GOVERNMENT OF PAKISTAN
Ministry of Housing & Works
Environment & Urban Affairs Division

Building Energy Code of Pakistan

MAY 1990

PREPARED BY:

THE NATIONAL ENERGY CONSERVATION CENTRE
PLANNING & DEVELOPMENT DIVISION
GOVERNMENT OF PAKISTAN

ENERCON

بسم الله الرحمن الرحيم

PREFACE

The Energy Crisis of the early 1970s resulted in a dramatic change in the planning and operation of construction activities in the developed countries, the emphasis being on optimal utilization of energy. In Pakistan, the last few years have witnessed the growing menace of energy shortage or 'load-shedding". Although it could be contributed to a slower rate of increase in our generation capacity, there are numerous other factors which have been widening the gap between demand and supply in all sectors of our economy, especially the building sector.

According to a conservative estimate, buildings in Pakistan consume more than 40% of the total electricity produced. The demand of this sector is growing at the rate of almost 14% per annum, the highest among all other sectors. Rapid urbanization and resultant construction of buildings and rising standards of living are considered to be the causes of increased demand in this sector.

However, a critical evaluation would reveal that most of the current buildings are not designed keeping in view local climatic conditions. Excessive use of concrete and glass, high levels of illumination and heavy reliance on space conditioning equipment are a common feature of our buildings. These buildings need extra energy to be made comfortable for their occupants.

Although a Building Code of Pakistan exists, it does not address this issue. Therefore, the National Energy Conservation Centre (ENERCON), Planning and Development Division was requested by the Environment and Urban Affairs Division, to come up with a Building Energy Code, as an addendum to the Building Code of Pakistan. The draft Code prepared by ENERCON,was presented to a Review Committee, constituted by the Environment and Urban Affairs Division (composition given on pages iii - iv). Due to the technical nature of the Code, a Technical Sub-Committee was formed (composition given on pages v - vi). which went through each and every clause. The Code was finally approved by the Review Committee on the recommendation of the Technical Sub-Committee after incorporating necessary amendments in the light of the comments of the members of both the committees.

This Code gives minimum performance standards for building windows and openings, heating, ventilating and air-conditioning (HVAC) equipment and lighting. Though mostly based on American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE) standards, every effort has been made to ensure its applicability in our buildings. In accordance with the Building Code of Pakistan, which divides Pakistan into five climatic zones, standards have been provided for each zone.

In order to ensure general understanding of the Code for a large-scale compliance, ENERCON has also' prepared a Compliance Handbook for use in conjunction with this Code. It explains most of the terms and other technical aspects with the help of illustrative examples.

The building Energy Code is non mandatory at this stage. Both ENERCON and the Environment and Urban Affairs Division shall help the building professionals through introductory workshops and seminars to understand the conceptual basis of the Code. This is expected to ensure that the designs of buildings comply with the Code and are energy efficient. Once the infrastructure has substantially developed, the Code may be promulgated on a mandatory basis.

The Code will be reviewed by the Environment and Urban Affairs Division in consultation with ENERCON periodically as and when needed but not later than five years. Any valuable comments for its improvement will be highly appreciated.

We are grateful to ENERCON and the members of the two committees who made their valuable contribution to make this noble task a successful one.

(S.A.S. Ainuddin)
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Part 1 - ADMINISTRATION AND ENPORCEMBNT

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Part 1 - ADMINISTRATION AND ENFORCEMENT

1.1 Title

This code shall be known as the Building Energy Code of Pakistan hereinafter referred to as the "code".

1.2 8CODe

This code shall apply to all buildings as defined in Part 1.4, Applicability, and for which an application for building permit is filed after the effective date of this code. This code addresses only the energy conservation aspects of buildings, and as such, does not cover the structural, siting and other requirements found in the Building Code of Pakistan or other local building codes.

1.3 Coordination With Other Codes

The requirements of this code are to be coordinated with those of the Building Code of Pakistan. Coordination with other codes not equal to the Building Code of Pakistan shall be made only with the approval of the Ministry of Housing and Works.

1.4 Applicability

1.4.1 New Buildinas

This code shall apply to all areas enclosed by the structure of permanent buildings and that are primarily intended for human habitation, e.g. residences, offices, shops, schools, hotels, government buildings, etc. Exempt from this code are buildings or areas of buildings that are intended to be used primarily for manufacturing, warehousing or storage, agriculture, or industrial processing.

1.4.2 **Existing Buildings**

1.4.2.1 **Changres in Use**

Changes in use of a building that are primarily for human habitation and that require a building permit, shall make those areas subject to the requirements of this code.

1.4.2.2 Remlacement *or* Major Modification of **Equipment**

Replacement or major modification of the HVAC or lighting equipment in existing buildings shall be governed by the requirements of this code.

