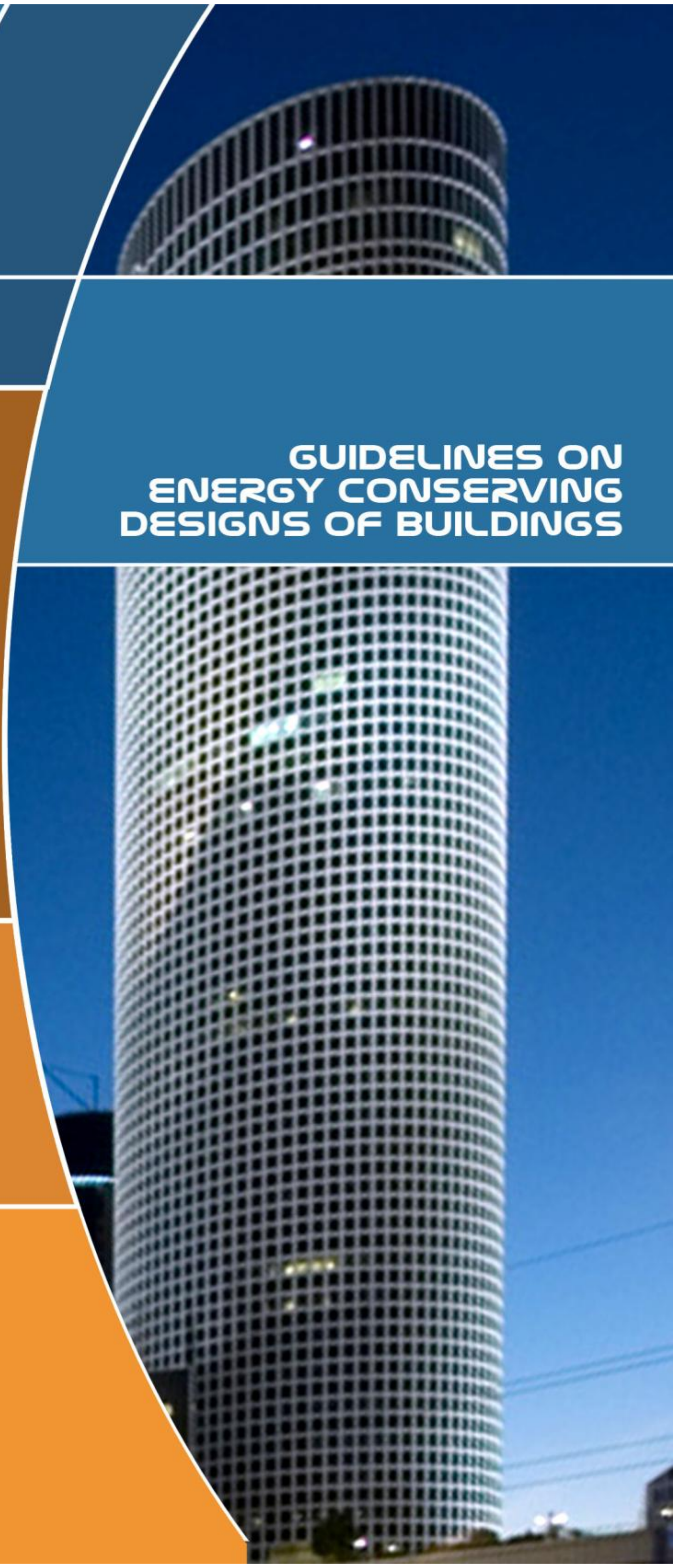
GUIDELINES ON ENERGY CONSERVING DESIGNS OF BUILDINGS



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DEPARTMENT OF ENERGY
Energy Center, Merritt Rd., Fort Bonifacio, Taguig

MESSAGE

With climate change already affecting our lives, there is a need to design buildings that will have the least impact to the environment. Appropriate lighting in buildings, for instance, will greatly contribute to energy conservation. By conserving energy, we lessen our use of carbon-based fuels and it is but one way to address climate change.

We need to design buildings by considering the entire life cycle process without sacrificing functionality and economic returns. I am confident that this is going to be the advent of more environmentally safe buildings.

The purpose of this guideline is to provide a reference for building industry professionals and implement energy efficient systems, including efficient lighting, within the buildings. This booklet will serve as another milestone for the government in its attempt to address climate change through energy efficiency.

Angelo T. Reyes
Secretary

Preface

This document, Guidelines on Energy Conserving Design of Buildings, addresses the need to provide energy efficiency guidelines in the design and construction of buildings in the Philippines.

These Guidelines form part of the efforts of the Department of Energy (DOE) through the Philippine Efficient Lighting Market Transformation Project (PELMATP), as supported by the United Nations Development Programme - Global Environmental Facility (UNDP-GEF), to address the barriers to the widespread use of energy-efficient lighting systems in the Philippines.

These Guidelines were developed thru a consensus development process facilitated by the Institute of Integrated Electrical Engineers of the Phils., Inc. (IIEE), Philippine Lighting Industry Association (PLIA) and the Energy Efficiency Practitioners Association of the Philippines (ENPAP) together with various experts, professionals and stakeholders from Bureau of Product Standards (BPS), Department of Public Works and Highways (DPWH), DOE-Lighting and Appliance Testing Laboratory (DOE-LATL), Fujihaya, Manila Electric Company (MERALCO), Philippine Society of Mechanical Engineers (PSME), Philippine Society of Ventilation, Air Conditioning and Refrigeration (PSVARE), United Architects of the Philippines (UAP).

Though conscientious efforts have been exerted to make the contents of these guidelines as technically sound as possible, it is advised that it be applied by duly qualified and competent professionals. Any concern or issue as to its applicability, accuracy or completeness of this document shall be addressed to the Department of Energy for further validation and interpretation.

In this second printing, prominent changes were done more for clarity and relevance to certain provisions of international standards, especially ASHRAE, by additions and deletions. Data on *Table 3.4 Maximum*

Lighting Power Density for Building Interiors were adjusted to conform with data provided by the Department of Energy – EECD. Also, values for *Table 6.1 Outdoor Requirements for Ventilation* were changed to align with data from ASHRAE while provisions for Commercial Stores and Sports and Amusement Facilities were deleted and placed under consideration. Moreover, values from *Table 6.6 Minimum Performance Rating of Various Airconditioning System* were attuned to be consistent with the latest standards. The Committee deemed it also necessary to include figures of basic hood styles used in kitchen ventilation to provide practitioners for clarity.

Comments on the Guidelines regarding omissions and errors, as well as, conflicts with accepted international standards are most welcome and will be highly appreciated. All suggestions will be studied and considered for inclusion in the Guidelines's next edition.

Table of Contents

TABLES	**PAGE**

FIGURES	**PAGE**

APPENDIX	**PAGE**

Section 1. Purpose

1.1 To encourage and promote the energy conserving design of buildings and their services to reduce the use of energy with due regard to the cost effectiveness, building function, and comfort, health, safety and productivity of the occupants.

1.2 To prescribe guidelines and minimum requirements for the energy conserving design of new buildings and provide methods for determining compliance with the same to make them always energy-efficient.

Section 2. Application and Exemption

2.1 Application

2.1.1 These guidelines are applicable to the design of:

a. New buildings and their systems; and
b. Any expansion and/or modification of buildings or systems.

2.1.2 These guidelines shall not be used to circumvent any applicable safety, health or environmental requirements.

2.2 Exemptions

2.2.1 Residential dwelling units; and

2.2.2 Areas with industrial/manufacturing processes.

Section 3. Lighting

3.1 Scope

This section shall apply to the lighting of spaces and areas of buildings, such as:

3.1.1 Interior spaces of buildings;

3.1.2 Exterior areas of buildings such as entrances, exits, loading docks, parking areas, etc.;

3.1.3 Roads, grounds and other exterior areas including open-air covered areas where lighting is required and is energized through the building's electrical service.

3.2 Exemptions

The following are exempted but are encouraged to use energy efficient lighting system whenever applicable.

3.2.1 Areas devoted for theatrical productions, television broadcasting, audio-visual presentations and those portions of entertainment facilities where there are special or customized lighting needs.

3.2.2 Specialized lighting system for medical or dental purposes.

3.2.3 Outdoor athletic facilities.

3.2.4 Display lighting required for art exhibits, products, and merchandise.

3.2.5 Exterior lighting for public monuments.

3.2.6 Special lighting for research laboratories.

3.2.7 Emergency lighting that is automatically "off" during normal operations.

3.2.8 High-risk security areas requiring additional special lighting.

3.2.9 Rooms for elderly persons and people with disability requiring special lighting needs.

3.3 General Requirements of Energy-Efficient Lighting Design

This Guideline sets out the minimum requirements for achieving energy-efficient lighting installations. The requirements of this Guideline are generally expressed in terms of illumination level, luminous efficacy, and lighting power density. In the course of selecting an appropriate indoor illumination level for a space, energy efficiency should be taken into consideration in addition to other lighting requirements. On the other hand specific efficiency requirements for each type of lamp, control gear and luminaires shall conform to relevant Philippine National Standards.

3.3.1 The lighting design shall utilize the energy efficient lighting equipment. The lighting system shall be so chosen as to provide a flexible, effective and pleasing visual environment in accordance with the intended use, but with the least possible energy requirements.

3.3.2 The use of task-oriented lighting shall be used whenever practicable.

3.3.3 In the design of general lighting in buildings with centralized air conditioning equipment, consideration should be given to integrated lighting and air conditioning systems which use luminaires with heat removal capabilities. (See related requirement in Section Air Conditioning.)

3.3.4 The lighting system shall be designed for expected activity. The task shall be analyzed in terms of difficulty, duration, criticalness and location in order to determine the lighting needs throughout the space, always keeping in mind that higher illumination levels than necessary are likely to waste energy while on the other hand, levels lower than needed could impair visual effectiveness. Table 3.1 lists the recommended illuminance levels.

3.3.5 The most efficient lamps appropriate to the type of lighting, color rendition and color appearance shall be selected. The use of such types of lamps reduces power requirements. Refer to Table 3.2 Efficacy Ranges and Color Rendering Indices of Various Lamps.

3.3.6 In general, the normal artificial light source should be the fluorescent lamp. In down light installation, high-pressure discharge lamps can be used. In large high bay areas, high-pressure discharge lamps should be used. Where good color rendering is required, the tubular fluorescent lamp and other high-pressure discharge lamps except high-pressure sodium lamps should be used. However, if moderate color rendering is of comparatively minor importance, high-pressure sodium lamps can be used. If very good color rendering is required, the tubular fluorescent lamp should be used.

3.3.7 The most efficient combination of luminaires, lamps and ballasts appropriate for the lighting task and for the environment shall be selected so that lamp light output is used effectively. The selected luminaire should meet the requirements with respect to light distribution, uniformity and glare control. The use of highly polished or mirror reflectors are recommended to reduce the number of lamps installed without reducing the illumination level. Where ballasts are used, these should be of the electronic type or low loss type with a power factor of at least 85%.

3.3.8 The highest practical room surface reflectance should be considered in the lighting design. The use of light finishes will attain the best overall efficiency of the entire lighting system. Dark surfaces should be avoided because these absorb light. Table 3.3 lists the recommended room surface reflectances.

3.3.9 Selective switching possibilities should be provided so that individual or specific group of fixtures can be turned off when not needed and lighting levels can be adapted to changing needs.

3.3.10 The lighting system shall be so designed that day lighting can be coordinated with artificial lighting, taking into consideration the problems of glare, brightness imbalance and heat buildup in the building interior.

3.3.11 In selecting lighting systems, the costs of operation and energy usage and not simply the initial cost should be considered.

3.4 Maximum Allowable Power Density for Building Interior Lighting Systems

3.4.1 The total lighting power density for the interior spaces of buildings shall not exceed the maximum values for building areas/activities as specified in Table 3.4

3.5 Maximum Allowable Power Density for Building Exterior Lighting Systems

3.5.1 Lighting power requirements for building exteriors shall not exceed the values given in Table 3.5.

3.5.2 Basic power lighting requirements for roads and grounds shall not exceed the values given in Table 3.6.

3.6 Lighting Controls

All lighting systems except those required for emergency or exit lighting for security purposes shall be provided with manual, automatic or programmable controls.

3.6.1 Each space enclosed by walls or ceiling-height partitions shall be provided with at least one lighting control, capable of turning off all the lights within the space.

Exception: Continuous lighting required for security purposes.

3.6.2 One lighting control point shall be provided for each task lighting.

3.6.3 The general lighting of any enclosed area 10 m^2 or larger in which the connected load exceeds 10 W/m^2 for the whole area shall be controlled so that the load for the lights may be reduced by at least 50% while maintaining a reasonably uniform level of illuminance throughout the area. This may be done with the use of dimmers, by dual switching of alternate lamps, or by switching each luminaire or each lamp.

3.6.4 The number of control points required shall be at least one for every 1,500 W of connected lighting load, provided it shall also comply with Section 3.6.3. For the purpose of determining the total number of control points, Table 3.7 shall be used.

3.6.5 Exterior lighting not intended for 24 hours continuous use shall be automatically switched by a timer, photocell or a timer-photocell combination but provided with manual override.

