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FOREWORD

With the unstable supply and possible shortage of fossil fuels in the future, efforts to conserve energy should be seriously considered. The building sector in the Philippines is one of the energy-intensive sectors of the national economy. Building energy consumption accounts for about 15 to 20 percent of the nationwide electric power consumption. It is therefore imperative that buildings that will be erected in the future be designed in accordance with energy conservation concepts in order to contribute to the nationwide effort to avert an energy crisis or at least mitigate its worse effect. Furthermore, actions should now be taken to rationalize the use of energy in existing buildings and their services so that energy wastages will be prevented.

These guidelines aim to attain efficient energy utilization in buildings. It contains energy conservation guidelines for the design of buildings and their services. The guidelines are based on present day viewpoint and are therefore subject to review, with regard to urgency and rigidity, as time passes.

The overall objective of the guidelines is to save energy in the building sector and pave the way for designers/architects to apply energy conservation principles and techniques in their designs. To be able to meet this objective, the guidelines were developed to address the aspects of design of new buildings as well as the upgrading of existing buildings.

The guidelines provide recommendations at the design stage of buildings, as well as retrofits to existing units but exclude residential units and premises using large quantities of process heat. Moreover, the guidelines recommend means of achieving energy-efficient utilization without compromising the comfort, safety and health of the occupants. Majority of the factors that affect the use of energy in buildings are considered.

Levels for environmental conditions, performance characteristics and general design criteria for building services, etc. are suggested. These were drawn out from existing local and foreign codes, standards, basic design practices, etc., as well- as energy surveys and audits.

ACKNOWLEDMENT

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Technical assistance was provided by the members of the Philippine Technical Review Committee (PTRC) composed of representatives from both private and government sectors and the Lawrence Berkeley Laboratory (LBL) group. The P5 - Air Conditioning Equipment Group, and the P3 and P4 - Building Envelope Design and Configuration, and Reflective and Insulating Materials groups, respectively, also provided relevant data in the formulation of the guidelines.

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Section 1.0 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 2.0 APPLICATION AND EXEMPTION

2.1 Requirements are set forth for the design of new energy-efficient buildings for human occupancy, covering their exterior envelopes and the selection of their systems and equipment for power, lighting, air conditioning and other energy-consuming auxiliary systems.

2.2 These guidelines are applicable to the design of new buildings classified as offices, hotels, shopping centers and hospitals as well as those portions of industrial buildings that are used primarily for human occupancy.

2.3 Buildings with industrial and/or process requirements may exclude those areas devoted to the process from these requirements. Buildings or portions thereof whose peak design rate of energy usage is less than 10 W/M2 of gross floor area for all purpose are excluded from these requirements.

Section 3.0 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

3.2.1 Industrial areas of manufacturing concerns, storage areas and processing facilities.

3.2.2 Areas devoted for theatrical productions, television broadcasting, audio-visual presentations and those portion of entertainment facilities such as stage areas in hotel ballrooms, discos, night clubs and casinos where lighting is an essential technical element.

3.2.3 Specialized luminaires for medical or dental purposes.

3.2.4 Outdoor athletic facilities.

3.2.5 Display lighting required for art exhibit or display in galleries, museums and monuments.

3.2.6 Exterior lighting for public monuments.

3.2.7 Special lighting for research laboratories.

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

3.2.9 High risk security areas identified by local ordinances or regulations or by security or safety personnel as requiring additional lighting.

3.2.10 Classrooms specifically designed for the hard-of-seeing, hard-of-hearing and for elderly persons.

3.2.11 Lighting for dwelling units.

3.3 General Requirements of Energy- Efficient Lighting Design

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

3.3.2 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.

3.3.3 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. Table 3.2 shows that high intensity discharge lamps are more efficient than incandescent lamps.

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, escalators
	100 - 200	Hotel bedrooms, lavatories
Lighting for working interiors	200 - 300	Infrequent reading and writing
	300 - 750	General offices, typing and computing
	300 - 750	Conference rooms
	500 - 1 000	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	**Efficacy Range(*) (lumens/watt)**	**Color Rendering Index (CRI)**
Incandescent Lamp (10-100 W)	15-25	100
Fluorescent Lamp (10-40 W)	50-95	52-86
HP Mercury Fluorescent (50-2000 W)	40-63	20-45
Metal Halide (up to 10000 W)	75-95	70
LP Sodium Lamp (20-200 W)	100-180	-
BP Sodium Lamp (50-100 W)	80-130	25

Note: Values exclude power usage of ballasts.