1.4.2.3 Replacement or Maior Modification of Roof

Replacement or major modification of the roof of an existing building shall be governed by the requirements of this code.

1.4.2.4 Additions to Existincg Buildings

Any addition to an existing building shall be governed by the requirements of this code.

1.5 Enforcement

1.5.1 Plans and Specifications

Review and approval of plans and specifications under this code shall be part of and in accordance with the Building Code of Pakistan. Permits, certificates and notices required for construction shall not be issued by the authority giving electric or gas connections or oil storage unless all requirements of this code are met.

1.5.2 Inspection

All work, materials and equipment pertaining to this code shall be subject to the inspection procedures and requirements set forth in the Building Code of Pakistan.

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Part 2 - DEFINITIONS

Part 2 - DEFINITIONS

The following definitions are stipulated for the purposes of this document:

ABMA : American Boiler Manufacturers Association
ANSI : American National Standards Institute
ARI : Air-Conditioning and Refrigeration Institute (U.S.)

ASHRAE : American Society of Heating Refrigerating and Air-Conditioning Engineers
ASME : American Society of Mechanical Engineers

Air changes per hour (ACE). Number of complete changes of interior air by outdoor air per hour.

Air Infiltration. The uncontrolled air exchange in a building due to air leakage through cracks and interstices in any building element and around windows and doors of a building, caused by the pressured effects of wind and/or the effect of differences in the indoor and outdoor air density.

Air transport factor. The ratio of the rate of usefui sensible heat removal from the conditioned space to the energy input to the supply and return fan motor(s), expressed in consistent units and under the designated operating conditions.

Automatic. Self-acting, operating by its own mechanism when actuated by some impersonal influence, as for example, a change in current strength, pressure, temperature or mechanical configuration.

Boiler capacity. The rate of heat output in W(Btu/h) measured at the boiler outlet, at the design inlet and outlet conditions and rated fuel/energy input.

British thermal unit (Btu). Approximately the amount of heat required to raise the temperature of one pound of water by one Fahrenheit degree, at 60 F. International Steam Table Btu x 1.055 = kJ.

Building envelope. The element's of a building which enclose conditioned spaces through which thermal energy may be transferred to or from the exterior or to or from unconditioned spaces exempted by the provisions (See Section 3.)

Building project. A building or group of buildings, including on-site energy conversion or electric-generating facilities which utilize a single submittal for a construction permit or are within the boundary of a continuous area under one ownership.

C = thermal conductance. The thermal transmission in unit time through unit area of a particular body or assembly having defined surfaces, when unit aver9ge temperature is established between the surfaces: W/m9.C (Btu/ft%h.F).

Coefficient of performance (COP) - cooling. As defined in the following paragraphs:

- Electric Packaged Equipment (Cooling Mode)	4.3.1
- Electrically Operated HVAC System Components (Cooling Mode)	4.3.2
- Heat Operated Equipment (Cooling Mode)	4.3.3

Coefficient of performance (COP), pump - heating Mode. As defined in para 4.3.4.

Comfort 8nV8lOp8. The area on a psychrometric chart enclosing all those conditions described in ANSI/ASHEAE Standard 55-74, Fig. 1, as being comfortable.

Conditioned floor area. The horizontal projection of that portion of interior space which is contained within exterior walls and which is conditioned directly or indirectly by an energy-using system.

Conditioned space. Space within a building which is provided with heated and/or cooled air or surfaces and, where required, with humidification or dehumidification means so as to maintain a space condition falling within the comfort zone set forth in ANSI/ASHEAE Standard 55-74 "Thermal Environmental Conditions for Human Occupancy.11

Cooled space. Space within a building which is provided with a positive cooling supply.

D.O.E. Department of Energy (U.S.)

Dwelling unit. A single housekeeping unit comprised of one or more rooms providing complete, independent living facilities for one or more persons including permanent provisions for living, sleeping, eating, cooking and sanitation.

Economiser cycle. A control sequence of an air supply system that modulates the quantity of outdoor air supplied for the purpose of space conditioning in order to reduce or eliminate the use of refrigeration energy for cooling.

Efficiency, HVAC system. The ratio of the useful energy output (at the point of use) to the energy input for a designated time period, expressed in percent.

Energy. The capacity for doing work: taking a number of forms which may be transformed from one into another, such as thermal (heat), mechanical (work), electrical, and chemical: in SI units, measured in joules (J), where 1 joule = 1 watt-second; in customary units, measured in kilowatt hours (kWh) or British thermal units (Btu).

Energy efficiency **ratio** (EER). The ratio of net equipment cooling capacity in Btu/h to total rate of electric input in watts under designated operating conditions. When SI units are used this ratio becomes equal to COP. (See coefficient of performance.)

Enthalyy. A thermodynamic property of a substance defined as the sum of its internal energy plus the quantity Pv/J: where P = pressure of the substance, v = its volume, and J = the mechanical equivalent of heat; formerly called total heat and heat content.