3.6.6 Hotel and motel guest rooms shall have one master switch at the main entry door that turns off all permanently wired lighting fixtures and switched receptacles, except for security lighting, if required. This switch may be activated by the insertion and removal of the room key.

3.6.7 Where adequate day lighting is available, local manual or automatic controls such as photoelectric switches or automatic dimmers shall be provided in day lighted spaces. Controls shall be provided so as to operate rows of lights parallel to facade/exterior wall.

3.6.8 Feature display lighting in retail and wholesale stores shall be separately switched on circuits not more than 20 amperes. If there are more than four of these display circuits, the display lighting shall be automatically controlled by a programmable timer with provisions for temporary override by store personnel.

3.6.9 Valance lighting in retail and wholesale stores shall be switched independent of general and display lighting.

3.7 Control Location

3.7.1 All lighting controls shall be readily accessible to space occupants.

3.7.2 Switches for task lighting areas 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 Section 3.6.

Exceptions:

1. *Lighting control requirements for spaces, which must be, used as a whole should be controlled in accordance with the work activities and controls may be centralized in remote locations. These areas include public lobbies of office buildings, hotels and hospitals; retail and department stores and warehouses; storerooms and service corridors under centralized supervision.*

2. *Manual and automatic control devices may reduce the number of controls required by using an equivalent number of controls from Table 3.7.*

3. *Automatic controls.*

4. *Programmable controls.*

5. *Controls requiring trained operators.*

6. *Controls for safety hazards and security.*

3.8 Compilation of Information

a. Data of lamps and luminaires.
b. Lighting power density and projected illumination per area/application.
c. Relevant drawings and plans.

Table 3.1 Recommended Design Illuminance Levels

Task	Min. & Max. (Lux)	Applications
Lighting for infrequently used areas	50 – 150	Circulation areas and corridors
	100 – 200	Stairs
	100 – 200	Hotel, escalators
Lighting for working interiors	200 – 300	Infrequent reading and writing
	300 – 750	General offices, typing and computing
	300 – 750	Conference rooms
	500 – 1000	Deep-plan general offices
	500 – 1000	Drawing offices
Localized lighting for exacting tasks	500 – 1000	Proofreading
	750 – 1500	Designing, architecture and machine engineering
	1000 – 2000	Detailed and precise work

Table 3.2 Efficacy Ranges and Color Rendering Indices of Various Lamps

Lamp Type	Rated Power Ranges (watts)	Efficacy Ranges (lumens per watt)	Minimum Color Rendering Index (CRI)
Incandescent Lamp	10 - 100	10 – 25	100
Compact Fluorescent Lamp	3 - 125	41 - 65	80
Linear Fluorescent Lamp halophosphate triphosphor	 10 – 40 14 - 65	 55 - 70 60 - 83	 70 80
Mercury Vapor Lamp	50 -2000	40 - 63	20
Metal Halide Lamp	Up to 1000	75 - 95	65
Low Pressure Sodium Lamp	20 -200	100 - 180	0
High Pressure Sodium Lamp	50 - 250	80 - 130	21

Table 3.3 Recommended Room Surface Reflectances

Surface	% Reflectance
Ceilings	80-92
Walls	40-60
Furnitures	26-44
Floors	21-39

Table 3.4 Maximum Lighting Power Density for Building Interiors

Area/Activity	Lighting Power Density (W/m^2)
Auditoriums, Churches	8
Food Service Snack Bars and Cafeteria Leisure/Dining Bar	 14 10
Offices and Banks	10
Retail Stores (*) Type A (**) Type B (***)	 23 22
Shopping Centers/Malls/Arcades	15
Clubs/Basements/Warehouses/ General Storage Areas	2
Commercial Storage Areas/Halls Corridors/Closets	4
Schools Preparatory/Elementary High School Technical/Universities	 17 18 18
Hospitals/Nursing Homes	16
Hotels/Motels Lodging rooms/Guest rooms Public Areas Banquet/Exhibit	 12 17 20

Notes:
(*) Value is based on data provided by the Department of Energy-EECD.
(**) Includes general merchandising and display lighting except for store front, etc.
(***) Type A -Fine and mass merchandising.
(****) Type B -General, food and miscellaneous merchandising.

Table 3.5 Maximum Values for Lighting Power for Building Exteriors

Building Area/Space	Lighting Power
Exits (w/ or w/o canopy)	60 W/Lm of door opening
Entrance (w/o canopy)	90 W/Lm of door opening
Entrance (w/ canopy) High traffic (e.g., retail,,hotel, airport, theater, etc.) Light traffic (e.g.,hospital, office, school, etc.)	 100 W/m^2 of area w/ canopy 10 W/m^2 of area w/ canopy
Loading area	3 W/m^2
Loading door	50 W/Lm of door opening
Total power allowance for the exterior (inclusive of above allowances) of building perimeter for buildings of up to 5 storey (above ground) plus 6W/Lm of building perimeter for each additional storey	100 W/Lm

Note: W/Lm = watts per linear meter

Table 3.6 Maximum Values for Lighting Power for Roads and Grounds

Area/Space	Lighting Power (W/m^2)
Store and work area	2.0
Other activity areas for casual use (e.g., picnic grounds, gardens, parks, etc.)	1.0
Private driveways/walkways	1.0
Public driveways/walkways	1.5
Private parking lots	1.2
Public parking lots	1.8

Table 3.7 Control Types and Equivalent Number of Control Points

Type of Control	Equivalent Number of Control Points
Manually operated on-off switch	1
Occupancy Sensor	2
Timer – programmable from the space being controlled	2
3 Level step-control (including off) or pre-set dimming	2
4 Level step-control (including off) or pre-set dimming	3
Continuous (Automatic) dimming	3

Section 4. Electric Power and Distribution

4.1 Scope

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

4.2 Electric Motors

4.2.1 This section shall apply to any general-purpose, T-frame, single speed, foot-mounted, polyphase induction motor of design A and B configuration that is continuous rated and operating at 230/460 volts, 60 Hz, as defined in NEMA Standard MG 1. Motors affected are rated from 1 to 200 hp, drip-proof and totally enclosed fan-cooled enclosures. It shall not apply to other types as regard to the efficiency requirements.

4.2.2 A motor's performance shall equal or exceed the nominal full load efficiency levels given in Table 4.1. Motors operating more than 750 hours a year should be of energy efficient types as shown in Table 4.2. Energy efficient motors are higher quality motors with increased reliability, providing savings in reduced downtime, replacement and maintenance cost.

4.2.3 The nameplates of these motors shall include not only all the information required by the Philippine Electrical Code Part 1, but also the rated full load efficiency and full load power factor as determined by Philippine National Standard PNS IEC 61972:2005 (IEC published 2002), Methods for Determining Losses and Efficiency of Three Phase Cage Induction Motors.

High efficiency motors are basically high flux density, low core loss and low current density motors which should be employed whenever applicable.

4.2.4 Motor Selection

4.2.4.1 The type and the size of the squirrrel-cage induction motor shall be selected only after an accurate determination of the starting and running requirements of the load has been made, taking into account the following factors:

1. maximum overload expected
2. ambient conditions
3. power supply conditions
4. future expansion
5. deterioration of the driven load
6. duty cycle
7. speed

4.2.4.2 The first five factors above should be considered carefully as they suggest the selection of larger motors at the expense of low power factor and low efficiency.

4.2.4.3 In cases where higher kW rating is necessary due to special requirements of the application, the motor rating may be increased but not to exceed 125% of the calculated maximum load to be served. If this rating is not available, the next higher rating may be selected.

4.2.4.4 Motors with high speeds are generally more efficient than those of lower speeds and should be considered as much as possible.

4.2.4.5 Where an application requires varying output operation of motor-driven equipment such as a centrifugal pump, a variable speed drive shall be considered instead of throttling the output of the pump.

4.2.4.6 Other applicable requirements specified in the latest edition of the Philippine Electrical Code Part 1 shall be complied with.

4.3 Transformers

4.3.1 All owner-supplied transformers that are part of the building electrical system shall have efficiencies not lower than 98%. The transformer should be tested in accordance with relevant Philippine

National Standards (PNS) at the test conditions of full load, free of harmonics and at unity power factor.

4.3.2 The average power factor of the loads being served by the transformers at any time should not be less than 85%. In cases where load power factors are below this value, capacitors or power factor improving devices shall be provided so that automatic or manual correction can be made.

4.3.3 Transformer load grouping schemes shall be so designed such that the transformer~~s~~ is loaded to not less than 75% of its full load ratings and that no-load circuits or partially loaded circuit combinations should be minimized as much as possible.

4.3.4 Disconnect switches or breakers shall be provided at the primary (supply) side of transformer to allow electrical disconnection during no load period.

4.3.5 Transformers located inside a building should have sufficient ventilation and should have a direct access from the road for ease of maintenance at all times.

4.4 Power Distribution

4.4.1 In the calculation of the wire sizes to be used, the Philippine Electrical Code, Part I have specified the procedure and the factors to be considered in order to arrive at the minimum acceptable wire size.

4.4.2 The sum of the operating cost over the economic life of distribution system should be minimized rather than the initial cost only. Operating cost shall include but not limited to maintenance and energy losses.

4.5 Metering for Energy Auditing

4.5.1 Buildings whose designed connected electrical load is 250 kVA and above shall have metering facilities capable of measuring voltage, current, power factor, maximum demand and energy consumption. In addition, it shall have provision for feeder metering facilities.

4.5.2 For metering facilities should have capabilities of measuring energy consumption and current. Where possible, a feeder circuit shall be serving a particular group of loads sharing the same function for better monitoring and control. These loads can be grouped as follows:

4.5.2.1 Lighting Load

4.5.2.2 Chillers

4.5.2.3 Air Handling Units, Unitary Air Conditioning Systems

4.5.2.4 Other Motor Loads (exhaust fan, pumps, etc.)

4.5.3 In multiple tenant buildings, each tenant unit shall have a provision for measuring the tenant's energy consumption. Power to common utilities such as water pump, elevator, etc. need not meet these tenant provisions.

4.5.4 In order to facilitate metering safely and quickly by qualified personnel, an adequate working space in front of the electrical panels and meters shall be provided.

Table 4.1 Minimum Acceptable Full Load Efficiency

Motor Size	Open Drip-Proof Motors			Totally Enclosed Fan-Cooled Motors		
	revolutions per minute			revolutions per minute		
	1200	1800	3600	1200	1800	3600
0.8 kW (1 hp)	72.0	77.0	80.0	-	72.0	75.5
1.2 kW (1.5 hp)	82.5	82.5	82.5	82.5	81.5	78.5
1.6 kW (2 hp)	84.0	82.5	82.5	82.5	82.5	82.5
2.4 kW (3 hp)	85.5	86.5	82.5	84.0	84.0	82.5
4.0 kW (5 hp)	86.5	86.5	85.5	85.5	85.5	85.5
6.0 kW (7.5 hp)	88.5	88.5	85.5	87.5	87.5	85.5
8.0 kW (10 hp)	90.2	88.5	87.5	87.5	87.5	87.5
12.0 kW (15 hp)	89.5	90.2	89.5	89.5	88.5	87.5
16.0 kW (20 hp)	90.2	91.0	90.2	89.5	90.2	88.5
20.0 kW (25 hp)	91.0	91.7	91.0	90.2	91.0	89.5
24.0 kW (30 hp)	91.7	91.7	91.0	91.0	91.0	89.5
32.0 kW (40 hp)	91.7	92.4	91.7	91.7	91.7	90.2
40.0 kW (50 hp)	91.7	92.4	91.7	91.7	92.4	90.2
48 kW (60 hp)	92.4	93.0	93.0	91.7	93.0	91.7
60 kW (75 hp)	93.0	93.6	93.0	93.0	93.0	92.4
80 kW (100 hp)	93.0	93.6	93.0	93.0	93.6	93.0
100 kW (125 hp)	93.6	93.6	93.0	93.0	93.6	93.0
120 kW (150 hp)	93.6	94.1	93.6	94.1	94.1	93.6
160 kW (200 hp)	94.1	94.1	93.6	94.1	94.5	94.1

Table 4.2 Minimum Acceptable Full Load Efficiency for High Efficient Motors

Motor Size	Open Drip-Proof Motors			Totally Enclosed Fan-Cooled Motors		
	revolutions per minute			revolutions per minute		
	1200	1800	3600	1200	1800	3600
0.8 kW (1hp)	74.0	80.0	82.5	74.0	80.0	82.5
1.2 kW (1.5hp)	84.0	84.0	82.5	85.5	84.0	82.5
1.6 kW (2 hp)	85.5	84.0	84.0	86.5	84.0	84.0
2.4 kW (3 hp)	86.5	86.5	84.0	87.5	87.5	85.5
4.0 kW (5hp)	87.5	87.5	85.5	87.5	87.5	87.5
6.0 kW (7.5 hp)	88.5	88.5	87.5	89.5	89.5	88.5
8.0 kW (10 hp)	90.2	89.5	88.5	89.5	89.5	89.5
12.0 kW (15 hp)	90.2	91.0	89.5	90.2	91.0	90.2
16.0 kW (20 hp)	91.0	91.0	90.2	90.2	91.0	90.2
20.0 kW (25 hp)	91.7	91.7	91.0	91.7	92.4	91.0
24.0 kW (30 hp)	92.4	92.4	91.0	91.7	92.4	91.0
32.0 kW (40 hp)	93.0	93.0	91.7	93.0	93.0	91.7
40.0 kW (50 hp)	93.0	93.0	92.4	93.0	93.0	92.4
48 kW (60 hp)	93.6	93.6	93.0	93.6	93.6	93.0
60 kW (75 hp)	93.6	9.41	93.0	93.6	94.1	93.0
80 kW (100 hp)	94.1	94.1	93.0	94.1	94.5	93.6
100 kW (125 hp)	94.1	94.5	93.6	94.1	94.5	94.5
120 kW (150 hp)	94.5	95.0	93.6	95.0	95.0	94.5
160 kW (200 hp)	94.5	95.0	94.5	95.0	95.0	95.0

Section 5. Overall Thermal Transfer Value of Building Envelope

5.1 Scope

This section applies to air-conditioned buildings with a total cooling load of 175 kW or greater. The requirements and guidelines of this section cover external walls, roofs and air leakage through the building envelope.

