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# TELANGANA ENERGY CONSERVATION BUILDING CODE (TSECBC) GUIDELINES



**Telangana Energy Conservation  
Building Code**

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# 1 Purpose

The purpose of this code is to provide minimum requirements for the energy-efficient design and construction of buildings.

## Background Note

The states of Telangana and Andhra Pradesh adopted a mandatory Energy Conservation Building Code (ECBC) for commercial buildings in 2014, applicable to both states after bifurcation. To streamline and modernize compliance to the code, the Greater Hyderabad Municipal Corporation (GHMC) has developed an online city-wide ECBC compliance system. The GHMC Town and Country Planning Department has integrated the compliance into the online Development Permission Management System (DPMS) for buildings approval. As knowledge partners, the Administrative Staff College of India (ASCI), International Institute of Information Technology, Hyderabad (IIIT) and the Natural Resources Defense Council (NRDC) along with key experts have been working with state and city officials to develop and implement the code.

In this effort, the TS ECBC Guidelines is a technical document developed after several discussions, to aid and expedite the adoption of ECBC in the state of Telangana for real-estate developers, building architects, consultant and other stakeholders.

## 2 Scope

The code is applicable to commercial buildings and other non-residential buildings that meet any of the following criteria:

1. plot area of 1000  $m^2$  or more
2. built up area of 2000  $m^2$  or more
3. buildings primarily used as Multiplexes, Hospitals, Hotels or Convention Centers irrespective of their built up area

### 2.1 Applicable Building Systems

The provisions of this code shall apply to -

- (a) Building envelopes, except for unconditioned storage spaces or warehouses;
- (b) Mechanical systems and equipment, including heating, ventilating, and air conditioning;
- (c) Service hot water heating;
- (d) Interior and exterior lighting; and
- (e) Electrical power and motors.

### 2.2 Exemptions

The provisions of this code shall not apply to

- (a) Buildings that do not use either electricity or fossil fuel; or
- (b) Equipment and portions of building systems that use energy primarily for manufacturing processes.

### 2.3 Safety, Health and Environmental Codes Take Precedence

Where this code is contrary to any of the provisions of laws relating to safety, health, or environment, the provisions of safety, health or environmental laws shall apply.

### 2.4 Reference Standards

National Building Code 2016 is the reference document/standard for lighting levels, HVAC, comfort levels, and natural ventilation.

# 3 Administration and Enforcement

## 3.1 Compliance Requirements

### 3.1.1 Mandatory Requirements

- (a) Compliance of this code shall be mandatory for buildings specified in section 2.
- (b) All Government notifications related to energy conservation or mandatory use of any product/process or equipment shall be complied with.

### 3.1.2 New Buildings

New buildings shall comply with either the provisions of section 4 to 8 of this code or the Whole Building Performance Method of Appendix B. In case of mixed use buildings if the commercial part qualifies for the applicability of this code as per section 2 then the commercial part of the building need to comply with this code.

### 3.1.3 Additions to Existing Buildings

Where the addition plus the existing building exceeds the builtup area threshold of section 2, additions shall comply with the provisions of section 4 to 8. Compliance may be demonstrated in either of the following ways:

1. The addition alone shall comply with the applicable requirements, or
2. The addition, together with the entire existing building shall comply with the requirements of this code that would apply to the entire building, as if it were a new building;

Exception to section 3.1.3: When space conditioning is through the existing systems and equipment, the existing system and equipment need not comply with this code. However, any new equipment installed must comply with specific requirements applicable to that equipment.

### 3.1.4 Alterations to Existing Buildings

Where the existing building exceeds the conditioned floor area threshold as specified in section 2, the portions of a building and its systems that are being altered shall meet the provisions of section 4 to 8. The specific requirements for alterations are described in the following subsections.

Exception to section 3.1.4: When the entire building complies with all of the provisions of section 4 to 8 as if it were a new building.

#### 3.1.4.1 Building Envelope

Alterations to the building envelope shall comply with the requirements of section 4 for fenestration, insulation, and air leakage applicable to the portions of the buildings and its systems being altered.

Exception to section 3.1.4.1: The following alterations need not comply with these requirements provided such alterations do not increase the energy usage of the building:

- (a) Replacement of glass in an existing sash and frame, provided the U-factor and SHGC of the replacement glazing are equal to or lower than the existing glazing;
- (b) Modifications to roof/ceiling, wall or floor cavities which are insulated to full depth with insulation; and
- (c) Modifications to walls and floor without cavities and where no new cavities are created.

#### **3.1.4.2 Heating, Ventilation and Air Conditioning**

Alterations to building heating, ventilating, and air conditioning equipment or systems shall comply with the requirements of section 5 applicable to the portions of the building and its systems being altered. Any new equipment or control devices installed in conjunction with the alteration shall comply with the specific requirements applicable to that equipment or control device.

#### **3.1.4.3 Service Water Heating**

Alterations to building service water heating equipment or systems shall comply with the requirements of section 6 applicable to the portions of the building and its systems being altered. Any new equipment or control devices installed in conjunction with the alteration shall comply with the specific requirements applicable to that equipment or control device.

#### **3.1.4.4 Lighting**

Alterations to building lighting equipment or system shall comply with the requirements of section 7 applicable to the portions of the building and its systems being altered. New lighting systems, including controls, installed in an existing building and any change of building area type as listed in Table 7.1 shall be considered an alteration. Any new equipment or control devices installed in conjunction with the alteration shall comply with the specific requirements applicable to that equipment or control device.

Exception to section 3.1.4.4: Alterations that replace less than 50% of the luminaries in a space need not comply with these requirements provided such alterations do not increase the connected lighting load.

#### **3.1.4.5 Electric Power and Motors**

Alteration to building electric power systems and motor shall comply with the requirements of section 8 applicable to the portions of the building and its systems being altered. Any new equipment or control devices installed in conjunction with the alteration shall comply with the specific requirements applicable to that equipment or control device.

### **3.2 Compliance Approaches**

The building shall comply with the mandatory provisions of sections 4.2, 5.2, 6.2, 7.2, and 8.2; building components shall be tested as per the provisions given in section 4.4, 5.4, 6.4, 7.4, and 8.4 and either of the following:

- (a) Prescriptive Method (sections 4.3, 5.3, 6.3, 7.3 and 8.3)
- (b) Whole Building Performance Method of Appendix B

Consistent with Section 22 of Telangana Building Rules, 2012 and to encourage compliance, the ULB shall adopt the following compliance rating methodology as described in the Table 3.1. Compliance by prescriptive method to get TS\* is mandatory for all the new buildings as per definition given in section 2(aa). However, builder/owner/developer can adopt TS\*\* and above on voluntary basis.

### **3.3 Administrative Requirements**

Administrative requirements relating to permit requirements, enforcement, interpretations, claims of exemption, approved calculation methods, and rights of appeal are specified by the Authority having Jurisdiction.

#### **3.3.1 Professional Statement**

Professional statement for energy analysis shall be prepared to identify the compliance format and to demonstrate how the project design and the construction complies with TSECBC.

#### **3.3.2 Professional Responsibility**

Professional responsibility for energy analysis and compliance for any method adopted by builder/owner/developer shall be fixed on respective TS Empanelled architect or BEE empanelled architect who submits the professional statement.

Table 3.1: TSECBC Compliance Rating Methodology

Category	Compliance Requirement
TS*	Compliance by prescriptive method as per TSECBC or compliance by whole building performance method with energy savings up to 5% above base case
TS**	Compliance by whole building performance method with energy savings of $>5$ and $\leq 10\%$ above base case
TS***	Compliance by whole building performance method with energy savings of $>10$ and $\leq 15\%$ above base case
TS****	Compliance by whole building performance method with energy savings of $>15$ and $\leq 20\%$ above base case
TS*****	Compliance by whole building performance method with energy savings of $>20$ and $\leq 30\%$ above base case
TS*****	Compliance by whole building performance method with energy savings above 30% of base case

## 3.4 Compliance Documents

### 3.4.1 General

Plans and specifications shall show all pertinent data and features of the building, equipment, and systems in sufficient detail to permit authority having jurisdiction to verify that the building complies with the requirements of this code. Details shall include, but are not limited to:

- (a) Building Envelope: insulation materials and their R-values; fenestration U- factors, solar heat gain coefficients (SHGC), visible light transmittance, and air leakage, overhangs and side fins, building envelope sealing details;
- (b) Heating, Ventilation, and Air Conditioning: system and equipment types, sizes, efficiencies and controls, economizers, variable speed drives, piping insulation, duct sealing, insulation and location, system balancing report;
- (c) Service Hot Water and Pumping: Service hot water and pumping, waste heat recovery system, and solar water heating system;
- (d) Lighting: lighting schedule showing type, number, and wattage of lamps and ballasts, automatic lighting shut off, occupancy sensors, other lighting controls, and lamp efficacy of exterior lamps;
- (e) Electrical Power: electric schedule showing transformer losses, motor efficiencies, and power factor correction devices, electric check metering and monitoring system; and
- (f) Energy simulation report, if Whole Building Performance (WBP) method is selected for the compliance.

### 3.4.2 Supplemental Information

The authority having jurisdiction may require supplemental information necessary to verify compliance with this code, such as calculations, worksheets, compliance forms, manufacturer literature, or other data.

### 3.4.3 Inspection by Urban Local Bodies

The ULB has full authority to implement the TSECBC including but not limited to:

- (a) **TSECBC Compliance Application Fees.** The applicant shall pay the TSECBC compliance application fee to the ULB, as determined by MAUD and the ULB, for every TSECBC compliance application that is submitted to the ULB for approval. The ULB has the authority to develop a fee payment schedule and periodically modify fee amounts.
- (b) **Progress Inspections.** The ULBs have the authority to determine the required inspection documentation to verify TSECBC compliance for the envelope, heating, ventilation and air conditioning, service hot water and pumping, lighting and electrical power of the building, during the construction and occupancy phases.

- (c) **Incentive Structures.** The ULB and MAUD have the authority to provide incentives for compliance with TS\*\*\* or higher categories of the TSECBC Compliance Rating. The incentives may be in the form of expedited processing of the certificate of construction and occupancy certificate filed by the applicant.
- (d) **Energy Analysis Disclosure.** The ULB has the authority to disclose the energy analysis results at any time.
- (e) **TSECBC Trainings and Education.** The ULB is authorized to develop training for ULB staff and inspectors; education and outreach programs to design professionals; and programs for licensing professionals and inspectors on TSECBC compliance.
- (f) **Compliance and Enforcement.** The ULB has broad authority to ensure compliance and take enforcement actions for violations of this GO.
  - (i) The ULB has the authority to appeal to BEE to revoke the empanelment certification for BEE empanelled architects that sign TSECBC compliance applications for buildings found to be non-compliant.
  - (ii) The ULB has the authority to blacklist BEE empanelled architects that repeatedly submit non-compliant energy analysis or falsely any documents pursuant to this GO for TSECBC compliance.
  - (iii) The ULB has the authority to develop a program utilizing third party assessors or inspectors to ensure compliance with the TSECBC.

# 4 Envelope

## 4.1 General

The building envelope shall comply with the mandatory provisions of section 4.2 and the prescriptive criteria of section 4.3. Building envelope components shall be tested as per the provisions given in section 4.4.

## 4.2 Mandatory Requirements

### 4.2.1 Fenestration: Light to Solar Gain (L/S)

Fenestration shall have ratio of Light to Solar Gain (L/S) not less than 1.

### 4.2.2 Building Envelope Sealing

The following areas of the enclosed building envelope shall be sealed, caulked, gasketed, or weather stripped to minimize air leakage

- (a) Joints around fenestration and door frames;
- (b) Openings between walls and foundations and between walls and roof and wall panels;
- (c) Openings at penetrations of utility services through, roofs, walls, and floors;
- (d) Site- built fenestration and doors;
- (e) Building assemblies used as ducts or plenums; and
- (f) All other openings in the building envelope.

### 4.2.3 Roof Surface

Roofs shall have initial solar reflectance of not less than 0.30 and an initial emittance no less than 0.75.

## 4.3 Prescriptive Requirements

### 4.3.1 Roofs

Roofs shall have the maximum assembly U-factor of  $0.4 \text{ W/m}^2\text{K}$ .

#### 4.3.1.1 Cool Roofs

Roofs with slopes less than 20 degrees shall have initial solar reflectance of not less than 0.70 and an initial emittance no less than 0.75.

### 4.3.2 Opaque Walls

Opaque walls shall have the maximum assembly U-factor of  $0.73 \text{ W/m}^2\text{K}$ .

### 4.3.3 Vertical Fenestration

Vertical fenestration shall comply with area weighted U-factor, SHGC and VLT as given in Table 4.1. Vertical fenestration area is limited to a maximum of 60% of the gross wall area for the prescriptive requirement.

Exception to section 4.3.3: Overhangs and/or side fins may be applied in determining the SHGC for the proposed design. An adjusted SHGC, accounting for overhangs and/or side fins, is calculated by using the tool available at <http://mfactor.ecbctool.in>

Exception to SHGC Requirements in section 4.4.3: Vertical Fenestration areas located more than 2.2 m above the level of the floor (daylight glazing) are exempt from the SHGC requirement in Table 4.1 if the following conditions are compiled with:-

An interior light shelf is provided at the bottom of this fenestration area, with an interior projection factor not less than:

- (a) 1.0 for EW, SE, SW, NE, and NW orientations;
- (b) 0.5 for S orientation; and
- (c) 0.35 for N orientation

Table 4.1: Vertical Fenestration Requirements

WWR $\leq$ 40%			40% < WWR $\leq$ 60%		
Maximum U factor W/m <sup>2</sup> K	Maximum SHGC	Minimum VLT	Maximum U factor W/m <sup>2</sup> K	Maximum SHGC	Minimum VLT
2.84	0.25	0.25	2.84	0.20	0.20

#### 4.3.4 Skylights

Skylights shall comply with the maximum U factor and maximum SHGC requirements of Table 4.2. Skylight areas are limited to a maximum of 3% of the gross roof area for the prescriptive requirement.

Table 4.2: Skylight U factor and SHGC requirement SSR  $\leq$  3%

Maximum U factor W/m <sup>2</sup> K	Maximum SHGC
4.26	0.35

## 4.4 Testing Standards

Table 4.3 gives the testing standards. Products/materials can follow any of the following three alternatives.

- (a) Get test certificate from manufactures/independent labs as per the standards given Table 4.3.
- (b) Get the calculated values from accredited test labs.
- (c) Take default value from Appendix C.

Table 4.3: Envelope Testing Standard

Component	Standard
Fenestration U value and SHGC	ISO 15099
Cool Roof Reflectance	ASTM C1549, ASTM E903, ASTM 1918
Cool Roof Emittance	ASTM E 408 71 OR ASTM C1371
Measure the steady state heat transfer through flat slab	ISO 8301
U value of roofs and walls	U-factor calculation includes building material only an does not include air films

# 5 Heating, Ventilation and Air conditioning

## 5.1 General

All heating, ventilation, and air conditioning equipment and systems shall comply with the mandatory provisions of section 5.2 and the prescriptive criteria of section 5.3. All HVAC components shall be tested as per the provisions given in section 5.4.

## 5.2 Mandatory Requirements

### 5.2.1 Load Calculations

Heating and cooling system design loads for the purpose of sizing systems and equipment shall be determined in accordance with ISHRAE method of load calculation or ANSI/ASHRAE/ACCA Standard 183.

### 5.2.2 Natural Ventilation

Natural ventilation shall comply with the design guidelines provided for natural ventilation in the National Building Code of India 2016 Part 8 Section 1,

### 5.2.3 Minimum Equipment Efficiencies

#### 5.2.3.1 Ceiling Fan

Ceiling Fan efficiency shall meet BEE three star rating efficiency.

#### 5.2.3.2 Unitary, Split, and Packaged Air Conditioner

Unitary Air Conditioner and Split air conditioner shall meet BEE three star rating efficiency. Packaged air conditioner shall meet IS 8148.

#### 5.2.3.3 Cooling Equipment

Cooling equipment shall meet or exceed the minimum efficiency requirements of Table 5.1 and 5.2. Heating and cooling equipment not covered in table shall comply with ASHRAE 90.1- 2010 section 6.4.1.

Table 5.1: Chillers Efficiency

Equipment Class	Minimum COP	Minimum IPLV
Air Cooled Chiller < 530kW	2.9	3.16
Air Cooled Chiller ≥ 530kW	3.05	3.32
Centrifugal Water Cooled Chiller ≤ 530kW	5.0	5.25
Centrifugal Water Cooled Chiller ≥ 530 kW and <1050 kW	5.55	5.9
Centrifugal Water Cooled Chiller ≥ 1050 kW	6.1	6.4
Reciprocating Compressor Water Cooled Chiller all sizes	4.2	5.05
Rotary Screw and Scroll Compressor Chiller < 530 kW	4.7	5.49
Rotary Screw and Scroll Compressor Chiller ≥ 530 kW and < 1050 kW	5.4	6.17
Rotary Screw and Scroll Compressor Chiller ≥ 1050 kW	5.75	6.43

Table 5.2: Electrically Operated Variable Refrigerant Flow Air Conditioners Minimum Efficiency Requirements air cooled (Cooling mode)

Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency
<19 kW	All	VRF multisplit system	3.81 SCOP <sub>c</sub>
≥19 kW and <40 kW	Electric resistance (or none)	VRF multisplit system	3.22 COP <sub>c</sub> 3.60 ICOP <sub>c</sub>
≥19 kW and <40 kW	Electric resistance (or none)	VRF multisplit system with heat recovery	3.16 COP <sub>c</sub> 3.55 ICOP <sub>c</sub>
≥40 kW and <70 kW	Electric resistance (or none)	VRF multisplit system	3.11 COP <sub>c</sub> 3.46 ICOP <sub>c</sub>
≥40 kW and <70 kW	Electric resistance (or none)	VRF multisplit system with heat recovery	3.05 COP <sub>c</sub> 3.40 ICOP <sub>c</sub>
≥70 kW	Electric resistance (or none)	VRF multisplit system	2.78 COP <sub>c</sub> 3.11 ICOP <sub>c</sub>
≥70 kW	Electric resistance (or none)	VRF multisplit system with heat recovery	2.73 COP <sub>c</sub> 3.05 ICOP <sub>c</sub>

<sup>a</sup> SCOP<sub>c</sub> - seasonal coefficient of performance—cooling

## 5.2.4 Controls

### 5.2.4.1 Zone Thermostatic Controls

The supply of heating and cooling energy to each zone shall be individually controlled by thermostatic controls responding to temperature within the zone.

Exceptions: Independent perimeter systems that are designed to offset only building envelope loads shall be permitted to serve one or more zones also served by an interior system, provided that

- (a) the perimeter system includes at least one thermostatic control zone for each building exposure having exterior walls facing only one orientation for 15 contiguous meters or more and
- (b) the perimeter system heating and cooling supply is controlled by a thermostatic control(s) located within the zone(s) served by the system.

Exterior walls are considered to have different orientations if the directions they face differ by more than 45 degrees.