Exterior envelope. (See building envelope.)

Fenestration. Any light-transmitting opening in a building wall or roof.

Gross floor area. The sum of the areas of one or more floors of the building, including basements, mezzanine and intermediate-floored tiers and penthouses of headroom height, 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.

Gross wall area. See section 3.2 for definition.

HVAC. Heating, ventilating and air conditioning.

HVAC system. A system that provides either collectively or individually the processes of comfort heating, ventilating, and/or air conditioning within or associated with a building.

HVAC system equipment. The word "equipment" used without modifying adjective, may, in accordance with common industry usage, apply either to HVAC system equipment or HVAC system components.

HVAC system efficiency. (See efficiency, HVAC system.)

Heated space. Space, within a building, which is provided with a positive heat supply. Finished living space within a basement, or in the presence of registers or heating devices designed to supply heat to a basement space, shall automatically define that space as heated space.

Humidistat. A regulatory device, actuated by changes in humidity, used for automatic control of relative humidity.

Illumination. The density of the luminous flux incident on a surface: it is the quotient of the luminous flux by the area of the surface when the latter is uniformly illuminated.

Luminaire. A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

MCF . Customary term for one thousand cubic feet.

Manual. Capable of being operated by personal intervention (adjective). (See automatic).

Marked rating. The design load operating conditions of a device as shown by the manufacturer on the nameplate or otherwise marked on the device.

OTTV . Overall thermal transfer value. The maximum thermal transfer permissible into the building through its walls or roof, due to solar heat gain and outdoor-in-door temperature difference, as determined by the equation appearing in Section 3.3.1.

Opaque areas. All exposed areas of a building envelope which enclose conditioned space, except openings for windows, skylights, doors and building service systems.

Outdoor air. **Air taken purposely from the outdoors and, therefore, not previously circulated through the system.**

Packaged terminal air-conditioner (PTAC). A **factory-selected combination of heating and/or cooling components, assemblies or sections, intended to serve a room or zone.**

Packaged terminal heat pump. **A factory-selected combination of heating and cooling components, assemblies or sections, intended for application in an individual room or zone.**

Positive **cooling** supply. **Cooling deliberately supplied to a space, such as through a supply register. Also, cooling indirectly supplied to a space through uninsulated surface of space cooling components, such as evaporator coil and cooling distribution systems.**

Positive heat supply. **Heat deliberately supplied to a space such as through a supply register, radiator or heating element. Also, heat indirectly supplied to a space through uninsulated surface of service water heaters and space heating components such as furnaces, boilers, and heating and cooling distribution systems.**

Power. In connection with machines, power is the time rate of doing work. In connection with the transmission of energy of all types, power refers to the rate at which energy is transmitted. In SI Units it is measured in joules per second (J/s) or in watts (W) in customary units, it is measured in watts (W) or British thermal units per hour (Btu/h).

R **= Thermal resistance. The reciprocal of thermal conductance: $(m^2 \cdot {}^{\circ}C)/W$ or $(hr \cdot ft^2 \cdot {}^{\circ}F)/Btu$.**

Recommend. Suggest as appropriate: not required.

Recooling. The removal of heat by sensible cooling of the supply air (directly or indirectly) that has been previously heated above the temperature to which the air is to be supplied to the conditioned space for proper control of the temperature of that space.

Recovered energy. **Energy utilized which would otherwise be wasted (i.e., not contribute to a desired end use) from an energy utilization system.**

Reheat. The application of sensible heat to supply air that has been previously cooled below the temperature of the conditioned space by either mechanical/ absorption refrigeration or the introduction of outdoor air to provide cooling.

Residential building. Living units of one story, two stories, or other low-rise or high-rise multi-family dwellings.

Room air conditioner. An encased assembly designed as a unit primarily for mounting in a window or through a wall, or as a console. It is designed primarily to provide free delivery of conditioned air to an enclosed space, room or zone. It includes a prime source of refrigeration for cooling and dehumidification and means for circulating and cleaning air, and may also include means for ventilating and heating.

Short Ton. Customary term for two thousand pounds mass.

Service systems. All energy-using systems in a building that are operated to provide services for the occupants or processes housed therein, including HVAC, service water heating, illumination, transportation, cooking or food preparation, laundering or similar functions.

Shading coefficient (SC).

$$SC = \frac{\text{Solar Heat Gain of Feestration System}}{\text{Solar Heat Gain of Double Strength Clear Glass (single layer)}}$$

Note: To be compared under the same conditions.

Shall. Term used to indicate provisions that are mandatory within the code.

Should. Term used to indicate provisions which are not mandatory but which are desirable as good practice.