The design criterion for building envelope, known as the Overall Thermal Transfer Value (OTTV), shall be adopted. The OTTV requirement which shall apply only to air-conditioned buildings is aimed at achieving the energy conserving design for building envelopes so as to minimize external heat gain and thereby reduce the cooling load of the air conditioning system.

5.2 Concept of OTTV

5.2.1 The solar heat gain through building envelope constitutes a substantial share of heat load in a building, which will have to be eventually absorbed by the air-conditioning system at the expense of energy input. To minimize solar heat gain into a building is therefore the first and foremost consideration in the design of energy efficient building. The architectural techniques used to achieve such purpose are too numerous to mention. Siting and orientation of a rectangular building to avoid exposure of its long facades to face east and west, for instance, is a simple means of reducing solar heat gain if the building sites permits. Appropriate choice of building shape to minimize building envelope area and selection of light colors for wall finish to reflect solar radiation are other common sense design alternatives to lower solar heat input.

5.2.1.1 The OTTV concept takes into consideration the three basic elements of heat gain through the external walls of a building, as follows:

- **a.** heat conduction through opaque walls;
- **b.** heat conduction through glass windows;
- **c.** solar radiation through the glass windows.

5.2.2 These three basic elements of heat input are averaged out over the whole envelope area of the building to give an overall thermal transfer value, or OTTV in short. This concept, in essence, helps to preserve a certain degree of flexibility in building design.

5.2.3 For the purpose of energy conservation, the maximum permissible OTTV has been set at 45 W/m^2.

5.2.4 OTTV Formula for Building Envelope

5.2.4.1 To calculate the OTTV of an external wall, the following basic formula shall be used:

$$\text{OTTV} = \frac{(\text{Aw x Uw x TDeq}) + (\text{Af x Uf x } \Delta\text{T}) + (\text{Af x SC x SF})}{\text{Ao}}$$

Where:

OTTV	:	overall thermal transfer (W/m^2)
Aw	:	opaque wall area (m^2)
Uw	:	thermal transmittance of opaque wall (W/m^2 ºK)
TDeq	:	equivalent temperature difference (ºK), see sub paragraph 5.2.4.1.1
Af	:	fenestration area (m^2)
Uf	:	thermal transmittance of fenestration (W/m^2)
ΔT	:	temperature difference between exterior and interior
SC	:	shading coefficient of fenestration
SF	:	solar factor (W/m^2), see sub paragraph 5.2.5.1.2
Ao	:	gross area of exterior wall (m^2) = Avs + Af

5.2.4.1.1 Equivalent Temperature Difference

Equivalent Temperature Difference (TDeq) is that temperature difference which results in the total heat flow through a structure as caused by the combined effects of solar radiation and outdoor temperature. The TDeq across a structure takes into account the types of construction (mass and density), degree of exposure, time of day, location and orientation of the construction and design condition. By adopting the TDeq concept, the unsteady heat flow through a construction may then be calculated using the steady state heat flow equation:

$$q = A \text{ x } U \text{ TDeq}$$

For the purpose of simplicity in OTTV calculation, the TDeq of different types of construction have been narrowed down to three values according to the densities of the constructions, as given in Table 5.1.

5.2.4.1.2 Solar Factor

The Solar Factor for vertical surfaces has been experimentally determined for this zone. From data collected over a period of time for the eight primary orientations, the average Solar Factor for vertical surfaces has been worked out to be 130 W/m^2. This figure has to be modified by a correction factor when applied to a particular orientation and also if the fenestration component is sloped at an angle skyward. For the purpose of the building regulations, any construction having a slope angle of more than 70^o with respect to the horizontal shall be treated as a wall. For a given orientation and angle of slope, the Solar Factor is to be calculated from the following formula:

$$SF : 130 \text{ x } CF \ (W/m^2)$$

Where CF is the correction factor with reference to the orientation of the façade and the pitch angle of the fenestration component and is given in Table 5.2.

5.2.4.2 As walls at different orientations receive different amounts of solar radiation, it is necessary in general to compute first the OTTVs individual walls, then the OTTV of the whole building envelope is obtained by taking the weighted average of these values. To calculate for the envelope of the whole building, the following formula shall be used:

$$OTTV = \frac{A_{01} \text{ x } OTTV_1 + A_{02} \text{ x } OTTV_2 + \ldots + A_{ox} \text{ x } OTTV_x}{A_{01} + A_{02} + A_{ox}}$$

5.2.4.3 The gross area of an exterior wall shall include all opaque wall areas, window areas and door areas, where such surfaces are exposed to outdoor air and enclose an air-conditioned space. The fenestration area shall include glazing, glazing bars, mullions, jambs, transoms, heads and sills of window construction and shall be measured from the extreme surfaces of the window construction

5.2.4.4 Where more than one type of material and/or fenestration is used, the respective term or terms shall be expanded into sub-elements, such as

$$(Aw_1 \text{ x } Uw_1 \text{ x } TDeq_1) + (Aw_2 \text{ x } Uw_2 \text{ x } TDeq_2), \text{ etc.}$$

5.2.4.5 In the case of a mixed-use building where the residential portion and the commercial portion are distinctly and physically separated from each other, e.g., in the form of a residential tower block and a commercial podium, the OTTVs of the two portions should be separately computed.

5.2.4.6 Exterior Walls (with Day lighting)

5.2.4.6.1 The calculation procedure for the OTTV of exterior walls considering day lighting is the same as given Section 5.2. The day lighting aspect is explained in the following sections.

5.2.4.6.2 A credit for day lighting is provided for several reasons. In day lighting applications, the Window to Wall Ratio (WWR) is usually large. Glazing allows more heat gain to the interior space than an isolated wall and, due to this; a larger WWR normally causes a higher level of cooling needs in the space. However, artificial lighting energy savings due to day lighting can be greater than the additional energy penalty for space cooling due to the increased glazed surface area when the building envelope is carefully designed to allow day lighting. The transparent portions of the building envelope should be designed to prevent solar gains above that necessary for effective for day lighting. To make sure that day lighting is being effectively utilized, automatic day lighting controls shall be used to turn off the artificial lights when sufficient natural light is available.

5.2.4.6.3 Day lighting credit may be taken for those areas with installed automatic lighting controls for all lights within 4 meters of an exterior wall. Day lighting credit is accounted for by a 10% reduction in the OTTVs. These reduced OTTV values are then used in the calculation of the building’s OTTV using Equation 5.2.4.1.

5.2.4.6.4 If the automatic day lighting control credit is taken, then the visible transmittance of the fenestration system used for that exterior wall(s) where day lighting is applied shall not be less than 0.25.

5.2.5 Air Leakage

5.2.5.1 General

The infiltration of warm air and exfiltration of cold air contribute substantially to the heat gain of an air-conditioned building. As a basic requirement, buildings must not have unenclosed doorways, entrances, etc., and where heavy traffic of people is anticipated, self-closing doors must be provided.

5.2.6 Weather-stripping of Windows and Doors

5.2.6.1 The concept of OTTV is based on the assumption that the envelope of the building is completely enclosed to minimize the infiltration of warm air and exfiltration of cool air. Infiltration and exfiltration contribute substantially to the building's heat gain, as the warmer infiltrated air must be cooled in order to maintain the desired comfort condition.

5.2.6.2 As a basic requirement, the building must not have unenclosed doorways, entrances, etc. For commercial buildings where heavy traffic of people is anticipated, self-closing doors should be provided.

5.2.6.3 To further minimize the exfiltration of cool air and infiltration of warm air through leaky windows and doors, effective means of weather-stripping should also be incorporated.

5.2.6.4 Preferably, doors and windows should be designed to meet the following criteria when tested under a pressure differential of 75 Pa:

a. windows: leakage to limit to 2.77 m^3/h per meter of sash crack

b. swinging revolving or sliding doors: leakage to limit to 61.2 m^3/h per meter of door crack

c. air curtains may be used in very high volume entrances only when revolving or self-closing sliding doors are not appropriate.

5.3 Units Located at the Perimeter of the Building Envelope in Air-conditioned Buildings

5.3.1 Subject to Subsection 5.3.2, in air-conditioned building where shops or other units are designed such that they located along the perimeter of the building envelope, the door openings of such shops or units shall be designed to face the interior of the building.

5.3.2 Where the door opening of any shop or unit is designed to pen to the exterior of the building, then:

a. That shop or unit with the door opening to the exterior shall be completely separated from the other parts of the building; and

b. That shop or unit, if it is to be air-conditioned, shall have its own individual air-conditioning system separate and independent from the main or central system.

5.3.3 Zoning for Temperature Cool

5.3.3.1 At least one thermostat for the regulations of space temperature shall be provided for each separate air handling system and zone.

5.3.3.2 Each air handling system shall be equipped with a readily accessible means of shutting off or reducing the energy used for the air-conditioning system during periods of non-use or alternative uses of building spaces or zones served by the system.

5.3.3.3 For the purpose of meeting the requirements of Subsection 5.3.3.2, the following devices shall be regarded as satisfactory:

a. Manually adjustable automatic timing devices;
b. Manual devices for use by operating personnel; or
c. Automatic control systems.

5.3.4 In any development, an automatic control device acceptable to the Building Authority shall be installed in every guest room for the purpose or automatically switching off the lighting and reducing the air-conditioning when a room is not occupied.

5.3.4.1 All buildings used or intended to be used as offices, a hotel or shop or a combination thereof shall be provided with data logging facilities for the collection of data for energy auditing.

5.4 Roof Insulation and Roof OTTV

5.4.1 Thermal Transmittance of Roof

5.4.1.1 Solar heat gain into a building through an uninsulated roof increases air temperature indoor. In all buildings, directional radiation received on the roof can be one of the main causes of thermal discomfort.

5.4.1.2 For an air-conditioned building, solar heat gain through the roof also constitutes a substantial portion of the cooling load. From on-site solar radiation measurements taken, the intensity of the radiation on a horizontal surface can be as much as 3 times of that on a vertical surface.

The purpose of roof insulation is therefore two-folds: to conserve energy in air-conditioned buildings and to promote thermal comfort in non air-conditioned buildings. In both cases, the building regulations require that the roof shall not have a thermal transmittance or U-value greater than the values tabulated in Table 5.3.

5.4.1.3 Where more than one type of roof is used, the average thermal transmittance for the gross area of the roof should be determined from:

$$Ur = \frac{Ar_1 \text{ x } Ur_1 + Ar_2 \text{ x } Ur_2 + \ldots + Ar_x \text{ x } Ur_x}{Ar_1 \text{ x } Ar_2 + \ldots + Ar_x}$$

Equation 5.1

Where:

U_r : the average thermal transmittance of the gross roof area (W/m^2 ^oK)

U_{r1} : U_{rx} : the respective thermal transmittance of different roof sections (W/m^2 ^oK)

A_{r1} : A_{rx} : the respective area of different roof sections (m^2)

Similarly, the average weight of the roof should be calculated as follows:

$$Wr = \frac{Ar_1 \text{ x } Wr_1 + Ar_2 \text{ x } Wr_2 + \ldots + Ar_x \text{ x } Wr_x}{Ar_1 \text{ x } Ar_2 + \ldots + Ar_x}$$

Equation 5.2

Where:

Wr	:	average weight of roof (kg/m^2)
Wr_1 Wr_n	:	the respective weight of different roof sections (kg/m^2)

5.5 OTTV of Roof

5.5.1 In the case of air-conditioned building, the concept of overall thermal transfer value, or OTTV, is also applicable to its roof if the latter is provided with skylight. The OTTV concept for roof takes into consideration three basic elements of heat gain, as follows:

a. heat conduction through opaque roof;
b. heat conduction through skylight;
c. solar radiation through skylight.

The maximum permissible OTTV for roofs is set at 45 W/m^2, which is the same as that for walls.