3.3.4 In general, the normal artificial light source should be the fluorescent lamp. In downlight 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.

3.3.5 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 is recommended to reduce the number of lamps installed without reducing the illumination level. Where ballasts are used, these should be of the low loss type and with a power factor of at least 85%.

3.3.6 The highest practical room surface reflectances 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.

Table 3.3 RECOMMENDED ROOM SURFACE REFLECTANCES

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

3.3.7 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.

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

3.3.9 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 load for the interior spaces of buildings shall not exceed the summation of the maximum values for building areas/activities as specified in Table 3.4.

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	14
Leisure/Dining Bar	10
Offices and Banks	21
Retail Stores (*)	
Type A (**)	23
Type B (***)	22
Shopping Centers/Malls/Arcades	15
Clubs/Basements/Warehouses/ General Storage Areas	2
Commercial Storage Areas/Halls	

	Corridors/Closets	4
Schools		
	Preparatory/Elementary	17
	High School	18
	Technical/Universities	18
Hospitals/Nursing Homes		16
Hotels/Motels		
	Lodging rooms/Guest rooms	12
	Public Areas	17
	Banquet/Exhibit	20

Notes: *(*) Includes general merchandising and display lighting except for store front, etc.*
(**) Type A -Fine and mass merchandising.
(***) Type B -General, food and miscellaneous merchandising.

3.5 Maximum Allowable Power Density for Building Exterior Lighting Systems

3.5.1 Basic 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.

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.)	100 W/m2 of canopied area
Light traffic (e.g.,hospital, office, school, etc.)	10 W/M2 of canopied area
Loading area	3 W/jn2
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 storeys (above ground) plus 6W/Lm of building perimeter for each additional storey	100 W/Lm

Note: WILm = Watts per linear meter

Table 3.6 MAXIMOM 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

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 location or group of task locations within an area of 45 m^2 or less.

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 minimum number of controls required shall be determined using Table 3.7 which lists the types of lighting controls and the equivalent number of control points they represent. The minimum number of controls, however, shall not be less than one for each 1500 W of connected lighting load.

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, except bathrooms, 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.

Table 3.7 CONTROL TYPES AND EQUIVALENT NUMBER OF CONTROL POINTS

Type of Control	Equivalent Number of Control Points
Manually operated on-off switch	I
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

3.6.7 Where adequate daylighting is available, local manual or automatic controls such as photo-electric switches or automatic dimmers shall be provided in daylighted 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 should be so located to be readily accessible by space occupants.

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

Section 4.0 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 all permanently wired squirrel-cage induction type motors of 0.4 kW size and larger serving the building. It shall not apply to other types as regards efficiency requirements.

4.2.2 Motors expected to operate more than 500 hours a year shall have full load efficiencies not less than the values shown in Table 4.1.

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.

Table 4.1 MINIMUM ACCEPTABLE FULL LOAD EFFICIENCY

Motor Size	Min. Efriciency (%)
0.4 kW (1/2 HP)	77.0
0.8 kW (1 HP)	82.5
4.0 kW (5 HP)	84.0
8.0 kW (10 HP)	87.5
40.0 kW (50 HP)	89.5
80.0 kW (100 HP)	91.0
100.0 up (150 11P)	91.7

Notes: 1. Table 4.1 applies to single speed polyphase squirrel-cage induction motors with nominal speeds of 1200, 1800 or 3600 RPM at 60 Rz with open, drip-proof or totally enclosed fan-cooled enclosures.

2. Motors operating more than 750 hours per year should be of the high efficiency type with efficiencies higher than those listed High-efficiency motors are presently available with typical nominal efficiencies of:

4.0 kW	*89.5916*
8.OkW	*91.0%*
40.OkW	*92.1%*
75.OkW	*95.1%*
150.0 kW	*96.2%*

3. Motors with ratings different from those listed shall have efficiency ratings higher or greater than those listed for the next lower size.

4.2.4 Motor Selection

4.2.4.1 The type and the size of the SC 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 Loads of lower duty cycle may be powered by smaller motors which will have good overall efficiencies.

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

4.2.4.6 Where an application requires varying output operation of motor-driven equipment such as a centrifugal pump, a variable speed induction motor with a variable frequency supply should be considered instead of throttling the output of the pump. The former is a high efficiency operation, while the other is a low efficiency operation.