### 5.2.4.2 Off-Hour Controls

HVAC systems shall have the off-hour controls for automatic shutdown. HVAC systems shall be equipped with at least one of the following:

- (a) Controls that can start and stop the system under different time schedules for seven different day types per week, are capable of retaining programming and time setting during loss of power for a period of at least ten hours, and include an accessible manual override, or equivalent function, that allows temporary operation of the system for up to two hours
- (b) An occupant sensor that is capable of shutting the zone system off when no occupant is sensed for a period of up to 30 minutes

## 5.2.5 Zone Isolation

HVAC systems serving zones that are intended to operate or be occupied non simultaneously shall be divided into isolation areas. Zones may be grouped into a single isolation area provided it does not exceed 2000 m<sup>2</sup> of conditioned floor area nor include more than one floor. Each isolation area shall be equipped with isolation devices capable of automatically shutting off the supply of conditioned air and outdoor air to and exhaust air from the area. Each isolation area shall be controlled independently by a device meeting

the requirements of Section 5.2.4.2. For central systems and plants, controls and devices shall be provided to allow stable system and equipment operation for any length of time while serving only the smallest isolation area served by the system or plant.

### 5.2.6 Ventilation Fan Controls

Fans with motors greater than 0.56 kW shall have automatic controls complying with Section 5.2.4.2 that are capable of shutting off fans when not required.

Exception: HVAC systems intended to operate continuously.

### 5.2.7 Enclosed Parking Garage Ventilation

Enclosed parking garage ventilation systems shall automatically detect contaminant levels and stage fans or modulate fan airflow rates to 50% or less of design capacity, provided acceptable contaminant levels are maintained.

Exceptions:

- (a) Garages less than 3000  $m^2$  with ventilation systems that do not utilize mechanical cooling or mechanical heating
- (b) Garages that have a garage area to ventilation system motor nameplate kW ratio that exceeds 150  $m^2/kW$  and do not utilize mechanical cooling or mechanical heating.

### 5.2.8 Piping and Duct Work Insulation

#### 5.2.8.1 Piping

Piping shall be thermally insulated in accordance with Tables 5.3 and 5.4.

Table 5.3: Minimum Piping Insulation Thickness Cooling Systems (Chilled Water, Brine, and Refrigerant)

Fluid Operating Temperature	Insulation Conductivity		Nominal Pipe or Tube Size mm				
	Conductivity W/m °C	Mean Rating Temperature °C	<25	25 to <40	40 to <100	100 to <200	≥ 200
				Insulation Thickness, mm			
4°C to 16°C	0.030 to 0.039	24	15	15	25	25	25
<4°C	0.029 to 0.037	10	15	25	25	25	40

<sup>a</sup> For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows:  $T = r(1 + t/r)^{K/k} - 1$  where T = minimum insulation thickness (mm), r = actual outside radius of pipe (mm), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (W/(m-°C)); and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.

<sup>b</sup> For direct-buried cooling system piping, insulation is not required.

<sup>c</sup> The table is based on steel pipe. Nonmetallic pipes schedule 80 thickness or less shall use the table values. For other nonmetallic pipes having thermal resistance greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per foot than a steel pipe of the same size with the insulation thickness shown in the table.

#### 5.2.8.2 Duct Work

Ductwork shall be insulated in accordance with Table 5.5.

Table 5.4: Minimum Piping Insulation Thickness Heating and Hot water Systems (Steam, Steam Condensate, Hot water heating, and Domestic water systems)

Fluid Operating Temperature	Insulation Conductivity		Nominal Pipe or Tube Size mm				
	Conductivity W/m °C	Mean Rating Temperature °C	<25	25 to <40	40 to <100	100 to <200	≥ 200
>177°C	0.046 to 0.049	121	115	125	125	125	125
122°C to 177°C	0.042 to 0.046	93	80	100	115	115	115
94°C to 121°C	0.039 to 0.043	66	65	65	80	80	80
61°C to 93°C	0.036 to 0.042	52	40	40	50	50	50
41°C to 60°C	0.032 to 0.040	38	25	25	40	40	40

<sup>a</sup> For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows:  $T = r(1 + t/r)^{K/k} - 1$  where T = minimum insulation thickness (mm), r = actual outside radius of pipe (mm), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (W/(m-°C)); and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.

<sup>b</sup> For direct-buried heating and hot-water system piping, reduction of these thicknesses by 40 mm shall be permitted (before thickness adjustment required in footnote [a]) but not to thicknesses below 25 mm.

<sup>c</sup> The table is based on steel pipe. Nonmetallic pipes schedule 80 thickness or less shall use the table values. For other nonmetallic pipes having thermal resistance greater than that of steel pipe, reduced insulation thicknesses are permitted if documentation is provided showing that the pipe with the proposed insulation has no more heat transfer per foot than a steel pipe of the same size with the insulation thickness shown in the table.

Table 5.5: Duct Work Insulation  $m^2°C/W$

Duct Location	Required Insulation	
	Supply Ducts	Return Ducts
Exterior	R-1.06	R-0.62
Ventilated Attic	R-1.06	R-0.62
Unventilated Attic without Roof Insulation	R-1.4	R-0.62
Unconditioned Space <sup>a</sup>	R-0.6	No Requirement
Indirectly Conditioned Space <sup>b</sup>	No Requirement	No Requirement
Buried	R-0.6	No Requirement

<sup>a</sup> Includes crawlspaces both ventilated and non ventilated.

<sup>b</sup> Include return air plenums with or without exposed roofs above.

## 5.2.9 Ductwork and Plenum Leakage

### 5.2.9.1 Duct Sealing

Ductwork and all plenums with pressure class ratings shall be constructed to Seal Class A, as required to meet the requirements of Section 5.2.9.2, and with standard industry practice. Openings for rotating shafts shall be sealed with bushings or other devices that seal off air leakage. Pressure-sensitive tape shall not be used as the primary sealant unless it has been certified to comply with UL-181A or UL-181B by an independent testing laboratory and the tape is used in accordance with that certification. All connections shall be sealed, including but not limited to spin-ins, taps, other branch connections, access doors, access panels, and duct connections to equipment. Sealing that would void product listings is not required. Spiral lock seams need not be sealed. All duct pressure class ratings shall be designated in the design documents.

### 5.2.9.2 Duct Leakage Tests

Ductwork that is designed to operate at static pressures in excess of 750 Pa and all ductwork located outdoors shall be leak-tested according to industry-accepted test procedures. Representative sections totaling no less than 25% of the total installed duct area for the designated pressure class shall be tested. All sections shall be selected by the building owner or the designated representative of the building owner.

Positive pressure leakage testing is acceptable for negative pressure ductwork.

The maximum permitted duct leakage shall be

$$L_{max} = C_L(P^{0.65}/1000)$$

where

$L_{max}$	=	maximum permitted leakage, L/s·m <sup>2</sup> duct surface area
$C_L$	=	6, duct leakage class, L/s·m <sup>2</sup> duct surface area at 250 Pa
P	=	test pressure, which shall be equal to the design duct pressure class rating, Pa

## 5.2.10 System Balancing

### 5.2.10.1 General

Construction documents shall require that all HVAC systems be balanced in accordance with generally accepted engineering standards. Construction documents shall require that a written balance report as per Associated Air Balance Council (AABC) be provided to the owner or the designated representative of the building owner of HVAC systems serving zones with a total conditioned area exceeding 500 m<sup>2</sup>.

### 5.2.10.2 Air System Balancing

Air systems shall be balanced in a manner to first minimize throttling losses. Then, for fans with fan systems power greater than 0.75 kW, fan speed shall be adjusted to meet design flow conditions.

### 5.2.10.3 Hydronic System Balancing

Hydronic Systems shall be proportionately balanced in a manner to first minimize throttling losses, then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions.

Exceptions:

- (a) Impellers need not be trimmed nor pump speed adjusted for pumps with pump motors of 7.5 kW or less;
- (b) Impellers need not be trimmed when throttling results is no greater than 5% of the nameplate horsepower draw, or 2.2 kW, whichever is greater.

## 5.2.11 Condensers

### 5.2.11.1 Condenser Locations

Care shall be exercised in locating the condensers in such a manner that heat sink is free of interference from heat discharge by devices located in adjoining spaces and also does not interfere with such other systems installed nearby. Manufacturer guidelines regarding placement of condenser must be followed. The condensers (outdoor units) especially of single unit room split air conditioners shall be located in shaded and well ventilated area closest to the evaporator (indoor unit). In case of unavailability of shaded area, the condensers shall be provided with artificial shading to prevent direct heating of the unit during day time by the sun light. The unitary air conditioners shall also be installed at suitable locations to avoid direct sunlight and shading may be provided for improved performance. The piping system connecting the outdoor and indoor units shall be insulated as per section 5.2.8 and the length of such pipes shall not exceed the length as specified by the manufacturer.

All cooling towers and closed circuit fluid coolers shall have either two speed motors, pony motors, or variable speed drives controlling the fans.

### 5.2.11.2 Treated Water for Condensers

Buildings using centralized cooling water systems shall use soft water as specified by manufacturer for the condenser and chilled water systems.

## 5.2.12 Zone Sealing

The automatic door closure and door gaps sealing arrangement should be provided in all air conditioned rooms.

## 5.3 Prescriptive Requirements

Compliance shall be demonstrated with the requirements in section 5.3.1 through section 5.3.2 for each HVAC system.

### 5.3.1 Fan System Power and Efficiency

#### 5.3.1.1 Fan System Power

Each HVAC system at fan system design conditions shall not exceed the allowable fan system motor nameplate kW as shown in Table 5.6. This includes supply fans, return/relief fans, exhaust fans, and fan-powered terminal units associated with systems providing heating or cooling capability. Single-zone variable-air-volume systems shall comply with the constant-volume fan power limitation.

Exceptions:

- (a) Hospital, vivarium, and laboratory systems that utilize flow control devices on exhaust and/or return to maintain space pressure relationships necessary for occupant health and safety or environmental control may use variable-volume fan power limitation.
- (b) Individual exhaust fans with motor nameplate kW of 0.75 kW or less.

Table 5.6: Fan Power Limitation

Fan system	Limit	Constant Volume	Variable Volume
motor nameplate kW	Allowable nameplate motor kW	$\text{kW} \leq L/S_S \cdot 0.0017$	$\text{kW} \leq L/S_S \cdot 0.0024$

<sup>a</sup>  $L/S_S$  = maximum design supply airflow rate to conditioned spaces served by the system in liters per second

<sup>b</sup> kW = maximum combined motor nameplate kW

#### 5.3.1.2 Motor Name plate kilowatts

For each fan, the selected fan motor shall be no larger than the first available motor size greater than the input kW. The fan input kW must be indicated on the design documents to allow for compliance verification by the code official.

#### 5.3.1.3 Fan Efficiency

Fans shall have a fan efficiency grade (FEG) of 67 or higher based on manufacturers certified data, as defined by AMCA 205. The total efficiency of the fan at the design point of operation shall be within 15 percentage points of the maximum total efficiency of the fan.

Exceptions:

- (a) Single fans with a motor nameplate kilowatts of 3.75 kW or less
- (b) Fans outside the scope of AMCA 205
- (c) Fans that are intended to only operate during emergency conditions

#### 5.3.1.4 Supply Air Temperature Reset

Multiple zone HVAC systems must include controls that automatically reset the supply air temperature in response to representative building loads, or to outdoor air temperature. The controls shall reset the supply air temperature at least 25% of the difference between the design supply air temperature and the design room air temperature. Controls that adjust the reset based on zone humidity are allowed. Zones that are expected to experience relatively constant loads, such as electronic equipment rooms, shall be designed for the fully reset supply temperature.

### 5.3.1.5 Fan Control

DX cooling system with mechanical cooling capacity  $\geq 19$  kW and chilled-water cooling system having fan motor size  $\geq 0.75$  kW shall be designed to vary the indoor fan airflow as a function of load and shall comply with the following requirements:

- (a) DX and chilled-water cooling units that control the capacity of the mechanical cooling directly based on space temperature shall have a minimum of two stages of fan control. Low or minimum speed shall not exceed 66% of full speed. At low or minimum speed, the fan system shall draw no more than 40% of the fan power at full fan speed. Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.
- (b) All other units, including DX cooling units and chilled water units that control the space temperature by modulating the airflow to the space, shall have modulating fan control. Minimum speed shall not exceed 50% of full speed. At minimum speed, the fan system shall draw no more than 30% of the power at full fan speed. Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation.

## 5.3.2 Variable Flow Hydronic Systems

### 5.3.2.1

Chilled or hot-water systems shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to not more than the larger of:

- (a) 50% of the design flow rate; or
- (b) The minimum flow required by the equipment manufacturer for proper operation of the chiller or boilers.

### 5.3.2.2

Water cooled air conditioning or heat pump units with a circulation pump motor greater than or equal to 3.7 kW shall have two way automatic isolation valves on each water cooled air conditioning or heat pump unit that are interlocked with the compressor to shutoff condenser water flow when the compressor is not operating.

### 5.3.2.3

Chilled Water and Condenser Water pump power Chilled water or condenser water systems that must comply with either section 5.3.2.1 or section 5.3.2.2 and that have pump motors greater than or equal to 3.7 kW shall be controlled by variable speed drives.

### 5.3.2.4 Chilled Water and Condenser Water Pump Power

The design chilled water pump power shall be less than or equal to 350 kW/1000 L/s. Chilled-water systems serving air conditioned area of 11,000  $m^2$  or more shall have primary/secondary systems with variable-speed drives on the secondary pumping loop. Chilled-water pumps in systems serving less than 11,000  $m^2$  cooling capacity shall have primary/secondary systems with secondary pump riding the pump curve. The design condenser-water pump power shall be less than or equal to 310 kW/1000 L/s.

### 5.3.2.5 Heat Rejection Equipment

The fan system on a heat rejection device powered by an individual motor or array of motors with a connected power, including the motor service factor, totaling 3.8 kW or more shall have controls and/or devices (such as variable speed control) that shall result in fan motor demand or no more than 30% of design wattage at 50% of the design air flow and that shall automatically modulate the fan speed to control the leaving fluid temperature or condensing temperature/pressure or the heat rejection device.

Exceptions:

- (a) Condenser fans serving multiple refrigerant circuits
- (b) Condenser fans serving flooded condensers

### 5.3.2.6 Chilled Water Supply Temperature Reset

For chilled water system with a design capacity exceeding 100 kW supplying chilled-water to comfort conditioning system, supply temperature shall be reset based on outdoor dry-bulb temperature using the following schedule: 7°C at 27°C and above, 12°C at 16°C and below, and ramped linearly between 7°C and 12°C at temperatures between 27°C and 16°C.

## 5.4 Testing Standards

Table 5.7 gives the testing standards.

Table 5.7: HVAC Testing Standards

Component	Standard
Natural Ventilation	NBC 2016 PART 8 Section 1
Unitary Air Conditioner	BEE Star Rating IS 1391 PART 2
Split Air Conditioner	BEE Star Rating IS 1391 PART 2
Packaged Air Conditioner	ISO 8148
Boilers	IS 13980
Air Cooled Chillers Water Cooled Chillers	AHRI 551 AHRI 591
VRF system	AHRI 1230
Duct Work and Piping Insulation	ASTM C 518
Fan Efficiency	AMCA 205
Duct Insulation R-value	Measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 24°C at the installed thickness.

# 6 Service Hot Water and Pumping

## 6.1 General

All service water heating equipment and system shall comply with the mandatory provisions of section 6.2. All service hot water and pumping components shall be tested as per the provisions given in section 6.4.

## 6.2 Mandatory Requirements

### 6.2.1 Load Calculation

Service water heating system design loads for the purpose of sizing systems and equipment shall be determined in accordance with manufacturers published sizing guidelines or generally accepted engineering standards and handbooks acceptable to the adopting authority e.g. ASHRAE Handbook: HVAC Applications.

### 6.2.2 Solar Water Heating

Commercial establishments like Hotels, Hospitals, and Guest houses with a centralized system shall have solar water heating for at least 1/5 of the design capacity:

Exception to section 6.2.2: systems that use heat recovery for at least 1/5 of the design capacity.

### 6.2.3 Equipment Efficiency

Service water heating equipment shall meet or exceed the performance and minimum efficiency requirement presented in available Indian Standards.

- (a) Solar water heater shall meet the performance/minimum efficiency level mentioned in IS 13129 Part (1 and 2)
- (b) Gas Instantaneous Water heater shall meet the performance/minimum efficiency level mentioned in IS 15558 with above 80% thermal efficiency; and
- (c) Electric water heater shall meet the performance /minimum efficiency level mentioned in IS 2082.

### 6.2.4 Supplementary Water Heating System

Supplementary water heating system shall be designed to maximize the energy efficiency of the system and shall incorporate the following design features in cascade:

- (a) Maximum heat recovery from hot discharge system like condensers of air conditioning units;
- (b) Use of gas fired heaters wherever gas is available; and
- (c) Electric heater as last resort.

### 6.2.5 Piping Insulation

Piping insulation shall comply with section 5.2.8.1. The entire hot water system including the storage tanks, pipelines shall be insulated conforming to the relevant IS standards on materials and applications.

### 6.2.6 Heat Traps

Vertical pipe risers serving storage water heaters and storage tanks not having integral heat traps and serving a non-recirculating system shall have heat traps on both the inlet and outlet piping as close as practical to the storage tank.

### 6.2.7 Swimming Pools

Heated pools shall be provided with a vapor retardant pool cover on or at the water surface. Pools heated to more than 32°C shall have a pool cover with a minimum insulation value of R-2.1:  
Exception to section 6.2.7: Pools deriving over 60% of their energy from site- recovered energy or solar energy source.

### 6.2.8 Compliance Documentation

The application for approval shall furnish detailed calculation showing the design to ensure that at least 20% of the heating requirement shall be met from solar heat/ heat recovery and not more than 80% of the heat shall be met from electrical heating. Wherever gas is available, not more than 20% of the heat shall be met from electrical heating.

## 6.3 Prescriptive Requirements

There is no prescriptive requirement in this section.

## 6.4 Testing Standards

Table 6.1 gives the testing standards.

Table 6.1: Testing Standard

Component	Standard
Solar Water Heater	IS 13129 Part 1 and 2
Gas Instantaneous Water Heater	IS 15558
Electric Water Heater	IS 2082

# 7 Lighting

## 7.1 General

Lighting systems and equipment shall comply with the mandatory provisions of section 7.2 and the prescriptive criteria of section 7.3. All lighting components shall be tested as per the provisions given in section 7.4.

The lighting requirements in this section shall apply to:

- (a) Interior spaces of buildings;
- (b) Exterior building features, including facades, illuminated roofs, architectural features, entrances, exits, loading docks, and illuminated canopies; and
- (c) Exterior building grounds lighting that is provided through the buildings electrical service

Exception to 7.1: Emergency lighting that is automatically off during normal building operation and is powered by battery, generator, or other alternate power source.

## 7.2 Mandatory Requirements

### 7.2.1 Interior Lighting Control

#### 7.2.1.1 Local Control

There shall be one or more manual lighting controls in each enclosed space that controls all of the lighting in the space. Each control device shall control an area no larger than  $250 m^2$ . The device installed to comply with this provision shall be readily accessible and located so that the occupants can see the controlled lighting when using the control device.

Exception: Remote location of this local control device or devices shall be permitted for reasons of safety or security when each remote control device has an indicator pilot light as part of or next to the control device and the light is clearly labeled to identify the controlled lighting.

#### 7.2.1.2 Partial Automatic ON

No more than 25% of the lighting power for the general lighting shall be allowed to be automatically turned on.

