R1=0.4 R2=1.4-1.8	R1=0.6 R2=0.2-0.6	R1=0.6 R2=0.8-1.8	R1=0.8 R2=0.2-0.6	R1=0.8 R2=0.8-1.8	R1=1 R2=0.2-0.4	R1=1 R2=0.6-1.2	R1=1 R2=1.4-1.8	R1=1.2-1.8 R2=0.2-1.8
North/South	0.71	0.62	0.56	0.59	0.49	0.46	0.52	0.43	0.5	0.4	0.51	0.41	0.38	0.38
East	0.77	0.69	0.62	0.63	0.54	0.5	0.54	0.44	0.49	0.39	0.48	0.39	0.35	0.33
West	0.77	0.69	0.61	0.64	0.54	0.51	0.56	0.46	0.52	0.42	0.52	0.42	0.38	0.38
NE/SW	0.73	0.63	0.55	0.6	0.48	0.44	0.51	0.39	0.47	0.36	0.48	0.36	0.32	0.32
NW/SE	0.75	0.66	0.58	0.63	0.52	0.48	0.55	0.44	0.52	0.41	0.52	0.42	0.38	0.38

Figure 7. Egg crate shading coefficients

EGG CRATE SHADING COFFICIENTS

R1&R2	R1=0.2 R2=0.2	R1=0.2 R2=0.4-0.6	R1=0.2 R2=0.6-0.8	R1=0.4 R2=0.2-0.4	R1=0.4 R2=0.6-1.2	R1=0.4 R2=1.4-1.8	R1=0.6 R2=0.2-0.6	R1=0.6 R2=0.8-1.8	R1=0.8 R2=0.2-0.6	R1=0.8 R2=0.8-1.8	R1=1 R2=0.2-0.4	R1=1 R2=0.6-1.2	R1=1 R2=1.4-1.8	R1=1 2-1.8 R2=0.2-1.8
North/South	0.71	0.62	0.56	0.59	0.49	0.46	0.52	0.43	0.5	0.4	0.51	0.41	0.38	0.38
East	0.77	0.69	0.62	0.63	0.54	0.5	0.54	0.44	0.49	0.39	0.48	0.39	0.35	0.35
West	0.77	0.69	0.61	0.64	0.54	0.51	0.56	0.46	0.52	0.42	0.52	0.42	0.38	0.38
NE/SW	0.73	0.63	0.55	0.6	0.48	0.44	0.51	0.39	0.47	0.36	0.48	0.36	0.32	0.32
NW/SE	0.75	0.66	0.58	0.63	0.52	0.48	0.55	0.44	0.52	0.41	0.52	0.42	0.38	0.38

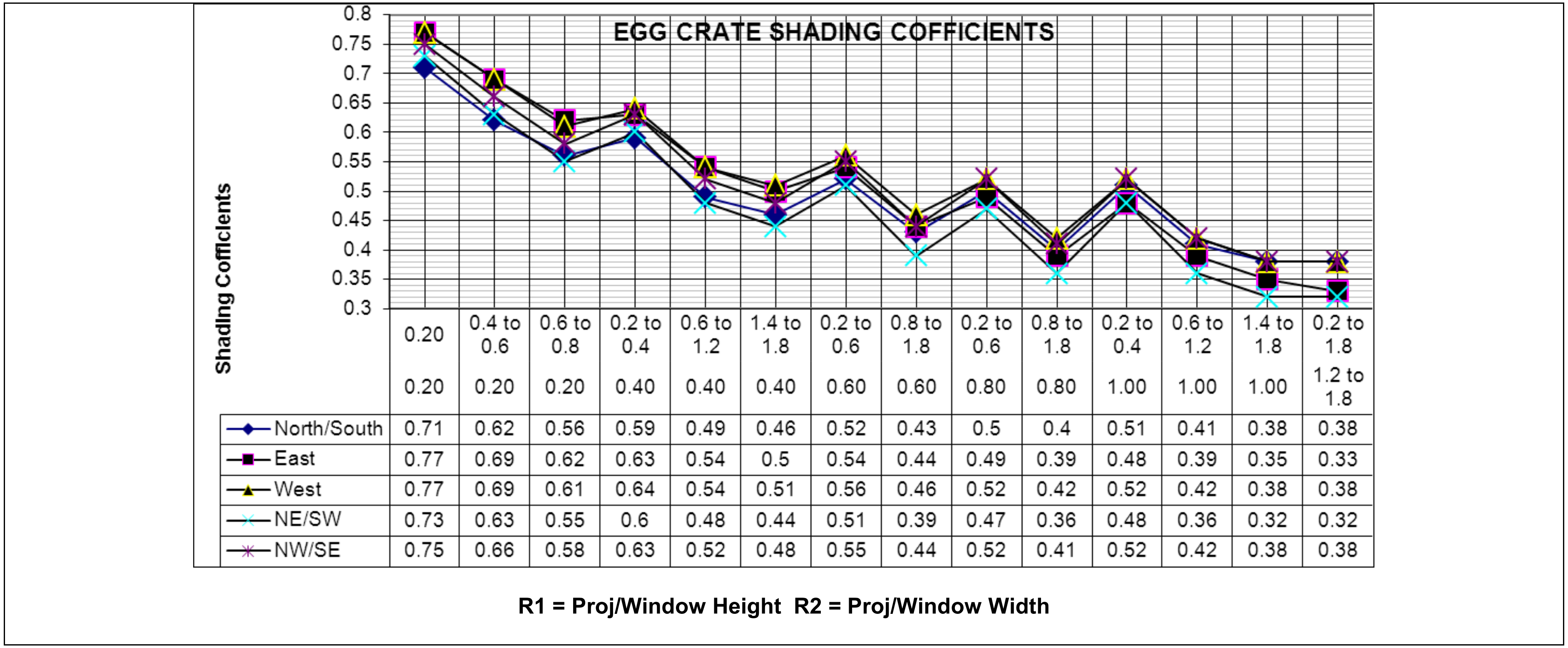


Figure 8. Egg Crate Shading Coefficients

EGG CRATE SHADING COFFICIENTS

R1	0.20	0.20	0.20	0.40	0.40	0.40	0.60	0.60	0.80	0.80	1.00	1.00	1.00	1.2 to 1.8
R2	0.20	0.4 to 0.6	0.6 to 0.8	0.2 to 0.4	0.6 to 1.2	1.4 to 1.8	0.2 to 0.6	0.8 to 1.8	0.2 to 0.6	0.8 to 1.8	0.2 to 0.4	0.6 to 1.2	1.4 to 1.8	0.2 to 1.8
North/South	0.71	0.62	0.56	0.59	0.49	0.46	0.52	0.43	0.5	0.4	0.51	0.41	0.38	0.38
East	0.77	0.69	0.62	0.63	0.54	0.5	0.54	0.44	0.49	0.39	0.48	0.39	0.35	0.33
West	0.77	0.69	0.61	0.64	0.54	0.51	0.56	0.46	0.52	0.42	0.52	0.42	0.38	0.38
NE/SW	0.73	0.63	0.55	0.6	0.48	0.44	0.51	0.39	0.47	0.36	0.48	0.36	0.32	0.32
NW/SE	0.75	0.66	0.58	0.63	0.52	0.48	0.55	0.44	0.52	0.41	0.52	0.42	0.38	0.38

5.4 Daylighting

5.4.1 Saving in energy consumption for lighting due to daylighting technique is greater than the cooling energy penalties from additional glazed surface provided that the building envelope is carefully designed for daylighting. Fenestration for the purpose of daylighting should be designed to prevent direct solar radiation while allowing diffused light for effective daylighting. The recommended range of daylight factor is 1.0 % to 3.5 %.

5.4.2 In order to take advantage of daylight harvesting, the visible light transmission of the daylight fenestration system should not be less than 30 %.

Alternative compliance is to provide lighting simulation study showing daylight factor of 1 % at a minimum depth of 3 m from the facade building. This simulation study should have glare protection devices in place. The glare protection devices should limit the luminance intensity of the daylight fenestration to a value less than 2,000 cd/m² at the worst case condition with direct sunlight impacting on the daylight fenestration.

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 7.