Solar energy source. Source of natural daylighting and of thermal, chemical or electrical energy derived directly from conversion of incident solar radiation.

system. A combination of equipment and/or controls, accessories, interconnecting means, and terminal elements by which energy is transformed so as to perform a specific function, such as HVAC, service water heating or illumination.

Terminal element. The means by which the transformed energy from a system is finally delivered; i.e., registers, diffusers, lighting fixtures, faucets, etc.

Thermostat. An automatic control device actuated by temperature and designed to be responsive to temperature.

U value or thermal transmittance. The coefficient of heat transmission (air to air). It is the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films W/m .C (Btu/ft2.h.F). The U value applies to combinations of different materials used in series along the heat flow path, single materials and materials that comprise a building section, cavity air spaces, and surface air films on both sides of a building element.

U_o value or thermal transmittance, overall. The overall (average) heat transmission of a gross area of the exterior building envelope $W/m^2.C$ ($Btu/ft^2.h.F$). The U_o value applies to the combined effect of the time rate of heat flows through the various parallel paths, such as windows, doors, and opaque construction areas, comprising the gross area of one or more exterior building components, such as walls, floor, or roof/ceiling.

Unitary cooling and heating equipment. One or more factory-made assemblies which normally include an evaporator or cooling coil, a compressor and condenser combination, and may include a heating function as well. Where such equipment is provided in more than one assembly, the separate assemblies shall be designed to be used together.

Unitary heat pump. One or more factory-made assemblies which normally include an indoor conditioning coil, compressor(s) and outdoor coil or refrigerant-to-water heat exchanger, including means to provide both heating and cooling functions. When such equipment is provided in more than one assembly, the separate assemblies shall be designed to be used together.

Ventilation. The process of supplying or removing air by natural or mechanical means to or from any space. Such air may or may not have been conditioned.

Ventilation air. That portion of supply air which comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space.

Water-chilling package, absorption. A factory designed and prefabricated assembly (not necessarily shipped as a single package) of one or more condensers; evaporators (water coolers); absorbers; and generators: with interconnections and accessories, used for chilling water.

Water-chilling package, centrifugal or rotary. A factory-designed and prefabricated assembly (not necessarily shipped as one package) of one or more centrifugal or rotary compressors: condensers; and water-coolers (evaporators); with interconnections and accessories, used for chilling water.

Water-chilling package, reciprocating. A factory designed and prefabricated assembly, self-contained or condenserless, of one or more reciprocating compressors: condensers (self-contained only): water coolers (evaporator); and interconnections and accessories; used for chilling water. The condenser may be air-evaporatively, or water-cooled.

Watt (W). SI unit of powe equal to one joule per second (J/s). Also, the power delivered by one volt with one ampere flowing (unity power factor). (See power.)

Whole House Fan. A mechanical fan system used to exhaust air from the interior of a building to the exterior and which can transfer the air with little or no resistance.

Zone. A space or group of spaces within a building with heating and/or cooling requirements sufficiently similar so that comfort conditions can be maintained through-out by a single controlling device.

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Part 3 · BUILDING ENVELOPE

Appendices

Part 3 - BUILDING ENVELOPE

3.1 Scope

The criteria set forth in this chapter establish the minimum energy conservation requirements for the building envelope. Design criteria that result in greater levels of energy conservation shall be allowed provided they are not in conflict with any requirement of this code or the Building Code of Pakistan.

In addition to the criteria set forth in this section, the proposed design should consider energy conservation in determining the orientation of the building on its site; the geometric shape of the buildings: the building aspect ratio (ratio of length to width); the number of stories for **a** given floor area requirement; the thermal mass of the building; the exterior surface color; shading or reflections from adjacent structures, surrounding surfaces or vegetation; opportunities for natural ventilation: and wind direction and speed. For a national standard the above considerations are difficult if not impossible to quantify. However, particularly on a local basis, many of these items including the effects of mass, passive solar and daylight utilization can be quantified and therefore should be considered in the building design.

For the purpose of meeting the requirements of this code, the building envelope shall comply with both the conduction (Uo and R) requirements and the Overall Thermal Transfer Value (OTTV) requirements as set forth in this code.

3.2 Conduction (U_o and R) Requirements

A roof assembly shall be considered as all components of the*roof/ceiling envelope through which heat flows, thus creating a building transmission heat loss or gain, where such assembly is exposed to outdoor air.

The gross area of a roof assembly consists of the total exterior surface of such assembly (except for return air plenums, noted below), including skylights.

Where return air ceiling plenums are employed, the roof/ceiling assembly shall:

a. for thermal transmittance purposes, not include the ceiling proper nor the plenum space as part of the assembly, and

b. for gross area purposes, be based upon the interior face of the upper plenum surface.

The gross area of exterior walls measured on the exterior surface consists of all opaque wall areas (including foundation walls, between floor spandrels, peripheral edges of floors, etc.), window areas (including sash),. and door areas.