4.1.4.7 High efficiency motors are basically high flux density, low core loss and low current density motors which should be applied properly in order to obtain maximum energy savings.

4.2.4.8 Other applicable requirements specified in the Philippine Electrical Code, Part I 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 90% at rated load conditions.

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 transformers are loaded to not less than 75% of their 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 for transformers which are anticipated to have no loads during certain periods.

4.3.5 The transformers should be located inside a building so that water, dirt, heat and corrosive atmosphere will not impair the efficiency and operation of the transformers. However, sufficient ventilation should be provided.

4.3.6 Where it is necessary to install transformers within a building space which is air-conditioned, the space shall be enclosed by acceptable means and provided with appropriate temperature-control fan to exhaust generated heat to the outside.

4.3.7 The installation of transformers indoors shall comply with Article 6.9 - "Transformer and Transformer Vaults" of the Philippine Electrical Code, Part 1.

4.3.8 In the selection of transformers, extreme care should be exercised so that they are not unjustifiably large. Oversized transformers operate at low power factor and low efficiency.

4.3.9 In order to minimize heat losses due to current, the transformers should be set such that the utilization voltage is on the higher end of the allowable voltage range so that motor currents, line currents and transformer currents are reduced. In this manner, the I^2R losses is reduced and efficiency is improved.

4.4 Power Distribution

4.4.1 All distribution lines that lead to the different loads and equipment, such as lights, motors and transformers, have resistances and therefore heat up. These affect the efficiency of distribution and therefore should be minimized.

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

4.4.3 To conserve energy, the wire size should be increased by one or two sizes depending on which is more critical: first cost or energy cost.

4.5 Sub-metering and Check-metering

4.5.1 Buildings whose designed connected electrical load is over 250 kVA shall have the distribution system designed to include sub-metering facilities.

4.5.2 The electrical power feeders for each facility of the building for which sub-metering is required shall be subdivided into the following categories:

4.5.2.1 Lighting and receptacle outlets;

4.5.2.2 Power systems (for ventilation and air conditioning, elevators, computers, 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 sub-metering provisions.

4.5.4 The feeders for each category in Section 4.5.2 may include provisions for check metering for energy conservation monitoring.

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

Section 5.0 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 (with and without daylighting), roofs (with and without skylights) and air leakage through the building envelope.

5.2 Exterior Walls (without Daylighting)

5.2.1 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 of building envelopes so as to minimize external heat gain and thereby reduce the cooling load of the air conditioning system.

5.2.2 The Overall Thermal Transfer Value (OTTV) for the exterior walls of buildings shall not exceed 48 W/m^2. The OTTV for all walls of a building is the weighted average of all OTTV's ($OTTV_i$) computed for the individual walls.

5.2.3 The Overall Thermal Transfer Value (OTTVi) for each exterior wall section that has a different orientation shall be determined using Equation 5. 1.

$$OTTV = 12.65\ A\ (1\text{-}WWR)\ U_w + 3.35\ (WWR)\ U_g + SF\ (WWR)\ SC$$
[Equation 5. 1 a - Offices)

$$OTTV = 5.40\ A\ (I\ \text{-}WWR)\ U_w + 1.\ 10\ (WWR)\ U_g + SF\ (WWR)\ SC$$
[Equation 5. lb - Hotels]

where: A = Solar absorptance of the opaque wall. Typical values are given in Table 5. 1;

WWR = Window-to-wall ratio for the orientation under consideration;

Uw = U-value of the opaque wall (W/ m^2-°C). Thermal conductivities of building materials are given in Table 5.2;

U_g = U-value of window glass (W/m^2-°C). Typical U-values of glass are given in Table 5.5;

SF = Solar Factor (W/m^2). The SF values for the different orientations are listed in Table 5.6;

SC = Shading coefficient of window glass. Values of SC are given in Table 5.7. Manufacturers data may also be used.

5.2.4 The Overall Thermal Transfer Value (OTTV) for the total wall area of the building shall be determined using Equation 5.2. The OTTV is the weighted average of the $OTTV_i$'s for each wall calculated using Equation 5. 1.

$$OTTV = \frac{A, (OTTV_1) + A_2 (OTTV_2) + \ldots + A_i (OTTV_i)}{A_l + A_2 \ldots + A_i}$$

[Equation 5.2)

where: Ai — Gross area of the ith exterior wall (m^2). The gross area includes the opaque wall surface and the window surface for the wall being considered.