Table 7. Maximum U-value for roof (W/m²K)

Roof Weight Group	Maximum U-Value (W/m²K)
Light (Under 50 kg/m²)	0.4
Heavy (Above 50 kg/m²)	0.6

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:

$$U_r = \frac{(A_{r1} \times U_{r1}) + (A_{r2} \times U_{r2}) + ... + (A_{rn} \times U_{rn})}{A_{r1} + A_{r2} + ... + A_{rn}} \quad (4)$$

where

U_r is the average thermal transmittance of the gross area (W/m² K);

U_{r1} is the respective thermal transmittance of different roof sections (W/m² K*);* and

A_{r1} is the respective area of different roof sections (m²).

The average weight of the roof is calculated as follows:

$$W_r = \frac{(A_{r1} \times W_{r1}) + (A_{r2} \times W_{r2}) + ... + (A_{r\,n} \times W_{r\,n})}{A_{r1} + A_{r2} + ... + A_{r\,n}} \quad (5)$$

where,

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

A_{r1} is the respective area of different roof sections (m^2); and

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

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 recommended RTTV is 25 W/m^2.

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

$$RTTV = \frac{\left(A_r \times U_r \times T_{Deq}\right) + (A_s \times U_s \times \Delta T) + (A_s \times SC \times SF)}{A_0} \quad (6)$$

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 8;

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 construction have been standardised as in Table 8:

Table 8. Equivalent temperature difference for roof

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

5.6.5 Solar factor

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

$$SF = 323 \text{ x } OF \tag{7}$$

where

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

OF is the orientation factor with reference to the orientation of the roof and the pitch angle of its skylight and is given as in Table 9.

Table 9. Solar orientation factor for roof

Slope angle (°)	Orientation				
	North/South	East	West	Northeast/ Southeast	Northwest/ Southwest
5 - 30	1.00	1.01	0.99	1.01	0.99
35 - 45	0.88	0.96	0.83	0.94	0.84
50 - 55	0.77	0.88	0.73	0.84	0.73
60 - 65	0.68	0.81	0.66	0.77	0.65
NOTE. The orientation 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:

$$RTTV = \frac{(A_{01} \text{ x } RTTV_1) + (A_{02} \text{ x } RTTV_2) + \ldots.+ (A_{0n} \text{ x } RTTV_n)}{A_{01} + A_{02} + \ldots.+ A_{0n}} \tag{8}$$

where

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

A_{0i} is the respective area of different roof sections (m^2); and

$RTTV_i$ is the respective roof thermal transfer 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 Submission procedure

The following information shall be provided by a professional architect or professional engineer:

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.

5.8 Air leakage

5.8.1 General requirement

The building envelope should provide adequate barrier to prevent uncontrolled mixing of outside air with air-conditioned space.

NOTE. The energy required to remove moisture from uncontrolled leakages of outside air into the building is one of the highest energy load contributed by the external environment into a building in the tropical climate. In a leaky building, the energy used to remove moisture would be higher than the energy used to remove heat contributed by solar radiation.

5.8.2 All open-able fenestration and doors between conditioned space and non-conditioned space should have an advisory label on it requesting that fenestration and doors are to be kept closed when not in use.

5.8.3 Any duct that provides a connection between conditioned space to outside air should have a damper in between to prevent air leakages into conditioned space when the duct is not in operation.

5.8.4 Where the false ceiling is used as return air plenum to the AHU (air handling unit); partitions should be placed in the false ceiling space between conditioned space and naturally ventilated space to prevent air leakages.

5.8.5 Vestibules

It is recommended that a door that separates conditioned space from the exterior is protected by an enclosed vestibule, with all doors opening into and out of the vestibule equipped with self-closing devices. Vestibules should be designed so that in passing through the vestibule it is not necessary for the interior and exterior doors to open at the same time. Interior and exterior doors should have a minimum distance between them of not less than 2.5 meters when in closed position.

Exceptions to 5.8.5 can be made in the following cases:

a) doors in buildings less than four stories above ground;

b) doors are not intended to be used as a building entrance door, such as mechanical or electrical equipment rooms;

c) doors opening directly from a residential unit;

d) doors that open directly from a space less than 300 sq meter in area;

e) doors in building entrances with revolving doors; and

f) doors used in primarily to facilitate vehicular movement or material handling and adjacent personnel doors.

5.8.6 It is recommended that the following areas of the building envelope be sealed, caulked, gasketed, or weather-stripped to minimise air leakage:

a) joints around fenestration and door frames;

b) junctions between walls and foundations, between walls at building corners, between walls and structural floors or roofs, and between walls and roof or wall panels;

c) openings at penetrations of utility services through roofs, walls and floors;

d) site-built fenestration and doors;

e) building assemblies used as ducts or plenums;

f) joints, seams, and penetrations of vapor retarders; and

g) all other openings in the building envelope surrounding conditioned space.

5.8.7 The above, shall not reduce the outside air ventilation rate as specified in 8.1.4.

6 Lighting

6.1 Introduction

The compliance to this clause requires the compliance to MS ISO 8995 (which is the minimum safety standard for interior lighting) and MS 825 (which is the minimum safety standard for exterior spaces).

6.1.1 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 shall 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. The prescribed colour rendering index (CRI) for a particular task application should also be considered in conjunction with the illuminance level.

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

Table 10. Recommended average illuminance levels

Task and Applications	Illuminance (Lux)	Minimum CRI
a) Lighting for infrequently used area:		
- Minimum service illuminance	20	30
- Interior walkway and car-park	100	40
- Hotel bedroom	100	60
- Lift interior	100	40
- Corridor, passageways, stairs	100	40
- Escalator, travellator	150	40
- Entrance and exit	100	60
- Staff changing room, locker and cleaner room, cloak room, lavatories, stores.	100	60
- Entrance hall, lobbies, waiting room	100	60
- Inquiry desk	300	80
- Gate house	200	80
b) Lighting for working interiors		
- Infrequent reading and writing	200	80
- General offices, shops and stores, reading and writing	300 - 400	80
- Drawing office	300 - 400	85
- Restroom	150	80
- Restaurant, canteen, cafeteria	200	80
- Kitchen	150 - 300	80
- Lounge	150	60
- Bathroom	150	80
- Toilet	100	60
- Bedroom	100	80
- Class room, library	300 - 500	80
- Shop/supermarket/department store	200 - 750	80
- Museum and gallery	300	80
c) Localised lighting for exacting task		
- Proof reading	500	80
- Exacting drawing	1000	80
- Detailed and precise work	2000	80

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 Where discharge lamps are used, ballast loss shall not exceed the values in Table 10a.

Table 10a. Recommended Loss Values for Ballast

No	Lamp Type	Maximum Allowable Losses
1	Fluorescent lamps, compact fluorescent	4 W
2	Sodium 70 W	15 W
3	Sodium 100 W	20 W
4	Sodium 150 W	22 W
5	Sodium 250 W	30 W
6	Sodium 400 W	45 W
7	Metal Halide 70 W	16 W
8	Metal Halide 100 W	16 W
9	Metal Halide 150 W	20 W
10	Metal Halide 250 W	34 W
11	Metal Halide 400 W	40 W
12	Metal Halide 1000 W	60 W
13	Mercury 80 W	12 W
14	Mercury 125 W	15 W
15	Mercury 250 W	18 W
16	Mercury 400 W	28 W

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

6.3 Maximum allowable power intensity for illumination systems

Lighting load shall not exceed the corresponding maximum power intensity value as specified in Table 11. For Table 11 assumes power intensity to include ballast losses, luminaire performances and all requirements for compliance to minimum safety standards as prescribed in 6.1.

Table 11. Unit lighting power (including ballast loss) allowance

Type of Usage	Max. lighting power intensity (W/m²)
a) Lighting for infrequently used area:	
- Minimum service illuminance	3 W/m²
- Interior walkway and car-park	5 W/m²
- Hotel bedroom	5 W/m²
- Lift interior	5 W/m²
- Corridor, passageways, stairs	5 W/m²
- Escalator, travellator	6 W/m²
- Entrance and exit	5W/m²
- Staff changing room, locker and cleaner room, cloak room, lavatories, stores.	5 W/m²
- Entrance hall, lobbies, waiting room	5 W/m²
- Inquiry desk	11 W/m²
- Gate house	8 W/m²
b) Lighting for working interiors	
- Infrequent reading and writing	8 W/m²
- General offices, shops and stores, reading and writing	14 W/m²
- Drawing office	14 W/m²
- Restroom	6 W/m²
- Restaurant, canteen, cafeteria	8 W/m²
- Kitchen	11 W/m²
- Lounge	6 W/m²
- Bathroom	6 W/m²
- Toilet	5 W/m²
- Bedroom	5 W/m²
- Class room, library	18 W/m²
- Shop/supermarket/department store	24 W/m²
- Museum and gallery	11 W/m²
- Proof reading	18 W/m²
- Exacting drawing	40 W/m²
- Detailed and precise work	60 W/m²

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 the power intensities in Table 12. The area shall be the net site area excluding the built-up area.