5.5.1.1 To calculate the OTTV of a roof, the following basic formula shall be used.

$$OTTV = \frac{(Ar \times Ur \times TDeq) + (As \times Us \times \Delta T) + (As \times SC \times SF)}{Ao}$$

Equation 5.3

Where,

OTTV	:	overall thermal transfer value (W/m^2)
Aw	:	opaque wall area (m^2)
Uw	:	thermal transmittance of opaque wall ($W/m^2\,°K$)
TDeq	:	equivalent temperature difference (°K), see sub-paragraph 5.2.2.1
As	:	skylight area (m^2)
Us	:	thermal transmittance of skylight area ($W/m^2\,°K$)
T	:	temperature difference between exterior and interior design conditions
SC	:	shading coefficient of skylight
SF	:	solar factor (W/m^2), see sub paragraph 5.2.2.2
Ao	:	gross area of roof (m^2) = Ar + As

5.5.1.1.1 Equivalent Temperature Difference

For the purpose of simplicity in OTTV calculation, the TDeq of different types of roof constructions have been standardized in Table 5.4.

5.5.1.1.2 Solar Factor

For a given orientation and angles of slope, the Solar Factor is given by:

$$SF = 320 \text{ x } CF \ (W/m^2) \qquad \text{Equation 5.4}$$

Where CF is the correction factor with reference to the orientation of the roof and the pitch angle of its skylight and is given in Table 5.5.

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

$$OTTV = \frac{Ao_2 \text{ x } OTTV_2 + Ao_2 \text{ x } OTTV_2 + \ldots + Ao_x \text{ x } OTTV_x}{Ao_1 + Ao_2 + \ldots + Ao_x}$$

Equation 5.5

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

5.5.1.4 When more than one type of material and/or skylight is used, the respective term or terms shall be expanded into sub-elements as:

$$(Ar_1 \text{ x } Ur_1 \text{ x } TDeq.,) + (Ar_2 \text{ x } Ur_2 \text{ x } TDeq_2) + \ldots$$

5.5.1.5 The OTTV requirement for roof applies to an air-conditioned building and is over the U-value requirement.

5.5.1.6 The OTTV of the roof should not be computed together with the walls. Each should be treated separately.

5.5.1.7 The use of reflective coatings which are reasonably impervious to moisture degradation are strongly recommended for roofs as stop overlays.

5.5.1.8 The values in Table 5.3 may be exceeded by 50% if any one of the following applies:

a. The roof area is shaded from direct solar radiation by ventilated double roof;

b. External roof surface reflective treatments are used where the solar reflectivity is equal to or greater than 0.7 and the treatment is free from algae growth.

5.6 Submission Procedure

At the time of submission of building plans, the architect should provide the information on roof insulation by:

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

b. If the building is air-conditioned, calculating the OTTV of the walls and roof assembly.

Table 5.1 Equivalent Temperature Difference for Walls

Wall Construction Mass Per Unit Area	TDeq
0 –125 kg/m^2	15 ºK
126 – 195 kg/m^2	12 ºK
Above 195 kg/m^2	10 ºK

Table 5.2 Solar Correction Factor Wall

Slope Angle	Orientation							
	N	NE	E	SE	S	SW	W	NW
70º	1.32	1.63	1.89	1.65	1.32	1.65	1.89	1.63
75º	1.17	1.48	1.75	1.50	1.18	1.50	1.75	1.48
80º	1.03	1.33	1.59	1.35	1.04	1.35	1.59	1.33
85º	0.87	1.17	1.42	1.19	0.89	1.19	1.42	1.17
90º	0.72	1.00	1.25	1.02	0.74	1.02	1.25	1.00

Note: The correction factors for other orientations and other pitch angles are found by interpolation.

Table 5.3 Maximum U-value for Roof

Weight Group	Weight Range (kg/m^2)	Maximum Thermal Transmittance (W/m^2 K)	
		Air-conditioned Building	Non air-conditioned Building
Light	Under 50	0.5	0.8
Medium	50 to 230	0.8	1.1
Heavy	Over 230	1.2	1.5

Table 5.4 Equivalent Temperature Difference for Roof

Roof Construction (Mass Per Unit Area)	TDeq
0 – 50 kg/m^2	24 ºK
51– 230 kg/m^2	20 ºK
Over 230 kg/m^2	16 ºK

Table 5.5 Solar Correction Factor for Roof

Slope Angle	Orientation							
	N	NE	E	SE	S	SW	W	NW
0º	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5º	1.00	1.01	1.02	1.02	1.00	1.02	1.02	1.01
10º	1.01	1.03	1.04	1.03	1.01	1.03	1.04	1.03
15º	1.01	1.03	1.05	1.03	1.01	1.03	1.05	1.03
20º	1.00	1.03	1.06	1.03	1.01	1.03	1.06	1.03
25º	0.98	1.02	1.06	1.03	0.99	1.03	1.06	1.02
30º	0.95	1.01	1.03	1.01	0.97	1.01	1.05	1.01
35º	0.93	0.98	1.03	0.99	0.94	0.99	1.03	0.98
40º	0.90	0.96	1.01	0.96	0.91	0.96	1.01	0.96
45º	0.86	0.92	0.98	0.92	0.87	0.93	0.98	0.92
50º	0.81	0.89	0.95	0.89	0.83	0.89	0.95	0.89
55º	0.77	0.84	0.91	0.85	0.78	0.85	0.91	0.84
60º	0.71	0.85	.86	0.80	0.73	0.80	0.86	0.79
65º	0.66	0.74	0.81	0.75	0.67	0.75	0.81	0.74

Note:

1. The Correction Factors for other orientations and other pitch angles may be found by interpolation.

2. For the purpose of the building regulations, any construction with a pitch angle less than 70º shall be treated as a roof.

Section 6. Air Conditioning and Ventilating System

6.1 Scope

The requirements in this Section represent minimum design criteria. The designer should evaluate other energy conservation measures, which may be applicable to the proposed building.

6.2 Load Calculation

6.2.1 Calculation Procedures

Cooling system design loads for the purpose of sizing system and equipment should be determined in accordance with the procedures in the latest edition of the ASHRAE Handbook of Fundamentals or other equivalent publications.

6.2.2 Indoor Design Conditions

The indoor conditions in an air-conditioned space shall conform to the following:

1. Design Dry Bulb Temperature	25 ºC
2. Design Relative Humidity	55%
3. Maximum Dry Bulb Temperature	27 ºC
4. Minimum Dry Bulb Temperature	23 ºC
5. Maximum Relative Humidity	60 %
6. Minimum Relative Humidity	50 %

Note:
Indoor design conditions may differ from those presented above because of special occupancy or process requirement, source control, air contamination or local regulations.

6.2.3 Outdoor Design Conditions

The outdoor conditions shall be taken as follows:

1. Design Dry Bulb Temperature 35 ºC
2. Design Wet Bulb Temperature 27 ºC

6.2.4 Ventilation

The quality and quantity of air used to ventilate air-conditioned spaces shall always be sufficient and acceptable to human occupation and comply with applicable health and/or air quality requirements. Ventilation requirements shall conform to the design criteria in Table 6.1.

Exception: Outdoor air quantities may exceed those shown in Table 6.1 because of special occupancy or process requirements, source control, air contamination or local regulations.

6.2.5 Kitchen Ventilation

Figures 6.1 through 6.6 show the six basic hood styles for Type 1 applications. The style names are not used universally in all standards and codes but are well accepted in the industry. The styles are as follows:

1. Wall-mounted canopy – Used for all types of cooking equipment located against the wall. (See Figure 6.1)

2. Single-island canopy – Used for all types of cooking equipment in a single-line island configuration. (See Figure 6.2)

3. Double-island canopy – Used for all types of cooking equipment mounted back-to-back in an island configuration. (See Figure 6.3)

4. Back shelf – Used for counter-height equipment typically located against the wall, but could be freestanding. (See Figure 6.4)

5. Eyebrow – Used for direct mounting to oven and some dishwashers. (See Figure 6.5)

6. Pass-over – Used over counter-height equipment when pass-over configuration (from the cooking side to the serving side) is required**.** (See Figure 6.6)

6.3 System Design and Sizing.

Air conditioning system and equipment shall be sized as close as possible to the space and system loads calculated in accordance with Section 6.2. The design of the system and the associated equipment and controls should take into account important factors such as nature of application, type of building construction, indoor and outdoor conditions, internal load patterns, control methods for efficient energy utilization and economic factors.

6.3.1 Engineered systems and equipment should be properly sized and selected to meet maximum loads and should have good unloading characteristics to meet the minimum load efficiency. These should be arranged in multiple units or increments of capacity to meet partial and minimum load requirements without short cycling.

Chilled water systems 700 kW (200 TR) or less – minimum of 2 chiller units.

Above 700 kW to 4218 kW (1200 TR) – minimum of 3 chiller units.

Above 4218 kW to 8787 kW (2500 TR) – minimum of 4 chiller units.

Above 8787 kW – depends on the good judgment of the design engineer.

6.3.2 Considerations should be given at the design stage for providing centralized monitoring and control to achieve optimum operation with minimum consumption of energy.

6.4 Fan System Design Criteria

6.4.1 General

The following design criteria apply to all air conditioning fan systems used for comfort ventilating and/or air conditioning. For the purpose of this Section, the energy demand of a fan system is the sum of the demand of all fans, which are required to operate at design conditions to supply air from the cooling source to the conditioned space(s) or exhaust it to the outdoors.

Exception: Systems with a total fan motor power requirement of 7.5 kW or less.

6.4.2 Constant Volume Fan Systems

For fan systems that provide a constant air volume whenever the fans are operating, the power required by the motor of the combined fan system at design conditions shall not exceed 0.5 $W/m^3/h$.

6.4.3 Variable Air Volume (VAV) Fan Systems

6.4.3.1 For fan systems that are able to vary system air volume automatically as a function of load, the power required by the motors of the combined fan system at design conditions shall not exceed 0.75 $W/m^3/h$.

6.4.3.2 Individual VAV fans with motors rated at 7.5 kW and larger shall include controls and devices such as variable speed drive necessary to make the fan motor operate efficiently even at flow rates of as low as 40% of the rated flow.

6.5 Pumping System Design Criteria

6.5.1 General

The following design criteria apply to all pumping systems used for comfort air conditioning. For purposes of this Section, the energy demand of a pumping system is the sum of the demand of all pumps that are required to operate at design conditions to supply fluid from the cooling source to the conditioned space(s) and return it back to the source.

Exception: Systems with total pump motor power requirement of 7.5 kW or less.

6.5.2 Pressure Drop

Chilled water and cooling water circuits of air conditioning systems shall be designed at a maximum velocity of 1.2 m/s for a 51 mm diameter pipe and a pressure drop limit of 39.2 kPa per 100 equivalent meter for piping over 51 mm diameter. To minimize erosion for the attainment of the piping system, the water velocities found in Table 6.3 should not be exceeded.

6.5.3 Variable flow

Pumping systems that are provided with control valves designed to modulate or step open or close, depending on the load, shall be required for variable fluid flow. The system shall be capable of reducing system flow to 50% of the design flow or less.

Flow may be varied using variable speed driven pumps, multiple stage pumps or pumps riding their performance characteristic curves. Pumps with steep performance curve shall not be used since they tend to limit flow rates. Variable speed or staged pumping should be employed in large pumping systems.

Exceptions:

1. Systems where a minimum flow greater than 50% of the design flow rate is required for the proper operation of the equipment served by the system.

2. Systems that serve only one control valve.

6.6 Air Distribution System Design Criteria

6.6.1 General

The temperature and humidity of the air within the Conditioned space shall be maintained at an air movement from 0.20 to 0.30 m/s.

6.6.1.1 The air in such conditioned space(s) should at all times be in constant motion sufficient to maintain a reasonable uniformity of temperature and humidity but shall not cause objectionable draft in any occupied portion(s). In cases wherein the only source of air contamination is the occupant, air movement shall have a velocity of not more than 0.25 m/s as the air enters the space.

6.6.2 Air Distribution

Air distribution should be designed for minimum resistance and noise generation. Ductworks should deliver conditioned air to the spaces as directly, quietly and economically as possible and return the air to the cooling source. When the duct layout has few outlets, conventional low velocity design, which corresponds, to a flow resistance of 0.8 to 1.5 Pa per equivalent meter shall be used. In complex systems with long runs and medium to high pressure of 375 to 2000 Pa ductwork should be designed at pressure drop of not greater than 3 to 5 Pa per equivalent meter.

6.6.3 Separate Air Distribution System

6.6.3.1 Areas that are expected to operate non-simultaneously for more than 750 hours per year shall served by separate air distribution systems. As an alternative, off-hour controls shall be provided in accordance with Section 6.7.3.

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

Exception: Areas requiring comfort cooling only that 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 areas is no more than 25% of the total system supply air or the total conditioned area is less than 100 sq. m.

6.6.3.3 Separate air distribution systems should be considered for areas having substantially different cooling characteristics, such as perimeter zones in contact to interior zones.

6.6.3.4 Use of light-troffers as path for return air maybe considered to reduce the power for air circulation of centralized air conditioning system.

6.7 Controls

6.7.1 System Control

6.7.1.1 Each air-conditioned system shall be provided with at least one control device for the regulation of temperature.

6.7.1.2 All mechanical ventilation system (supply and exhaust) equipment either operating continuously or not shall be provided with readily accessible manual and/or automatic controls or other means of volume reduction, or shut-off when ventilation is not required.