OTTVi — Overall thermal transfer value for the ith wall, as calculated using Eqn. 5. 1.

Table 5.1 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	
Asbestos cement, white	42
Asbestos cement, 6 mos. exposure	61
Asbestos cement, 12 mos. exposure	71
Asbestos cement, 6 yrs. exposure	83
Asbestos cement, red	69
Tile clay, red	64
Tile	65-91
Miscellaneous	
Aluminum, polished	15
Concrete	60
Concrete, rough	60

(Table 5.1 continued)

Building Material	Percentage (%)
Plaster, white wall	7
Wood	60
Asbestos cement board, white	59
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

Table 5.2 THERMAL CONDUCTIVITIES OF BUILDING MATERIALS

Construction materials	**Density (kg/m^3)**	**Thermal Conductivity ($W/m-^oC$)**
Asbestos cement sheet	1488	.0.317
Asbestos insulating board	720	0.108
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
Polyurcthane, foam	24	0.024
PVC flooring	1360	0.713

(Table 5.2 continued)

Construction materials	Density (kg/m^3)	Thermal Conductivity ($W/m\text{-}^{O}C$)
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

Note: Thermal conductivities are per unit of length thickness.

Table 5.3 AIR SPACE RESISTANCES FOR WALLS AND ROOFS

Type of Air Space	Thermal Resistance (m^2-$^oC/W$)		
	5 min	20 mm	100 mm
Air Space Resistances (R_a) for Walls			
Vertical air space (Heat flows horizontally)			
(a) High Emissivity	0.110	0.148	0.160
(b) Low Emissivily	0.250	'0.578	0.606
Air Space Resistances, (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) slopcd air space 22.5^o	0.110	0.148	0.165
(iii) sloped air space 45^o	0.110	0.148	0.158
(b) Low Ernissivity			
(i) horizontal air space	0.250	0.572	1.423
(ii) sloped air space 22.5^o	0.250	0.571	1.095
(iii), sloped air space 45^o	0.250	0.570	0.768
Attic Space Resistances (R_{attic})			
(a) High Ernissivity		0.458	
(b) Low Emissivity		1.356	

Notes: 1. Ordinarily, high emissivity is assuined for air spaces bounded by building materials of moderately smooth 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 45^o is permitted. For angle beyond 45^o, the value for 45^o 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, extropolation 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.

Table 5.4 SURFACE FILM RESISTANCES

Type of Surface	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
45^o sloped (smooth finish)	0.15
Flat (reflective finish)	0.80
45^o sloped (reflective finish)	0.39
Outside surface	
Flat or sloped	0.56

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

Table 5.5 GLASS THERMAL TRANSMITTANCE VALUES

Glass Type	U-Value (Glass only) (W/m^2-^oC) Exposed	Sheltered
Flat Glass		
Single pane, clear	5.91	4.60
Single pane, with low ernittance 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

Table 5.6 SOLAR FACTORS FOR VARIOUS BUILDING WALL ORIENTATIONS

Orientation	Type A (W/m^2)	Type B (W/m^2)	Type C (W/m^2)
North	88.2	ID1.0	96.7
East	184.3	202.4	166.2
South	138.9	165.1	157.2
West	154.5	175.7	182.2
Northeast	133.7	145.9	122.0
Southwest	150.1	174.6	176.8
Southeast	176.0	199.5	171.6
Northwest	119.1	134.3	138.8
Average (All Orientations)	143.1	162.3	151.4

Notes: Type A -All daylight hours operation (e.g., Hotels, Hospitals).
Type B -Operation between 0700 HRS to 1700 HRS (e.g., Offices).
Type C - Operation between 0900 HRS to 1800 HRS (e.g., Stores).

Table 5.7 GLASS SHADING COEFFICIENTS

Glazing Type	Shading Coefficient
Single Glass	
3 mm Clear	1.00
6 mm Clear	0.95
13 mm Clear	0.88
6 mm Heat Absorbing	0.67
13 mm Heat Absorbing	0.50
Reflective, coated	0.30-0.60
Insulating Glass	
6 mm air space	0.89
13 mm air space	
Clear Out and In	0.83
Heat Absorbing Out and In	0.55
Reflective, coated	0.20-0.40

Notes: 1. For reflective glass, see manufacturer's literature for exact values.
2. For shading coefficients of glass with indoor shading devices, see Chapter 27 of ASHRAE Handbook of Fundamentals (1989).