Table 12. Building exteriors maximum lighting power intensity allowance

Building Exteriors	Max. lighting power intensity (W/m^2)
Uncovered parking areas	2
Uncovered driveways	2
Pedestrian malls	5
Landscape areas	5

6.4.3 For facilities with multiple buildings, the building exterior 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 should be provided with manual, automatic or programmable controls. For lighting loads exceeding 100 kW automatic control should be provided.

6.5.2 Lighting zones control for daylight energy savings scheme. The minimum number of lighting control for daylight energy savings scheme should take into consideration the following criteria:

a) all spaces enclosed by walls or ceiling height partitions should 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 should be at least one switch for each 1 kW of connected load; and

d) availability of lighting zones control for energy saving.

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 should not be credited as increasing the number of controls to meet the requirements of this subclause.

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) should be controlled in accordance with the work activities, and controls may be centralised in remote locations.

6.6 Control accessibility

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

a) lighting control requirements for spaces which shall 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 should 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.

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

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

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

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

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

a) the design 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

These subclauses apply to the energy efficiency requirements of electric motors, cables, 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 to optimise the cost of ownership. Cost of ownership includes the capital cost of the equipment and the cost of energy used over the equipment life time. The cost of energy used shall take into account the future electricity tariff increases, whether due to gas subsidy removal or basic escalation, or CPI (consumer price index) based.

Supply system voltage has significant impact on losses. Hence, the supply voltage should be maintained as close as possible to the design/optimum voltage of the equipment installed. It shall be noted that the nominal low voltage (LV) supply in Malaysia has been rationalised to 230/400 V from the previous 240/415 V, while the higher voltages remain as they are.

Supply voltage should also consider the magnitudes of loads fed and the supply distances from the local voltage transformation substation, especially for large constant loads with high load factors.

7.1 Alternating Current (A.C.) Electric motors

A.C. 2 pole, 4 pole and 6 pole, 3 phase induction motors, in the range 0.75 kW to 370 kW should be specified as high efficiency motors (IEC high efficiency motors, efficiency class IE2), where appropriate as mentioned under clause 7.1.2.

7.1.1 Output rating and duty

Unless specific circumstances apply, motor continuous rating should not exceed 30 % of its estimated maximum load.

7.1.2 Motor efficiencies

Only motors of IE2 (High Efficiency) and IE3 (Premium Efficiency) classification as shown in Tables 13, 14 and 15 should be used where operating hours exceed 750 hr per year. Decisions on motor selection between IE2 and IE3 should be done on an economic justification basis.

Table 13. Efficiency Class Definition for 2-Pole Motors

Motor Capacity (kW)	Motor Efficiency (%)		
	Motor Class IE3	Motor Class IE2	Motor Class IE1
0.75	80.7	77.4	72.1
1.1	82.7	79.6	75.0
1.5	84.2	81.3	77.2
2.2	85.9	83.2	79.7
3	87.1	84.6	81.5
4	88.1	85.8	83.1
5.5	89.2	87.0	84.7
7.5	90.1	88.1	86.0
11	91.2	89.4	87.6
15	91.9	90.3	88.7
18.5	92.4	90.9	89.3
22	92.7	91.3	89.9
30	93.3	92.0	90.7
37	93.7	92.5	91.2
45	94.0	92.9	91.7
55	94.3	93.2	92.1
75	94.7	93.8	92.7
90	95.0	94.1	93.0
110	95.2	94.3	93.3
132	95.4	94.6	93.5
160	95.6	94.8	93.8
200	95.8	95.0	94.0
220	95.8	95.0	94.0
250	95.8	95.0	94.0
300	95.8	95.0	94.0
330	95.8	95.0	94.0
375	95.8	95.0	94.0

Table 14. Efficiency Class Definition for 4-Pole Motors

Motor Capacity (kW)	Motor Efficiency (%)		
	Motor Class IE3	Motor Class IE2	Motor Class IE1
0.75	82.5	79.6	72.1
1.1	84.1	81.4	75.0
1.5	85.3	82.8	77.2
2.2	86.7	84.3	79.7
3	87.7	85.5	81.5
4	88.6	86.6	83.1
5.5	89.6	87.7	84.7
7.5	90.4	88.7	86.0
11	91.4	89.8	87.6
15	92.1	90.6	88.7
18.5	92.6	91.2	89.3
22	93.0	91.6	89.9
30	93.6	92.3	90.7
37	93.9	92.7	91.2
45	94.2	93.1	91.7
55	94.6	93.5	92.1
75	95.0	94.0	92.7
90	95.2	94.2	93.0
110	95.4	94.5	93.3
132	95.6	94.7	93.5
160	95.8	94.9	93.8
200	96.0	95.1	94.0
220	96.0	95.1	94.0
250	96.0	95.1	94.0
300	96.0	95.1	94.0
330	96.0	95.1	94.0
375	96.0	95.1	94.0

Table 15. Efficiency Class Definition for 6-Pole Motors

Motor Capacity (kW)	Motor Efficiency (%)		
	Motor Class IE3	Motor Class IE2	Motor Class IE1
0.75	78.9	75.9	70.0
1.1	81.0	78.1	72.9
1.5	82.5	79.8	75.2
2.2	84.3	81.8	77.7
3	85.6	83.3	79.7
4	86.8	84.6	81.4
5.5	88.0	86.0	83.1
7.5	89.1	87.2	84.7
11	90.3	88.7	86.4
15	91.2	89.7	87.7
18.5	91.7	90.4	88.6
22	92.2	90.9	89.2
30	92.9	91.7	90.2
37	93.3	92.2	90.8
45	93.7	92.7	91.4
55	94.1	93.1	91.9
75	94.6	93.7	92.6
90	94.9	94.0	92.9
110	95.1	94.3	93.3
132	95.4	94.6	93.5
160	95.6	94.8	93.8
200	95.8	95.0	94.0
220	95.8	95.0	94.0
250	95.8	95.0	94.0
300	95.8	95.0	94.0
330	95.8	95.0	94.0
375	95.8	95.0	94.0

7.2 Cabling

7.2.1 Whilst minimum sizes of cables can be determined from MS IEC 60364-5-52, 7.2.2 can provide optimisation of cables to include cable losses.

7.2.2 The cross-section area of the cables and wires shall can be optimised for energy savings and economic considerations by the method prescribed in MS IEC 60287-3-2 (which include losses due to I^2R, laying conditions and harmonics).

7.2.3 Besides the cable size selection, cable laying practices impact the economic aspects of power system cabling. Cable ratings are normally "derated" for the different laying methods, especially where multiple single core cable are laid in common cable trenches, and the laying of multiple cables in close proximity, resulting in the need for larger cables or multiple circuits to feed the desired loads.

7.3 Transformers

7.3.1 All supply voltage transformers in the building's electrical system shall be selected based on their overall efficiency according to their load profile, taking account of the capital cost and cost of losses. Such a selection can be based on the following typical loss characteristics for the different transformer ratings as shown in Tables 16, 17 and 18. The losses indicated in Tables 16, 17 and 18 are valid for low voltage distribution transformers and shall be applicable for secondary windings from 400 V to 433 V.

Table 16. Table of transformer losses for 6600/433 V and 11000/433 V

Capacity (kVA)	No-Load Loss (W)	On-Load Loss (W)	Total Losses (W)	Efficiency
100	300	1 500	1 800	**98.23**
300	600	2 800	3 400	**98.86**
500	1 000	4 100	5 100	**98.99**
750	1 200	6 000	7 200	**99.05**
1000	1 400	7 000	8 400	**99.16**

Table 17. Table of transformer losses for 22000/433 V

Capacity (kVA)	No-Load Loss (W)	On-Load Loss (W)	Total Losses (W)	Efficiency
100	240	1 600	1 840	**98.19**
300	700	4 400	5 100	**98.33**
500	900	7 300	8 200	**98.39**
750	1 200	9 200	10 400	**98.63**
1000	1 500	11 700	13 200	**98.70**

Table 18. Table of transformer losses for 33000/433 V

Capacity (kVA)	No-Load Loss (W)	On-Load Loss (W)	Total Losses (W)	Efficiency
100	300	1 500	1 800	**98.23**
300	730	4 500	5 230	**98.29**
500	1 020	7 180	8 200	**98.39**
750	1 385	9 200	10 085	**98.61**
1000	1 665	11 850	12 515	**98.67**
1500	2 200	15 000	17 200	**98.87**

7.3.2 Assessment of transformer efficiency in terms of load and no load losses may be effected using the following:

$$\text{Transformer loss percentage} = \frac{(LL + NLL) \times 100}{P.F \times KVA}$$

Where

LL is load losses in kW (winding losses);

NLL is no load losses in kW (iron losses);

$P.F$ is power factor of load; and

KVA is rated transformer capacity in KVA.