6.7.2 Zone Control

6.7.2.1 Each air-conditioned zone shall be controlled by individual thermostatic controls responding to temperature within the zone.

6.7.2.2 Systems that serve zones that can be expected to operate non-simultaneously for more than 750 hours per year (i.e. approximately 3 hours per day on a 5 day week basis) shall include isolation devices and controls to shut off the supply of conditioned air to each zone independently.

Isolation is not required for:

1. For zones expected to operate continuously.
2. Systems which are restricted by process requirements.
3. Gravity and other non-electrical ventilation system may be controlled by readily accessible manual damper.

6.7.3 Control Area

6.7.3.1 The supply of conditioned air to each zone/area should be controlled by individual control device responding to the average temperature within the zone. Each controlled zone shall not exceed 465 sq. m in area.

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

6.7.3.3 Zones may be grouped into a single isolation area provided the total conditioned floor area does not exceed 465 sq. m per group nor include more than one floor.

6.7.4 Temperature Controls

Where used to control comfort cooling, temperature controllers should be capable of being set locally or remotely by adjustment or selection of the sensors, between 23 ºC and 27 ºC or in accordance with local regulations.

6.7.5 Location

Thermostats in controlled zones should be located where they measure a condition representative of the whole space and where they are not affected by direct radiation, drafts, or abnormal thermal conduction or stratification.

6.8 Piping Insulation

6.8.1 All chilled water piping shall be thermally insulated in accordance with Table 6.4 to prevent heat gain and avoid sweating on the insulation surface. The insulation shall be suitably protected from damage.

6.8.2 Chiller surfaces especially the evaporator shell and compressor Suction line(s) should be insulated to prevent sweating and heat gain. Insulation covering surfaces on which moisture can condense or those exposed to ambient conditions must be vapor-sealed to prevent any moisture seepage through the insulation or to prevent condensation in the insulation.

Exceptions:

1 Piping that conveys fluids that have not been cooled through the use of fossil fuels or electricity.

2. Piping at fluid temperatures between 20 ºC and 40 ºC.

3. When the heat gain of the piping without insulation does not increase the energy requirements of the building.

6.8.3 For materials with thermal resistance greater than 0.032 sq. m ºC/W-mm, the minimum insulation thickness shall be as follows:

$$t = \frac{0.032 \text{ x thickness in Table 6.4}}{\text{actual R value}} \qquad \text{Equation 6.1}$$

Where :
t = minimum thickness in mm
R = actual thermal resistance, sq. m ºC/W-mm

6.8.4 For materials with thermal resistance lower than 0.028 sq. m ºC/W-mm, the minimum insulation thickness shall be:

$$t = \frac{0.028 \text{ x thickness in Table 6.4}}{\text{actual R value}} \qquad \text{Equation 6.2}$$

Where:
t = minimum thickness in mm
R = actual thermal resistance, sq. m ºC/W-mm

6.9 Air Handling System Insulation

6.9.1 All air handling ducts and plenums installed as part of the air distribution system and which are outside of air-conditioned spaces shall be thermally insulated sufficiently to minimize temperature rise of the air stream within them and to prevent surface condensation. Insulated ducts located outside of buildings shall be jacketed for rain tightness and for protection against damage. Air ducts or plenums within air-conditioned spaces may not be insulated if the temperature difference, TD, between the air outside and within the ducts or plenums would not cause surface condensation. Due consideration should be paid to the due point temperature of the air surrounding the ducts or plenums.

The required insulation thickness shall be computed using insulation material having resistivity ranging from 0.023 to 0.056 sq. m ºC/W-mm and the following equation:

$$L = \frac{kRs\,(Dp - to)}{(Db - Dp)} \qquad \text{Equation 6.3}$$

Where:
Db = ambient still air-dry bulb temperature, ^{o}C
Dp = dew point, ^{o}C
To = operating temperature, ^{o}C
Rs = surface thermal resistance = 0.115 sq. m ^{o}C/W-mm
k = mean thermal conductivity, W-mm/sq. m ^{o}C
L = thickness, mm

Exceptions:

1. When the heat gain of the ducts, without insulation, will not increase the energy requirements of the building
2. Exhaust air ducts.

6.9.2 The thermal resistance of the insulation, excluding film resistance should be:

$$R = \frac{TD}{347} = \text{sq. m ºC/W-mm} \qquad \text{Equation 6.4}$$

Where:
TD = temperature differential in ºC

6.10 Air Conditioning Equipment

6.10.1 Minimum Equipment Performance

Air conditioning equipment shall have a minimum performance corresponding to the rated conditions shown in Table 6.5. Data furnished by equipment supplier or manufacturer or certified under a nationally recognized certification program or rating procedure shall be acceptable to satisfy these requirements.

6.10.1.1 Performance Rating

The performance rating of the air conditioning equipment shall be measured by its EER or kWe/TR whichever is applicable.

The EER shall not be less than those quoted in Table 6.6 while kWe/TR shall not be greater than the figures in the same table.

6.10.2 Field-assembled Equipment and Components

6.10.2.1 When components from more than one supplier are used as parts of the air conditioning system, component efficiencies shall be specified based on the data provided by the suppliers/manufacturers, which shall provide a system that complies with the requirements of Section 6.10.1.

6.10.2.2 Total on-site energy input to the equipment shall be determined by the energy inputs to all components such as compressor(s), pump(s), fan(s), purge device(s), lubrication accessories and controls.

6.10.3 Air Conditioning Equipment Controls

Air conditioning equipment should have a means of controlling its capacity based on load requirement.

6.10.4 Air Conditioning Equipment with Energy Efficiency Ratio (EER) Label.

The designer shall consider air conditioning unit with the highest EER label available (particularly window and split types) to ensure high cooling capacity but low power consumption of the equipment. For details, please refer to PNS 396-1, Household appliances Energy Efficiency Ratio (EER) and labeling requirements – Part 1: Non-ducted air conditioners.

$$\text{Energy Efficiency Ratio (EER)} = \frac{\text{Cooling capacity, kJ/h}}{\text{Power input, W}}$$

Equation 6.5

Note: 1TR = 12,000 BTU/h
1 BTU = 1.055 kJ

6.11 Heat Recovery

Whenever there is a big demand for hot water requirement and if economical, heat recovery system shall be adopted.

6.12 Thermal Comfort in Non Air Conditioned Building

6.12.1 General Principles of Thermal Comfort

6.12.1.1 The main variables that affect human comfort are as follows:

a. dry bulb temperature;
b. relative humidity or wet bulb temperature;
c. air movement;
d. ventilation; and
e. thermal radiation from hot surface(ceiling, walls, and glass window).

To lesser extent, certain other factor also affects human comfort like indoor air quality.

6.12.1.2 In tropical climate, warm and humid conditions prevail during most parts of the year. Therefore, for non air-conditioned buildings, the control of these factors affecting comfort, such as ventilation, air movement and radiation from ceiling and walls, are very important in the local context.

6.12.2 Thermal Comfort by Natural Ventilation

6.12.2.1 Apart from meeting physiological needs, ventilation also serves to provide during a thermally comfortable indoor environment by removing indoor heat gain from various sources. The formula which relates ventilation to indoor temperature build-up is given as follows:

$$Q = \frac{q_s}{\rho C_p (T_2 - T_1)} \qquad \text{Equation 6.6}$$

Where:

Q	:	ventilation rate, m^3/sec
q_s	:	sensible heat gains, W
ρ	:	air density, kg/m^3 (about 1.2)
C_p	:	specific heat of air, J/kg-^oK (about 1000)
$(T_2 - T_1)$	:	total temperature rise of incoming air, ^oK

6.12.2.2 As a general rule, ventilation rate of 2.8 m^3/min to 5.7 m^3/min per person is adequate in practice if the average indoor air temperature rise of not more than 14 ºC is to be maintained as a result of body heat. Where power-driven and other heat sources are present, a higher ventilation rate is necessary.

6.12.3 Natural Ventilation by Window Opening

6.12.3.1 The influence of the size of windows on the internal air movement depends to a great extent on whether the room is crossed-ventilated. If the window is located on one wall of a room, its size will have little effect on the internal air velocity. However, an even distribution of windows and the correct choice of sashes will help to improve the ventilation even when the windows are located on one wall.

6.12.3.2 When cross ventilation in a room is assured, the relationship between ventilation rate and design wind speed is governed by the following equation:

$$Q = 17\ C_e\ V\ A \qquad \text{Equation 6.7}$$

Where:
- Q : ventilation rate in m^3/min
- C_e : effectiveness of opening (C_e is assumed to be 0.5 to 0.6 for perpendicular winds and 0.25 to 0.35 for diagonal winds)
- V : design wind speed in km/h
- A : area of opening in m^2

6.12.3.3 The design wind speed for a particular type of structure, locality and orientation has to be duly corrected to allow for height and screening effects of other buildings. The coefficient of discharge C_e is found to decrease fairly rapidly with an increase in the distance between the two openings in series, i.e., with an increase in room width. At 5.5 m, it will level off to about 0.47. In Equation 6.7, C_e is used to modify the external wind speed.

To determine the wind velocity near a building, the wind available at the time and height of the building, as well as the velocity gradient due to the ground friction, must be considered.

A general equation, known as the 'Power Law' is given by Equation 6.8:

$$Vz = Vg \frac{(Z)^a}{Zg} \qquad \text{Equation 6.8}$$

Where:
- Vz : velocity at height z, m/s
- Vg : gradient velocity, m/s
- Z : height, m
- Zg : gradient height, m
- a : a power index as given in the following table

Values of 'a'

Type of Country	Zg (meter)	a
Open country	274	0.16
Moderately rough, wooded country, small town	396	0.28
Rough, center of large town	518	0.40

6.12.3.4 Natural Ventilation by Jack Roof and Roof Ventilator

6.12.3.4.1 The performance of roof ventilators is normally rated in terms of speed and indoor and outdoor temperature differential to take into account the two natural motive forces of ventilation: thermal force and wind effect. The performance for roof cowls can be rated in the simplified equations as follows:

$$Q = 208\ AV \qquad \text{Equation 6.9}$$

Where:
Q = ventilation rate (m^3/h)
A = throat area of ventilator (cm^2)
V = wind speed (km/h)

6.12.3.4.2 For jack roof, the performance is poorer than that of roof cowl and there is no quantitative assessment of jack roof. However, assuming that jack roof are about 50% as efficient as cowl ventilators since the winward side of a jack roof does not act as exhaust opening, it has been worked out that the net area of opening of jack roofs required per metre run of a building is about 1.2 m^2 for a building width of 18 m.

6.12.3.4.3 Jack roof or roof ventilator should not be situated more than 9 m from other jack roof or roof ventilator. For jack roof, a minimum net area of 1.2 m^2 per meter run of jack roof is necessary, and for roof cowl ventilator, design should be substantiated by anticipated performance based on manufacturer's data or calculated from Equation 6.9.

6.12.3.5 Provisions for Natural Ventilation and Lighting

6.12.3.5.1 In natural regulations, it is specified that every building shall be provided with:

a. natural lighting by means of windows, skylights, fan-lights, doors, and other approved natural light transmitting media; and

b. natural ventilation by means of windows, skylights, fanlights, doors, louvers or similar ventilation openings.

6.12.3.5.2 In general, openings facing the sky, street courtyard or airweil will be considered as acceptable sources of natural lighting and ventilation.

6.12.3.5.3 In the case of a building other than factory or warehouse, any part of the building within 9 m from an acceptable opening shall be deemed to be adequately and ventilated by natural means.

6.12.3.5.4 In the case of a factory or warehouse, the maximum effective coverage of any window and other opening on an external wall shall be deemed to be 12 m from the opening, whereas the coverage of any jack roof or other opening on the roof shall be deemed to be 9 m measured horizontally from the opening.

6.12.3.5.5 In addition, the building regulations also specify that every room in any building be provided with natural lighting and ventilation by means of one or more sources having an aggregate of not less than x percent of the floor space of the room, of which at least y percent shall have opening to allow free uninterrupted passage of air. The respective values of x and y are given in Table 6.7 according to the types of occupancy or types of usage of the room.

6.12.3.5.6 In the case of public garages, two or more slides of the garage shall have opening for cross ventilation and the area opening shall be at least 50% of the area of the wall where is located.

6.12.3.5.7 For terrace houses having a depth greater than 12m, permanent ventilation from front to rear shall be provided to facilitate cross ventilation by suitable vents in all front, back and cross walls at each floor. Such vents shall have a net opening area of not less than 0.4 m^2 each.

6.12.3.6 Mechanical Ventilation

6.12.3.6.1 Where site conditions dictate that the normal requirements for natural lighting and ventilation cannot be met, the building regulations may allow the use of mechanical ventilation as substitute.

6.12.3.6.2 According to the regulations, the quantity of fresh air supply for mechanical ventilation of any room or space in a building shall be in accordance with the specified rates in Table 6.8.

Unless justified by exceptional circumstances, the ventilation rate shall not be exceeded by more than 30%.