5.3 Exterior Walls (with Daylighting)

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

5.3.2 A credit for daylighting is provided for several reasons. In daylighting 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 daylighting 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 daylighting. The transparent portions of the building envelope should be designed to prevent solar gains above that necessary for effective daylighting. To make sure that daylighting is being effectively utilized, automatic daylighting controls shall be used to turn off the artificial lights when sufficient natural light is available.

5.3.3 Daylighting credit may be taken for those areas with installed automatic lighting controls for all lights within 4 meters of an exterior wall. Daylighting credit is accounted for by a 10% reduction in the $OTTV_i$'s (as calculated using Equation 5.1) of that particular wall where daylighting is applied. These reduced $OTTV_i$ values are then used in the calculation of the building's OTTV using Equation 5.2.

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

5.4 Roofs (without Skylights)

5.4.1 Solar heat gain through the roof can contribute a substantial amount to the cooling load of an air-conditioned building. Hence, roofs should be provided with adequate insulation in order to conserve energy.

5.4.2 All roofs shall be provided with insulation. Roofs shall not have a thermal transmittance value greater than the values listed in Table 5.8.

Table 5.8 MAXIMUM THERMAL TRANSMITTANCE VALUES OF ROOFS

Weight Group	Weight Range (kgs/m^2)	Max. U-Value ($W/m^2.^oC$)
Light	Under50	0.50
Medium	50-230	0.80
Heavy	Over 230	1.20

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

5.4.4 The values in Table 5.8 may be exceeded by 50% if any one of the following applies:

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

2. 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.

5.5 Air Leakage

5.5.1. 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.

5.5.2 Windows

Windows shall be designed to limit air leakage. The air infiltration rate shall not exceed 2.8 m^3/hr per linear meter of sash crack when tested under a pressure differential of 75 Pa. Manufacturers shall provide documentation certifying compliance with this criterion.

5.5.3 Swinging, Revolving or Sliding Doors

These types of doors shall be used at all entrances and they shall be designed to limit air leakage. The air infiltration rate shall not exceed 61.2 m^3/hr per linear meter of door crack when tested under a pressure differential of 75 Pa. Manufacturers shall provide documentation certifying compliance with this criterion.

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

5.5.4 Effective means of caulking and weatherstripping shall be used to seal all penetrations through the exterior surfaces of the building.

Section 6.0 AIR CONDITIONING 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 Calculations

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°C
2. Design Relative Humidity55%
3. Maximum Dry Bulb
   Temperature 27°C
4. Minimum Dry Bulb
   Temperature 23°C
5. Maximum Relative Humidity 60%
6. Minim,um Relative Humidity 50%

Note:Indoor design conditions may differ from those presented above because of special occupancy or process requirements, 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 34°C
2. Design Wet Bulb Temperature 27°C

6.2.4 Ventilation

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

Table 6.1 OUTDOOR AIR REQUIREMENTS FOR VENTIOLATION

Facility/Area	Outdoor Air Requirements (1/s) Smoking	Non-Smoking
Commercial Stores		
Sales floors & showrooms	12.5	2.5
Stockrooms	12.5	2.5
Dressing rooms		2.5
Malls & arcades	5.0	3.5
Shipping & receiving areas	5.0	2.5
Warehouses	5.0	2.5
Elevators	-	7.5
Smoking areas	25.0	-
Sports & Amusement Facilities		
Ballrooms & discos	17.5	3.5
Bowling alleys (seats)	17.5	3.5
Gymnasiums	-	10.0
Spectator areas	17.5	3.5
Game rooms	17.5	3.5
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

(Table 6.1 continued)

Facility/Area	**Outdoor Air Requirements (l/s)**	
	Smoking	**Non-Smoking**
Offices		
Work areas	10.0	2.5
Meeting & waiting areas	17.5	3.5
Hospitals		
Patient rooms	17.5 (c)	3.5 (c)
Medical procedure areas	17.5	3.5
Operating rooms	-	10.0
Recovery & ICU rooms	-	7.5
Autopsy rooms	-	30.0
Physical therapy areas	-	7.5
Educational Facilities		
Classrooms	12.5	2.5
Laboratories	-	5.0
Training shops	17.5	3.5
Libraries	-	2.5
Auditoriums		3.5

Notes: (a) All figures are in liters per second (l/s) per person, except:
(b) Unit is on a per room basis;
© Unit is on a per bed basis.