Loss calculations would be: Iron (no load) loss + copper (load) loss.

Iron losses = NLL x 8760 kWh/year, where NLL is the iron (no load loss) loss in kW Copper, or load losses = LLF x LL x 8760 kWh/year, where LLF is the loss load factor (nominally 0.3 x LF + 0.7 x LF^2) and the LL is the copper loss in kW at full load.

The total loss should be summed over the transformer life and calculated on a "net present worth" basis over that period at a reasonable discount factor, and at estimated escalating economic tariffs over the same period.

Other methods for selection of transformer that can be adopted include assessment of "Total Present Worth" of "Capital cost plus the capitalisation of the energy losses over the transformer lifetime".

7.3.3 Transformer configuration should maintain a firm capacity that meets the full load requirements and shall not exceed 150 % of the load demand.

7.3.4 Distribution transformers should be located as close as possible to their load centres. As a general guide Table 19 can be used for this purpose.

Table 19. Location of distribution transformers

Load fed by transformer	Distance of transformer from load centres
> 600 A	Not more than 20 meters
300 A to 600 A	Not more than 100 meters

7.3.5 Where harmonics content is significant, a transformer with higher harmonics withstand capability should be selected.

7.4 Inverters

Inverters or variable speed drives (VSDs) should be used for motors serving fluctuating loads. VSDs can reduce energy consumption by adjusting motor speeds to cater for variable torque loads like fans and pumps, which traditionally vary their output by energy consuming mechanical means.

These inverters can also serve as motor starting mechanisms/devices to minimise voltage fluctuation disturbances to adjacent consumers due to high starting current. Starting mechanisms used shall suit the load capacity, starting frequency and the overall "system stiffness" at the location. In general "soft-start" mechanisms should be the preferred options.

Except for consumer networks fed from their own MV (medium voltage) supply transformer substations, DOL (direct on line) starting shall be limited to motors not exceeding 5.0 kW (or 7.5 hp) capacity. For critical applications, such as hospitals and some manufacturing processes, the inverters need to be able to withstand or 'ride through' short duration voltage dips.

The electronics in the VSDs, however, may result in increased harmonics and voltage spikes which may cause problems such as premature failures of motor insulation systems, increased motor losses, increased dielectric stress, overheating, resonance problems between the inductive and capacitive parts of the power network, malfunctioning of control systems, overloading and premature aging of capacitors, interference with telecommunications and computers, disturbances in ripple control systems, high currents in neutral conductors, etc. To overcome this, suitable harmonics filters will have to be used.

7.5 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.

The average power factor of the loads being served by the transformer should not be less than 0.85 or the utility tariff's penalty baseline. In cases where load power factors fall below the baseline penalty value, power factor correction to a value exceeding the penalty baseline should be provided for, whether through automatic or manual correction.

Power factor correction capacitors should be the low loss type with losses per kVAR not exceeding 0.35 W at upper temperature limit excluding the losses in the discharge resistors.

7.6 Sub metering

To facilitate monitoring of energy consumption and energy management, electrical energy meters should be installed at strategic load centres to identify consumption by functional use (air conditioning, lighting etc.) and refer also to 9.8.

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 should be determined in accordance with the procedures described in the latest edition of the ASHRAE Handbook, or other equivalent publications.

8.1.2 Indoor design conditions

Room comfort condition is dependent on various factors including air temperature, mean radiant temperature, humidity, clothing insulation, metabolic rate and air movement preference of the occupant.

For the purpose of engineering design, room comfort condition should consider the following three main factors:

a) dry bulb temperature;

b) relative humidity; and

c) air movement (air velocity).

In general, an individual feels comfortable when metabolic heat is dissipated at the rate at which it is produced. The human body temperature needs to be maintained at a constant 37 ± 0.5 °C regardless of the prevailing ambient condition. The higher the space relative humidity, the lower the amount of heat the human body will be able to transfer by means of perspiration/evaporation. If the indoor air temperature is high and the relative humidity is high (above around 11.5 g vapour per kg dry air), the human body will feel uncomfortable. Generally, the relative humidity for indoor comfort condition should not exceed 70 %.

Air movement (or air velocity) is essential for bodily comfort as it enhances heat transfer between air and the human body and accelerates cooling of the human body. Air movement in an occupied space gives a feeling of freshness by lowering the skin temperature, and the more varied the air currents in velocity and direction, the better the effect. A draught is created when the temperature of the moving air is too low and/or the velocity is too high. At normal comfort room temperature (24 °C to 26 °C), the acceptable air velocity would be in the region of 0.15 m/s to 0.50 m/s.

The indoor design conditions of an air-conditioned space for comfort cooling should be as follows:

a) recommended design dry bulb temperature	24 º C - 26 °C
b) minimum dry bulb temperature	23 ° C
c) recommended design relative humidity	50 % - 70 %
d) recommended air movement	0.15 m/s - 0.50 m/s
e) maximum air movement	0.70 m/s

8.1.3 Outdoor design parameters

The recommended outdoor design parameters shall be as follows:

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

8.1.4 Ventilation

Outdoor air-ventilation rates should 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 due to special occupancy or process requirements or source control of air contamination or indoor air quality consideration.

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, should include efficiency devices such as variable speed drive, high efficiency motor, efficient unloading devices, 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 two chillers or a single multi-compressor chiller should 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 the required cooling load.

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

8.2.5 Pump system efficiency

For chilled water or condenser water pumping system operating for more than 750 hours a year, the pump efficiency shall be:

a) > 70 % for flowrate between 50 m^3/h to 100 m^3/h;

b) > 73 % for flowrate between 100 m^3/h to 270 m^3/h; and

c) > 80 % for flowrate exceeding 270 m^3/h.

8.3 Separate air distribution systems

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. As an alternative off-hour controls should be provided in accordance with 8.4.4.

8.3.2 Zones with special process temperature and/or humidity requirements should be served by separate air distribution system/s from those serving zones requiring only comfort cooling, or should include supplementary provisions so that the primary system/s 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 (3 m room depth) in contrast to interior zones.

8.3.4 For air conditioned space requiring exhaust air volume in excess of 3400 m^3/h, 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.

8.4 Controls

8.4.1 Temperature control

Each system should be provided with at least one thermostat for the regulation of temperature. Each thermostat should be capable of being set by adjustment or selection of sensors over a minimum range of between 23 °C to 27 °C. Multi-stage thermostat should be provided for equipment exceeding 35/65 kWr in conjunction with 8.2.4.

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 defined in 8.3.

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. A readily accessible manual or automatic means should be provided to partially restrict or shut off the cooling input (for the exposure) to each floor.

8.4.1.2 Control setback and shut-off

Each system should 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.

8.4.1.3 Multi zone systems

These systems, other than those employing variable air volumes for temperature control should 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.

8.4.2 Humidity control

In a system requiring moisture removal to maintain specific selected relative humidity in spaces or zones, no new source of energy (such as electric reheat) should be used to produce a space relative humidity below 70 % for comfort cooling purposes.

8.4.2.1 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, should 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 should be controlled to sequence reheat and cooling.

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, super heater heat reclaim, heat recovery wheel, heat pipe or any other energy recovery technology.

8.4.4 Off-hour control

8.4.4.1 ACMV system should 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.

8.4.4.2 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 m^3/h or less;

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

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

8.4.4.3 Systems that serve zones which can be expected to operate non-simultaneously for more than 750 hours per year should 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.

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

8.4.4.5 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.

8.4.5 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.

8.4.6 Fan system efficiency

For fan system with air flow rate exceeding 17 000 m^3/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 0.42 W per m^3/h of air flow rate.

8.5 Piping insulation

All piping installed to serve buildings and within buildings should be adequately insulated to prevent excessive energy losses. Additional 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; and

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 installed in or on buildings should 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 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; and

d) exhaust air ducts subject to qualification as in 8.6 a).