Exception: Toilets, stairs, and corridors.

#### 7.2.1.3 Bilevel Lighting Control

The general lighting in the space shall be controlled so as to provide at least one intermediate step in lighting power or continuous dimming in addition to full ON and full OFF. At least one intermediate step shall be between 30% and 70% (inclusive) of full lighting power.

Exception: Corridors and lobby.

#### 7.2.1.4 Automatic Daylight Responsive Controls for Sidelighting/Toplighting

In any space where the combined input power of all general lighting completely or partially within the primary sidelighted/toplighting areas is more than 50% power required by Table 7.1/7.2, the general lighting in the primary sidelighted/toplighting areas shall be controlled by photocontrols.

#### 7.2.1.5 Automatic Full OFF

All lighting shall be automatically shut off within 20 minutes of all occupants leaving the space. A control device meeting this requirement shall control no more than  $250 m^2$ .

Exceptions: The following lighting is not required to be automatically shut off:

- (a) General lighting and task lighting in shop and laboratory classrooms
- (b) General lighting and task lighting in spaces where automatic shutoff would endanger the safety or security of room or building occupants

### **7.2.2 Parking Garage Lighting Control**

Lighting power of each luminaire shall be automatically reduced by a minimum of 30% when there is no activity detected within a lighting zone for 20 minutes. Lighting zones for this requirement shall be no larger than 500 m<sup>2</sup>.

### **7.2.3 Exterior Lighting Control**

Lighting for all exterior applications not exempted in section 7.3.5 of the code shall be controlled by a photo sensor or astronomical time switch that is capable of automatically turning off the exterior lighting when daylight is available or the lighting is not required. All building façade and landscape lighting shall be automatically shut off from midnight or business closing whichever is later. If the business starts before 7 AM then the lights can again be turned on at the start of business.

### **7.2.4 Additional Control**

The following lighting applications shall be equipped with a control device to control such lighting independently of general lighting,-

- (a) Display/ Accent Lighting: Display or accent lighting greater than 300 m<sup>2</sup> area shall have a separate control device;
- (b) Case Lighting: in cases used for display purposes greater than 300 m<sup>2</sup> areas shall be equipped with a separate control device;
- (c) Hotel and Motel Guest Room Lighting: Hotel and motel guest rooms and guest suites shall have a master control device at the main room entry that controls all permanently installed luminaires and switched receptacles;
- (d) Task Lighting: Supplemental task lighting including permanently installed under shelf or under cabinet lighting shall have a control device integral to the luminaires or controlled by a wall mounted control device provided the control device complies with section 7.2.1.
- (e) Non-visual Lighting: Lighting for non-visual applications, such as plant growth and food-warming, shall be equipped with a separate control device; and
- (f) Demonstration Lighting: Lighting equipment that is for sale or for demonstrations in lighting education shall be equipped with separate control device accessible only to authorized personnel.

### **7.2.5 Signage/Advertising Signage**

Internally illuminated exit signs shall not exceed 5 W per face. The lighting power density in case of signage/advertisement signage should not exceed 50 W/m<sup>2</sup> for internally illuminated signage and 25 W/m<sup>2</sup> for externally illuminated signage.

### **7.2.6 Exterior Building Grounds Lighting**

Luminaires for exterior building grounds lighting that operate at greater than 100 W shall contain lamps having minimum efficacy of 80 lm/W unless the luminaire is controlled by a motion sensor or exempt under section 7.1.

## **7.3 Prescriptive Requirements**

### **7.3.1 Interior Lighting Power**

The installed interior lighting power for a building or a separately metered or permitted portion of a building shall be calculated in accordance with section 7.3.4 and shall not exceed the interior lighting power allowance determined in accordance with either section

Exception for 7.3.1: The following lighting equipment and application shall not be considered when determining the interior lighting power allowance, nor shall the wattage for such lighting be included in the installed interior lighting power. However, any such lighting shall not be exempt unless it is an addition to general lighting and is controlled by an independent control device,-

- (a) Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments;
- (b) Lighting that is integral to equipment or instrumentation and is installed by its manufacturer;
- (c) Lighting specifically designed for medical or dental procedures and lighting integral to medical equipment;
- (d) Lighting integral to food warming and food preparation equipment;
- (e) Lighting for plant growth or maintenance;
- (f) Lighting in spaces specifically designed for use by the visually impaired;
- (g) Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions;
- (h) Lighting in interior spaces that have been specifically designated as a registered interior historic landmark;
- (i) Lighting that is an integral part of advertising or directional signage;
- (j) Exit signs;
- (k) Lighting that is for sale or lighting educational demonstration systems;
- (l) Lighting for theatrical purposes, including performance, stage, and film or video production;
- (m) Athletic playing areas with permanent facilities for television broadcasting.

### 7.3.2 Building Area Method

Table 7.1: Interior Lighting Power Building Area Method\*

Building Area Type	LPD W/m <sup>2</sup>	Building Area Type	LPD W/m <sup>2</sup>
Automotive Facility	9.7	Museum	11.8
Convention Center	12.9	Office	10.8
Dining : Bar Lounge/Leisure	14.0	Parking Garage	3.2
Dinning: Cafeteria/Fast Food	15.1	Performing Arts Theater	17.2
Dinning : Family	17.2	Police/Fire Station	10.8
Dormitory./Hostel	10.8	Post Office/Town Hall/	11.8
Gymnasium	11.8	Religious Building	14.0
Health care – clinic	10.8	Retail/Mall	16.1
Hospital/Health Care	12.9	School/University	12.9
Hotel	10.8	Sports Arena	11.8
Library	14.0	Transportation	10.8
Manufacturing Facility	14.0	Warehouse	8.6
Motel	10.8	Workshop	15.1
Motion Picture Theater	12.9		

\* In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

Determination of interior lighting power allowance (watts) by the building area method shall be in accordance with the following:

- (a) Determine the allowed lighting power density from Table 7.1 for each appropriate building area type;
- (b) Calculate the gross lighted floor area for each building area type; and
- (c) The interior lighting power allowance is the sum of the products of the gross lighted floor area of each building area times the allowed lighting power density for that building area types.

In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

### 7.3.3 Space Function Method

Determination of interior lighting power allowance (watts) by the space function method shall be in accordance with the following:

Table 7.2: Interior Lighting Power Space Function Method

Space Function	LPD W/m <sup>2</sup>	Space Function	LPD W/m <sup>2</sup>
Office – Enclosed	11.8	· For Reading Area	12.9
Office –Open plan	11.8	· For Stacks	18.3
Conference, meeting, multipurpose	14	Hospital	
Classroom, lecture, training	15.1	· For Emergency	29.1
Lobby *	14	· For Recovery	8.6
· For Hotel	11.8	· For Nurse Station	10.8
· For Performing Arts Theater	35.5	· For Exam Treatment	16.1
· For Motion Picture Theater	11.8	· For Pharmacy	12.9
Audience/Seating Area *	9.7	· For Patient Room	7.5
· For Gymnasium	4.3	· For Operating Room	23.7
· For Convention Center	7.5	· For Nursery	6.5
· For Religious Building	18.3	· For Medical Supply	15.1
· For Sports Arena	4.3	· For Physical Therapy	9.7
· For Performing Arts Theater	28	· For Radiology	4.3
· For Motion Picture Theater	12.9	· For Laundry- Washing	6.5
· For Transportation	5.4	Automotive – Service Repair	7.5
Atrium –First Three Floors	6.5	Manufacturing Facility	
Atrium- each additional floor	2.2	· For Low Bay(<8m ceiling)	12.9
Lounge/Recreation*	12.9	· For High Bay(>8m ceiling)	18.3
· For Hospital	8.6	· For Detailed Manufacturing	22.6
Dining Area*	9.7	· For Equipment Room	12.9
· For HOTEL	14	· For Control Room	5.4
· For Motel	12.9	Hotel/Motel Guest Rooms	11.8
· For Bar Lounge/Leisure Dining	15.1	Museum	
· For Family Dining	22.6	For General Exhibition	10.8
· Food Preparation	12.9	For Restoration	18.3
Laboratory	15.1	Bank Office- Banking Activity Area	16.1
Restrooms	9.7	Retail	
Dressing/Locker/Fitting Room	6.5	· For Sales Area	18.3
Corridor/Transition*	5.4	· For Mall Concourse	18.3
· For Hospital	10.8	· Sports area	
· For Manufacturing Facility	5.4	· For Ring Sports Area	29.1
Stairs-Active	6.5	· For Court Sports Area	24.8
Active Storage*	8.6	· For Indoor Field Area	15.1
· For Hospital	9.7	· Warehouse	
Inactive Storage	3.2	For Fine Materials Storage	15.1
· For Museum	8.6	· For Medium/Bulky Materials Storage	9.7
Electrical/Mechanical Facility	16.1	· Parking Garage-Garage Area	2.2
Workshop	20.5	Transportation	
Convention Center- Exhibit Space	14	For Airport- Concourse	6.5
Library		For Air/Train/Bus Baggage Area	10.8
For Card File and Cataloging	11.8	For Ticket Counter Terminal	16.1

\* All facilities except the following.

- Determine the appropriate building type from Table 7.2 and the allowed lighting power density;
- For each space enclosed by partitions 80% or greater than ceiling height, determine the gross interior floor area by measuring to the center of the partition wall. Include the floor area of balconies or other projections. Retail spaces do not have to comply with the 80% partition height requirements; and
- The interior lighting power allowance is the sum of the lighting power allowances for all spaces. The lighting power allowance for a space is the product of the gross lighted floor area of the space times

the allowed lighting power density for that space.

### 7.3.4 Installed Interior Lighting Power

The installed interior lighting power calculated for compliance with section 7.3 shall include all power used by the luminaires, including lamps, ballasts, current regulators, and control devices except as specifically exempted in section 7.1:

Exception to section 7.3.4: If two or more independently operating lighting systems in a space are controlled to prevent simultaneous user operation, the installed interior lighting power shall be based solely on the lighting system with the highest power.

#### 7.3.4.1 Luminaire Wattage

Luminaire wattage incorporated into the installed interior lighting power shall be determined in accordance with the following,-

- (a) The wattage of incandescent luminaires with medium base sockets and not containing permanently installed ballasts shall be the maximum labeled wattage of the luminaires;
- (b) The wattage of luminaires containing permanently installed ballasts shall be the operating input wattage of the specified lamp/ ballast combination based on values from manufacturers catalogs or values from independent testing laboratory reports;
- (c) The wattage of all other miscellaneous luminaire types not described in (a) or (b) shall be the specified wattage of the luminaires; and
- (d) The wattage of lighting track, plug-in bus way, and flexible lighting systems that allow the addition and/ or relocation of luminaires without altering the wiring of the system shall be the larger of the specified wattage of the luminaires included in the system or 135 W/m. Systems with integral overload protection such as fuses or circuit breakers shall be rated at 100% of the maximum rated load of the limiting device.

### 7.3.5 Exterior Lighting Power

For building exterior lighting applications specified in Table 7.3 the connected lighting power shall not exceed the specified lighting power limits specified for each of these applications. Trade- off between applications is not permitted. Exterior lighting for all other applications (except those included in the Exception to section 7.3.5) shall comply with the requirements of section 7.2.6.

Table 7.3: Exterior lighting power

Exterior Lighting Applications	Power Limits
Building entrance (with canopy )	8.1 W/m <sup>2</sup> of canopied area
Building entrance (without canopy )	90 W/lin m of door width
Building exit	60 W/lin m of door width
Building facades	1.1 W/m <sup>2</sup> of vertical illuminated façade area

Exception to section 7.3.5: Lighting used for the following exterior application is exempt when equipped with an independent control device,-

- (a) Specialized signal, directional, and marker lighting associated with transportation;
- (b) Lighting used to highlight features of public monuments and registered historic landmark structures or buildings; and
- (c) Lighting that is specifically designated as required by health or life safety statute, ordinance, or regulation.

## 7.4 Testing Standard

There is no test standard for this section.

# 8 Electrical Power

## 8.1 General

Electrical equipment and systems shall comply with the mandatory requirements of section 8.2. All electrical equipment and systems shall be tested as per the provisions given in section 8.4.

## 8.2 Mandatory Requirements

### 8.2.1 Transformers

#### 8.2.1.1 Maximum Allowable Distribution Transformer Losses

Distribution transformers of the proper ratings and design must be selected to satisfy the minimum acceptable efficiency at 50% and full load rating.

Total losses for oil filled transformers shall meet IS 1180. Total losses for dry transformers should conform as per the standard of Indian Standard IS 2026: Part 11 2007.

#### 8.2.1.2 Measurement and Reporting of Transformer Losses

All measurement of losses shall be carried out by using calibrated digital meters of class 0.5 or better accuracy and certified by the manufacturer. All transformers of capacity of 500 kVA and above would be equipped with additional metering class current transformers (CTs) and potential transformers (PTs) additional to requirements of utilities so that periodic loss monitoring study may be carried out.

### 8.2.2 Energy Efficient Motors

Motors shall comply with the following:

- (a) All permanently wired polyphase motors of 0.375 kW or more serving the building shall have a minimum acceptable nominal full load motor efficiency not less than IS 12615 for energy efficient motors;
- (b) Motor horsepower ratings shall not exceed 20% of the calculated maximum load being served;
- (c) Motor nameplates shall list the nominal full-load motor efficiencies and the full-load power factor;

### 8.2.3 Power Factor Correction

All electricity supplies exceeding 100 A, 3 phases shall maintain their power factor between 0.95 lag and unity at the point of connection.

### 8.2.4 Check- Metering and Monitoring

- (a) All services exceeding 1000 kVA shall have permanently installed metering to record demand (kVA), energy (kWh), and total power factor. The metering shall also display current (in each phase and the neutral), voltage (between phases and between each phase and neutral), and Total Harmonic Distortion (THD) as a percentage of total current.
- (b) All services not exceeding 1000 kVA but over 65 KVA shall have permanently installed electric metering to record demand (kVA), energy (kWh), and total power Factor (or kVARh).
- (c) All services not exceeding 65 kVA shall have permanently installed electrical metering to record energy (kWh).
- (d) Measurement devices shall be installed in new buildings to monitor the electrical energy use for each of the following separately:
  - Total electrical energy
  - HVAC systems
  - Interior lighting

- Exterior lighting
- Receptacle circuits

Recording and Reporting. The electrical energy usage for all loads specified in this section shall be recorded a minimum of every 15 minutes and reported at least hourly, daily, monthly, and annually. The data for each tenant space shall be made available to that tenant. The system shall be capable of maintaining all data collected for a minimum of 36 months.

## 8.2.5 Power Distribution Systems in Buildings

### 8.2.5.1 Power Distribution System Losses

The Power cabling shall be adequately sized as to maintain the building power distribution losses not to exceed 1% of the total power usage. Record of design calculation for the losses shall be maintained.

## 8.2.6 Automatic Receptacle Control

The following shall be automatically controlled:

- At least 50% of all 220 volt 5 and 10 amp receptacles in all private offices, conference rooms, rooms used primarily for printing and/or copying functions, break rooms, classrooms, and individual work-stations
- At least 25% of branch circuit feeders installed for modular furniture not shown on the construction documents

This control shall function on any of the following:

- a scheduled basis using a time of day operated control device that turns receptacles off at specific programmed times an independent program schedule shall be provided for controlled areas of no more than 500  $m^2$  and not more than one floor (the occupant shall be able to manually override the control device for up to two hours),
- an occupant sensor that shall turn receptacles off within 20 minutes of all occupants leaving a space, or
- an automated signal from another control or alarm system that shall turn receptacles off within 20 minutes after determining that the area is unoccupied.

All controlled receptacles shall be permanently marked to visually differentiate them from uncontrolled receptacles and are to be uniformly distributed throughout the space.

Exceptions: Receptacles for the following shall not require an automatic control device:

- Receptacles specifically designated for equipment requiring continuous operation (24 hours/day, 365 days/year)
- Spaces where an automatic control would endanger the safety or security of the room or building occupant(s).

## 8.3 Prescriptive Requirement

There is no prescriptive requirements.

## 8.4 Testing Standard

Table 8.1 gives the testing standards.

Table 8.1: Testing Standard

Component	Standard
Dry Type Transformer	IS 2026 PART 11 2007
Oil Filled Transformer	IS 1180

## **Appendix A: Definitions, Abbreviations and Acronyms**

### **1.1 General:**

Certain terms, abbreviations and acronyms are defined in this section for the purposes of this code. These definitions are applicable to all sections of this code. Terms that are not defined shall have their ordinarily accepted meanings within the context in which they are used. Webster's Third New International Dictionary of the English Language, Unabridged, copyright 1986, shall be considered as providing ordinarily accepted meanings.

### **1.2 Definitions:**

**"Addition"**: an extension or increase in floor area or height of a building outside of the existing building envelope;

**"Alteration"**: any change, rearrangement, replacement, or addition to a building or its system and equipment; any modification in construction or building equipment;

**"Annual fuel utilization efficiency (AFUE)"**: an efficiency description of the ratio of annual output energy to annual input energy as developed in accordance with requirements of U.S. Department of Energy (DOE) 10 CFR Part 430;

**"Area"**: see roof and wall, conditioned floor, day lighted, façade, fenestration, lighted floor

**"Astronomical time switch"**: an automatic time switch that makes an adjustment for the length of the day as it varies over the year;

**"Authority having jurisdiction"**: the Authority responsible for enforcing this code;

**"Automatic"**: self-acting, operating by its own mechanism, when actuated by some non-manual influence, such as a change in current strength, pressure, temperature, or mechanical configuration;

**"Automatic control device"**: a device capable of automatically turning loads off and on without manual intervention;

**"Balancing, air system"**: adjusting airflow rates through air distribution system devices, such as fans and diffusers, by manually adjusting the position of dampers, splitters vanes, extractors, etc., or by using automatic control devices, such as constant air volume or variable air volume boxes;

**"Balancing, hydronic system"**: adjusting water flow rates through hydronic distribution system devices, such as pumps and coils, by manually adjusting the position valves, or by using automatic control devices, such as automatic flow control valves;

**"Ballast"**: a device used in conjunction with an electric-discharge lamp to cause the lamp to start and operate under proper circuit conditions of voltage, current, waveform, electrode heat, etc.

**"Boiler"**: a self-contained low-pressure appliance for supplying steam or hot water;

**"Boiler, packaged"**: a boiler that is shipped complete with heating equipment, mechanical draft equipment, and automatic controls; usually shipped in one or more sections. A packaged boiler includes factory-built boilers manufactured as a unit or system, disassembled for shipment, and reassembled at the site;

**"Building"**: a structure wholly or partially enclosed within exterior walls, or within exterior and party walls, and a roof, affording shelter to persons, animals, or property;

**"Building, existing"**: a building or portion thereof that was previously occupied or approved for occupancy by the authority having jurisdiction;

**"Building complex"**: a group of buildings in a contiguous area under single ownership;

**"Building entrance"**: any doorway, set of doors, turnstiles, or other form of portal that is ordinarily used to gain access to the building by its users and occupants.