The design of buildings for energy conservation may increase the water vapor pressure differentials between the interior and exterior environments. Vapor retarders, air infiltration and operating interior relative humidity should be considered to maintain the thermal and moisture integrity of the envelope (see ASHRAE Handbook 1989 Fundamentals).

U-values and R-values shall be calculated in accordance with the Building Energy Code Compliance Handbook or ASHRAE Handbook, 1989 Fundamentals.

3.2.1 Roofs/Ceilingss

The thermal transmission value **(U_o)** for the gross area of the roof shall not exceed the value given in Table 3.0. As an alternative, Equation 1 and Equation la can be used to determine acceptable combinations of U-values for different sections of the gross roof area, including skylights, hatchs, etc. To meet this requirement, insulation materials may be placed either above, below or within the roof deck.

Equation 1

$$U_o = \frac{U_{r1} \times A_{r1} + U_{r2} \times A_{r2} + \text{---}\ u \times A}{A_{r1} + A_{r2} + \text{---}\ A_{rn}}$$

Where U_o = the **overall thermal transmittance** of the **gross area** of the roof (W/m^2 C)

U_{r1}, U_{r2}, U_{rn} = the respective thermal transmittance of different roof sections (W/m^2 C)

A_{r1}, A_{r2}, A_{rn} = **the respective area** of different roof sections (m^2)

Equation 1a

Where skylight/glazing is used on the roof, the thermal transmittance for the gross area of the roof should be determined from:

$$U_o = \frac{U_r \times A_r + U_g \times A_g}{A_o}$$

Where Uo = the overall thermal transmittance of the gross roof area (W/m^2 C)

A_o = gross area of the exterior roof

Ur = the thermal transmittance of the components of the opaque roof area (W/m^2 C)

A_r = opaque roof area (m^2)

U_g = the thermal transmittance of the glazing area (W/m^2 C)

A_g = the glazing area (m^2)

Where more than one type of roof ceiling and or skylight is used, the Ur term for that exposure shall be expanded into sub elements as:

$$(U_{r1} \times A_{r1}) + (U_{r2} \times A_{r2}) + \text{---} \text{ etc.}$$

3.2.2 Surfaces Separating Conditioned and Unconditioned Spaces

For surfaces that separate conditioned and unconditioned space, the U_o value shall not exceed the value given in Table 3.0.

3.2.3 Walls

The gross wall area above grade shall have thermal, transmission value, U_o, not exceed the values in Table 3.0. Equation 2 shall be used to determine the acceptable combinations to meet these requirements. There are no thermal requirements for wall sections below grade.

Table 3.0

Allowable Conductance and Resistance Values*

ELEMENT	SYMBOL	UNITS	1	2	3	4	5
Wells	U_o	W/m^2	2.67	2.56	2.22	2.50	2.22
		$Btu/hr.ft^2$	0.47	0.45	0.39	0.44	0.39
Roofs/Ceilings	U_o	W/m^2	0.58	0.58	0.58	0.58	0.58
		$Btu/hr.ft^2$	0.10	0.10	0.10	0.10	0.10
Shaded Roofs & Floors **Exposed** **to** Weather***	U_o	W/m^2	1.16	1.16	1.16	1.16	1.16
		$Btu/hr.ft^2$	0.20	0.20	0.20	0.20	0.20
Floors Unheated Spaces	" 0	W/m^2	2.27	1.70	1.42	1.70	1.42
		$Btu/hr.ft^2$	0.40	0.30	0.25	0.30	0.25
Heated Slab on Grade	R	m^2/W	0.44	0.63	0.74	0.67	0.74
		$hr.ft^2/Btu$	2.50	3.60	4.20	3.60	4.20

* U_o values listed **are maximum,**
R **values** listed **are** minimum requirements

** **See** Appendix I.

*** If en **air space** exists between the roof end ceiling, and the **space** is well ventilated, the ceiling **is** considered **shaded** (provided insulation is placed on the ceiling).

Equation 2

$$U_o = \frac{U_w \times A_w + U_g \times A_g + U_d \times A_d}{A_o}$$

where U_o = the overall **thermal transmittance** of the gross **wall area** (W/m^2 C)

A_o =**grossarea** of the exterior surfaces above **grade** (m^2)
(**that is,** $A_w + A_g + A_d$)

A_w = Opaque **wall area** (m^2)

V_w = the thermal transmittance of the components of the opaque wall • r*. (W/m^2 C)

A_g = glazing area (m^2)

U_g = the thermal transmittance of the glazing area (W/m^2 C)

A_d = door area (m^2)

U_d = thermal transmittance of the door area (m^2)

Where more than one type of wall, window and/or door is used, the U&A terms for these items shall be expanded into sub elements as:

$(U_{w1} A_{w1}) + (U_{w2} A_{w2})$ etc.