8.7 Duct construction

All ductwork should be constructed and erected in accordance with ANSI/SMACNAHVAC Duct Construction Standards - Metal and Flexible published by Sheet Metal and Air Conditioning Contractors' National Association (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.

8.9 ACMV systems

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

a) central system

This type of system in turn comprises:

i) water* distribution

Under this component, a centrifugal, rotary, screw, scroll or reciprocating, compression refrigeration or absorption refrigeration type water-chilling package generates chilled water to a central piping system which supplies the chilled water, as required, to the conditioned space(s) of a building.

*includes other fluids e.g. glycol or brine solutions

ii) air distribution

This component consists of terminal units which receive recirculated room air (plus outside air as required) from a central duct system, performs the required ventilating and/or air-conditioning functions, and delivers the conditioned air to the central duct system, for final delivery to the conditioned space(s) of a building. These terminal units receive chilled water from the central piping system to perform the cooling and dehumidification functions.

The water chilling package, including its heat-rejecting element, pumps and the terminal units are termed as ACMV System Components under 8.11.

b) unitary system

In this system, one or more assembled units, which include an evaporator or cooling coil, compressor and condenser, perform the cooling and dehumidification functions on the re-circulated air from the conditioned space (plus outside air as required). The distribution of air from the unitary system into the conditioned space can either be of non-ducted or ducted type.

These systems are termed as ACMV System Equipment under 8.10.

8.10 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.

8.10.1 ACMV system equipment, electrically operated, cooling mode

8.10.1.1 ACMV system equipment as per in 8.10.1.2 whose energy input in the cooling mode is entirely electric, should show a coefficient of performance (COP) cooling as defined in 3.2 at the standard rating conditions specified in Table 20 and additional standard rating conditions specified in applicable standards for particular ACMV system equipment not less than values shown in Table 21.

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

Table 20. ACMV system equipment, electrically driven[1]: Standard rating temperatures - cooling[2]

Item	Air-cooled		Water-cooled (water-source)	
	Dry-bulb	Wet-bulb	Inlet	Outlet
Room air entering equipment (˚C)	27.0	19.0	-	-
Condenser ambient (air-cooled) (˚C)	35.0	24.0	-	-
Refrigerant-water heat exchanger (˚C)	-	-	30.0	35.0

NOTES:

1. Data in this table apply to the following types of equipment:
   a) central Air Conditioners: Air, Evaporatively and Water Cooled, ISO 13253; and
   b) commercial/Industrial Unitary Air- Conditioning Equipment, MS ISO 5151, ISO 13253.
2. 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 flow resistance, as provided in the applicable standards.

Table 21. Unitary air conditioners, electrically driven: Minimum COP - cooling

Equipment		Size	Sub-category	Minimum COP
			Non-Inverter type	Inverter type [1]
Air conditioners: Air cooled with condenser	<19 kWr	Single Split/Package	2.8	3.0
		Multi-split	2.8	3.2
	≥ 19 kWr and < 35 kWr	Split or Package	2.8	3.5
	≥ 35 kWr	Split or Package	2.7	2.9
Air conditioners: Water and evaporatively cooled	< 19 kWr	Split or Package	3.6	4.0
	≥ 19 kWr and < 35 kWr	Split or Package	3.7	4.4
	≥ 35 kWr	Split or Package	3.8	4.4

NOTE:

1. The COP for the inverter unit is the weighted value, which is calculated based upon the following equation:

$$COP_{weighted} = \left[COP_{100\%} \times 0.40\right] + \left[COP_{50\%} \times 0.60\right]$$

8.10.1.3 In calculating the COP of ducted systems, the effective power input (P_{eff}) of the indoor re-circulating fan is used, which is given as:

$$P_{\text{eff}} = P_{\text{input}} - \frac{q_{\text{v}} \Delta p_{\text{s}}}{0.3}$$

where

P_{input} the input power of the fan motor (W);

q_{v} is rated air flow rate (m^3/hr); and

Δp_s the external static pressure difference (Pa).

8.11 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, screw, scroll 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.

8.11.1 ACMV system components, electrically operated, cooling mode

ACMV system components, as listed in Table 23, whose energy input is entirely electrical, should, at the Standard Rating Conditions specified in Table 22 for water chillers and at additional standard rating conditions specified in applicable standards for particular system components show a Coefficient of Performance (COP) - cooling, as defined in 3.2 not less than the values shown in Table 23.

Table 22. ACMV system components, electrically driven[1] for water chillers: Standard rating conditions - cooling[2]

Conditions		Water Chilling Package
Leaving chilled water temperature	ºC (ºF)	6.67 (44)
Entering chilled water temperature	ºC (ºF)	12.22 (54)
Leaving condenser water temperature	ºC (ºF)	36.11 (97)
Entering condenser water temperature	ºC (ºF)	30.55 (87)
Fouling factor, water[c]		
Condenser	m^2 K/kW	0.044
Evaporator	m^2 K/kW	0.018
Condenser, ambient Temperature		
Air-cooled	ºC	35.0 DB
Evaporatively-cooled	ºC	24.0 WB

NOTES:

1. Data in this table apply to the following types of ACMV System Components: Centrifugal or Rotary or Reciprocating water-chilling packages complying to MS 2449.
2. Air-cooled unit ratings is rated at sea level at Barometric Pressure of 101.3 kPa.

The energy consumed by the external water pumps circulating chilled water, and the heat rejecting device (cooling tower or heat exchanger) are not included in the COP consideration for the ACMV system component, unless the device (i.e. air-cooled condenser) is integrally incorporated into the package by the manufacturer.

Table 23. Water chilling packages, electrically driven: Chiller energy performance rating

Equipment	Size	[1]COP at 100 % Load At M'sian test Conditions		[a]MPLV at MS Std Conditions		[2]COP at 100 % Load at Std AHRI test Conditions		[b]IPLV at AHRI Std Conditions	
		Minimum COP	Maximum kWe/RT	Minimum COP	Maximum kWe/RT	Minimum COP	Maximum kWe/RT	Minimum COP	Maximum kWe/RT
Air cooled, with condenser	< 105 kWr (30 RT)	2.79	1.26	3.20	1.10	2.79	1.26	3.66	0.96
	≥ 105 kWr and < 530 kWr (150 RT)	2.79	1.26	3.20	1.10	2.79	1.26	3.66	0.96
	≥ 530 kWr and < 1060 kWr (300 RT)	2.79	1.26	3.35	1.05	2.79	1.26	3.74	0.94
	≥ 1060 kWr (300 RT)	2.79	1.26	3.35	1.05	2.79	1.26	3.74	0.94
Water cooled, positive Displacement (Reciprocating, scroll, Rotary screw)	(< 260 kWr) (< 75 RT)	4.34	0.81	4.14	0.85	4.51	0.78	5.58	0.63
	> 260 < 530 kWr (150 RT)	4.34	0.81	4.14	0.85	4.51	0.78	5.67	0.62
	≥ 530 kWr and < 1060 kWr (300 RT)	4.95	0.71	4.45	0.79	5.17	0.68	6.06	0.58
	≥ 1060 kWr (300 RT)	5.41	0.65	4.82	0.73	5.67	0.62	6.51	0.54
Water cooled, Centrifugal	< 1060 kWr (300 RT)	5.33	0.66	5.02	0.70	5.58	0.63	5.86	0.60
	≥ 1060 kWr (300 to 600 RT)	5.86	0.60	5.41	0.65	6.06	0.58	6.39	0.55
	> 600 RT	5.96	0.59	5.58	0.63	6.17	0.57	6.51	0.54

NOTES :

[1] Tested at Malaysian Chilled Water and Condenser Water Temperatures as per Table 23. Chillers without condensers can be rated with matching condensers and comply with the chiller efficiency requirements.

[2] Tested at AHRI Leaving Chilled Water Temperature of 44 ˚F at 2.4 USGPM per tonne, and entering Condenser Water Temperature of 85 ˚F at 3 USGPM per tonne.