**"Building envelope"**: the exterior plus the semi-exterior portions of a building. For the purposes of determining building envelope requirements, the classifications are defined as follows:

- a) **Building envelope exterior**: the elements of a building that separate conditioned spaces from the exterior.
- b) **Building envelope semi-exterior**: the elements of a building that separate conditioned space from unconditioned space or that encloses semi-heated spaces through which thermal energy may be transferred to or from the exterior, or to or from unconditioned spaces, or to or from conditioned spaces;

**"Building exit"**: any doorway, set of doors, or other form of portal that is ordinarily used only for emergency egress or convenience exit;

**"Building grounds lighting"**: lighting provided through a building's electrical service for parking lot, site, roadway, pedestrian pathway, loading dock, and security applications;

**"Building material"**: any element of the building envelope through which heat flows and that heat is included in the component U -factor calculations other than air films and insulation;

**"Circuit breaker"**: a device designed to open and close a circuit by non automatic means and to open the circuit automatically at a predetermined over current without damage to itself when properly applied within its rating;

**"Class of construction"**:, for the building envelope, a subcategory of roof, wall, floor slab-on-grade floor, opaque door, vertical fenestration, or skylight;

**"Coefficient of performance (COP)-cooling"** the ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete refrigerating system or some specific portion of that system under designated operating conditions;

**"Coefficient of performance (COP)-heating"**: the ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete heat pump system including the compressor and, if applicable, auxiliary heat, under designated operating conditions;

**"Commercial building"**: all buildings except for multi-family buildings of three stories or fewer above grade and single-family buildings;

**"Construction documents"**: the drawings and specifications used to construct a building, building system, or portions thereof;

**"Control"**:to regulate the operation of equipment;

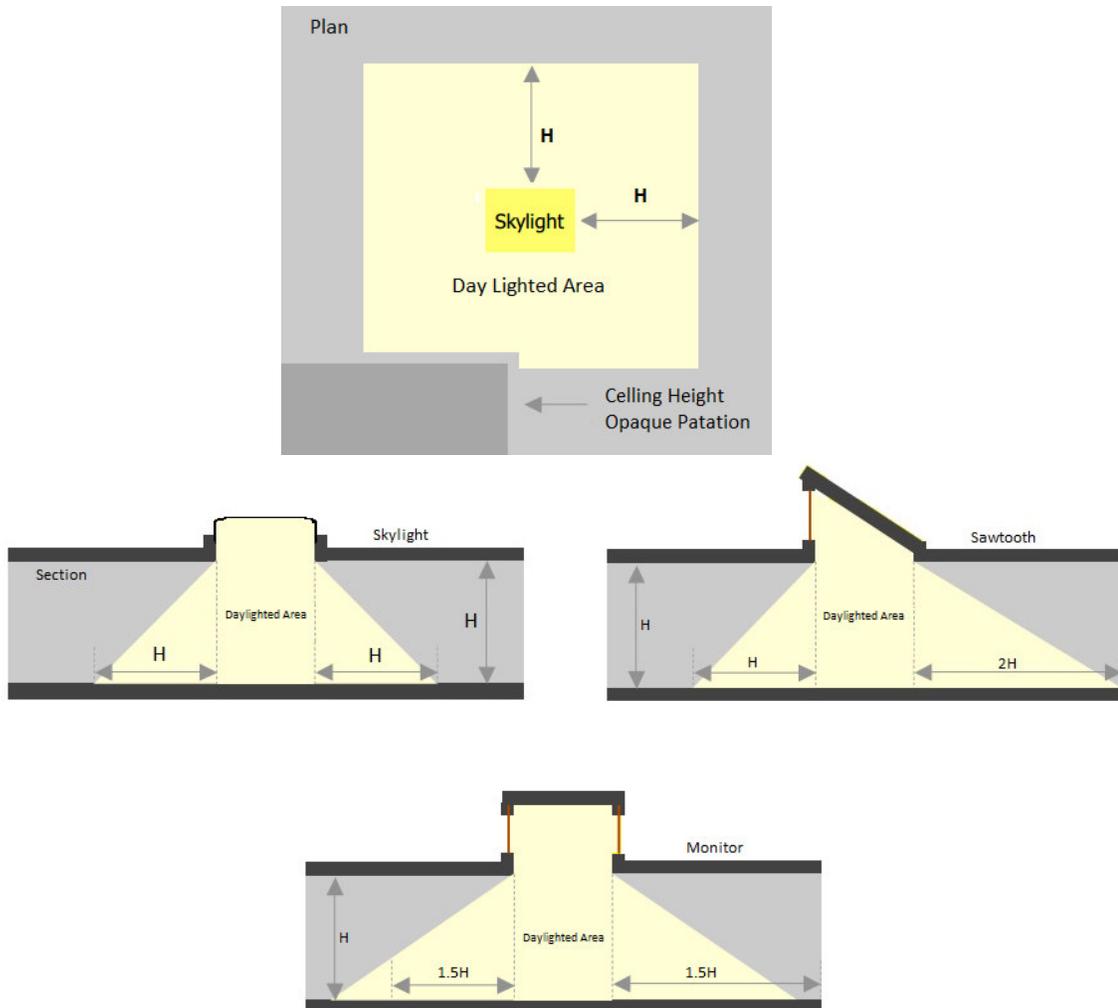
**"Control device"**: a specialized device used to regulate the operation of equipment;

**"Cool roof"**: a property of a surface that describes its ability to reflect and reject heat. Cool roof surfaces have both a light colour (high solar reflectance) and a high emittance (can reject heat back to the environment);

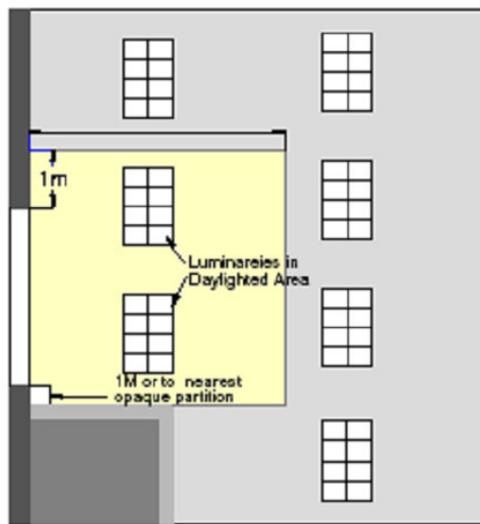
**"Daylighted area"**: the daylight illuminated floor area under horizontal fenestration (skylight) or adjacent to vertical fenestration (window), described as follows:

- a. **Horizontal fenestration**: the area under a skylight, monitor, or sawtooth configuration with an effective aperture greater than 0.001 (0.1% ). The

daylighted area is calculated as the horizontal dimension in each direction equal to the top aperture dimension in that direction plus either the floor-to-ceiling height ( $H$ ) for skylights, or  $1.5 H$  for monitors, or  $H$  or  $2 H$  for the saw tooth configuration, or the distance to the nearest 1000mm (42 in) or higher opaque partition, or one-half the distance to an adjacent skylight or vertical glazing, whichever is least, as shown in the plan and section figures below:



- b. **Vertical Fenestration:** the floor area adjacent to side apertures (vertical fenestration in walls) with an effective aperture greater than 0.06 (6%). The daylighted area extends into the space perpendicular to the side aperture a distance either two times the head height of the side aperture or to the nearest 1.35 m (54 in) or higher opaque partition, whichever is less. In the direction parallel to the window, the daylighted area extends a horizontal dimension equal to the width of the window plus either 1m (3.3 ft) on each side of the aperture, the distance to an opaque partition, or one-half the distance to an adjacent skylight or window, whichever is least.



**"Dead band"**: the range of values within which a sensed variable can vary without initiating a change in the controlled process;

**"Demand"**: the highest amount of power (average Btu/h over an interval) recorded for a building or facility in a selected time frame.

**"Design capacity"**: output capacity of a system or piece of equipment at design conditions;

**"Design conditions"**: specified environmental conditions, such as temperature and light intensity, required to be produced and maintained by a system and under which the system must operate;

**"Distribution system"**: a device or group of devices or other means by which the conductors of a circuit can be disconnected from their source of supply;

**"Door"**: all operable opening areas ( which are not fenestration) in the building envelope, including swinging and roll -up doors, fire doors and access hatches. Doors that are more than one-half glass are considered fenestration. For the purposes of determining building envelope requirements, the classifications are defined as follows:

- a. **Door, non-swinging**: roll-up sliding, and all other doors that are not swinging doors.
- b. **Door, swinging**: all operable opaque panels with hinges on one side and opaque revolving doors;

**"Door area"**: total area of the door measured using the rough opening and including the door slab and the frame;

**"Dwelling unit"**: a single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking, and sanitation;

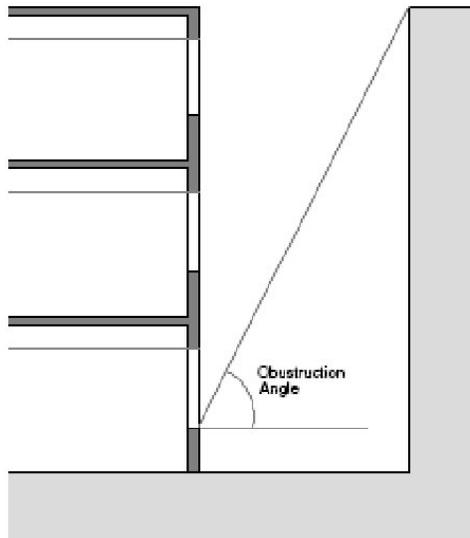
**"Economizer, air"**: a duct and damper arrangement and automatic control system that together allow a cooling system to supply outdoor air to reduce or eliminate the need for mechanical cooling during mild or cold weather.

**"Economizer, water"**: a system by which the supply air of a cooling system is cooled indirectly with water that is itself cooled by heat or mass transfer to the environment without the use of mechanical cooling;

**"Effective aperture"**: Visible Light Transmittance x Window-to-wall Ratio.  
( $EA = VLT \times WWR$ );

**"Effective aperture, horizontal fenestration"**: a measure of the amount of daylight that enters a space through horizontal fenestration (skylights). It is the ratio of the skylight area times the visible light transmission divided by the gross roof area above the day lighted area. See also day lighted area.

**"Effective aperture, vertical fenestration"**: a measure of the amount of daylight that enters a space through vertical fenestration. It is the ratio of the daylight window area times its visible light transmission plus half the vision glass area times its visible light transmission and the sum is divided by the gross wall area. Daylighted window area is located 2.2 m (7 ft) or more above the floor and vision window area is located above, 1 m (3 ft) but below 2.2 m (7 ft). The window area, for the purposes of determining effective aperture shall not include windows located in light wells when the angle of obstruction ( $\alpha$ ) of objects obscuring the sky dome is greater than  $70^\circ$ , measured from the horizontal, nor shall it include window area located below a height of 1 m (3 ft). See also day lighted area;



**"Efficacy"**: the lumens produced by a lamp/ballast system divided by the total watts of input power (including the ballast), expressed in lumens per watt;

**"Efficiency"**: performance at a specified rating condition;

**"Remittance"**: the ratio of the radiant heat flux emitted by a specimen to that emitted by a blackbody at the same temperature and under the same conditions;

**"Enclosed building"**: a building that is totally enclosed by walls, floors, roofs, and openable devices such as doors and operable windows;

**"Energy"**: the capacity for doing work. It takes a number of forms that may be transformed from one into another such as thermal (heat), mechanical (work), electrical, and chemical. Customary measurements are watts (W);

**"Energy Efficiency Ratio (EER)"**: the ratio of net cooling capacity in Btu/h to total rate of electric input in watts under designated operating conditions;

**"Energy Factor (EF)"**: a measure of water heater overall efficiency;

**"Envelope performance factor"**: the trade-off value for the building envelope performance compliance option calculated using the procedures specified in Appendix D clause 12. For the purposes of determining building envelope requirements the classifications are defined as follows:

- a. Base envelope performance factor: the building envelope performance factor for the base design,
- b. Proposed envelope performance factor: the building envelope performance factor for the proposed design;

**"Equipment"**: the devices for comfort conditioned, electric power, lighting, transportation, or service water heating including, but not limited to, furnaces, boilers, air conditioners, heat pumps, chillers, water heaters, lamps, luminaires, ballasts, elevators, escalators, or other devices or installations;

**"Equipment, existing"**: the equipment previously installed in an existing building;

**"Façade area"**: the area of the façade, including overhanging soffits, cornices, and protruding columns, measured in elevation in a vertical plane, parallel to the

plane of the face of the building. Non -horizontal roof surfaces shall be included in the calculations of vertical façade area by measuring the area in a plane parallel to the surface;

**"Fan system power"**: the sum of the nominal power demand (nameplate W or HP) of motors of all fans that are required to operate at design conditions to supply air from the heating or cooling source to the conditioned space(s) and return it to the source of exhaust it to the outdoors;

**"Fenestration"**: all areas (including the frames) in the building envelope that let in light, including windows, plastic panels, clerestories, skylights, glass doors that are more than one-half glass, and glass block walls.

- a. Skylight: a fenestration surface having a slope of less than 60 degrees from the horizontal plane. Other fenestration, even if mounted on the roof of a building, is considered vertical fenestration.
- b. Vertical fenestration: all fenestration other than skylights. Trombe wall assemblies, where glazing is installed within 300mm (12 in) of a mass wall, are considered walls, not fenestration;

**"Fenestration area"**: the total area of the fenestration measured using the rough opening and including the glazing, sash, and frame. For doors where the glazed vision area is less than 50% of the door area, the fenestration area is the glazed vision area. For all other doors, the fenestration area is the door area;

**"Floor area gross"**: the sum of the floor areas of the spaces within the building including basements, mezzanine and intermediate-floored tiers, and penthouses with headroom height of 2.5 m (7.5 ft) or greater. It is measured from the exterior faces of exterior walls or from the centerline of walls separating buildings, but excluding covered walkways, open roofed-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, chimneys, roof overhangs, and similar features:

- a. Gross building envelope floor area: the gross floor area of the building envelope, but excluding slab-on-grade floors.
- b. Gross conditioned floor area: the gross floor area of conditioned spaces.
- c. Gross lighted floor area: the gross floor area of lighted spaces.
- d. Gross semi-heated floor area: the gross floor area of semi-heated spaces;

**"Flue damper"**: a device in the flue outlet or in the inlet of or upstream of the draft control device of an individual, automatically operated, fossil fuel-fired appliance that is designed to automatically open the flue outlet during appliance operation and to automatically close the flue outlet when the appliance is in standby condition;

**"Fossil fuel"**: the fuel derived from a hydrocarbon deposit such as petroleum, coal, or natural gas derived from living matter of a previous geologic time;

**"Fuel"**: a material that may be used to produce heat or generate power by combustion;

**"Generally accepted engineer standard"**: the specification, rule, guide, or procedure in the field of engineer or related thereto, recognized and accepted as authoritative;

**"Grade"**: the finished ground level adjoining a building at all exterior walls;

**"Guest room"**: any room or rooms used or intended to be used by a guest for sleeping purposes;

**"Heat capacity"**: the amount of heat necessary to raise the temperature of a given mass by 1<sup>0</sup>C (1<sup>0</sup>F). Numerically, the heatcapacity per unit area of surface ( $W/m^2-^0C\{Btu /ft^2-^0F\}$ ) is the sum of the products of the mass per unit area of each individual material in the roof, wall, or floor surface multiplied by its individual specific heat;

**"Heating Seasonal Performance Factor (HSPF)":** the total heating output of a heat pump during its normal annual usage period for heating (in Btu) divided by the total electric energy input during the same period;

**"Historic":** a building or space that has been specifically designed as historically significant;

**"HVAC System":** the equipment, distribution systems, and terminals that provide, either collectively or individually, the processes of heating, ventilating, or air conditioned to a building or portion of a building;

**"Infiltration":** the uncontrolled inward air leakage through cracks and crevices in any building element and around windows and doors of a building caused by pressure differences across these elements due to factors such as wind, inside and outside temperature differences (stack effect), and imbalance between supply and exhaust air systems;

**"Installed interior lighting power":** the power in watts of all permanently installed general, task, and furniture lighting systems and luminaires;

**"Integrated part-load value (IPLV)":** a single number figure of merit based on part-load EER, COP, or kW/ton expressing part-load efficiency for air-conditioning and heat pump equipment on the basis of weighted operation at various load capacities for the equipment;

**"Kilovolt-ampere (kVA)":** the product of the line current (amperes) times the nominal system voltage (kilovolts) times 1.732 for three-phase currents. For single – phase applications, kVA is the product of the line current (amperes) times the nominal system voltage (kilovolts);

**"Kilowatt (kW)":** the basic unit of electric power, equal to 1000W;

**"Labeled":** the equipment or materials to which a symbol or other identifying mark has been attached by the manufacturer indicating compliance with specified standard or performance in a specified manner;

**"Lamp":** a generic term for man-made light source often called bulb or tube;

**"Lighted floor area, gross":** the gross floor area of lighted spaces;

**"Lighting, decorative":** the lighting that is purely ornamental and installed for aesthetic effect. Decorative lighting shall not include general lighting;

**"Lighting, emergency":** lighting that provides illumination only when there is a general lighting failure;

**"Lighting, general":** lighting that provides a substantially uniform level of illumination throughout an area. General lighting shall not include decorative lighting or lighting that provides a dissimilar level of illumination to serve a specialized application or feature within such area;

**"Lighting Efficacy (LE)":** the quotient of the total lumens emitted from a lamp or lamp/ballast combination divided by the watts of input power, expressed in lumens per watt;

**"Lighting system":** a group of luminaires circuited or controlled to perform a specific function;

**"Lighting power allowance":**

- a. Interior lighting power allowance: The maximum lighting power in watts allowed for the interior of a building.
- b. Exterior lighting power allowance: The maximum lighting power in watts allowed for the exterior of a building;

**"Lighting Power Density (LPD)":** the maximum lighting power per unit of area of a building classification of space function

**"Low-rise residential":** the single-family houses, multi-family structures of three stories or fewer above grade, manufactured houses (mobile homes), and manufactured houses (modular);

**"Luminaries"**: a complete lighting unit consisting of a lamp or lamps together with the housing designed to distribute the light, position and protect the lamps, and connect the lamps to the power supply;

**"Manual (non-automatic)"**: requiring personal intervention for control. Non-automatic does not necessarily imply a manual controller, only that personal intervention is necessary;

**"Manufacturer"**: the company engaged in the original production and assembly of products or equipment or a company that purchases such products and equipment manufactured in accordance with company specifications;

**"Mean temperature"**: one-half the sum of the minimum daily temperature and maximum daily temperature;

**"Mechanical cooling"**: reducing the temperature of a gas or liquid by using vapor compression, absorption and desiccant dehumidification combined with evaporative cooling, or another energy-driven thermodynamic cycle. Indirect or direct evaporative cooling alone is not considered mechanical cooling;

**"Metering"**: the instruments that measure electric voltage, current, power etc;

**"Multifamily high rise"**: multifamily structures of four or more stories above grade;

**"Multifamily low-rise"**: multifamily structures of three or less stories above grade;

**"Multiplication factor (M)"**: indicates the relative reduction in annual solar cooling load from overhangs and/or side fins with given projection factors, relative to the respective horizontal and vertical fenestration dimensions;

**"Non-automatic"**: *See Manual*

**"Occupant sensor"**: a device that detects the presence or absence of people within an area and causes lighting, equipment, or appliances to be regulated accordingly;

**"Opaque"**: all areas in the building envelope, except fenestration and building service openings such as vents and grills;