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 efficiently. 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

6.3.3 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 motors of the combined fan system at design conditions shall not exceed 0.5 W/m^3/hr.

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/hr.

6.4.3.2 Individual VAV fans with motors rated at 7.5 kW and larger shall include controls and devices 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) or heat transfer device(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 m for piping over 51 mm diameter. To minimize erosion for the attainment of the piping system, the following water velocities should not be exceeded:

Table 6.2 MAXIMUM WATER VELOCITY TO MINIMIZE EROSION

Normal Operation (hours per year)	Water Velocity (fps)	(m/s)
1500	10	3.1
2000	9.5	2.9
3000	9	2.7
4000	8	2.4
6000	7	2.1
8000	6	1.8

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

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 curves shall not be used since they tend to limit system flow rates. Variable speed or staged pumping should, be employed in large pumping systems.

Exception:

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.

6.5.4 Pumping Energy Consumption

The amount of energy used in hydronic systems can be gauged from the Water Transport Factor. This is the ratio of the rate of sensible heat change in the circulating water to power input to all pump motors operating in the circulating system, with the heat change measured at the main heat exchange device (e.g., chillers, condensers, etc.).

6.5.4.1 The water transport factor shall not be less than the following values:

Chilled water system	30
Cooling water system (Open or Closed)	50
Hot water system	60

6.5.4.2 For constant volume flow systems, the factor should be based on the design water flow.

6.5.4.3 For variable volume flow, the factor should be based on 75% of the maximum design water flow.

6.6 Air Distribution System Design Criteria

6.6.1 General

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

6.6.1.2 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

6.6.2.2 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 m shall be used. In complex systems with long runs and medium to high pressures of 375 to 2000 Pa, ductwork should be designed at pressure drop of not greater than 3 to 5 Pa per equivalent m.

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 be 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 m^2.

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

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 per 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 zones expected to operate continuously.

Exception:

1. *Systems which are restricted by process requirements such as combustion air intakes.*
2. *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 m^2 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 m^2 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 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 6.3 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.

Exception:

1. *Piping that convey 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.

Table 6.3 MINIMUM INSULATION THICKNESS FOR VARIOUS PIPE SIZES

Types (°C)	Piping System Range drains to 50	Fluid Temp. Condensate less	P I P E S I Z E S (mm) 76	50 or larger	63 to	89 and
Cbilled Water	4.5 to 13.0 25	38	38	50		
Refrige rant or Brine	4.5 and below 50	50	63	63		

Note: Insulation thicknesses (mm) in Table 6.3 are based on insulation having thermal resistivity in the range of 0.028 to 0.032 m^2-°C1W-mm on a flat surface at a mean temperature of 24°C. Minimum insulation thickness shall be increased for materials having R values less than 0.028 m^2-°C1W-mm or may be reduced for materials having R values greater than 0.028 m^2-°C/W-mm.

6.8.3 For materials with thermal resistance greater than 0.032 m^2-°C/W-mm, the minimum insulation thickness shall be:

$$t = \frac{0.032 \times \text{thickness in Table 6.3}}{\text{Actual R value}}$$

[Equation 6.1]

where: t = minimum thickness, mm
R=actual thermal resistance, m^2-°C/ W-mm

6.8.4 For materials with thermal resistance lower than 0.028 m^2-°C/W-mm, the minimum insulation thickness shall be:

$$t = \frac{0.028 \times \text{thickness in Table 6.3}}{\text{Actual R value}}$$

[Equation 6.2]

where: t = minimum thickness, mm.
R= actual thermal resistance, m^2-°C/ 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 raintightness 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 relative humidity of 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 m^2-°C/W-mm and the following equation:

$$L = \frac{kR_s (D_p - t_o)}{(D_b - D_p)}$$

where: D_b = ambient still air dry bulb temperature, °C
D_p = dew point, °C
t_o = operating temperature, °C
R_s = surface thermal resistance
= 0. 115 m^2-°C/W
k = mean thermal conductivity, W-mm/m^2-°C
L thickness, mm

Exception:

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 resistances, should be:

$$R = \frac{TD}{347} \ m^2\text{-°C/W-mm}$$

[Equation 6.3]

where TD is in °C.