[a] MPLV denotes Malaysia Part Load Value which is a single part load efficiency figure of merit calculated per method described in MS 2449 at Malaysia Standard Rating Conditions, where for part-load entering condenser water temperatures (ECWT), the temperature should vary linearly from the selected ECWT at 100 % load to 26.67 °C (80 °F) at 50 % load and fixed at 26.67 °C (80 °F) for 50 % to 0 % load, and is defined by the following formula:

(For part-load entering air dry bulb temperatures, the temperature should be vary linearly from selected EDB at 100 % load to 25.55 °C (78 °F) at 33 % load and fixed at 25.55 °C (78 °F) for 33 % to 0 % loads).

$$MPLV = \frac{1}{\left[\left(\frac{0.01}{A}\right) + \left(\frac{0.29}{B}\right) + \left(\frac{0.65}{C}\right) + \left(\frac{0.05}{D}\right)\right]}$$

Where

A = kWe/RT at 100 %

B = kWe/RT at 75 %

C = kWe/RT at 50 %

D = kWe/RT at 25 %

[b] IPLV denotes Integrated Part Load Value which is a single number part-load efficiency figure of merit calculated per method described in AHRI 550/90 where for part-load entering condenser water temperatures (ECWT), the temperature should vary linearly from the selected ECWT at 100 % load to 18.33 °C (65 °F) at 50 % loads, and fixed at 18.33 °C (65 °F) for 50 % to 0 % loads and is defined by the following formula:

$$IPLV = \frac{1}{\left[\left(\frac{0.01}{A}\right) + \left(\frac{0.42}{B}\right) + \left(\frac{0.45}{C}\right) + \left(\frac{0.12}{D}\right)\right]}$$

Chiller efficiency rating compliance shall meet either Minimum COP at 100 % Load Condition or Minimum MPLV and not at both conditions. Note that COP is applicable to a single chiller.

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

8.12.1 Coefficient of performance (COP) - Cooling

The definition in 3.2 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 25 when tested at standard rating conditions shown in Table 24.

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 24. 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[1]	**Units**	**Temperatures**	**Temperatures**
Entering condenser air	ºC	35.0 DB, 24.0 WB	-
Water chillers[2]			
Leaving chilled water	ºC (ºF)	6.67 (44)	6.67 (44)
Fouling factor	m^2 K/kW	0.018	0.018
Entering chilled water	ºC (ºF)	12.22 (54)	12.22 (54)
Entering condenser	ºC (ºF)	30.55 (87)	30.55(87)
Fouling factor	m^2 K/kW	0.044	0.044
Leaving condenser water	ºC (ºF)	36.11 (97)	36.11 (97)

NOTES:

1. Per ANSI Standard Z21.40.1 and Addenda for Gas-fired absorption summer air-conditioning appliances.
2. Per AHRI Standard 560 for Absorption water-chilling packages.

Table 25. 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]
Not applicable	0.95	0.6	1.0

NOTES:

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

2. [b] As listed in Table 20 at sea level.

3. [c] Minimum COP = $\dfrac{\text{Net cooling output}}{\text{Total heat input (electrical auxillary input included)}}$

8.13 System testing and commissioning

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

Hydraulic system balancing should be accomplished in a manner to minimise throttling losses and the pump impeller should be trimmed or pump speed should be 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 Operation and maintenance manual and as-built drawings

An operation and maintenance manual and as-built drawings should be provided to the owner. The 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 air conditioning plants which includes, but not limited to air handling units 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.

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 with air-conditioned space $\geq$ 4 000 m^2. The EMS is a state-of-the-art system and is microprocessor based. Generally, the EMS has three main functions:

a) control of equipment;

b) monitoring of equipment; and

c) integration of equipment sub-systems.

9.2 Control of equipment

The primary purpose of the control of equipment is to save energy by (preferably real-time) optimisation system controls. This is performed by the EMS function of the building automation system through;

a) scheduling and manual overriding;

b) control of set points;

c) report and record operational alarms; and

d) ensure correct and safe sequence of operation (for maximum demand limiting).

9.3 Monitoring of equipment

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

a) providing centralised information of current equipment conditions;

b) providing information of equipment conditions through basic trending;

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

d) providing analytical tools to aid the study and management of equipment operations and energy performance.

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 monitored, stored and reported in a consistent format; and

d) overall system reliability; the intelligent controller of an equipment subsystem may be configured to provide redundancy as a standby unit for another system/s without incurring additional cost.

9.5 Energy consuming areas

9.5.1 Air conditioning and mechanical ventilation (ACMV) system

The system is typically the largest energy consumer in the building and has the largest energy savings potential. The EMS shall 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 is recommended for inclusion in the EMS as specified in 9.7.

If included in EMS, the following should be considered;

a) the capability and capacity of facilities management to maintain and operate EMS controlled lighting system.

b) as lighting system in EMS is typically ‘a massively switched array’, its design and implementation needs to account for maintainability and flexibility for scaling up and changes.

9.5.3 Others

Any other large energy consuming equipment such as water pump sets, electric or gas heaters and others should be included under the EMS programme. It is recommended that monitoring of renewable energy sources such as solar and wind energy systems be included to assist users visualise energy balance and thence maximise the harvesting of such renewable energy sources. Also due the inter-relationship between water and energy, it is recommended for the EMS to monitor and capture data on water use efficiency as well as incorporate water leakage alarm.

However, it is typically not appropriate to apply the EMS to control equipment such as computers.

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 on as follows:

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 or 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 Air handling units (AHUs)

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 AHUs should be controlled by an intelligent controller which integrates with the EMS.

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

For Variable Air Volume AHU system, the EMS should be capable of adjusting the set point based on (but not restricted to), static pressure reset inside the main supply air duct.

Control of outdoor air supply to the AHU is recommended to be based on demand control ventilation to optimise energy consumption while maintaining healthy indoor air quality, for example by incorporating CO_2 sensor.

9.6.3 Terminal units

Terminal units which include variable air volume (VAV) boxes and fan coil units (FCUs) should be integrated with the EMS for start/stop control. Some applications may require a number of FCUs to be grouped together as a common zone for start/stop control by the EMS.

9.6.4 Unitary systems

Unitary systems are designed to be self-contained or packaged units. Where unitary systems are provided with independent/dedicated control and monitoring of energy and performance, such provisions should have the capability of integration or high level interface for energy consumption and performance control (start/stop, temperature control, etc.) with the EMS.

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

c) duty cycling algorithm.

9.6.6 Pumps

Chilled water and condenser water pumps larger than 2 kWe and operating for more than 750 hours per year should incorporate digital power meter/s linked to the EMS.

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 should not be less than one for every 1 000 W of connected lighting power.

For applications where automatic control is feasible, savings in lighting energy may be further realised through (but not limited to) incorporating devices such as “Lighting Sweep Logic” where lights turned off at night will remain off by means of the EMS periodically “sweeping” them off.

9.7.2 Common areas

Lighting for common areas includes:

a) decorative lighting;

b) security lighting;

c) lobby lighting;

d) corridor lighting; and

e) facade lighting.

Where appropriate, 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 or light level detection.

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. 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 should be equipped with utility consumption (utility refers to electricity, fuel, gas, compressed air, etc.) 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 and/or external supplied cooling water;

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 and optimisation control logic;

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 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.

EMS monitoring should consist of the following categories (but not limited to) of data collection;

a) energy consumption;

b) pattern identification/profiling; and

c) operation alarm notification.

The level of actual energy consumption is based on the collection of energy usage data by power meters while pattern identification requires the mapping of building activities that are known to have specific energy consumption characteristics. Where applicable, provision should also be made for automatic conversion of fuel energy use into its electrical energy equivalent. Accurate and meticulous information from pattern identification (more than what would appear on a total utility bill) will enable users to formulate feasible energy savings strategies.

EMS Software that monitors energy should be able to do (preferably real time) reporting and capable of comparing recent data against historical data. Such monitoring can be useful for users who wish to track the energy consumption of very specific areas in a building, analyse days while taking weather into consideration and identify energy consumption that is unexpected or incongruous with previous data. All of these monitoring functions provide a user with opportunities to streamline energy usage.

EMS software that allows comparison of meter readings with utility bills can help users keep track of both historical and present energy consumption and identify possible mistakes and anomalies. With some types of energy management software, users can set their own acceptable energy usage levels or implement energy savings plans. If these levels or plans are exceeded, the software can alert a user through email or text messages.

Ideally, the EMS should be capable of providing the following types of information (but not limited to) on trending:

a) temperature;

b) pressure;

c) damper and valve position commands, including variable frequency drive control signals;

d) virtual points (internal calculations such as enthalpy or changing set-points and targets);

e) (ON/OFF) status or stage;

f) flow rate (water, air or fuel);

g) alarm state;

h) current;

i) power demand (kW);

j) energy consumption (kWh, therms, gallons, etc.); and

k) revolutions per minute (RPM).