**"Orientation"**: the direction an envelope element faces and includes the direction of a vector perpendicular to and pointing away from the surface outside of the element. For vertical fenestration, the two categories are north-oriented and all other;

**"Outdoor (outside) air"**: air that is outside the building envelope or is taken from the outside the building that has not been previously circulated through the building;

**"Over current"**: any current in excess of the rated current of the equipment of the capacity of the conductor. It may result from overload, short circuit, or ground fault;

**"Packaged Terminal Air Conditioner (PTAC)"**: a factory-selected wall sleeve and separate unencased combination of heating and cooling components, assemblies, or sections. It may include heating capability by hot water, steam, or electricity, and is intended for mounting through the wall to service a single room or zone;

**"Party wall"**: a firewall on an interior lot line used or adapted for joint service between two buildings;

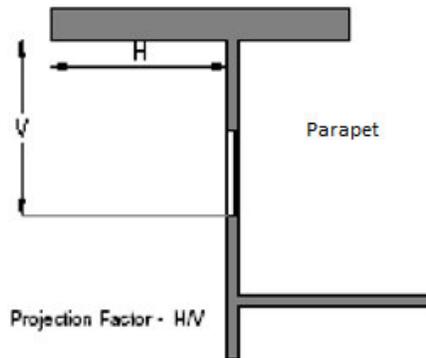
**"Permanently installed"**: the equipment that is fixed in place and is not portable or movable;

**"Plenum"**: a compartment or chamber to which one or more ducts are connected, that forms a part of the air distribution system and that is not used for occupancy or storage. A plenum often is formed in part or in total by portions for the building;

**"Pool"**: any structure, basin, or tank containing an artificial body of water for swimming, diving, or recreational bathing. The terms include, but not limited to, swimming pool, whirlpool, spa, hot tub;

**"Process load"**: the load on a building resulting from the consumption or release of process energy;

**"Projection factor, overhang"**: the ratio of the horizontal depth of the external shading projection divided by the sum of the height of the fenestration and the distance from the top of the fenestration to the bottom of the farthest point of the external shading projection, in consistent units;



**"Projection factor, side fin"**: the ratio of the horizontal depth of the external shading projection divided by the distance from the window jamb to the farthest point of the external shading projection, in consistent units;

**"R-value (thermal resistance)"**: the reciprocal of the time rate of heat flow through a unit area induced by a unit temperature difference between two defined surfaces of material or construction under steady-state conditions. Units of R are  $\text{m}^2\text{-}^\circ\text{C}/\text{W}$  ( $\text{h}\text{-ft}^2\text{-}^\circ\text{F}/\text{Btu}$ ). For the prescriptive building envelope option, R-value is for the insulation alone and does not include building materials or air films;

**"Readily accessible"**: capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc. In public facilities, accessibility may be limited to certified personnel through locking covers or by placing equipment in locked rooms;

**"Recirculating system"**: a domestic or service hot water distribution system that includes a close circulation circuit designed to maintain usage temperatures in hot water pipes near terminal devices (e.g., lavatory faucets, shower heads) in order to reduce the time required to obtain hot water when the terminal device valve is opened. The motive force for circulation is either natural (due to water density variations with temperature) or mechanical (recirculation pump);

**"Reflectance"**: the ratio of the light reflected by a surface to the light incident upon it;

**"Resistance, electric"**: the property of an electric circuit or of any object used as part of an electric circuit that determines for a given circuit the rate at which electric energy is converted into heat or radiant energy and that has a value such that the product of the resistance and the square of the current gives the rate of conversion of energy;

**"Reset"**: automatic adjustment of the controller set point to higher or lower value;

**"Residential"**: spaces in buildings used primarily for living and sleeping. Residential spaces include, but are not limited to, dwelling units, hotel/ motel guest rooms, dormitories, nursing homes, patient rooms in hospitals, lodging houses, fraternity/ sorority houses, hostels, prisons, and fire stations;

**"Roof"**: the upper portion of the building envelope, including opaque areas and fenestration, that is horizontal or tilted at an angle of less than 60° from horizontal;

**"Roof area, gross"**: the area of the roof measured from the exterior faces of walls or from the centerline of party walls;

**"Service"**: the equipment for delivering energy from the supply or distribution system to the premises served;

**"Service water heating"**: heating water for domestic or commercial purposes other than space heating and process requirements;

**"Set point"**: the point at which the desired temperature (°F) of the heated or cooled space is set;

**"Shading Coefficient (SC)"**: the ratio of solar heat gain at normal incidence through glazing to that occurring through 3 mm (1/8 in) thick clear, double – strength glass. Shading coefficient, as used herein, does not include interior, exterior, or integral shading devices;

**"Simulation program"**: a computer program that is capable of simulating the energy performance of building systems;

**"Single-zone system"**: HVAC system serving a single HVAC zone;

**"Site -recovered energy"**: waste energy recovered at the building site that is used to offset consumption of purchased fuel or electrical energy supplies;

**"Skylight roof ratio (SRR)"**: the ratio of the total skylight area of the roof, measured to the out side of the frame, to the gross exterior roof;

**"Slab-on-grade floor"**: the portion of a slab floor, of the building envelope that is in contact with ground and that is either above grade or is less than or equal to 24 in below the final elevation of the nearest exterior grade;

**"Solar energy source"**: source of thermal, chemical, or electrical energy derived from direction conversion of incident solar radiation at the building site;

**"Solar Heat Gain Coefficient (SHGC)"**: the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted or convected into the space;

**"Space"**: an enclosed space within a building. The classifications of spaces are as follows for the purpose of determining building envelope requirements:

- a. Conditioned space: a cooled space, heated space, or directly conditioned space.
- b. Semi- heated space: an enclosed space within a building that is heated by a heating system whose output capacity is greater or equal to 10.7 W/m<sup>2</sup> (3.4 Btu / h-ft<sup>2</sup>) of floor area but is not a conditioned space.
- c. An enclosed space within a building that is not conditioned space or a semi-heated space. Crawlspace, attics, and parking garages with natural or mechanical ventilation are not considered enclosed spaces;

**"Standard Design"**: a computer representation of a hypothetical design based on the actual proposed design as per appendix B. Whole Building Performance Method.

**"Storey"**: a portion of a building that is between one finished floor level and the next higher finished floor level or the roof, provided, however, that a basement or cellar shall not be considered a story;

**"System"**: a combination of equipment and auxiliary devices (e.g., controls, accessories, interconnecting means, and terminal elements) by which energy is transformed so it performs a specific function such as HVAC, service water heating, or lighting;

**"System, existing"**: a system or systems previously installed in an existing building;

**"Terminal"**: a device by which energy from a system is finally delivered, e.g., registers, diffusers, lighting fixtures, faucets, etc;

**"Thermal block"**: a collection of one or more HVAC zones grouped together for simulation purposes. Spaces need not be contiguous to be combined within a single thermal block;

**"Thermostat"**: an automatic control device used to maintain temperature at a fixed or adjustable set point;

**"Tinted"**:(as applied to fenestration) bronze, green, or grey coloring that is integral with the glazing material. Tinting does not include surface applied films such as reflective coatings, applied either in the field or during the manufacturing process;

**"Transformer"**: a piece of electrical equipment used to convert electric power from one voltage to another voltage;

**"U-factor (Thermal Transmittance)"**: heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side. Units of U are  $W/m^2 \cdot ^\circ C$  (Btu/h ft<sup>2</sup>°F);

**"Variable Air Volume (VAV) system"**: HVAC system that controls the dry bulb temperature within a space by varying the volumetric flow of heated or cooled supply air to the space;

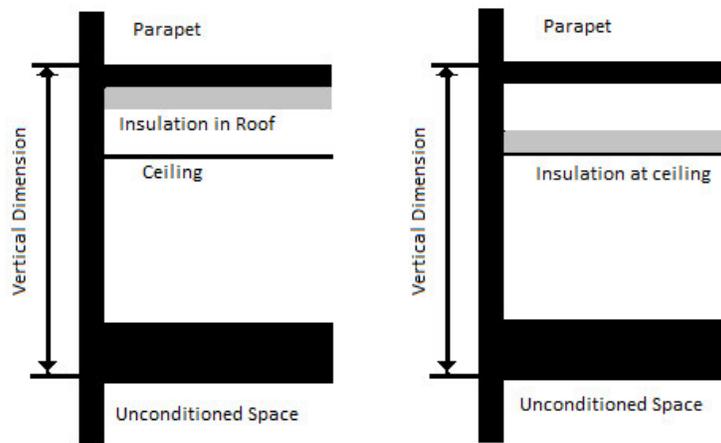
**"Vent damper"**: a device intended for installation in the venting system or an individual, automatically operated, fossil fuel- fired appliance in the outlet or downstream of the appliance draft control device, which is designed to automatically open the venting system when the appliance is in operation and to automatically close off the venting system when the appliance is in standby or shutdown condition;

**"Ventilation"**: the process of supplying or removing air by natural or mechanical means to or from any space. Such air is not required to have been conditioned;

**"Wall"**: the portion of the building envelope, including, opaque area and fenestration, that is vertical or tilted at an angle of 60<sup>0</sup>from horizontal or greater. This includes above and below grade walls, between floor spandrels, peripheral edges of floors, and foundation walls,

- a. **Wall, above grade**: a wall that is not below grade.
- b. **Wall, below grade**: that portion of a wall in the building envelope that is entirely below the finish grade and in contact with the ground;

**"Wall area, gross"**: the overall area of a wall including openings such as windows and doors measured horizontally from outside surface to outside surface and measured vertically from the top of the floor to the top of the roof. If roof insulation is installed at the ceiling level rather than the roof, then the vertical measurement is made to the top of the ceiling (Note that clause 4.3.1 does not allow roof insulation to be located on a suspended ceiling with removable ceiling panels). The gross wall area includes the area between the ceiling and the floor for multi-story buildings;



**"Water heater"**: vessel in which water is heated and is withdrawn for use external to the system;

**"Window Wall Ratio (WWR)"**: is the ratio of vertical fenestration area to gross exterior wall area. Gross exterior wall area is measured horizontally from the exterior surface; it is measured vertically from the top of the floor to the bottom of the roof;

**"Zone, HVAC"**: a space or group of space within a building with heating and cooling requirements that are sufficiently similar so that desired conditions (e.g. temperature) can be maintained throughout using a single sensor (e.g., thermostat or temperature sensor).

### 1.3 Abbreviations and Acronyms

AFUE	: Annual fuel utilization efficiency
ANSI	: American National Standards Institute
ARI	: Air-Conditioning and Refrigeration Institute
ASHRAE	: American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	: American Society for Testing and Materials
BIS	: Bureau of Indian Standards
Btu	: British thermal unit
Btu/h	: British thermal unit per hour
Btu/ft <sup>2</sup> ·°F	: British thermal unit per square foot degree Fahrenheit
Btu/h·ft <sup>2</sup>	: British thermal unit per hour square foot
Btu/h·ft <sup>0</sup> F	: British thermal unit per hour per linear foot per degree Fahrenheit
Btu/h·ft <sup>2</sup> ·°F	: British thermal units per hour square foot per degree Fahrenheit
C	: Celsius
cfm	: Cubic feet per minute
cm	: Centimeter
COP	: Coefficient of Performance
DOE	: U.S Department of Energy
EER	: Energy Efficiency Ratio
EC Act 2001	: Energy Conservation Act 2001
EF	: Energy Factor
F	: Fahrenheit
Ft	: foot
h	: hour
HC	: Heat Capacity
h·ft <sup>2</sup> ·°F/Btu	: Hour per square foot per degree Fahrenheit per British thermal unit
h·m <sup>2</sup> ·°C/W	: Hour per square meter per degree Celsius per Watt
hp	: Horsepower
HSPF	: Heating seasonal performance factor
HVAC	: Heating ,ventilation ,and Air Conditioning

I-P	: Inch Pound
in.	: inch
IPLV	: Integrated Part- Load Value
ISHRAE	: Indian Society of Heating Refrigeration & Air Conditioning Engineers
kVA	: kilovolt -ampere
kW	: kilowatt
kWh	: kilowatt- hour
LE	: Lighting efficacy
lin	: Linear
linft	: Linear foot
lin m	: Linear meter
lm	: lumen
LPD	: Lighting Power Density
m	: Meter
mm	: Millimeter
NAECA	: National Appliance Energy Conversation Act
PF	: Projection Factor
PTAC	: Packaged terminal air conditioner
R	: R-value (thermal resistance)
SC	: Shading Coefficient
SHGC	: Solar Heat Gain Coefficient
SL	: Standby Loss
VAV	: Variable air volume
VLT	: Visible light transmission
W	: Watt
W/ft <sup>2</sup>	: Watts per square feet
W/ m <sup>2</sup>	: Watts per square meter
W/m- <sup>0</sup> C	: Watts per lineal meter per degree Celsius
W/ m <sup>2</sup> - <sup>0</sup> C	: Watts per square meter per degree Celsius
Wh	: Watt hour

# Appendix B Whole Building Performance Method

## B.1 General

### B.1.1 Scope

The whole building performance method is an alternative to the prescriptive requirements contained in section 1 through section 8 of this code. It applies for all building types covered by the code.

### B.1.2 Compliance

A building complies with the whole building performance method when the estimated annual energy use cost of the proposed design is less than the standard design, even though it may not comply with the specific requirements of the prescriptive requirements in section 1 through section 8. The mandatory requirements of section 1 through section 8 shall be satisfied with the whole building performance method.

### B.1.3 Trade-offs Limited to Building Permit

The whole building performance method may be used for building permit applications that include less than the whole building; however, any design parameters that are not part of the building permit application shall be identical for both the proposed design and the standard design. Future improvements to the building shall comply with both the mandatory and prescriptive requirements.

### B.1.4 Documentation Requirements

Compliance shall be documented and submitted to the authority having jurisdiction. The information submitted shall include the following:

- (a) The annual energy use and cost for the proposed design and the standard design.
- (b) A list of the energy related building features in the proposed design that is different from the standard design.
- (c) The input and output report (s) from the simulation program including a breakdown of energy usage by at least the following components : lights, internal equipment loads, service water heating equipment, space heating equipment, space cooling and heat rejection equipment, fans and other HVAC equipment (such as pumps). The output reports shall also show the amount of time any loads are not met by the HVAC system for both the proposed design and standard design.
- (d) Explanation of any error messages noted in the simulation program output.

## B.2 Simulation General Requirements

### B.2.1 Energy Simulation Program

The simulation program shall be a computer based program for the analysis of energy consumption in buildings and be approved by the authority having jurisdiction. The simulation program shall be as under:-

- (a) Energy flows on an hourly basis for all 8,760 hours in the year;
- (b) Hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat set points, and HVAC system operation, defined separately for each day of the week and holidays;
- (c) Thermal mass effects;
- (d) Ten or more thermal zones;
- (e) Part-load and temperature dependent performance of heating and cooling equipment;
- (f) Airside and water-side economizers with integrated control; and
- (g) All of the standard design characteristics specified in this chapter.

## B.2.2 Climatic Data

The simulation program shall use hourly values of climatic data, such as temperature and humidity from representative climatic data, for the city in which the proposed design is to be located. For cities or urban regions with several climatic data entries, and for locations where weather data are not available, the designer shall select available weather data that best represent the climate at the construction site.

## B.2.3 Compliance Calculations

The proposed design and standard design shall be calculated using the following:

- (a) Same simulation program,
- (b) Same weather data, and
- (c) Same building operation assumptions (thermostat setpoints, schedules, internal gains, occupant loads, etc).

## B.3 Calculation of Proposed Design and the Standard Design Performance

### B.3.1 Energy Simulation model

The simulation model for calculating the proposed design and the standard design shall be developed in accordance with the requirements in Table B.4.

### B.3.2 HVAC Systems

The HVAC system type and related performance parameters for the standard design shall be determined as per table B.5 and the following rules:-

- (a) Other Components: Components and parameters not listed in Table B.5 or otherwise specifically addressed in this part shall be identical to those in the proposed design. (Exception to section B.3.2(a) where there are specific requirements in section 5.2.3, the component efficiency in the standard design shall be adjusted to the lowest efficiency level allowed by the requirement for that component type).
- (b) All HVAC and service water heating equipment in the standard design shall be modeled at the minimum efficiency levels, both part load and full load, in accordance with section 5.2.3.
- (c) Where efficiency ratings, such as EER and COP, include fan energy, the descriptor shall be broken down into its components so that supply fan energy can be modeled separately.
- (d) Minimum outdoor air ventilation rates shall be the same for both the standard design and the proposed design except when modeling demand control ventilation in proposed case
- (e) The equipment capacities (i.e. system coil capacities) for the standard building design shall be based on sizing runs for each orientation and shall be oversized by 15% for cooling and 25% for heating, i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the runs shall be 1.15 for cooling and 1.25 for heating.
- (f) Unmet load hours for the proposed design shall not differ from unmet load hours for the standard design by more than 50 hours. The maximum number of unmet hours shall not exceed 300 for either case.

### B.3.3 System Fan Power

System fan electrical power for supply, return, exhaust, and relief (excluding power to fan-powered VAV boxes) shall be calculated using the following formula:

$$P_{fan} = \text{input kW} / \text{fan motor efficiency}$$

Table B.1: Standard Case Fan Motor Power

Constant Volume	Variable Volume
$\text{kW}_i = L/s_S \times 0.0015 + A$	$\text{kW}_i = L/s_S \times 0.0021 + A$

<sup>a</sup> Where A is calculated using the pressure-drop adjustment from the proposed design and the design flow rate of the baseline building system

<sup>b</sup> Do not include pressure-drop adjustments for evaporative coolers or heat recovery devices

where

$P_{fan}$  = electric power to fan motor, W

input kW = input kilowatts of baseline fan motor from Table B.1

fan motor efficiency = the efficiency from Table B.2 for the next motor size greater than the input kW using a totally enclosed fan cooled motor at 1800 rpm

$L/s_S$  = maximum design supply airflow rate to conditioned spaces served by the system in litres per second

$\text{kW}_i$  = maximum combined fan input kilowatts

A = sum of  $(PD \times L/s_D/650000)$

where

PD = each applicable pressure drop adjustment in Pa

$L/s_D$  = the design airflow through each applicable device in litres per second

Table B.2: Performance Rating Method Motor Efficiency Requirements

Motor Kilowatts	Minimum Nominal Full-Load Efficiency, %
0.8	82.5
1.1	84.0
1.5	84.0
2.2	87.5
3.7	87.5
5.6	89.5
7.5	89.5
11.1	91.0
14.9	91.0
18.7	92.4
22.4	92.4
29.8	93.0
37.3	93.0
44.8	93.6
56.0	93.6
74.6	94.5
93.3	94.5
111.9	95.0
149.2	95.0

### B.3.4 Supply Air Temperature Reset

The air temperature for cooling shall be reset higher by 2.3°C under the minimum cooling load conditions.

### B.3.5 VAV Fan Part-Load Performance (Systems 2 and 3)

VAV system supply fans shall have variable-speed drives, and their part-load performance characteristics shall be modeled using either Method 1 or Method 2 specified in Table B.8.

### B.3.6 Type and Number of Chillers (Systems 2 and 3)

Electric chillers shall be used in the baseline building design regardless of the cooling energy source, e.g. direct fired absorption or absorption from purchased steam. The baseline building designs chiller plant shall be modeled with chillers having the number and type as indicated in Table B.3 as a function of building peak cooling load.