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 6.4. 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.

Table 6.4 STANDARD RATED CONDITIONS FOR AIR CONDITIONING SYSTEMS

Stream	Water Cooled Water Chillers (°C)	Air Cooled Water Chillers (°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 Inlet	-	-	27.0 DBT (*) 19.0 WBT (**)

Note: (*) Dry Bulb Temperature
(**) Wet Bulb Temperature

6.10.1.1 Coefficient of Performance (COP)

The COP of an air conditioning system is the ratio of the useful cooling effect to the total energy input. The total energy input refers to the combination of the energy inputs of all elements of the equipment, including but not limited to: compressor(s), pump(s), fan(s), cooling tower(s) and control(s).

6.10.1.2 Unitary Air Conditioning Units - Electrically Operated

This section applies to, but not necessarily limited to, room air conditioners, package air conditioners, direct expansion units and in general, all unitary equipment.

The COP shall not be less than those quoted in Table 6.5.

6. 10. 1.5 Water Chillers - Electrically Operated

This section applies to, but not necessarily limited to, individual components forming part of a system and which are not installed as part of a supplier's matched or complete system.

The COP at design full load shall not be less than the values shown in Table 6.5.

Table 6.5 MINIMUM PERFORMANCE RATING OF VARIOUS AIR CONDINIONING EQUIPMENT

Air Conditioning Equipment	**kW_e/kW_r**	**COP**
Unitary A/C units		
Up to 20 kW_r capacity	0.56	1.80
21 to 66 kW_r capacity	0.53	1.90
61 to 120 kW_r capacity	0.50	2.00
Over 120 kW_r capacity	0.48	2.10
Centrifugal chillers (up to 800 kW_r)		
air cooled	0.44	2.30
water cooled	0.25	4.00
Reciprocating chillers (up to 120 kW_r)		
air cooled	0.39	2.60
water cooled	0.26	3.85
Centrifugal chillers (above 800 kW_r)		
air cooled	0.37	2.70
water cooled	0.22	4.54
Reciprocating chillers (above 120 kW_r)		
air cooled	0.36	2.80
water cooled	0.28	3.60

Notes: kW_e/kW_r = *kilowatt electricity per kilowatt refrigeration*
KW_e/TR = *kilowatt electricity per ton of refrigeration*
I TR = *3.51685 k/W_r*
Table 6.5 sh6uld be in conformity with Table 6.4.

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

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

Section 7.0 STEAM AND HOT WATER SYSTEMS

7.1 Scope

This section applies to the energy conserving design of steam and hot water services in buildings such as hotels and hospitals. The purpose of this section is to provide criteria for 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 In large scale schemes, a choice has to be made between central storage of hot water with a circulating loop and individual storage heaters placed locally at demand centers. 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.

7.3 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.

Table 7.1 MINIMUM PERFORMANCE RATINGS OF STEAM AND HOT WATER SYSTEMS EQUIPMENT

Equipment	Minimum Criteria
Shell Boiler (light oil fired)	
@ Rated Capacity	85% boiler eff.
@ Part Load Capacity	80% boiler eff.
Shell Boiler (heavy oil fired)	
@ Rated Capacity	85% boiler eff.
@ Part Load Capacity	80% boiler eff.
Unfired Storage Tanks (all volumes)	
Surface lleat Loss (niax)	43 W/m2

7.4 Hot Water Temperature

The maximum hot water supply temperatures shall be as follows:

For washing, etc.	400C
For hot baths	450C
For kitchen use	600C

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 +/- 30C of the temperatures set in Sec. 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 I/s. Lavatories in public areas of buildings shall have taps with controlled flow at a rate not exceeding 0.05 Us. 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 Us 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 Eqn. 7. 1. t_2 = 50.8 d,9 f ((1+ 2 tj/do) exp (r_2/r_1) –1]

[Equation7.1]

where: t, 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. mm

Subscript I 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.

Table 7.2. MINIMUM PIPE INSULATION (HEATING SYSTEM

System Types	Fluid Temp. Range (^{O}C)	P I P E S I Z E S (mm)				
		Runouts to 50	25 or less	31 to 50	63 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 & (e) above	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 - 0.0 _,6
(d) R = 0.02i - 0. 028
(e) R = 0.025 - 0.029

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.