3.3 Overall Thermal Transfer Value (OTTV) Requirements

The cooling design criterion for walls, floors and roof/ceilings is to be known as the Overall Thermal Transfer Value (OTTV). It is aimed at achieving the design of a building envelope that adequately reduces heat gain by both conduction and solar radiation in order to reduce the cooling load of the air conditioning system. The OTTV concept is based on three basic methods of heat gains through the external envelope of a building:

(a) heat conduction through opaque walls, roof/ceiling and floors

(b) heat conduction through windows and/or skylights

(c) solar radiation through windows and/or skylights

The OTTV calculation shall be for all climate zones (shown in Appendix I) of Pakistan and shall not exceed the values given in Table 3.3.

3.3.1 Equivalent Temperature Difference

Solar radiation on the building is a cyclic heat input. The outdoor air temperature also varies during the 24 hr period in a day. The Equivalent Temperature Difference (TDeq) concept shall be adopted so that the variable heat flow through the envelope may be calculated using the steady heat flow equation:

$$q = A \times U_o \times TD_{eq}$$

The TDEq across the envelope takes into account the types of construction (mass and density), degree of exposure, time of the day, location, and orientation and design conditions.

For simplicity in OTTV calculations, the TDEq of different types of construction have been simplified and should be the values as follows:

TDeq for Walls:

TD_{eq} (C) = 26.7 - 0.0371 Wt Where Wt is in kg/m^2*

TD_{eq} (F) = 48.0 - 0.3257 Wt Where Wt is in lb/ft^2*

TDeq for ceiling/roof. see Table 3.1

Table 3.1

TD_{eq} for ceilings/roofs:

U/TC (s^{-1})	.360	.420	.480	.540	.600	.960	1.32	1.68	2.04	2.40	6.00
TD_{eq} (C)	16.7	19.5	22.2	25.0	27.8	30.6	33.3	36.1	30.9	41.7	44.4
U/TC (hr^{-1})	.006	.007	.008	.009	.010	.016	.022	.028	.034	.040	.100
TD_{eq} (F)	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0

TC = Specific heat x Density x Thickness

= (kJ/kg C) x (kg/m^3) x (m)/1000
= (BTU/lb P) x (lb/ft^3) x (ft)

U = Overall U-value of roof assembly

TC is calculated as the rum of the TC's for each layer in roof construction

3.3.2. <u>Solar Factor</u>

The OTTV calculations requires a solar factor for glazing areas. The solar factor value for vertical surfaces for Pakistan should be taken as specified in Table 3.2. For a given orientation the solar factor may be taken from the following:

* Note: For weight of construction mass more than 489 Kg/m^2 (100 lbs/ft^2)
The value TD_{eq} should be taken as 8C (14F)

Table 3.2

Solar Factor for Walls and Roofs
W/m^2 ($Btu/h.ft^2$)

CLIMATE ZONE *	N	NE NW	E W	SE SW	S	ROOF
1	117 (37)	450 (143)	561 (178)	350 (111)	135 (43)	471 (150)
2	110 (35)	432 (137)	561 (178)	378 (120)	167 (53)	471 (150)
3	110 (35)	432 (137)	561 (178)	378 (120)	167 (53)	471 (150)
4	104 (33)	422 (134)	558 (177)	410 (130)	217 (69)	471 (150)
5	104 (33)	416 (132)	558 (177)	425 (135)	252 (80)	471 (150)

* See Appendix I

3.3.3 **Overall Thermal Transfer Value**

For the purposes of energy conservation, the maximum permissible OTTV shall be as per Table 3.3 for walls and ceilings/roofs.

TABLE 3.3

Maximum Overall Thermal Transfer Values

CLIMATE ZONE*	WALLS W/m^2	WALLS $Btu/hr.ft^2$	ROOFS W/m^2	ROOFS $Btu/hr.ft^2$
1	91	29	26.8	8.5
2	95	30	26.8	8.5
3	95	30	26.8	8.5
4	98	31	26.8	8.5
5	101	32	26.8	8.5

*** See Appendix I**

To calculate the OTTV for external walls, the following formula shall be used:

$$OTTV_w = \frac{(U_w \times A_w \times TD_{eq}) + (A_f \times SF \times SC) + (U_g \times A_g \times T)}{A_o}$$

Where $OTTV_w$ = Overall thermal transfer value for walls, (W/m^2)

A_w = Opaque wall area (m^2)

U_w = thermal transmittance of opaque wall (W/m^2)

TD_{eq} = Equivalent temperature difference C)

A_g = Glazing area (m^2)

U_g = Thermal transmittance of glazing (W/m^2C)

T = Temperature difference between exterior and interior design conditions (C)

SC = Shading coefficient of fenestration

SF = Solar/corrected solar factor (W/m^2)

A_d = Door area (m^2)

A_o = Gross area of the exterior surface (m^2) (that is, $A_w + A_g + A_d$)

Where there is more than one type of material and/or fenestration the respective term or terms shall be expanded into subelements.

$$(U_{w1} \times A_{w1} \times TD_{eq1}) + (U_{w2} \times A_{w2} \times TD_{eq2}) + --$$

The gross area of the exterior wall shall include all opaque wall areas, window areas and door areas where such surfaces are exposed to outdoor air and enclose conditioned space. The fenestration area shall be measured from extreme surfaces of window construction.