6.12.3.7 Thermal Insulation

6.12.3.7.1 Besides roof insulation, the building regulations also specify that in the case of a non air-conditioned building, any external wall abutting a habitable room shall have U-value of not more than 3.5 W/m ºK.

6.12.3.8 Sun-shading

6.12.3.8.1 To encourage the provision of sun-shading devices in residential building for the purpose of improving thermal comfort, the building regulations make a special provision to relax the requirement pertaining to boundary clearance. Where overhangs, canopies, awnings, or other sun-shading devices are provided, these devices are permitted to project up to a point not less than 1600 mm from the lot boundary instead of the normal requirement of 2300 mm for boundary clearance.

6.12.3.8.2 To take advantage of this relaxation, the designer should ensure that only non-combustible materials are used for the construction of the shading devices.

6.12.3.8.3 It should be noted that the relaxation is only in respect of the projection of the shading devices; whereas the walls from which such devices project shall comply with the normal boundary clearance requirement.

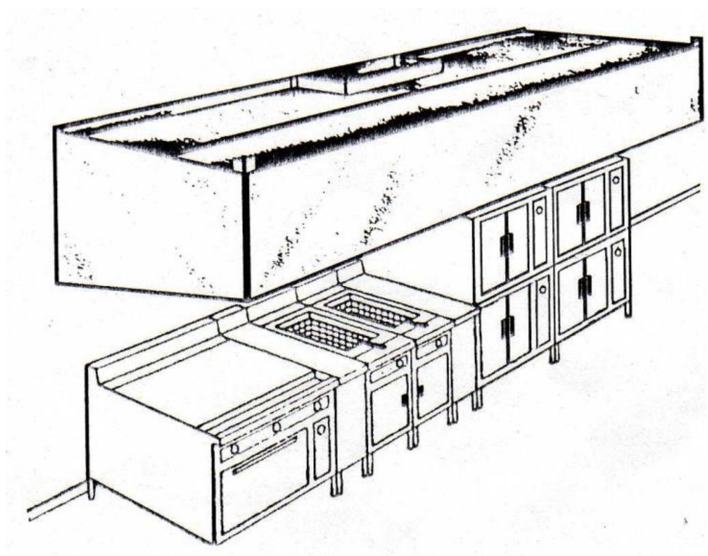


Figure 6.1 Wall Mounted Canopy

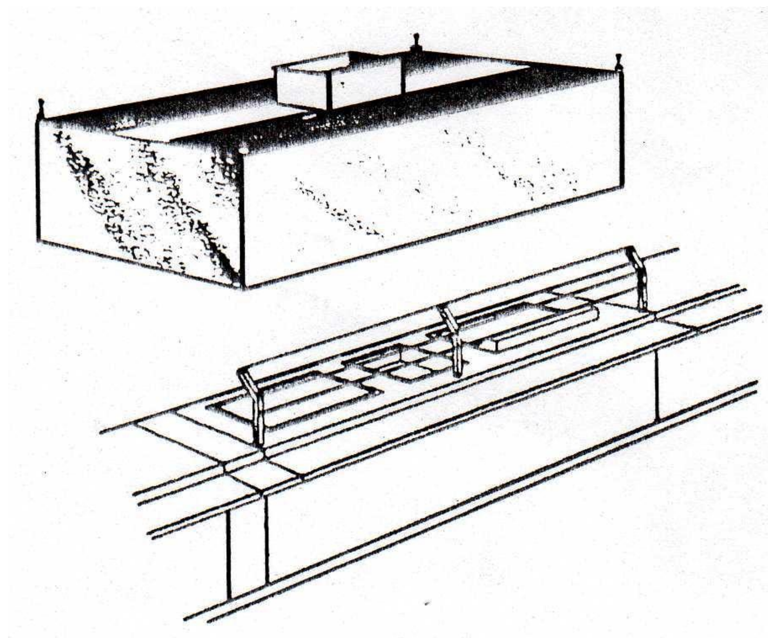


Figure 6.2 Single Island Canopy

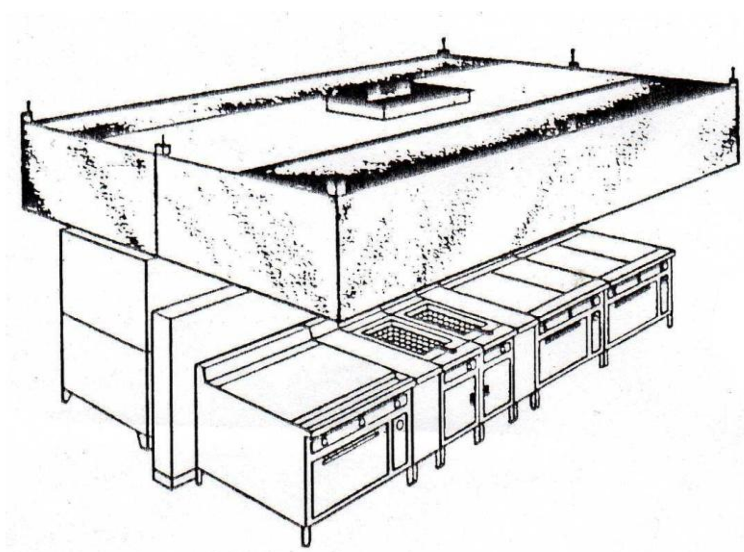


Figure 6.3 Double Island Canopy

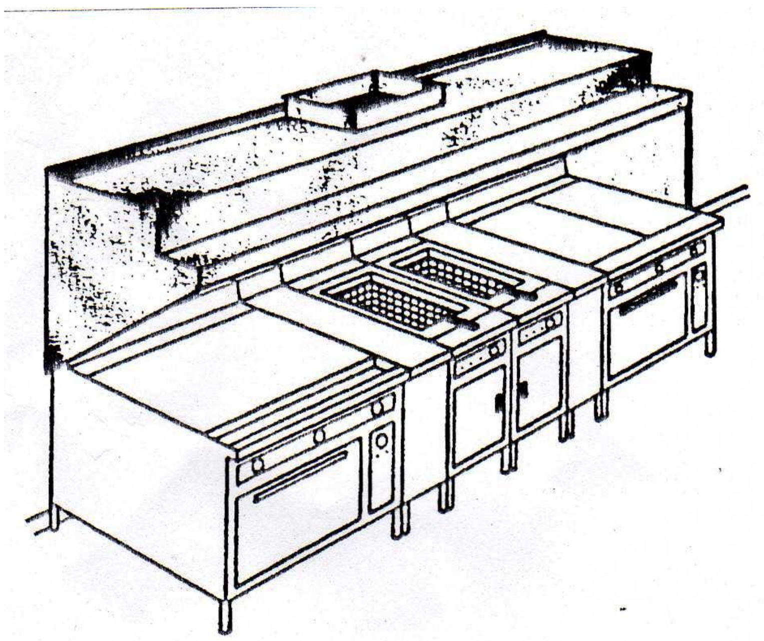


Figure 6.4 Back Shelf Canopy

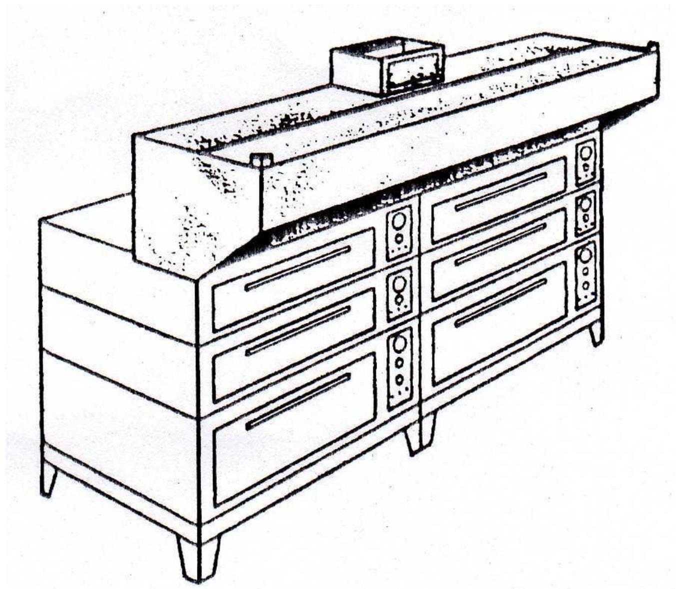


Figure 6.5 Eyebrow

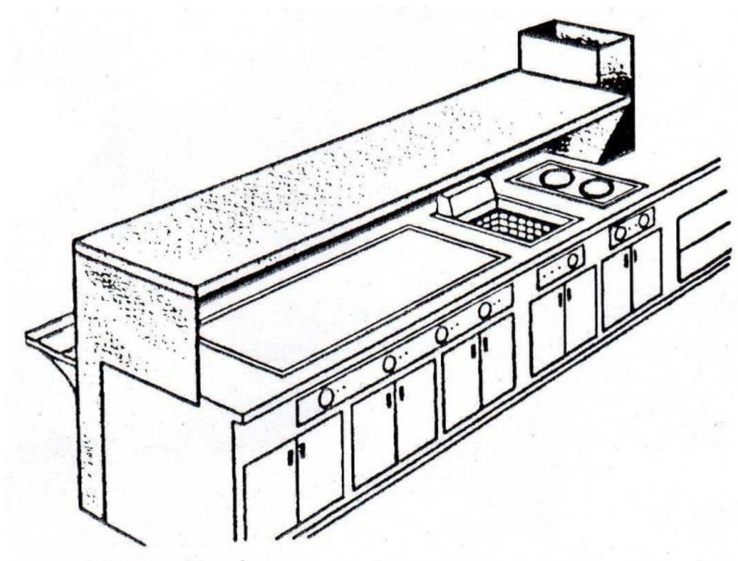


Figure 6.6 Pass-over

Table 6.1 Outdoor Air Requirements For Ventilation

Facility/Area	Outdoor Air Requirements (L/s)	
	Smoking	Non-Smoking
Hotels & Other Lodging Facilities		
Bedrooms (S/D)	15.0(b)	7.5(b)
Living rooms (suite)	10.0(b)	5.0(b)
Baths, toilets	25.0(b)	25.0(b)
Lobbies	7.5	2.5
Conference rooms (small)	17.5	3.5
Large assembly rooms	17.5	3.5
Offices		
Work areas	—	2.5
Meeting & waiting areas	—	3.5
Hospitals		
Patient rooms	-	3.5 (c)
Medical procedure areas	-	3.5
Operating rooms	-	10.0
Recovery & ICU rooms	-	7.5
Autopsy rooms	-	30.0
Physical therapy areas	-	7.5
Educational Facilities		
Classrooms	-	2.5
Laboratories	-	5.0
Training shops	-	3.5
Libraries	-	2.5
Auditoriums	-	3.5

Notes:
(a) All figures are in liters per second (l/s).
(b) Unit is on a per room basis.
(c) Unit is on a per bed basis.
(d) Outdoor air requirements for ventilation on Commercial Stores, Sports and Amusement Facilities, and other facilities/areas not covered above are under consideration.

Table 6.2 Typical Model Code Exhaust Flow Rates For Conventional Type 1 Hood

Wall-mounted canopy	Q= 0.5A
Single-island canopy	Q= 0.75A
Double-island canopy	Q= 0.5A
Eyebrow	Q= 0.5A
Back shelf/Pass-over	Q= 0.45 x Length of hood

Notes:

Q = exhaust flow rate, cu. m/sec

A = area of hood exhaust aperture, sq. m

Table 6.3 Maximum Water Velocity to Minimize Erosion

Normal Operation (hours per year)	**Water Velocity** (m/s)
1500	3.1
2000	2.9
3000	2.7
4000	2.4
6000	2.1
8000	1.8

Note: The noise criteria are not included anymore since noise in piping system is usually caused by entrained air which could be eliminated.

Table 6.4 Minimum Insulation Thickness For Various Pipe Sizes

Piping System Types	Fluid Temp. Range (°C)	Pipe Sizes (mm)			
		Condensate drains to 50	50 or less	63 to 76	89 and larger
Chilled Water	4.5 to 13.0	25	38	38	50
Refrigerant or Brine	4.5 and below	50	50	63	63

Note: Insulation thickness (mm) in Table 6.4 are based on insulation having thermal resistivity in the range of 0.028 to 0.032 sq. m ºC/W-mm on a flat surface at a mean temperature of 24 °C. Minimum insulation thickness shall be increased for materials having K value less than 0.028 sq. m °C/W-mm or maybe reduced for materials having K value greater than 0.032 sq. m °C/W-mm.