9.10 Training for users

Users should be comprehensively trained on the features and benefits of the EMS. The maintenance or building operators should be trained for the following, but not limited to:

a) setting of time schedule for equipment Start/Stop operation;

b) manual centralised equipment Start/Stop controls from the EMS;

c) manual by-pass of the EMS and resetting back to Auto Mode of the EMS;

d) historical retrieval and trending for data analysis; and

e) acknowledgement of alerts/alarms and troubleshooting of the EMS or equipment.

9.11 Testing and commissioning

To ensure proper and comprehensive operation of the EMS, the commissioning process should commence at the design phase of the project and continue through the construction phase and the warranty period. The process should include documentation of design intent and verification of equipment performance. Commissioning process should also verify that complete and accessible equipment documentation is available onsite and that facility staff is adequately trained to operate the EMS.

The scope of commissioning process should be specified in the task list issued by the system designer or independent commissioning specialist engaged by the building owner. Commissioning process shall include the following major stages:

a) perform design review on the system design and develop initial commissioning plan describing project specifications and requirements for the construction phase;

b) commissioning plan for the construction phase shall be finalised after selection of vendor and the commissioning specialist shall review and approve EMS submittals;

c) the commissioning specialist shall review functional test procedures that provide direction and documentation for execution of works by EMS vendor; and

d) result of functional tests shall be reviewed by commissioning specialist and all deficiencies corrected and retested by the EMS vendor.

The list of functional tests shall include the following:

a) Installation and initial checkout

A point-to-point and operational check should be performed before functional testing commences. Every control point in the system should undergo the following four tests:

i) hardware check

Verify wiring to each point and sensor location; software point address in the control system; point setting up in the local device controllers and all points in the controller or sensor are communicating properly with the control system.

ii) software load and check

Check is performed on each controller to verify that it is powered up and the software program (with setpoints, deadbands, etc.) is uploaded to the controller with proper communication with the EMS.

iii) calibration

Verify that all sensors are located away from interference that may cause erratic operation. Check all sensor readings in the EMS against a recently calibrated test instrument. Calibration should be performed as needed by entering an offset value to the EMS, or use other appropriate equivalent method. Inspect and note both extremes of the valve and damper actuator range and verify that the reading in the EMS matches a visual observation of that device.

iv) response check

Test open or close operation of controllers or actuators found in terminal units or other equipment by varying the set points, record output parameters (such as airflow, pressure, etc.) and verify that the readout in the EMS is consistent with the actual condition of the actuator. Observe proper staging.

b) Operational checkout

Run each component of equipment through the entire sequence of operation to verify that the system functions as intended. Initial checkout procedures described above will suffice as the operational checkout for small, standalone controllers, except for interaction tests with other equipment or tests for conditions such as power failure and fire alarm. The operational checkout is a debugging process prior to functionally test the system.

c) Functional testing

Perform functional testing to verify that the EMS and controlled equipment actually work as intended. Test procedures and documentation forms are applicable and each component of equipment is to be run through the entire sequence of operations, and all alarms are checked. System should also be tested on equipment interactions and interlocks by undergoing start-up, shutdown, unoccupied, and occupied modes, as well as power failure, manual modes, full and part-load conditions. Tests may be manual, where physical conditions, set points, or point values are changed and the system's response is observed (at the control system terminal, visually, or by handheld instruments) and documented. Some tests may require trending for a number of points in the system. The acquired test result and data may then be analysed in tabular or graphical form, verifying proper sequencing and operation. Portable data loggers may be required to complement monitoring equipment and verify proper operation. Seasonal or varying occupancy load testing may be conducted subsequently.

9.12 Post commissioning

Facility staff needs complete, clear, and accessible documentation of the control systems. As-built documentation shall be provided before functional testing is complete. Since functional testing always results in some changes, corrections, or enhancements to the control sequences, the commissioning specialist shall verify that the final as-built documentation reflects these changes.

The commissioning specialist or system designer shall review and approve O&M documentation and training plans, as well as verify that specific training is conducted.

Towards the end of the warranty period (typically one year), the commissioning specialist shall return to the site and review the system performance, interview the facility staff and help to address any outstanding issues still under warranty.

Training agenda should be provided for facility staff together with details such as personnel conducting the training; the qualification of the instructor; the topics covered, time expected on each topic, the technical rigor of each subject and any videotaping desired shall be dictated.

Optimisation shall be conducted once an EMS is in place and fully operational, to move beyond common EMS routines and into customization for maximum occupant comfort and minimum energy consumption. As buildings are dynamic, with frequent changes in floor plans, space use, weather conditions, plug loads and occupant densities, EMS optimisation is an on-going process.

Optimisation can be conducted with but not limited to the following basic EMS capabilities:

a) scheduling

Time clock and scheduling features can offer significant savings. Check on set schedules periodically to assess its relevancy to current operation and review opportunities to move beyond minimal utilisation with least significant effort or complexity.

b) set points

It is important to carefully analyze the net impact on energy consumption by adjusting space and equipment set points

c) alarms

EMS shall provide basic alarm functionality and options in specifying how alarms are monitored, reported, routed, and ultimately dealt with. Registering and recording alarms is necessary and critical in optimisation process.

d) safety

Safety devices should be set to protect equipment and the building itself from damage and reduce or eliminate the need for alarm reporting to remote sites and to engage after hour emergency service call. Safety setting should be recorded and made available in EMS sub-menu. Care is to be taken on safety provisions that protect lives and equipment (freeze-stat, high pressure limit, smoke detector, etc.) such that these should not rely on software and programming functions to work but should be hardwired.

e) basic monitoring and trending

EMS has the basic capability to monitor or record various parameters of equipment operation or trending. Trending is to be executed for points that control equipment; for monitored-only points that may have been installed, and for software or virtual points (calculated values such as resets). The trending features of EMS should be effectively commissioned and executed to meet commissioning plan requirements.

Diagnostics are EMS features that assess how equipment and systems are working and identify problems or opportunities for improvement. Diagnostics during post commissioning form the fundamental basis towards optimisation. Diagnostics can assist to investigate control loops and verify their operation, learn more about the building, and ensure that efficient and safe equipment operation continue. Diagnostics can be implemented successfully only with built-in software features in EMS that summarize logged results of scheduling, set points, alarms, safety settings and trending of all relevant parameters and which are presented to the facility staff in meaningful, compact and legible tabular or graphical forms for action. Requirement for such presentation should be clearly stated in the contract specification.

9.13 Prerequisites for optimizing EMS operation

The following items should be examined before attempting further enhancement:

a) EMS documentation - be adequate;

b) sequences of operation - compiled, examined and well understood;

c) current control strategies - compiled & examined;

d) calibration of equipment - calibrate all sensors and actuators; and

e) functional testing - ensure equipment is operating as intended.

10 Building energy simulation method (an alternative compliance method)

10.1 Scope of building energy simulation method

The building energy simulation method is a performance based approach to compute the predicted energy use of buildings.

10.2 The building energy simulation should be performed twice. The first simulation should be for a building as per design, referred to as the *design building*. The second simulation is for a reference building referred to as the *base building. The base building* shall meet the relevant minimum requirements as specified in this standard (see Clauses 5, 6, 7 and 8).

10.3 The *design building* shall be modelled accurately from the architectural design drawings available.

10.4 The *base building* shall be modelled as, the model assumed for deriving the OTTV, a ‘shoe-box’ building with the following characteristics:

a) Same floor area as the *design building*;

b) same number of floors as the *design building*;

c) same function (internal load) as the *design building*; and

d) complying with the minimum requirements for OTTV, RTTV, Lighting and ACMV components and equipment under Clause 5, 6, 7, and 8.

10.4.1 The *base building* shall be as functional as the *design building* and shall share all the same characteristic of the *design building* with the exception of the following:

a) building form;

b) building envelope;

c) daylighting& lighting control; and

d) ACMV system.

NOTE. This permits designers to compensate for a poor building envelope with a daylighting control system or/and a more efficient ACMV system.

10.5 Simulation programs

The *simulation program* should be a computer-based program for the analysis of energy consumption in buildings. The *simulation program* should include calculation methodologies for the building components being modelled and incorporate the following:

a) a minimum of 8,760 hours time step per year;

b) a minimum of hourly variation in occupancy, lighting power, miscellaneous equipment power, thermostat set-points, and ACMV system operation, defined separately for each day of the week and holidays;

c) thermal mass effects; and

d) sufficient thermal zone to model the *design building*.