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

$$OTTV_r = \frac{(U_r \times A_r \times TD_{eq}) + (SF_s \times A_s \times SC) + (U_s \times A_s \times \quad T)}{a}$$

Where

$OTTV_r$ = Overall thermal transfer value for roofs (W/m^2)

A_r = Opaque roof area (m^2)

U_r = Thermal transmittance of opaque roof area (W/m^2C)

TD_{eq} = Equivalent temperature difference (C)

A_s = Skylight area

U_s = Thermal transmittance of skylight area (W/m^2C)

T = Temperature difference between exterior and interior design conditions (C) (refer to Appendix II)

SC = Shading coefficient of skylight

SF = Solar factor (W/m^2). This shall be taken as 471 W/m^2 or 150 $Btu/hr.ft^2$ on horizontal surface.

A_o = Gross area of ceiling/roof (m^2) (that is, A_r + A,)

The gross area A, shall include all opaque roof area and skylight area where such surfaces are exposed to outdoor air and enclose conditioned space. When more than one type of material and/or skylight is used, the respective term or terms shall be expanded into sub-elements as:

$$(U_{r1} \times A_{r1} \times TD_{eq1}) + (U_{r2} \times A_{r2} \times TD_{eq2}) + --$$

Walls at different orientations and roofs consisting of different sections facing different orientations receive different amount of solar radiation. To calculate the OTTV for the envelope of the whole building, it is necessary to compute first the OTTVs of individual walls, then the OTTV of the whole building is obtained by weighted average values as follows:

$$OTTV = \frac{(OTTV_{w1} \times A_{w1}) + (OTTV_{w2} \times A_{w2}) + --}{A_{Wl} + A_{w2} + -- A_{wn}}$$

Similarly for ceilings/roofs

$$OTTV = \frac{(OTTV_{r1} + A_{r1}) + (OTTV_{r1} \times A_{r2}) +}{A_{r1} + A_{r2}\ t\ ---\ A_{rn}}$$

The OTTV of walls should not be computed 'with that of roof. Each component should be treated separately.

3.4 Air Infiltration

The requirements of this section shall apply only to those building components separating outdoor conditions from indoor conditions.

To minimize the effects of air infiltration, all doors and openable sections of windows of air conditioned buildings shall be weatherstripped.

All fixed window sections and other penetrations through the wall shall be caulked or otherwise sealed with a permanent material, for air-conditioned buildings.

3.5 Natural Ventilation

Natural ventilation should be designed for effective ventilation regardless of wind direction. There should be adequate ventilation when the wind does not come from the prevailing direction.

To obtain adequate air flow and velocity inside the buildings, the position of the openings relative to wind direction and the position and size of openings in adjacent or opposite walls should be carefully designed.

Acceptable practice for building ventilation should be in accordance with ASHRAE Handbook of Fundamentals, Chapter 23, edition 1989.

The minimum area of windows which must be openable for the purpose of natural ventilation shall be the following percentage of areas mentioned in Table 3.3 of Chapter 3 of the Building Code of Pakistan.

Residential (Bed rooms, Drawing rooms, Dining rooms, Kitchens)	50%
Water Closet, Toilet, Bathroom Laundry, etc.	100%
Stairs, Utility	50%
Corridor, Stair etc.	50%