Table B.3: Type and number of Chillers

Building Peak Cooling Load	Number and Type of Chiller(s)
≤1055 kW	1 water cooled screw chiller
>1055 kW, <2110 kW	2 water cooled screw chillers sized equally
≥2110 kW	2 water cooled centrifugal chillers minimum with chillers added so that no chiller is larger than 2813 kW, all sized equally

### B.3.7 Chilled-Water Design Supply Temperature (Systems 2 and 3)

Chilled-water design supply temperature shall be modeled at 6.7°C and return water temperature at 13°C.

### B.3.8 Chilled Water Supply Temperature Reset

Chilled-water supply temperature shall be reset based on outdoor dry-bulb temperature using the following schedule: 7°C at 27°C and above, 12°C at 16°C and below, and ramped linearly between 7°C and 12°C at temperatures between 27°C and 16°C.

### B.3.9 Heat Rejection

The heat rejection device shall be an axial fan open circuit cooling tower with variable speed fan control and shall have the performance of ≥ 3.40 L/s.kW at the following rating conditions

35.0 C entering water

29.4 C leaving water

23.9 C entering water

Condenser water design supply temperature shall be calculated using the cooling tower approach to the 0.4% evaporation design wetbulb temperature as generated by the formula below, with a design temperature rise of 5.6°C.

$$Approach_{5.6^{\circ}CRange} = 10.2 - 0.24 \times WB$$

where

WB is the 0.4% evaporation design wet-bulb temperature in °C; valid for wet bulbs from 12.8°C to 32.2°C.

The tower shall be controlled to maintain a 21°C leaving water temperature where weather permits, floating up to leaving water temperature at design conditions. The baseline building design condenser-water pump power shall be 310 kW/1000 L/s.

### B.3.10 Chilled water pump Power

The design pump power shall be less than or equal to 350 kW/1000 L/s. Chilled-water systems with a cooling capacity of 11,150 m<sup>2</sup> or more shall have primary/secondary systems with variable-speed drives on the secondary pumping loop. Chilled-water pumps in systems serving less than 11,150 m<sup>2</sup> cooling capacity shall have primary/secondary systems with secondary pump riding the pump curve.

Table B.4: Modelling Requirements for calculating proposed and standard

Proposed Building	Standard Design
Design Model	

Table B.4: Modelling Requirements for calculating proposed and standard

<b>Proposed Building</b>	<b>Standard Design</b>
<p>(a) The simulation model of the proposed design shall be consistent with the design documents, including proper accounting of fenestration and opaque envelope types and area; interior lighting power and controls; HVAC system types, sizes, and controls; and service water heating systems and controls.</p> <p>(b) When the whole building performance method is applied to buildings in which energy related features have not yet been designed (e.g., a lighting system), those yet to be designed features shall be described in the proposed design so that they minimally comply with applicable mandatory and prescriptive requirements from section 1 through section 8</p>	<p>The standard design shall be developed by modifying the proposed design as described in this table. Except as specifically instructed in this table, all building systems and equipment shall be modeled identically in the standard design and proposed design.</p>
<b>Space Use Classification</b>	
<p>The building type or space type classifications shall be chosen in accordance with section 7.3.2 or 7.3.3. More than one building type category may be used in a building if it is a mixed-use facility.</p>	<p>Same as proposed design</p>
<b>Schedules</b>	
<p>The schedules shall be typical of the proposed building type as determined by the designer and approved by the authority having jurisdiction.</p>	<p>Same as proposed design</p>
<b>Building Envelope</b>	

Table B.4: Modelling Requirements for calculating proposed and standard

<b>Proposed Building</b>	<b>Standard Design</b>
<p>All components of the building envelope in the proposed design shall be modeled as shown on architectural drawings or as installed for existing building envelopes.</p> <p>Exceptions: The following building elements are permitted to differ from architectural drawings.</p> <ul style="list-style-type: none"> <li>(a) Any envelope assembly that covers less than 5% of the total area of that assembly type e.g. exterior walls need not be separately described. If not separately described, the area of an envelope assembly must be added to the area of the adjacent assembly of that same type.</li> <li>(b) Exterior surfaces whose azimuth orientation and tilt differ by no more than 45 degrees and are otherwise the same may be described as either a single surface or by using multipliers.</li> <li>(c) For exterior roofs other than roofs with ventilated attics, the aged reflectivity shall be modeled. In case aged reflectivity is not available, reflectivity of 0.45 is to be modelled for high SRI paint.  For exterior walls, the aged reflectivity shall be modeled. In case aged reflectivity is not available, reflectivity of 0.45 is to be modelled for high SRI paint.</li> <li>(d) Manually operated fenestration shading devices such as blinds or shades shall not be modeled. Permanent shading devices such as fins, overhangs, and lightshelves shall be modeled.</li> </ul>	<p>The standard design shall have identical conditioned floor area and identical exterior dimensions and orientations as the proposed design except points noted below.</p> <ul style="list-style-type: none"> <li>(a) Orientation, The baseline building performance shall be generated by simulating the building with its actual orientation and again after rotating the entire building 90, 180, 270 degrees, then averaging the results. The building shall be modeled so that it does not shade itself.</li> <li>(b) Opaque assemblies roof and walls shall be modeled with assemblies provided in Table B.6 and B.7.</li> <li>(c) Fenestration – Fenestration areas shall equal that in the proposed design or 40% of gross above grade wall area, whichever is smaller, and shall be distributed on each face of the building in the same proportions in the proposed design. No shading projections are to be modeled; fenestration shall be assumed to be flush with the exterior wall or roof. Manually operated fenestration shading devices such as blinds or shades shall not be modeled. Fenestration U-factor shall be 2.84 W/sqm-K, and the solar heat gain coefficient shall 0.25.  Skylights: Skylight area shall be equal to that in the proposed building design or 3% of the gross roof area that is part of the building envelope, whichever is smaller. If the skylight area of the proposed building design is greater than 3% of the gross roof area, baseline skylight area shall be decreased by an identical percentage in all roof components in which skylights are located to reach the 3% skylight-to-roof ratio. Skylight orientation and tilt shall be the same as in the proposed building design. Skylight U-factor shall be 4.26 W/sqm-K and SHGC shall be 0.35.</li> <li>(d) Albedo. Roof and external wall shall be modeled with a reflectivity of 0.30.</li> </ul>
<b>Lighting</b>	

Table B.4: Modelling Requirements for calculating proposed and standard

<b>Proposed Building</b>	<b>Standard Design</b>
<p>Lighting power in the proposed design shall be determined as follows:</p> <ul style="list-style-type: none"> <li>(a) Where a complete lighting system exists, the actual lighting power shall be used in the model.</li> <li>(b) Where a lighting system has been designed lighting power shall be determined in accordance with either section 7.3.2 or 7.3.3.</li> <li>(c) Where no lighting exists or is specified, lighting power shall be determined in accordance with the section 7.3.2 for the appropriate building type.</li> <li>(d) Lighting system power shall include all lighting system components shown or provided for on plans (including lamps ballasts, task fixtures and furniture mounted fixtures).</li> </ul>	<p>Lighting power in the standard design shall be determined using the same categorization procedure (building area or space function) and categories as the proposed design with lighting power set equal to the maximum allowed for the corresponding method and category in either section 7.3.2 or section 7.3.3. Power for fixtures not included in the lighting power density calculation shall be modeled identically in the proposed design and standard design.</p>
<b>HVAC Systems</b>	
<p>The HVAC system type and all related performance parameters, such as equipment capacities and efficiencies, in the proposed design shall be determined as follows:</p> <ul style="list-style-type: none"> <li>(a) Where a complete HVAC System exists, the model shall reflect the actual system type using actual component capacities and efficiencies.</li> <li>(b) Where an HVAC System has been designed, the HVAC model shall be consistent with design documents. Mechanical equipment efficiencies shall be adjusted from actual design conditions to the standard rating conditions specified in section 5, if required by the simulation model,</li> <li>(c) Where no heating system exists or no heating system has been specified, the heating system shall be modeled as electric resistance. The system characteristics shall be identical to the system modeled in the standard design.</li> <li>(d) Where no cooling system exists or no cooling system has been specified, the cooling system shall be modeled as an air cooled single zone system, one unit per thermal block. The system characteristics shall be identical to the system modeled in the standard design.</li> </ul>	<p>The HVAC system type and related performance parameters for the standard design shall be determined from Table B.5 HVAC Systems Map. Equipment performance shall meet the requirements of section 5.2.3.</p>
<b>Service Hot-Water System</b>	

Table B.4: Modelling Requirements for calculating proposed and standard

<b>Proposed Building</b>	<b>Standard Design</b>
<p>The service hot water system type and all related performance parameters, such as equipment capacities and efficiencies, in the proposed design shall be determined as follows:</p> <ul style="list-style-type: none"> <li>(a) Where a complete service hot water system exists, the model shall reflect the actual system type using actual component capacities and efficiencies.</li> <li>(b) Where a service hot water system has been designed, the service hot water model shall be consistent with design documents.</li> <li>(c) Where no service hot water system exists or is specified, no service hot water heating shall be modeled.</li> </ul>	<p>The water heating shall be of the same type of the proposed design. For guest house facilities, hotels and hospitals the standard design shall have a solar system capable of meeting 20% of the design load. Systems shall meet the efficiency requirements of section 6.2.2 the pipe insulation requirements of section 5.2.8.1 and incorporate heat traps in accordance with section 6.2.5.</p>
<b>Receptacle and Other Loads</b>	
<p>Receptacle, motor and process loads shall be modeled and estimated based on the building type or space type category. These loads shall be included simulations of the building and shall be included when calculating the standard design and proposed design All end use load components within and associated with the building shall be modeled unless specifically excluded but not limited to, exhaust fans, parking garage ventilation fans, exterior building lighting swimming pool heaters and pumps elevators and escalators, refrigeration equipment and cooking equipment.</p>	<p>Receptacle motor and process loads shall be modeled the same as the proposed design. The water heating system shall be of the same type of the proposed design</p>
<b>Modeling Limitations to the Simulation Program</b>	
<p>If the simulation program cannot model a component or system included in the proposed design, one of the following methods shall be used with the approval of the authority having jurisdiction</p> <ul style="list-style-type: none"> <li>• Ignore the component if the energy impact on the trade offs, being considered is not significant.</li> <li>• Model the component substituting a thermodynamically similar component model.</li> <li>• Model the HVAC system components or systems using the standard design's HVAC system in accordance with section 6 of this table. Whichever method is selected, the component shall be modeled identically for both the proposed design and standard design models.</li> </ul>	<p>Same as proposed design.</p>
<b>Exterior Conditions</b>	
<p>Shading by Adjacent Structures All elements whose effective height is greater than their distance from a proposed building and whose width facing the proposed building is greater than one-third that of the proposed building shall be accounted for in the analysis.</p>	<p>Same as proposed building design</p>

Table B.5: HVAC Systems Map

	$\leq 3$ floors and $< 2,300 \text{ m}^2$	4 or 5 floors & $< 2,300 \text{ m}^2$ or $\leq 5$ floors & 2,300 to 14,000 $\text{m}^2$	$> 5$ floors or $> 14,000 \text{ m}^2$
Code	1	2	3
System type	Packaged rooftop air conditioner	Packaged rooftop VAV	VAV
Fan control	Constant volume	Variable volume air handler	Variable volume air handler
Cooling type	Direct expansion	Direct expansion	Chilled water*
Heating type	Electric resistance	Electric resistance	Electric resistance

\* Chiller Efficiency shall be as per Table 5.1.

Table B.6: External Wall Construction for Standard Design

SNO	Material	Thickness	Density	Specific heat	Conductivity	Resistance
		mm	$\text{kg}/\text{m}^3$	J/kg K	W/m K	$\text{m}^2 \text{ K}/\text{W}$
1	Plaster	18	1880	517	1.2	0.02
2	Brick	230	1660	164	0.589	0.39
3	Insulation	30	30	1247	0.0318	0.94
4	Plaster	18	1880	517	1.2	0.02

Table B.7: Roof Construction for Standard Design

SNO	Material	Thickness	Density	Specific heat	Conductivity	Resistance
		mm	$\text{kg}/\text{m}^3$	J/kg K	W/m K	$\text{m}^2 \text{ K}/\text{W}$
1	Plaster	18	1880	517	1.2	0.02
2	Insulation	75	30	1247	0.0318	2.37
3	RCC	150	2345	299	1.41	0.11
4	Plaster	18	1880	517	1.2	0.02

Table B.8: Part-Load performance for VAV fan systems

Method 1-Part Load Fan Power Data	
Fan Part Load Ratio	Fraction Full Load Power
0.00	0.00
0.10	0.03
0.20	0.07
0.30	0.13
0.40	0.21
0.50	0.30
0.60	0.41
0.70	0.54
0.80	0.68
0.90	0.83
1.00	1.00

Method 2—Part-Load Fan Power Equation

$$P_{fan} = 0.0013 + 0.1470 \times (PLR_{fan}) + 0.9506 \times (PLR_{fan})^2 - 0.0992 \times (PLR_{fan})^3$$

where

$P_{fan}$  = fraction of full-load fan power and  
 $PLR_{fan}$  = fan part-load ratio (current L/s/design L/s)

# Appendix C Default Values for Typical Constructions

## C.1 Procedure for Determining Fenestration Product U-Factor and Solar Heat Gain Coefficient

U-factors and solar heat gain coefficient (SHGC) be determined for the overall fenestration product (including the sash and frame) in accordance with ISO 15099.

In several cases, ISO 15099 suggests that individual national standards will need to be more specific and in other cases the ISO document gives users the choice of two options. This part clarifies these specific issues as they are to be implemented for this code:

1. clause 4.1 of ISO 15099: For calculating the overall U- factor , ISO 15099 offers a choice between the linear thermal transmittance (4.1.2) and the area weighted method ( 4.1.3). The area weighted method (4.1.3) shall be used.
2. clause 4.2.2 of ISO 15099: Frame and divider SHGC's shall be calculated in accordance with clause 4.2.2.
3. clause 6.4 of ISO 15099 refers the issue of material properties to national standards. Material conductivities and emissivities shall be determined in accordance with Indian standards.
4. clause 7 of ISO 15099 on shading systems is currently excluded.
5. clause 8.2 of ISO 15099 addresses environmental conditions. The following are defined for India:  
For U factor calculations:

$$T_{in} = 24^{\circ}C$$

$$T_{out} = 32^{\circ}C$$

$$V = 3.35m/s$$

$$T/m, out = T_{out}$$

$$T/m, in = T_{in}$$

$$I_s = 0W/m^2$$

For SHGC calculations:

$$T_{in} = 24^{\circ}C$$

$$T_{out} = 32^{\circ}C$$

$$V = 2.75m/s$$

$$T/m, out = T_{out}$$

$$T/m, in = T_{in}$$

$$I_s = 783W/m^2$$

6. clause 8.3 of ISO 15099 addresses convective film coefficients on the interior and exterior of the Window product in clause 8.3.1 of ISO 15099, simulations shall use the heat transfer coefficient based on the center of glass temperature and the entire window height ; this film coefficient shall be used on all indoor surfaces,, including frame sections. In clause 8.3.2 of ISO 15099, the formula from this section shall be applied to all outdoor exposed surfaces.
7. clause 8.4.2 of ISO 15099 presents two possible approaches for in corporating the impacts of self-viewing surfaces on interior radiative heat transfer calculations. Products shall use the method in clause 8.4.2.1 of ISO 15099 (Two-Dimensional Element to Element View Factor Based Radiation Heat Transfer Calculation). The alternate approach in clause 8.4.3 of ISO 15099 shall not be used.

**Default U-Factors and Solar Heat Gain Coefficients for Unrated Fenestration Products:**

All fenestration with U-factors, SHGC, or visible light transmittance determined, certified, and labeled in accordance ISO 15099 shall be assigned those values

**11.1.1 Unrated vertical fenestration:**

Unlabeled vertical fenestration, both operable and fixed shall be assigned the U factors, SHGC s, and visible light transmittances in Table 11.1.

**Table Error! No text of specified style in document.-1: Defaults for Unrated Vertical Fenestration**

(Overall Assembly including the Sash and Frame)

Frame type	Glazing Type	Clear Glass			Tinted Glass		
		U factor (W/m <sup>2</sup> -°C)	SHGC	VLT	U factor (W/m <sup>2</sup> -°C)	SHGC	VLT
All frame types	Single Glazing	7.1	0.82	0.76	7.1	0.70	0.58
Wood vinyl or fiber glass Frame	Double Glazing	3.3	0.59	0.64	3.4	0.42	0.39
Metal and Other frame type	Double Glazing	5.1	0.68	0.66	5.1	0.50	0.40

**Unrated Sloped Glazing and Skylights:**

Unrated sloped glazing and skylights, both operable and fixed shall be assigned the SHGCs and visible light transmittances in Table 11.1. To determine the default U-factor for unrated sloped glazing and skylights without a curb multiply the values in Table 11.1 by 1.2. To determine the default U factor for unrated skylights on a curb, multiply the values in Table 11.1 by 1.6.