Table 6.5 Standard Rated Conditions For Air Conditioning Systems

Stream	Water Cooled Water Chiller (°C)	Air Cooled Water Chiller (°C)	Water Cooled Package A/C Units, (°C)
Chilled Water Supply	7.0	7.0	-
Chilled Water Return	12.0	12.0	-
Cooling Water Supply	29.5	-	29.5
Cooling Water Return	35.0	-	35.0
Condenser Air Inlet	-	35.0	-
Evaporator Return Air	-	-	27.0 (*) 19.0 (**)

Note:
- * Dry Bulb Temperature
- ** Wet Bulb Temperature

Table 6.6 Minimum Performance Rating of Various Air Conditioning System

Air Conditioning Equipment	EER	kWe/TR
Unitary A/C units		
Up to 20 kW_r capacity	10.3	-
21 to 60 kW_r capacity	9.8	-
61 to 120 kW_r capacity	9.7	-
Over 120 kW_r capacity	9.5	-
Scroll chillers (up to 175 kW_r)		
Air cooled	-	1.0
Water cooled	-	0.8
Screw chillers (above 245 kW_r)		
Air cooled	-	0.8
Water cooled	-	0.65
Centrifugal chillers (up to 14 kW_r)		
Water cooled	-	0.58

Notes:

EER = kJ/kWh
See Equation 6.10.4
kW_e/TR = kilowatt electricity per ton of refrigeration
1TR = 3.51685 kW_r

Table 6.7 Size of Opening for Natural Lighting & Ventilation

Type of Occupancy or Usage of Room	x% of Floor Area of Room	y% of x open a
Residential	15%	50%
Store, Utility, Garage (in residential premises)	10%	50%
Water-closet, Toilet, Bathroom Laundry	10% or 0.2 m^2 (whichever is greater)	100%
Business	15%	50%
School classroom	20%	50%
Hospital, Nursing home	15%	100%
Lobby, Corridor, Staircase	10%	50%
Warehouse	10%	50%

Table 6.8 Fresh Air Supply for Mechanical Ventilation

Type of Building/Occupancy	Minimum Fresh Air Supply	
	Air Change per hour	m^3/h per person
Office	6	18
Restaurant, Canteen	6	18
Shop, Supermarket, Department Store	6	18
Workshop, Factory	6	18
Classroom, Theater, Cinema	8	-
Lobby, Concourse, Corridor, Staircase	4	-
Toilet, Bathroom	10	-
Kitchen (commercial, institutional & industrial)	20	-
Car Park	6	-

Note: Unless justified by exceptional circumstances, the ventilation rate shall not be exceeded by more than 30% of the above values.

Section 7. Steam and Hot Water Systems

7.1 Scope

This section applies to the energy conserving design of steam and hot water services in buildings that include but not limited to hotels, restaurants, hospitals, and laundry. The purpose of this section is to provide the criteria and minimum standards for energy efficiency in the design and equipment selection that will provide energy savings when applied to steam and hot water systems.

7.2 System Design and Sizing

7.2.1 The system with the lowest overall energy usage (considering the heat losses in the calorifier and the circulating loop of a centralized system and the total heat losses from a system of individual storage heaters) should be chosen.

7.2.2 Where steam is available, it is definitely more economical to use steam to generate hot water as compared to the use of electricity.

7.2.2.1 Use Heat Exchanger to heat the water from steam.

7.2.2.2 Heat pump may also be used to produce hot water. A heat pump is a refrigeration system with the condenser as a source of heat.

7.2.3 When steam is used, a centralized hot water generator should be placed as near as possible to the steam source in order to reduce piping heat losses.

7.2.4 For generation of steam, use boiler with an efficiency rating of 85% and above.

7.2.5 In the absence of steam, use a direct-fired hot water generator with an efficiency rating of 85% and above.

7.2.6 All forms of losses must be minimized if not eliminated, such as the following:

a. Insufficient insulation.
b. Pipe leakage.

7.3 Minimum Equipment Efficiency

All boilers and hot water storage tanks shall meet the criteria in Table 7. 1.

Exception: Hot water storage tanks having more than 2 m^3 of storage capacity need not meet the standby loss or heat loss requirements of Table 7.1 if the tank surface is thermally insulated with a suitable insulating material with R = 0.045 m^2- ºC/W-mm.

7.4 Hot Water Temperature

The maximum hot water supply temperatures shall be as follows:

For washing, etc.	45 ºC
For hot baths	45 ºC
For kitchen use	60 ºC

It is recommended that two separate systems be installed when two different temperatures are required to minimize piping heat losses. This should always be done where the demand at the lower temperature is greater than 25% of the demand at the higher temperature.

7.5 Controls

7.5.1 Hot water systems shall be equipped with effective automatic temperature controls, which are capable of holding the water temperature to ±3 ºC of the temperatures set in Section 7.4.

7.5.2 Systems designed to maintain usage temperatures in the circulating loop shall be equipped with automatic time switches or other controls that can be set to turn off the system when use of hot water is not required.

7.5.3 Manual controls shall also be provided to override the automatic controls when necessary. Controls shall be accessible to operating personnel.

7.5.4 Controls for Hot Water Conservation

7.5.4.1 Showers in bathrooms shall have outlets, which restrict the flow to not more than 0.2 L/s. Lavatories in public areas of buildings shall have taps with controlled flow at a rate not exceeding 0.05 L/s. This applies to both cold and hot water taps when separate taps are used.

7.5.4.2 Single outlet mixing taps with a flow of 0.05 L/s should be used in preference to separate cold and hot water taps.

7.5.4.3 Point-of-use water heaters shall only be considered if their use is guaranteed to reduce energy cost.

7.6 Piping Insulation

7.6.1 Circulating Systems

The insulation of steam, condensate and hot water lines shall conform to the requirements in Table 7.2 or an equivalent level as calculated in accordance with Equation 7.1.

$$t_2 = 50.8\, d_o\, [((1+ 2\, t_1/d_o)\exp^{(r2/r\,1)} - 1] \qquad \text{Equation7.1}$$

Where:

t_2 ,t_1 = minimum insulation thickness of materials with r_1 and r_2 thermal resistivity, respectively, mm

r_2, r_1 = thermal resistivities, m^2 - °C/W-mm

d_o = outside pipe diameter, m

Subscript 1 refers to values quoted in Table 7.2; subscript 2 refers to values corresponding to alternate insulating, material.

Note: The use of *asbestos in any portion of the piping system is not allowed

7.6.2 Non-circulating Systems

The first 2.5 m of outlet p1ping from a storage system that is maintained at a constant temperature and the inlet pipe between the storage tank and the heat trap shall be insulated as provided in Table 7.2 or to an equivalent level as calculated in accordance with Equation. 7.1.

7.7 Waste Heat Recovery and Utilization

7.7.1 Consideration should be given to the use of condenser heat, waste heat or solar energy to supplement hot water requirements.

7.7.2 Storage should be used to optimize heat recovery when the flow of heat to be recovered is out of phase with the demand for hot water.

Table 7.1 Minimum Performance Ratings of Steam and Hot Water Systems Equipment

Equipment	Minimum Criteria
Shell Boiler (light oil fired) @ Rated capacity @ Part load capacity	 85% boiler efficiency 80% boiler efficiency
Shell Boiler (heavy oil fired) @ Rated capacity @ Part load capacity	 85% boiler efficiency 80% boiler efficiency
Unfired Storage Tanks (all volumes) Surface heat loss (maximum)	 43 W/m^2

Table 7.2. Minimum Pipe Insulation (Heating Systems)

System Types	Fluid Temp. Range (°C)	Pipe Sizes (mm)				
		Runouts to 50	**25 or less**	**31 to 50**	**63 to 76**	**89 and larger**
Steam and Conden-sates	>180 (a)	38	63	63	76	89
	120-180 (b)	38	50	63	63	89
	95-120 (c)	25	38	50	50	50
	60-95 (d)	12	38	38	38	38
	40-60 (e)	12	25	25	25	38
Hot Water	40 & above (e)	12	25	25	38	38

Note: Thermal resistivity (m^2 – ºC/W-mm) ranges are as follows:

(a) R = 0,020 - 0.022
(b) R = 0.022 - 0.024
(c) R = 0. 023 - 0.026
(d) R = 0.02i - 0. 028
(e) R = 0.025 - 0.029

Appendix A. Percentage of Solar Radiation Absorbed by Selected Building Materials

Building Material	Percentage (%)
Brick (common)	
Light red	55
Red	68
Marble	
White	44
Dark	66
Polished	50 – 60
Metals	
Steel	45 – 81
Galvanized iron, new	64
Galvanized iron, dirty	92
Copper, polished	18
Copper, tarnished	64
Lead sheet, old	79
Zinc, polished	46
Paints	
White emulsion	12 – 20
White paint, 4.3 mm on aluminum	20
White enamel on iron	25 – 45
Aluminum oil base paint	45
Gray paint	75
Red oil base paint	74
Black gloss paint	90
Green oil base paint	50
Black paint, 4.3 mm on aluminum	94 – 98
Roofing materials	
Tile clay, red	64
Tile	65 – 91

Appendix A. (Continued)

Building Material	Percentage (%)
Miscellaneous	
Aluminum, polished	15
Concrete	60
Concrete, rough	60
Plaster, white wall	7
Wood	60
Aluminum foil	15
Ground Cover	
Asphalt pavement	93
Grass, green after rain	67
Grass, high and dry	67 – 69
Sand, dry	82
Sand, wet	91
Sand, white powdered	45
Water	94
Vegetable fields and shrubs, wilted	70
Common vegetable fields and shrubs	72 – 76
Ground, dry and plowed	75 – 80
Bare moist ground	90

Where specific material is not mentioned above, an approximate value may be assigned with the use of the following color guide:

Color	% Absorption
White, smooth surfaces	25 – 40
Gray to dark gray, light green	40 – 50
Green to dark green, red, brown	50 – 70
Dark brown, blue	70 – 80
Dark blue, black	80 – 90
Perfectly black	~ 100
Sand, wet	91
Sand, white powdered	45
Water	94
Vegetable fields and shrubs, wilted	70
Common vegetable fields and shrubs	72 – 76
Ground, dry and plowed	75 – 80
Bare moist ground	90

Note: All asbestos in building material shall be omitted to apply fiber cement board.

Appendix B. Thermal Conductivities of Building Materials

Construction Materials	Density (kg/m^3)	Thermal Conductivity (W/m-ºK)
Asphalt, roofing	2240	1.226
Bitumen		1.298
Brick		
(a) common	1925	0.721
(b) face	2085	1.297
Concrete	2400	1.442
	64	0.144
Concrete, light weight	960	0.303
	1120	0.346
	1280	0.476
Cork board	144	0.042
Fiber board	264	0.052
Fiber glass (see Glass Wool and Mineral Wool)		
Glass, sheet	2512	1.053
Glass wool, mat or guilt (dry)	32	0.035
Gypsum plaster board	880	0.170
Hard board		
(a) Standard	1024	0.216
(b) Medium	640	0.123
Metals		
(a) Aluminum alloy, typical	2672	211
(b) Copper, commercial	8794	385
(c) Steel	7840	47.6
Mineral wool, felt	32 – 104	0.032 – 0.035
Plaster		
(a) Gypsum	1216	0.370
(b) Perlite	616	0.115
(c) Sand/cement	1568	0.533
(d) Vermiculite	640 – 960	0.202 – 0.303
Polystyrene, expanded	16	0.035
Polyurethane, foam	24	0.024
PVC flooring	1360	0.713

Appendix B (Continued)

Construction Materials	Density (kg/m^3)	Thermal Conductivity (W/m-ºK)
Soil, loosely packed	1200	0.375
Stone, tile		
(a) Sandstone	2000	1.298
(b) Granite	2640	2.927
(c) Marble/terrazzo/ceramic/mosaic	2640	1.298
Tile, roof	1890	0.836
Timber		
(a) Across grain softwood	608	0.125
(b) Hardwood	702	0.138
(c) Plywood	528	0.138
Vermiculite, loose granules	80 – 112	0.065
Wood chipboard	800	0.144
Woodwool slab	400	0.086
	480	0.101

Appendix C. K-Values of Basic Materials

Construction Materials	Density (kg/m^3)	Thermal Conductivity (W/m-ºK)
Asbestos cement sheet	1488	0.317
Asbestos insulating board	720	0.108
Asphalt, roofing	2240	1.226
Bitumen		1.298
Brick		
(a) Dry (covered by plaster or tiles outside)	1760	0.807
(b) Common brickwall (brickwall directly exposed to weather outside)	1760	1.154
Concrete	2400	0.1442
	64	0.144
Concrete, light weight	960	3.303
	1120	0.346
	1280	0.476
Cork board	144	0.042
Fiber board	264	0.052
Fiber glass (see Glass Wool and Mineral Wool)		
Glass, sheet	2512	1.053
Glass wool, mat or guilt (dry)	32	0.035
Gypsum plaster board	880	0.170
Hard board		
(a) Standard	1024	0.216
(b) Medium	640	0.123
Metals	6272	211
	8784	385
	7840	47.6
Mineral wool, felt	32 – 104	0.035 – 0.032
Plaster		
(a) Gypsum	1216	0.370
(b) Perlite	616	0.115
(c) Sand/cement	1568	0.533
(d) Vermiculite	640 – 960	0.202 – 0.303
Polysterene, expanded	16	0.035
Polyurethane, foam	24	0.024
PVC flooring	1360	0.713
Soil, loosely packed	1200	0.375

Appendix C (Continued)

Construction Materials	Density (kg/m^3)	Thermal Conductivity (W/m-ºK)
Stone tile		
(a) Sand stone	2000	1.298
(b) Granite	2640	2.927
(c) Marble/terrazzo/ceramic/mosaic	2640	1.298
Tile, roof	1890	0.836
Timber		
(a) Across grain softwood	608	0.125
(b) Hardwood	702	0.138
(c) Plywood	528	0.138
Vermiculite, loose granules	80 – 112	0.065
Wood chipboard	800	0.144
Woodwool slab	400	0.086
	480	0.101