NOTE. Freeware and commercially available softwares such as, but not limited to, DOE-2, TRNSYS, ESP, IES, EnergyPlus may be used for this purpose.

10.5.1 The simulation program should have a report such as ASHRAE Standard 140, CIBSE: AM11 or equivalent and the report should be furnished by the software developer.

10.5.2 Climatic data

The simulation program should perform the simulation using a Test Reference Year weather data that consist of, at least, hourly values of climatic data, such as temperature and humidity from representative climatic data, for the city in which the *design building* is to be located. For cities or urban regions with several climatic data entries, and for locations where weather data are not available, the designer shall select weather data that best represent the climate at the construction site, but shall not be more than 300 km away of a design location and be of similar altitude and land/cityscape.

10.6 Compliance

Compliance will be established if:

a) the *design building annual energy use*, does not exceed the *base building annual energy use* as calculated by the same simulation program; and if

b) the energy *performance* rating for equipment or components specified in the *design building* are not less than the rating used to calculate the *base building* energy consumption.

10.7 Exceptional compliance

10.7.1 Utilisation of on-site renewable energy sources (such as photovoltaic) or site-recovered energy, is encouraged. The annual energy consumption of the *design building* is permitted to be reduced by subtracting 100 % of the annual renewable energy or site-recovered energy utilised.

10.7.2 If the on-site renewable energy sources or site-recovered energy sources meet or exceed the energy used by the *design building* as simulated as per the requirement here, modelling or simulation of the *base building* need not be performed.

Acknowledgements

Members of Technical Committee on Energy Efficiency of Buildings (Passive)

Prof Ir Dr K.S. Kannan (Chairman)	Universiti Teknologi Malaysia
Mr Luqmanul Hakim Tarmizi (Secretary)	SIRIM Berhad
Ir Chen Thiam Leong	Association of Consulting Engineers Malaysia
Mr Faizul Ideris/ Mr K. Logendran	Federation of Malaysian Manufacturers
Rosnida Mohd Yusof/ Ms Norhayati Mat Wajid	Jabatan Kerja Raya Malaysia
Ar Chan Seong Aun/ Ar Von Kok Leong	Pertubuhan Akitek Malaysia
Mr Faiz Mohd Yusof	SIRIM QAS International Sdn Bhd
Ir Francis Xavier Jacob	Suruhanjaya Tenaga
Prof Dr Abdul Razak Sapian	Universiti Islam Antarabangsa Malaysia
Prof Dr Azni Zain Ahmed/ Dr Nor Zaini Ikrom Zakaria	Universiti Teknologi MARA

Members of Working Group on Architecture and Passive Design Strategy

Prof Dr Abdul Razak Sapian (Chairman)	Universiti Islam Antarabangsa Malaysia
Mr Luqmanul Hakim Tarmizi (Secretary)	SIRIM Berhad
Dr Zuraini Denan/ Prof Sr Dr Md Najib Ibrahim	Universiti Islam Antarabangsa Malaysia
Ar Von Kok Leong	Malaysia Green Building Confederation
Ir Francis Xavier Jacob	Suruhanjaya Tenaga
Dato’ Prof Ar Dr Elias Salleh/ Dr Mohamad Fakri Zaky Jaafar	Universiti Putra Malaysia
Prof Dr Azni Zain Ahmed/ Dr Nor Zaini Ikrom Zakaria	Universiti Teknologi MARA

Members of Working Group on Air-conditioning and Mechanical Ventilation (ACMV)

Ir Chen Thiam Leong (Chairman)	Association of Consulting Engineers Malaysia
Mr Luqmanul Hakim Tarmizi (Secretary)	SIRIM Berhad
Mr Lee Chuan Yee/ Mr Tay Lee Weh	Acson Malaysia Sales & Service Sdn Bhd
Mr Mohd Amir Bidin	Carrier (Malaysia) Sdn Bhd
Mr Tan Yi Fang/ Mr Howard Heu	Daikin Air Conditioning (Malaysia) Sdn Bhd
Mr SP Wong	Dunham-Bush (Malaysia) Bhd
Mr Ooi Seng Chong	Group Associated (C&L) Sdn Bhd
Ir Zailani Nagin/ Ir Zulkifli Arshad	Jabatan Kerja Raya Malaysia
Ir Ong Ching Loon	Malaysia Chapter of American Society of Heating, Refrigerating and Air-Conditioning Engineers
Ir Ng Yong Kong	Malaysian Air Conditioning and Refrigeration Association
Mr Chin Wai Meng	O.Y.L Industries Sdn Bhd

Acknowledgements *(continued)*

Mr Yeo Sek Chong/ Mr Azman Abdullah	Superior Make Aircon Refrigeration Tech Sdn Bhd
Ir Soong Peng Soon	The Institution of Engineers, Malaysia
Mr Darren Lai	Trane Malaysia TM Sales and Services Sdn Bhd
Mr Shamsul Fazri Ramli/ Mr Ooi Seng Choong	York (Malaysia) Sales & Service Sdn Bhd

Members of Working Group on Lighting

Ir Looi Hip Peu (Chairman)	Association of Consulting Engineers Malaysia
Mr Luqmanul Hakim Tarmizi (Secretary)	SIRIM Berhad
Mr Lim Kim Poi	Federation of Malaysian Manufacturers
Ir Baihaki Azraee	Jabatan Kerja Raya Malaysia
Mr Ranjith Nithin/ Mr Ehsan Aswad/ Mr Ivan Tan/ Mr Yee Shi Min	Phillips (M) Sdn Bhd
Mr Mohd Azmeer Ahmad	SIRIM QAS International Sdn Bhd
Ir Francis Xavier Jacob	Suruhanjaya Tenaga
Mr Glenn Tiong	The Electrical and Electronics Association of Malaysia
Ir Lee Kok Chong/ Ir Yau Chau Fong	The Institution of Engineers, Malaysia

Members of Working Group on Electrical Power and Distribution

Ir Francis Xavier Jacob (Chairman)	Suruhanjaya Tenaga
Mr Luqmanul Hakim Tarmizi (Secretary)	SIRIM Berhad
Ir Looi Hip Peu	Association of Consulting Engineers Malaysia
Ir Lalchand Gulabrai	Federation of Malaysian Manufacturers
Mr Abdul Muhaimin Mahmud	Jabatan Kerja Raya Malaysia

Acknowledgements *(concluded)*

Members of Working Group on Energy Management System (EMS)

Ir Chen Thiam Leong (Chairman)	Association of Consulting Engineers Malaysia
Mr Luqmanul Hakim Tarmizi (Secretary)	SIRIM Berhad
Mr Lee Nye Ah	BICT Engineering Sdn Bhd
Ir Michael Kwan	George Kent (M) Bhd
Mr Yow Shing Chong/ Ms Els Cheng Lee Ching	Honeywell Sdn Bhd
Mr Mohd Faeiz/ Mr Abd Khalid Che Din	Jabatan Kerja Raya Malaysia
Mr Shaiful Hizam Husin/ Mr Nik Yusani Nik Ismail	Johnson Controls (M) Sdn Bhd
Mr Lim Fang Wei	M&C Engineering and Trading Sdn Bhd
Mr Andes Quek/ Mr Ong Ching Loon	Malaysia Chapter of American Society of Heating, Refrigerating and Air-Conditioning Engineers
Ir Ng Yong Kong	Malaysian Air Conditioning and Refrigeration Association
Mr Yap Chee Long	Metronic Engineering Sdn Bhd
Mr Khairol Suhardi Shaaban/ Mr Edison Kong	Solar District Cooling Sdn Bhd
Ir Soong Peng Soon	The Institution of Engineers, Malaysia

Members of Working Group on Overall Transfer Thermal Value (OTTV)

Ar Chan Seong Aun (Chairman)	Pertubuhan Akitek Malaysia
Mr Luqmanul Hakim Tarmizi (Secretary)	SIRIM Berhad
Mr CK Tang	Building Sector Energy Efficiency Project
Mr Faizul Ideris	Federation of Malaysian Manufacturers
Ar Von Kok Leong	Malaysia Green Building Confederation
Mr Woo Kok Woh	Malaysian Sheet Glass Sdn Bhd
Mr Kannan M Munisamy	The Institution of Engineers, Malaysia
Dr Mohamad Fakri Zaky Jaafar	Universiti Putra Malaysia