**Typical Roof constructions:**

For calculating the overall U-factor of a typical roof construction, the U-factor from the typical wall construction type and effective U –factor for insulation shall be combined according to the following equation:

$$U_{Total\ Roof} = \frac{1}{\frac{1}{U_{Typical\ Roof}} + \frac{1}{U_{Typical\ Insulation}}}$$

Where

- U<sub>Total Roof</sub> Total U factor of the roof with insulation
- U<sub>Typical Roof</sub> U-factor of the roof

$U_{\text{Typical Insulation}}$

U-factor of the effective insulation from table 11.2

**Table Error! No text of specified style in document.-2: Defaults for Effective U-factor for Exterior Insulation Layers**

Thickness	R-Value	U-Factor(W/m <sup>2</sup> -°k)
15mm(0.5")	0.70 (4)	1.420
20 mm(0.75")	1.06 (6)	0.946
25 mm (1.0")	1.41 (8)	0.710
40 mm(1.5")	2.11 (12)	0.568
50 mm(2.0")	2.82 (16)	0.406
65 mm (2.5")	3.52 (20)	0.284
75 mm(3.0")	3.70 (21)	0.270

**Typical Wall Constructions:**

For calculating the overall U-factor of a typical wall construction, the U-factors from the typical wall construction type and effective U -factor for insulation shall be combined according to the following equation:

$$U_{\text{Total Wall}} = \frac{1}{\frac{1}{U_{\text{Typical Wall}}} + \frac{1}{U_{\text{Typical Insulation}}}}$$

Where

- $U_{\text{Total Wall}}$  Total U factor of the wall with insulation
- $U_{\text{Typical Wall}}$  U-factor of the wall
- $U_{\text{Typical Insulation}}$  U-factor of the effective insulation from table 11.3

**Table Error! No text of specified style in document.-3: Defaults for Effective U-factor for Exterior Insulation Layers**

Thickness	R-Value	U-Factor(W/m <sup>2</sup> -°k)
15mm(0.5")	0.70 (4)	1.262
20 mm(0.75")	1.06 (6)	0.874
25 mm (1.0")	1.41 (8)	0.668
40 mm(1.5")	2.11 (12)	0.454
50 mm(2.0")	2.82 (16)	0.344
65 mm (2.5")	3.52 (20)	0.277
75 mm(3.0")	3.70 (21)	0.264

**Table 4: Typical thermal Properties of Common building and insulating Materials - Design Values<sup>a</sup>**

(Source: ASHRAE Fundamentals Handbook, 2001)

Description	Density Kg/m <sup>3</sup>	Conductivity <sup>b</sup> (K), W/mK	Conductance (C), W/m <sup>2</sup> K	Resistance <sup>c</sup> (R)		Specific Heat, KJ/(KgK)
				Per Inch Thickness ( 1/k), Km <sup>2</sup> /W	For Thickness Listed (1/C <sub>R</sub> ), Km <sup>2</sup> /W	
<b>BUILDING BOARD</b>						
Asbestos- cement board.....	1900	0.58	--	1.73	--	1.00
Asbestos- cement board.....3.2mm	1900	--	187.4	--	0.05	--
Asbestos- cement board.....6.4mm	1900	--	93.7	--	0.011	--
Gypsum or plaster board.....9.5 mm	800	-	17.6	--	0.056	1.09
Gypsum or plaster board.....12.7 mm	800	--	12.6	--	0.079	--
Gypsum or plaster board.....15.9 mm	800	--	10.1	--	0.099	--
Plywood (Douglas Fir) <sup>d</sup> .....	540	0.12	--	8.66	--	1.21
Plywood or wood panels.....19.0mm	540	--	6.1	--	0.16	1.21
Vegetable fiber board						
Sheathing regular density <sup>e</sup> ... 12.7mm	290	--	4.3	--	0.23	1.30
..... 19.8 mm	290	--	2.8	--	0.36	--
Sheathing intermediate density ..... 12.7 mm	350	--	5.2	--	0.19	1.30
Nail base sheathing <sup>e</sup> ..... 12.7mm	400	--	5.3	--	0.19	1.30
Shingle backer ..... 9.5mm	290	--	6.0	--	0.17	1.30
Sound deadening board .....12.7mm	240	--	4.2	--	0.24	1.26
Tile and lay in panels, pain or acoustic..... 12.7 mm	290	0.058	--	17.	--	0.59
.....19.0 mm	290	--	4.5	--	0.22	--
.....	290	--	3.0	--	0.33	--
Laminated paper board .....	480	0.072	--	13.9	--	1.38
Homogeneous board from repulped paper.....	480	0.072	--	13.9	--	1.17
Hardboard <sup>e</sup>						
Medium density .....	800	0.105	--	9.50	--	1.30
High density. Service tempered grade.& service grade	880	0.82	--	8.46	--	1.34
High density, standard tempered Grade.....	1010	0.144	--	6.93	--	1.34
.....						
Particle board <sup>e</sup>			-			
Low density.....	590	0.102	--	9.77	--	1.30
Medium density .....	800	0.135	--	7.35	--	1.30
High density.....	1000	0.170	--	5.90	--	1.30
Underlayment .....15.9mm	640	--	6.9	--	0.14	1.21
Wafer board .....	590	0.01	-	11.0	--	--
Wood sub floor..... 19.0mm	--	--	6.0	--	0.17	1.38
<b>BUILDING MEMBRANE</b>						
Vapour- permeable felt .....	--	--	94.9	--	0.011	--

Vapour seal, 2 layers of mopped 0.73kg/m <sup>2</sup> felt.....	--	--	47.4	--	0.21	--
Vapour seal, plastic film .....	--	--	--	--	Negl.	--
<b>FINISH FLOORING MATERIALS</b>						
Carpet and fibrous pad.....	-	-	2.73	--	0.37	1.42
Carpet and rubber pad.....	--	--	4.60	--	0.22	1.38
Cork tile.....3.2mm	--	--	20.4	--	0.049	2.01
Terrazzo.....25mm	--	--	71.0	--	0.014	0.80
Tile – asphalt linoleum, vinyl, rubber .....	-	-	113.6	--	0.009	1.26
Vinyl asbestos.....	-	-	--	-	--	1.01
Ceramic .....	-	--	--	--	--	0.80
Wood, hardwood finish.....19mm	--	-	8.35	--	0.12	--
<b>INSULATING MATERIALS</b>						
Blanket and batt <sup>1,9</sup>						
Mineral fiber fibrous form processed From rock, slag, or glass						
Approx. 75-100mm.....	6.4-32	--	0.52	--	1.94	--
Approx. 90mm.....	6.4-32	--	0.44	--	2.29	--
Approx. 90mm.....	19-26	--	0.38	--	2.63	--
Approx. 140-165mm.....	6.4-32	--	0.30	--	3.32	--
Approx. 140mm.....	10-16	--	0.27	--	3.67	--
Approx. 150-190mm	6.4-32	-	0.26	-	3.91	--
Approx. 210-250mm.....	6.4-32	--	0.19	--	5.34	--
Approx. 250-330mm.....	6.4-32	--	0.15	--	6.77	--
Board and slabs						
cellular glass.....	136	0.050	--	19.8	--	0.75
Glass fiber, organic bonded.....	64-140	0.036	--	27.7	--	0.96
Expanded perlite organic bonded	16	0.052	--	19.3	--	1.26
Expanded rubber (rigid).....	72	0.032	--	31.6	--	1.68
Expanded polystyrene extruded (Smooth skin surface ) CFC -12 Exp).	29-56					
(Expanded polystyrene, extruded (smooth skin surface) (HCFC- 142b Exp.) <sup>h</sup> .....	29-56	0.029	--	34.7	--	1.21
Expanded polystyrene, molded beads.....	16	0.037	--	26.7	--	--
	20	0.036	--	27.7	--	--
	24	0.035	--	28.9	--	--
	28	0.035	--	28.9	--	--
	32	0.033	--	30.2	--	--
Cellular polyurethane/ polyisocyanurate <sup>i</sup>						
(CFC.11 Exp.) (unfaced ).....	24	0.023-0.026	--	43.3-38.5	--	1.59
Cellular polyisocyanurate (CFC-11 Exp.) (gas- permeable facers)...	24-40	0.023-0.026	--	43.3-38.5	--	0.92
Cellular polyisocyanurate (CFC 11 exp) (gas impermeable facers)....	32	0.020	--	48.8	--	0.92
Cellular phenolic (closed cell). (CFC- 11, CFC 113 exp.) <sup>k</sup>	32	0.017	--	56.8	--	--
Cellular Phenolic (open cell).....	29-35	0.033	--	30.5	--	--
Mineral fiber with resin binder.....	240	0.042	--	23.9	--	0.71
Mineral fiberboard wet felted						
Core or roof insulation	260-270	0.049	--	20.4	--	--
Acoustical tile <sup>l</sup> .....	290	0.050	--	19.8	--	0.80
Acoustical tile <sup>l</sup> .....	340	0.053	--	18.7	--	--
Mineral fiberboard wet molded						
Acoustical tile <sup>l</sup>	370	0.060	--	16.5	--	0.59

Wood or cane fiberboard	-	-	-	-	-	-
Acoustic tile <sup>1</sup> .....12.7mm	--	--	4.5	--	0.22	1.30
Acoustical tile <sup>1</sup> .....19.0mm	--	--	3.0	--	0.33	--
Interior finish ( plank tile)	240	0.050	--	19.8	--	1.34
Cement fiber slabs (shredder wood with Portland Cement binder).....	400-430	0-072-0-076	--	13.9-13.1	--	--
Cement fiber slabs ( shredded wood with magnesia Oxysulfide binder).....	350	0.082	--	12.1	--	1.30
<i>Loose fill</i>			-		-	
Cellulosic insulation (milled paper or wood pulp .).....	37-51	0.039-0.046	--	25.6-21.7	--	1.38
Perlite. expanded .....	32-66	0.039-0.045	--	25.6-22.9	-	1.09
	66-120	0.045-0.052	--	22.9-19.4	--	--
	120-180	0.052-0.060	-	19.4-16.6	--	--
Mineral fiber rock, slag or glass) <sup>9</sup>			-	-	-	
Approx 95-130mm.....	9.6-32	--	--	--	1.94	0.71
Approx 170-220mm.....	9.6-32	--	--	--	3.35	--
Approx 190-250mm.....	9.6-32	--	--	--	3.87	-
Approx 260-350mm.....	9.6-32	--	--	--	5.28	--
Mineral fiber (rock slag, or glass) <sup>9</sup>			-	-	-	
approx 90mm ( closed side wall application ) .....	32-56	--	--	--	2.1-2.5	
Vermiculite , exfoliated.....	110-130	0.068	--	14.8	--	1.34
	64-96	0.063	--	15.7	--	--
<i>Spray Applied</i>			-		-	
Polyurethane foam.....	24-40	0.023-0.026	--	43.3-38.5	--	--
Urea formaldehyde foam.....	11-26	0.032-0.040	--	31.5-24.7	--	--
Cellulosic fiber .....	56-96	0.042-0.049	--	23.9-20.4	--	-
Glass fiber .....	56-72	0.038-0.039	--	26.7-25.6	--	--

#### Reflective Insulation $\epsilon$

Reflective material ( $\epsilon < 0.5$ ) in center of 20mm cavity forms two 10mm vertical air spaces <sup>m</sup> .....	--	--	1.76	--	0.57	--
---	----	----	------	----	------	----

#### METALS

( See Chapter 38, Table 3 of ASHRAE Fundamentals Handbook 2001)

#### ROOFING

Asbestos- cement shingles.....	1900	--	27.0	--	0.037	1.00
Asphalt roll roofing.....	1100	--	36.9	--	0.026	1.51
Asphalt shingles .....	1100	--	12.9	--	0.077	1.26
Built -up roofing .....	1100	--	17.0	--	0.058	1.46
Slate .....	13mm	--	114	--	0.009	1.26
Wood shingles. Plain and plastic film faced .....	-	-	6.0	--	0.166	1.30

#### PLASTERING MATERIALS

Cement plaster, sand aggregates.....	1860	0.72	--	1.39	--	0.84
Sand Aggregate .....	10mm	--	75.5	--	0.013	0.84
Sand Aggregate .....	20mm	--	37.8	--	0.026	0.84
Gypsum plaster,						
Lightweight aggregate .....	13mm	720	--	17.7	--	0.056
Lightweight aggregate.....	16mm.	720	--	15.2	--	0.066
Lightweight aggregate on metal lath.....	19mm	--	12.1	--	0.083	--
Perlite aggregate .....	720	0.22	--	4.64	--	1.34
Sand aggregate .....	1680	0.81	--	1.25	--	0.84
Sand aggregate.....	13mm	1680	--	63.0	--	0.016
Sand aggregate .....	16mm	1680	--	51.7	--	0.019
Sand aggregate on metal lath.....	19mm	--	43.7	--	0.023	--
Vermiculite aggregate.....	720	0.24	--	4.09	--	--

#### MASONRY MATERIALS

Masonry units

Brick , fired clay.....	2400	1.21-1.47	--	0.83-0.68	--	--
	2240	1.07-1.30	--	0.94-0.77	--	--
	2080	0.92-1.12	--	1.08-0.89	--	--
	1920	0.81-0.98	--	1.24-1.02	--	0.79
	1760	0.71-0.85	--	1.42-1.18	--	--
	1600	0.61-0.74	--	1.65-1.36	--	--
	1440	-0.52-0.62	--	1.93-1.61	--	--
	1280	0.43-0.53	--	2.31-1.87	--	--
	1120	0.36-0.45	--	2.77-2.23	--	--
Clay tile, hollow						
1 cell deep.....75mm	-	-	7.10	-	0.14	0.88
1 cell deep.....100mm	-	-	5.11	-	0.20	-
2 cells deep.....150mm.	-	-	3.75	-	0.27	-
2 cells deep.....200mm	-	-	3.07	-	0.33	-
2 cells deep.....250mm	-	-	2.56	-	0.39	-
3 cells deep.....300mm	-	-	2.27	-	0.44	-
Concrete blocks <sup>n,o</sup>						
Limestone aggregate						
200mm, 16.3kg, 2210 kg/m <sup>3</sup>	-	-	-	-	-	-
concrete, 2 cores.....						
same with perlite filled cores.....	-	-	2.73	-	0.37	-
300mm, 25kg, 2210kg/m <sup>3</sup> concrete, 2	-	-	-	-	-	-
cores.....						
Same with perlite filled	-	-	1.53	-	0.65	-
cores.....						
Normal mass aggregate ( sand and						
gravel) 200mm						
15-16 kg, 2020-2180 kg/m <sup>3</sup> concrete, 2	-	-	5.1-5.8	-	0.20-0.17	0.92
or 3 cores.....						
same with perlite filled	-	-	2.84	-	0.35	-
cores.....						
Same with vermiculite filled cores.....	-	-	3.0-4.1	-	0.34-0.24	-
300mm, 22.7kg, 2000kg/m <sup>3</sup> concrete,	-	-	4.60	-	0.217	0.92
2 cores .....						
Medium mass aggregate	-	-	3.3-4.4	-	0.30-0.22	-
(combinations of normal and low mass						
aggregate) 200mm, 12-13 kg, 1550-						
1790 kg/m <sup>3</sup> concrete, 2 or 3 cores						
Same with perlite filled cores.....	-	-	1.5-2.5	-	0.65-0.41	-
Same with vermiculite filled	-	-	1.70	-	0.58	-
cores.....						
Same with molded EPS (beads) filled	-	-	1.82	-	0.56	-
cores						
Same with molded EPS inserts in	-	-	2.10	-	0.47	-
cores.						
Low mass aggregate ( expanded	-	-	3.0-3.5	-	0.34-0.29	-
Shale, clay, slate or slag, pumice) 150						
mm 7.3-7.7 kg, 1360-1390 kg/m <sup>3</sup>						
concrete, 2 or 3 cores						
Same with perlite filled	-	-	1.36	-	0.74	-
cores.....						
Same with vermiculite Filled	-	-	1.87	-	0.53	-
cores.....						
200mm, 8.6-10.0mm, 1150-1380	-	-	1.8-3.1	-	0.56-0.33	0.88
kg/m <sup>3</sup> concrete						
Same with perlite filled cores.....	-	-	0.9-1.3	-	1.20-0.77	-
Same with vermiculite Filled cores	-	-	1.1-1.5	-	0.93-0.69	-
Same with molded EPS ( beads ) filled	-	-	1.19	-	0.85	-
cores .....						
Same with UF foam filled	-	-	1.25	-	0.79	-
cores.....						
Same with molded EPS inserts in	-	-	1.65	-	0.62	-
cores.						
300mm, 14.5-16.3 kg, 1280-1440	-	-	2.2-2.5	-	0.46-0.40	-
kg/m <sup>3</sup> concrete, 2 or 3 cores...						

Same with perlite filled cores.....	-	-	0.6-0.9	-	1.6-1.1	-
Same with vermiculite Filled cores.....	-	-	0.97	-	1.0	-
Stone lime, or sand						
Quartzitic and sandstone .....	2880	10.4	-	0.10	-	-
	2560	6.2	-	0.16	-	-
	2240	3.5	-	0.29	-	-
	1920	1.9	-	0.53	-	0.79
Calcite, dolomite, limestone marble and granite	2880	4.3	-	0.23	-	-
	2560	3.2	-	0.32	-	-
	2240	2.3	-	0.43	-	-
	1920	1.6	-	0.63	-	0.79
	1600	1.1	-	0.90	-	-
Gypsum partition tile						
75 by 300 by 760mm, solid.....	-	-	4.50	-	0.222	0.79
75 by 300 by 760mm, 4 cells	-	-	4.20	-	0.238	-
100 by 300 by 760mm, 3 cells	-	-	3.40	-	0.294	-
<i>Concretes<sup>o</sup></i>						
Sand and gravel or stone aggregate concretes ( concretes with more than 50% quartz or quartzite sand have Conductivities in the higher end of the range) .....	2400	1.4-2.9	-	0.69-0.35	-	==
	2240	1.3-2.6	-	0.77-0.39	-	0.8-1.0
	2080	1.0-1.9	-	0.99-0.53	-	-
Limestone concretes.....	2240	1.60	-	0.62	-	-
	1920	1.14	-	0.88	-	-
	1600	0.79	-	1.26	-	-
Gypsum- fiber concrete ( 87.5% gypsum, 12.5% wood chips )	816	0.24	-	4.18	-	0.88
Cement/lime, mortar and stucco.....	1920	1.40	-	0.71	-	-
	1600	0.97	-	1.04	-	-
	1280	0.65	-	1.54	-	-
Lightweight aggregate concretes						
Expanded shale, clay or slate, expanded slags:	1920	0.9-1.3	-	1.08-0.76	-	-
cinders; Pumice ( with density up to 1600 kg/m <sup>3</sup> )	1600	0.68-0.89	-	1.48-1.12	-	0.84
and scoria (sanded concretes have conductivities in the higher end of the range).....	1280	0.48-0.59	-	2.10-1.69	-	0.84
	960	0.30-0.36	-	3.30-2.77	-	-
	640	0.18	-	5.40	-	-
Perlite, Vermiculite and polystyrene beads	800	0.26-0.27	-	3.81-3.68	-	-
	640	0.20-0.22	-	4.92-4.65	-	0.63-0.96
	480	0.16	-	6.31	-	-
	320	0.12	-	8.67	-	-
Foam concretes	1920	0.75	-	1.32	-	-
	1600	0.60	-	1.66	-	-
	1280	0.44	-	2.29	-	-
	1120	0.36	-	2.77	-	-
Foam concretes and cellular concretes	960	0.30	-	3.33	-	-
	640	0.20	-	4.92	-	-
	320	0.12	-	8.67	-	-
<i>SIDING MATERIALS (on flat surface)</i>						
<i>Shingles</i>						
Asbestos- cement .....	1900	-	27.0	-	0.037	-
Wood 400mm, 190mm exposure .....	-	-	6.53	-	0.15	1.30
Wood double 400mm ,300mm exposure	-	-	4.77	-	0.21	1.17

Wood plus insul backer board, 8mm	-	-	4.03	-	0.25	1.30
.....	-	-	-	-	-	-
<i>Siding</i>						
Asbestos –cement 6.4mm., lapped	-	-	27.0	-	0.037	1.01
.....						
Asphalt roll siding .....	-	-	36.9	-	0.026	1.47
Asphalt insulating siding (12.7mm bed) .....	-	-	3.92	-	0.26	1.47
Hardboard siding 11mm .....	-	-	8.46	-	0.12	1.17
Wood drop , 20 by 200mm.....	-	-	7.21	-	0.14	1.17
Wood bevel 13 by 200mm lapped	-	-	6.98	-	0.14	1.17
.....						
Wood bevel 19 by 250mm lapped.....	-	-	5.40	-	0.18	1.17
Wood plywood 9.5mm., lapped	-	-	9.60	-	0.10	1.22
.....						
Aluminum steel or vinyl <sup>p,q</sup> over sheathing				-		
.....						
Hollow backed Insulating board backed 9.5mm nominal.....	-	-	9.31	-	0.11	1.22 <sup>q</sup>
9.5mm foil backed.....	-	-	3.12	-	0.32	1.34
.....	-	-	1.93	-	0.52	-
Architectural ( soda lime float) glass WOODS (12% moisture content) <sup>e,f</sup>	-	-	56.8	-	0.018	0.84
<i>Hard Woods</i>						1.63 <sup>s</sup>
Oak.....	659-749	0.16-0.18	-	6.2-5.5	-	-
Birch .....	682-726	0.167-0.176	-	6.0-5.7	-	-
Maple.....	637-704	0.157-0.171	-	6.4-5.8	-	-
Ash.....	614-670	0.153-0.164	-	6.5-6.1	-	-
<i>Softwoods</i>						1.63 <sup>s</sup>
Southern Pine.....	570-659	0.144-0.161	-	6.9-6.2	-	-
Douglas Fir- Larch.....	536-581	0.137-0.145	-	7.3-6.9	-	-
Southern Cypress.....	502-514	0.130-0.132	-	7.7-7.6	-	-
Hem –Fir, Spruce- Pine-Fir....	392-502	0.107-0.130	-	9.3-7.7	-	-
West Coast Woods, Cedars.....	347-502	0.098-0.130	-	10.3=7.7	-	-
California Redwood.....	392-448	0.107-0.118	-	9.4-8.5	-	-

For referencing a,b,c etc of the above table; refer to the notes on next pages

#### \*NOTES OF TABLE 11.4:

<sup>a</sup>Values are for a mean temperature of 24°C. Representative values for dry materials are intended as design (not specification) values for materials in normal use. Thermal values of insulating materials may differ from design values depending on their properties (e.g., density and moisture content, orientation, etc.) and variability experienced during manufacture. For properties of a particular product, use the value supplied by the manufacturer or by unbiased tests.