Appendix D. Air Space Resistances for Walls and Roofs

Types of Air Space	Thermal Resistance (m^2-ºC/W)		
	5 mm	20 mm	100 mm
Air space resistance (R_a) for Walls			
Vertical air space (Heat flows horizontally)			
(a) High Emissivity	0.110	0.148	0.160
(b) Low Emissivity	0.250	0.578	0.606
Air Space Resistancec, (R_a) for Roof			
Horizontal or sloping air space (Heat flows downward)			
(a) High Emissivity			
(i.) Horizontal air space	0.110	0.148	0.174
(ii.) Sloped air space 22.5º	0.110	0.148	0.165
(iii.) Sloped air space 45º	0.110	0.148	0.158
(b) Low Emissivity			
(i.) Horizontal air space	0.250	0.572	1.423
(ii.) Sloped air space 22.5º	0.250	0.571	1.095
(iii.) Sloped air space 45º	0.250	0.570	0.768
Attic Space Resistances (R_{attic})			
(a) High Emissivity		0.458	
(b) Low Emissivity		1.356	

Notes:

1. Ordinarily, high emissivity is assumed for air spaces bounded by building materials of moderatelysmooth surfaces. Low emissivity only applies where one or both sides of the air space is bounded by a reflective surface such as that of an aluminum foil.
2. Interpolation within the range of pitch angles from horizontal to 45º is permitted. For angle beyond 45º, the value for 45º can be used; no extrapolation is needed.
3. Interpolation within the range of thickness from 5 mm to 100 mm is permitted. For air space less than 5 mm, extrapolation basing on R_a = 0 for zero thickness is allowed; otherwise R is assumed to be zero. For air space greater than 100 mm, the R_a for 100 mm should be used, i.e. extrapolation is not permitted.
4. In the case of air space in roof, reflective foil used should be installed within the reflective surface facing downward as dust deposit will render an upward-facing surface ineffective after a while.

Appendix E. Surface Film Resistances

Types of Air Space	Thermal Resistance (m^2-ºC/W)
Walls	
Inside surface	
Smooth finishes	0.12
Reflective finishes	0.30
Outside surface	0.04
Roots	
Inside surface	
Flat (smooth finish)	0.16
45º sloped (smooth finish)	0.15
Flat (reflective finish)	0.80
45º sloped (reflective finish)	0.39
Outside surface	
Flat or sloped	0.56

Note: Interpolation between angles of slope from horizontal to 45º is valid.

Appendix F. Glass Thermal Transmittance Values

Glass Type	**U-Value (Glass only) (W/m^2-°C)**	
	Exposed	**Sheltered**
Flat Glass		
Single pane, clear	5.91	4.60
Single pane, with low emittance coating		
e = 0.60	5.68	4.54
e = 0.40	5.11	3.97
e = 0.20	4.26	3.12
Insulating Glass		
Double pane, clear		
4.8 mm air space	3.69	3.29
6.4 mm air space	3.46	3.12
12.5 mm air space	3.18	2.95
Double pane, with low emittance coating		
e = 0.60	3.01	2.78
e = 0.40	2.67	2.44
e = 0.20	2.21	2.04

To account for outside or inside sashes/frames, the following correction factors shall be used:

Glass Type	Correction Factors			
	Inside		Outside	
	Exposed	Sheltered	Exposed	Sheltered
Single pane				
Clear	0.48	0.60	0.48	0.60
Low e	0.50	0.56	0.65	0.77
Double pane				
Clear	0.64	0.65	0.65	0.66
Low e	0.71	0.70	0.80	0.98

Appendix G. Glass Performance Data

Glass Type		Monolithic	Monolithic
Code		FL	FL
Color		Clear	Clear
Thickness		15 mm	19 mm
Substrate		None	None
Visible Light, %			
Transmittance	TV	83.10	81.70
Reflectance, out	RV	8.80	8.70
Reflectance, in	RV’	8.80	8.70
Solar Energy, %			
Transmittance	TE	68.10	62.90
Reflectance, out	RE	7.60	7.20
Reflectance, in	RE’	7.60	7.20
Absorptance	AE	24.40	29.90
Shading Coefficient	SC	0.85	0.81
U-value, Summer W/m^2-ºK	U	5.70	5.63
U-value, Winter W/m^2-ºK	UW	6.05	5.89
Solar heat gain coefficient	SHGC	0.74	0.70
Relative heat gain W/m^2-ºK	RHG	582	554

Note:

1. Above data is on monolithic substrate only.
2. Calculation of U-value, Relative Heat Gain based on ASHRAE condition (GSBDL-GL)

Appendix H. Glass Performance Data

Glass Type	Clear-12	Dark Green-12	Bronze-12	Dark Blue-12
Code	FL	DNFL	BFL	DHFL
Color	Clear	Dark Green	Bronze	Dark Blue
Thickness	12 mm	12 mm	12 mm	12 mm
Substrate	None	None	None	None
Visible Light, %				
Transmittance	84.50	52.50	22.10	36.00
Reflectance, out	9.00	6.50	5.30	5.70
Reflectance, in	9.00	6.50	5.30	5.70
Solar Energy, %				
Transmittance	72.00	15.50	23.00	20.70
Reflectance, out	7.90	5.10	5.30	5.20
Reflectance, in	7.90	5.10	5.30	5.20
Absorptance	20.10	79.40	71.70	74.00
Shading Coefficient	0.89	0.43	0.49	0.47
U-value, Summer W/m^2-ºK	5.75	6.29	6.23	6.25
U-value, Winter W/m^2-ºK	6.17	6.17	0.43	6.17
Solar heat gain coefficient	0.77	0.37	0.47	0.41
Relative heat gain W/m^2-ºK	603	320	358	346

Note:

1. Above data is on monolithic substrate only.
2. Calculation of U-value, Relative Heat Gain based on ASHRAE condition (GSBDL-GL)

Appendix I. Glass Performance Data

Glass Type	Clear-10	Dark Green-10	Bronze-10	Dark Blue-10
Code	FL	DNFL	BFL	DHFL
Color	Clear	Dark Green	Bronze	Dark Blue
Thickness	10 mm	10 mm	10 mm	10 mm
Substrate	None	None	None	None
Visible Light, %				
Transmittance	85.60	57.50	27.90	42.00
Reflectance, out	9.10	6.80	5.40	6.00
Reflectance, in	9.10	6.80	5.40	6.00
Solar Energy, %				
Transmittance	75.10	20.70	28.90	26.50
Reflectance, out	8.00	5.20	5.50	5.40
Reflectance, in	8.00	5.20	5.50	5.40
Absorptance	16.90	74.00	65.60	68.10
Shading Coefficient	0.91	0.48	0.54	0.52
U-value, Summer W/m^2-ºK	5.78	6.32	6.26	6.28
U-value, Winter W/m^2-ºK	6.27	6.26	6.26	6.26
Solar heat gain coefficient	0.79	0.41	0.47	0.45
Relative heat gain W/m^2-ºK	620	349	389	377

Note:

1. Above data is on monolithic substrate only.
2. Calculation of U-value, Relative Heat Gain based on ASHRAE condition (GSBDL-GL)

Appendix J. Glass Performance Data

Glass Type	Clear-8	Dark Green-8	Bronze-8	Dark Blue-8
Code	FL	DNFL	BFL	DHFL
Color	Clear	Dark Green	Bronze	Dark Blue
Thickness	8 mm	8 mm	8 mm	8 mm
Substrate	None	None	None	None
Visible Light, %				
Transmittance	86.50	62.90	35.30	48.90
Reflectance, out	9.20	7.20	5.70	6.30
Reflectance, in	9.20	7.20	5.72	6.30
Solar Energy, %				
Transmittance	77.90	27.80	36.30	33.80
Reflectance, out	8.20	5.40	5.70	5.60
Reflectance, in	8.20	5.40	5.70	5.60
Absorptance	13.90	66.70	58.00	60.50
Shading Coefficient	0.94	0.53	0.60	0.58
U-value, Summer W/m^2-ºK	5.81	6.34	6.27	6.29
U-value, Winter W/m^2-ºK	6.36	6.35	6.35	6.35
Solar heat gain coefficient	0.81	0.46	0.52	0.61
Relative heat gain W/m^2-ºK	635	386	428	415

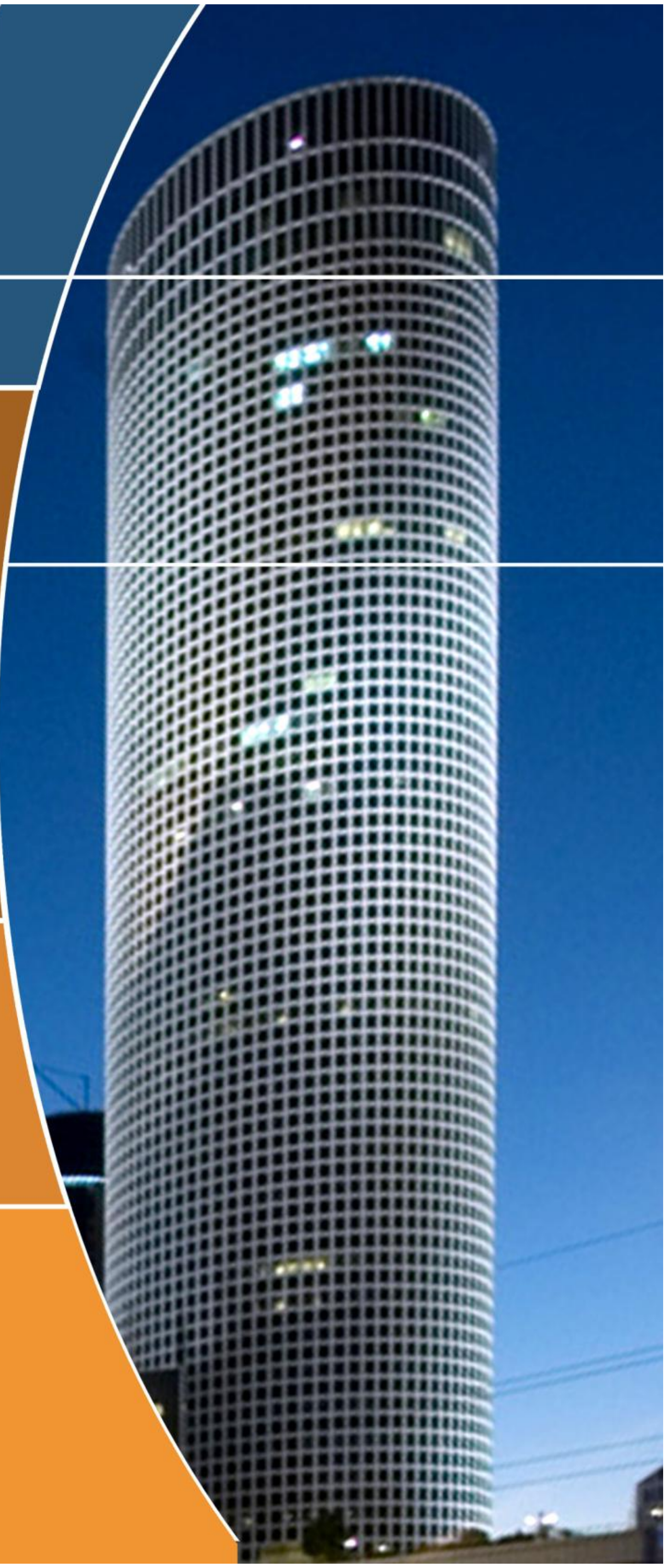
Note:
1. Above data is on monolithic substrate only.
2. Calculation of U-value, Relative Heat Gain based on ASHRAE condition (GSBDL-GL)

Appendix K. Glass Performance Data

Glass Type	**Clear-6**	**Dark Green-6**	**Bronze-6**	**Dark Blue-6**
Code	FL	DNFL	BFL	DHFL
Color	Clear	Dark Green	Bronze	Dark Blue
Thickness	6 mm	6 mm	6 mm	6 mm
Substrate	None	None	None	None
Visible Light, %				
Transmittance	87.50	68.90	44.70	57.00
Reflectance, out	9.20	7.60	6.10	6.80
Reflectance, in	9.20	7.60	6.10	6.80
Solar Energy, %				
Transmittance	80.50	37.40	45.60	43.20
Reflectance, out	8.60	5.80	6.20	6.00
Reflectance, in	8.60	5.80	6.20	6.00
Absorptance	10.90	56.90	48.30	50.70
Shading Coefficient	0.96	0.61	0.68	
U-value, Summer W/m^2-ºK	5.82	6.33	6.25	6.28
U-value, Winter W/m^2-ºK	6.44	6.44	6.44	6.44
Solar heat gain coefficient	0.83	0.53	0.59	0.57
Relative heat gain W/m^2-ºK	649	435	475	464

Note:

1. Above data is on monolithic substrate only.
2. Calculation of U-value, Relative Heat Gain based on ASHRAE condition (GSBDL-GL)



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