<sup>b</sup> The symbol  $\lambda$  is also used to represent thermal conductivity.

<sup>c</sup> Resistance values are the reciprocals of C before rounding off C to two decimal places.

<sup>d</sup>Lewis (1967).

<sup>e</sup> U.S. Department of Agriculture (1974).

<sup>f</sup>Does not include paper backing and facing, if any. Where insulation forms a boundary (reflective or otherwise) of an airspace, see Tables 2 and 3 for the insulating value of an

airspace with the appropriate effective emittance and temperature conditions of the space. Conductivity varies with fiber diameter. (See Chapter 23, Factors Affecting Thermal Performance). Batt, blanket, and loose-fill mineral fiber insulations are manufactured to achieve specified R-values, the most common of which are listed in the table. Due to differences in manufacturing processes and materials, the product thicknesses, densities, and thermal conductivities vary over considerable ranges for a specified R-value.

<sup>h</sup>This material is relatively new and data are based on limited testing.

<sup>i</sup>For additional information, see Society of Plastics Engineers (SPI) Bulletin U108. Values are for aged, unfaced board stock. For change in conductivity with age of expanded polyurethane/ polyisocyanurate, see Chapter 23, Factors Affecting Thermal Performance.

<sup>j</sup> Values are for aged products with gas-impermeable facers on the two major surfaces. An aluminium foil facer of 25  $\mu\text{m}$  thickness or greater is generally considered impermeable to gases. For change in conductivity with age of expanded polyisocyanurate, see Chapter 23, Factors Affecting Thermal Performance, and SPI Bulletin U108.

<sup>k</sup>Cellular phenolic insulation may no longer be manufactured. The thermal conductivity and resistance values do not represent aged insulation, which may have a higher thermal conductivity and lower thermal resistance. Insulating values of acoustical tile vary, depending on density of the board and on type, size, and depth of perforations.

<sup>m</sup> Cavity is framed with 20mm wood furring strips. Caution should be used in applying this value for other framing materials. The reported value was derived from tests and applies to the reflective path only. The effect of studs or furring strips must be included in determining the overall performance of the wall.

<sup>n</sup>Values for fully grouted block may be approximated using values for concrete with a similar unit density.

<sup>o</sup>Values for concrete block and concrete are at moisture contents representative of normal use.

<sup>p</sup>Values for metal or vinyl siding applied over flat surfaces vary widely, depending on amount of ventilation of airspace beneath the siding; whether air space is reflective or non reflective; and on thickness, type, and application of insulating backing-board used. Values are averages for use as design guides, and were obtained from several guarded hot box tests (ASTM C 236) or calibrated hot box (ASTM C 976) on hollow-backed types and types made using backing of wood fiber, foamed plastic, and glass fiber. Departures of +50% or more from these values may occur.

<sup>q</sup> Vinyl specific heat = 1.0 kJ/(kg.K)

<sup>r</sup>See Adams (1971), MacLean (1941), and Wilkes (1979). The conductivity values listed are for heat transfer across the grain. The thermal conductivity of wood varies linearly with the density, and the density ranges listed are those normally found for the wood species given. If the density of the wood species is not known, use the mean conductivity value. For

extrapolation to other moisture contents, the following empirical equation developed by Wilkes (1979) may be used:

$$k = 0.7494 + \frac{(4.895 \times 10^{-3} + 1.503 \times 10^{-4}M)p}{1 + 0.01M}$$

Where  $p$  is density of the moist wood in  $\text{kg}/\text{m}^3$ , and  $M$  is the moisture content in percent.

<sup>5</sup>From Wilkes (1979), an empirical equation for the specific heat of moist wood at  $24^\circ\text{C}$  is as follows:

$$C_p = 0.1442 \times \frac{(0.299 + 0.01M)}{(1+0.01M)} + DC_p$$

Where  $DC_p$  accounts for the heat of absorption and is denoted by  $DC_p = M(0.008037 - 1.325 \times 10^{-4}M)$

Where  $M$  is the moisture content in percent by mass.

Assuming parallel heat flow only, the calculated resistance is higher than that calculated on the assumption of isothermal planes. The actual resistance generally is some value between the two calculated values. In the absence of test values, examination of the construction usually reveals whether a value closer to the higher or lower calculated R-value should be used. Generally, if the construction contains a layer in which lateral conduction is high compared with transmittance through the construction, the calculation with isothermal planes should be used.

If the construction has no layer of high lateral conductance, the parallel heat flow calculation should be used. Hot box tests of insulated and uninsulated masonry walls constructed with block of conventional configuration show that thermal resistances calculated using the isothermal planes heat flow method agree well with measured values (Van Greem 1985, Valore 1980, Shu et al. 1979). Neglecting horizontal mortar joints in conventional block can result in thermal transmittance values up to 16% lower than actual, depending on the density and thermal properties of the masonry, and 1 to 6% lower, depending on the core insulation material (Van Greem 1985, McIntyre 1984). For aerated concrete block walls, other solid masonry, and multicore block walls with full mortar joints, neglecting mortar joints can cause errors in R-values up to 40% (Valore 1988). Horizontal mortar joints usually found in concrete block wall construction are neglected in Example 2.

### **Constructions Containing Metal**

Curtain and metal stud-wall constructions often include metallic and other thermal bridges, which can significantly reduce the thermal resistance. However, the capacity of the adjacent facing materials to transmit heat transversely to the metal is limited, and some contact resistance between all materials in contact limits the reduction. Contact resistances in building structures are only 0.01 to 0.1  $\text{K}\cdot\text{m}^2/\text{W}$ -too small to be of concern in many cases. However, the contact resistances of steel framing members may be important. Also, in

many cases (as illustrated in Example 3), the area of metal in contact with the facing greatly exceeds the thickness of the metal, which mitigates the contact resistance effects.

Thermal characteristics for panels of sandwich construction can be computed by combining the thermal resistances of the various layers. R-values for the assembled sections should be determined on a representative sample by using a hot box method. If the sample is a wall section with air cavities on both sides of fibrous insulation, the sample must be of representative height since convective airflow can contribute significantly to heat flow through the test section. Computer modeling can also be useful, but all heat transfer mechanisms must be considered. In Example 3, the metal member is only 0.5 mm thick, but it is in contact with adjacent facings over a 32mm-wide area. The steel member is 90 mm deep, has a thermal resistance of approximately  $0.0019 \text{ K}\cdot\text{m}^2/\text{W}$ , and is virtually isothermal. The calculation involves careful selection of the appropriate thickness for the steel member. If the member is assumed to be 0.5 mm thick, the fact that the flange transmits heat to the adjacent facing is ignored, and the heat flow through the steel is underestimated. If the member is assumed to be 32 mm thick, the heat flow through the steel is overestimated. In Example 3, the steel member behaves in much the same way as a rectangular member 32 mm thick and 90 mm deep.

# Appendix D Air Side Economizer Acceptance Procedures

## D.1 Construction Inspection

Prior to performance testing verify and document the following:

- System controls are wired correctly to ensure economizer is fully integrated (i.e. economizer will operate when mechanical cooling is enabled).
- Economizer lockout control sensor location is adequate (open to air but not exposed to direct sunlight nor in an enclosure; away from sources of building exhaust; at least 8 m away from cooling towers).
- System is provided with barometric relief, relief fan or return fan to control building pressure.

## D.2 Equipment Testing

Step 1: Simulate a cooling load and enable the economizer by adjusting the lockout control setpoint. Verify and document the following:

- Economizer damper modulates opens to 100% outside air.
- Return air damper modulates closed and is completely closed when economizer damper is 100% open.
- Economizer damper is 100% open before mechanical cooling is enabled.
- Relief fan or return fan (if applicable) is operating or barometric relief dampers freely swing open.

Step 2: Continue from Step 1 and disable the economizer by adjusting the lockout control setpoint. Verify and document the following:

- Economizer damper closes to minimum ventilation position.
- Return air damper opens to at or near 100%
- Relief fan (if applicable) shuts off or barometric relief dampers close. Return fan (if applicable) may still operate even when economizer is disabled.

# Appendix E Compliance Forms

## E.1 Envelope Summary

Envelope Summary					
Energy Conservation Building Code Compliance Forms					
Project Info	Project Address			Date	
				For Building Department Use	
	Applicant Name:				
	Applicant Address:				
Applicant Phone:					
<hr/>					
<b>Project Description</b>	New	Addition	Alteration	Change of Use	
	Prescriptive	Whole Building Performance			

Project Description	New	Addition	Alteration	Change of Use	
	Prescriptive	Whole Building Performance			
	Hospital, hotel, call center (24-hour)			Other building types (daytime)	
<b>Vertical Fenestration Area Calculation</b>  Note: Vertical fenestration area cannot exceed 40% of the gross wall area for prescriptive option.	Total Vertical Fenestration Area (rough opening)	Divided by	Gross Exterior Wall Area	Times 100 equals	% vertical Fenestration
	÷			X100=	
<b>Skylight Area Calculation</b>  Note: Vertical fenestration area cannot exceed 40% of the gross wall area for prescriptive option.	Total Skylight Area (rough opening)	Divided by	Gross Exterior Wall Area	Times 100 equals	% skylight
	÷			X100=	

**Hospital, hotel, call center (24 hour)**

**OPAQUE ASSEMBLY**

*Roof Minimum Insulation R-value*

Wall *Minimum Insulation R-value*

**FENESTRATION**

Vertical

*Maximum U-factor*

*Maximum SHGC (or SC)*

Overhang (yes or no)

*If yes, enter Projection Factor*

Side fins (yes or no)

*If yes, enter Projection Factor*

Skylight

*Maximum U-factor*

*Maximum SHGC (or SC)*

**Other building type (daytime)**

**OPAQUE ASSEMBLY**

*Roof Minimum Insulation R-value*

Wall *Minimum Insulation R-value*

**FENESTRATION**

Vertical

*Maximum U-factor*

*Maximum SHGC (or SC)*

Overhang (yes or no)

*If yes, enter Projection Factor*

Side fins (yes or no)

*If yes, enter Projection Factor*

Skylight

*Maximum U-factor*

*Maximum SHGC (or SC)*

## Building Permit Plans Checklist

Building Permit Plans Checklist					ENVELOPE Checklist		
2007 Energy Conservation Building Code Compliance Forms							
Project Address						Date	
The following information is necessary to check a building permit application for compliance with the building envelope requirements in the Energy Conservation Building Code, 2007.							
Applicability (yes, no, n.a.)	Code Section	Component	Information Required	Location on Plans	Building Department Notes		
<b>MANDATORY PROVISIONS (Section 4.2)</b>							
	4.2.1	Fenestration: Light to Solar Gain (L/S):					
	4.2.2	Bldg. env. Sealing	Indicate sealing, caulking, gasketing, and weather stripping				
	4.2.3	Cool Roof	initial solar reflectance and thermal emittance				
<b>PRESCRIPTIVE COMPLIANCE OPTION (Section 4.3)</b>							
	4.3.1	Roof	Indicate R-values on roof sections				
	4.3.1.1	Cool roof	Indicate minimum reflectance and emittance on plans				
	4.3.2	External Wall	Indicate R-values on wall sections				
	4.3.3	Vertical fenestration	(1) Indicate U-factors on fenestration schedule. Indicate if values are rated or default. If values are default, then specify frame type, glazing layers, gapwidth, low-e. (2) Indicate SHGC or SC on fenestration schedule. Indicate if values are rated or default. (3) Indicate if overhangs or side fins are used for compliance purposes. If so, provide projection factor calculation.				

			4.3.4	Skylights	(1) Indicate U-factors on fenestration schedule. Indicate if values are rated or default. If values are default, then specify frame type, glazing layers, gapwidth, low-e. (2) Indicate SHGC or SC on fenestration schedule. Indicate if values are rated or default		
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**Fan Equipment Schedule**

Equip. ID	Brand Name	Model No.	Total L/s	SP	kW	Flow Control	Location of Service

## Mechanical Checklist

Mechanical Permit Checklist				MECHANICAL Checklist		
Energy Conservation Building Code Compliance Forms						
Project Address					Date	
The flowing information is necessary to check a building permit application for compliance with the building envelope requirements in the Energy Conservation Building Code, 2007.						
Applicability (yes, no, n.a.)	Code Section	Component	Information Required	Location on Plans	Building Department Notes	
<b>HEATING, VENTILATION, AND AIR CONDITIONING (Chapter 5)</b>						
<b>MANDATORY PROVISIONS (Section 5.2)</b>						
	5.2.1	Load Calculations	Cooling and heating system design loads			
	5.2.2	Natural Ventilation	The design guidelines provided for natural ventilation in the project			
	5.2.3	Equipment efficiency	Provide equipment schedule with type, capacity, efficiency			
	5.2.4	Controls	Provide controls documentation			
	5.2.5	Zone Isolation				
	5.2.6	Ventilation Fan Controls	Provide plans, equipment details and program logics			
	5.2.7	Enclosed Parking Garage Ventilation	Provide plans, sensor details and program logics			
	5.2.8	Piping & ductwork	Provide insulation thickness, type and other details.			
	5.2.9	Ductwork and Plenum Leakage	Provide test reports			
	5.2.10	System balancing	Specify system balancing			
	5.2.11	Condensers	Provide documents related to cooling tower			
	5.2.11.2	Cooling tower, fluid cooler	Indicate two-speed motor, pony motor, or variable speed drive to control the fans			
	5.2.12	Ductwork	Specify sealing types and			

				sealing	locations		
<b>PRESCRIPTIVE COMPLIANCE OPTION (Section 5.3)</b>							
			5.3		Indicate whether project is complying with ECBC Prescriptive Option		
			5.3.1	Fan System Power and Efficiency	Provide power and efficiency details for all fans installed		
			5.3.2	Variable flow hydronic	Submit mechanical drawings and details.		
<b>SERVICE WATER HEATING AND PUMPING (Chapter 6)</b>							
<b>MANDATORY PROVISIONS (Section 6.2)</b>							
			6.2.1	Load Calculation	Service water heating system design loads		
			6.2.2	Solar water heating	Provide calculations to justify capacity to meet 20% threshold		
			6.2.3	Equipment efficiency	Provide equipment schedule with type, capacity, efficiency		
			6.2.4	Piping insulation	Indicate R-value of insulation		
			6.2.6	Heat traps	Indicate heat trap on drawings or provide manufacturers specifications to show that equipment has internal heat trap		
			6.2.7	Pool covers	Provide vapor retardant cover for pools		

## Lighting Summary

Lighting Summary				
Energy Conservation Building Code Compliance Forms				
Project Info	Project Address	Date		
		For Building Department Use		
	Applicant Name:			
	Applicant Address:			
	Applicant Phone:			
<b>Project Description</b>	New	Addition	Alteration	Change of Use
<b>Compliance Option</b>	Prescriptive	Whole Building Performance		
<b>Maximum Allowed Lighting Wattage (Interior, Section 7.3)</b>				
Location (floor/room no.)	Occupancy Description	Allowed Wattsper m <sup>2</sup> **	Area in m <sup>2</sup>	Allowed x Area
** Document all exceptions Allowed Watts			Total	
<b>Proposed Lighting Wattage (Interior)</b>				
Location (floor/room no.)	Fixture Description	Number of Fixtures	Watts/ Flxture	Watts Proposed
Total Proposed Watts may not exceed Total Allowed Wattage for Interior Total Allowed Watts				
<b>Maximum Allowed Lighting Wattage (Exterior, Section 7.4)</b>				
Location	Description	Allowed Wattsper m <sup>2</sup> or	Area in m <sup>2</sup> ( or lm for	Allowed watts x m <sup>2</sup>

		per lm	perimeter)	(or x lm)
Total Allowed				
Watts				
<b>Proposed Lighting Wattage (Exterior)</b>				
Location	Fixture Description	Number of Fixtures	Watts/ Fixture	Watts Proposed
Total Allowed				
Watts				

### Lighting Permit Checklist

Lighting Permit Checklist			LIGHTING Checklist			
Energy Conservation Building Code Compliance Forms						
Project Address					Date	
The following information is necessary to check a building permit application for compliance with the building envelope requirements in the Energy Conservation Building Code.						
Applicability (yes, no, n.a.)	Code Section	Component	Information Required	Location on Plans	Building Department Notes	
<b>LIGHTING (Section 7.2)</b>						
<b>MANDATORY PROVISIONS (Section 7.2)</b>						
	7.2.1	Interior Lighting Controls	Provide schedule with type and features, indicate locations			
	7.2.2	Parking Garage Lighting Control	Provide schedule with type and features			
	7.2.3	Exterior lighting control	Indicate photosensor or astronomical time switch			
	7.2.4	Signage/Advertising Signage	Indicate 5 watts maximum			

			7.2.5	Exterior Building grounds lighting	Indicate minimum efficacy of 80 lumens/Watt		
<b>PRESCRIPTIVE INTERIOR LIGHTING POWER COMPLIANCE OPTION (Section 7.3)</b>							
			7.3		Indicate whether project is complying with the Building Area Method (7.3.2) or the Space Function Method (7.3.3)		
			7.3.2	Building area method	Provide lighting schedule with wattage of lamp and ballast and number of fixtures. Document all exceptions.		
			7.3.3	Space function method	Provide lighting schedule with wattage of lamp and ballast and number of fixtures. Document all exceptions.		
			7.3.4.1	Luminaire wattage	Indicate on plans		
<b>PRESCRIPTIVE EXTERIOR LIGHTING POWER COMPLIANCE OPTION (Section 7.3.5)</b>							
			7.3.5	Building area method	Provide lighting schedule with wattage of lamp and ballast and number of fixtures. Document all exceptions.		

## Electrical Power

<b>MANDATORY PROVISIONS (Section 8.2)</b>							
			8.2.1	Transformers	Provide schedule with transformer losses		
			8.2.2	Motor efficiency	Provide equipment schedule with motor capacity, efficiency		
			8.2.3	Power factor correction	Provide schedule with power factor correction		
			8.2.4	Check metering	Provide check metering and monitoring		
			8.2.5	Power Distribution System Losses	Provide schedule with losses		
			8.2.6	Automatic Receptacle Control	Provide schedule and controls specifications		