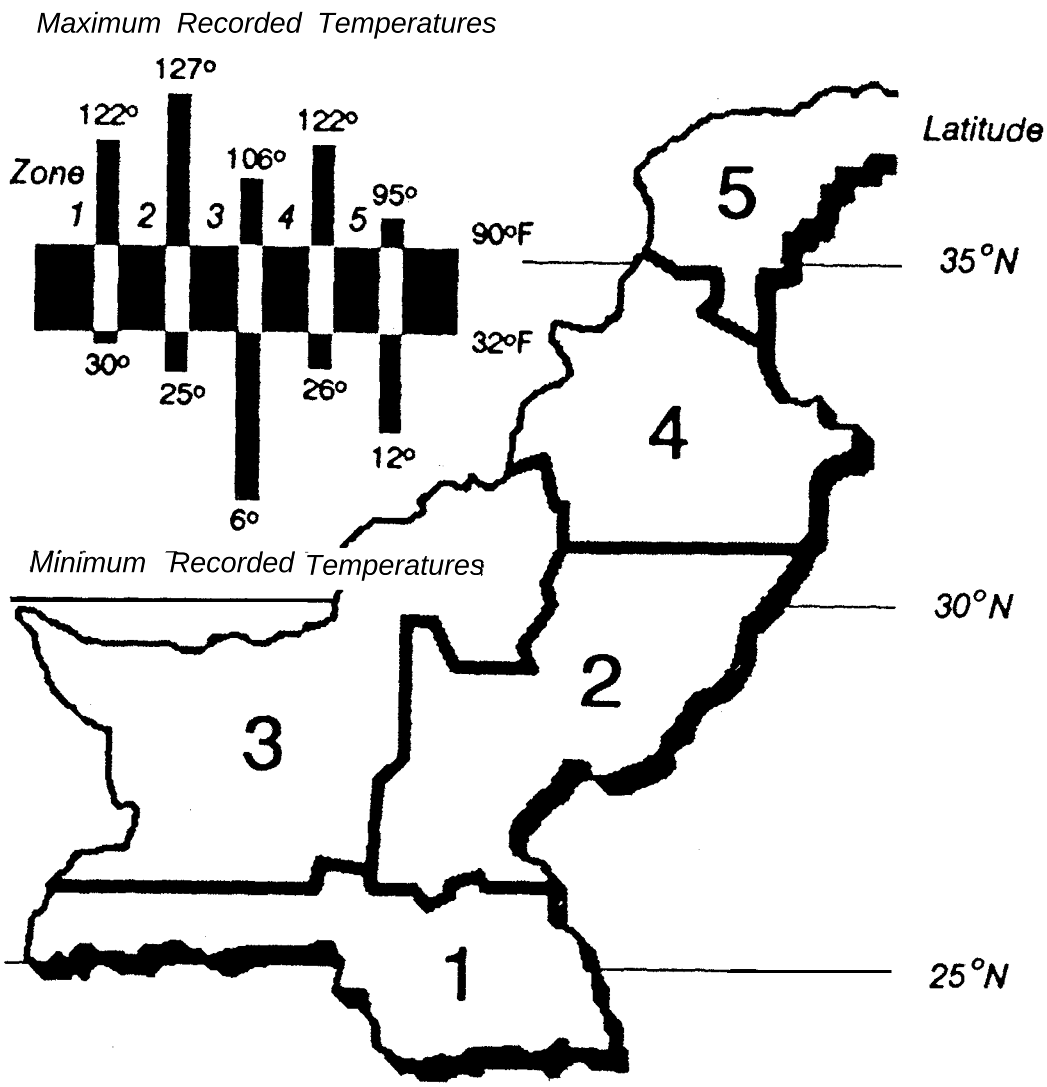
The total window area should be provided by at least two distinct windows which may be placed in adjacent or opposite walls. Each window should not have more than 70 percent of the total aperture area.

Wherever ceiling fans are used for cooling they should be of the blade diameter recommended in the Building Code of Pakistan, Table 9.6.

Whole house fans may be used for the purpose of ventilation and cooling. Where these are provided, they should be sized to provide a minimum of 20 air changes per hour for the entire house.

MAP OF CLIMATE ZONES AND LIST OF CITIES

Climate Zones of Pakistan



TOWNS AND CITIES IN CLIMATE ZONES
(IN ALPHABETICAL ORDER)

ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5
Badin	Bhawalnegar	Bela	Abbottabed	Chitral
Cauadar	Bhawalpur	Kalat	Bhakkar	Dir
Hyderabad	Chichawatni	Kharan	Bhalwal	Dassu
Jiuani	Chunian	Khuzdar	Chiniot	Gilgit
Karachi	Dadu	Loralai	Chakwal	Saidu Sharif
Mirpur Khan	D.G. Khan	Muslim Bagh	Charsada	Skardu
Pasni	Hasi lpur	Nushki	Daska	
Sanghar	Jacobabed	Pan j gur	Faisalabed	
Thatta	Kabiruala	Pishin	Fateh Jang	
Turbat	Kandiaro	Quetta	Gojra	
Uthal	Kashmore	Zhob	Gujranwala	
	Khai rpur		Guj rat	
	Khanewal		Haf izabad	
	Khanpur		Hassansbdal	
	Larkana		Haripur	
	Leiah		Islamabad	
	Lodhran		Jaranwala	
	Moro		Jauherabed	
	Multan		Jhang	
	Muzaffargarh		Jhel lum	
	Nauabshah		Kasur	
	Okara		Kharian	
	Pak Pattan		Khushab	
	Rajanpur		Kohat	
	Rahimyar Khan		Lahore	
	Sadiqabad		Mansehra	
	Sahiwal		Mardan	
	Shi karpur		Mianwali	
	Shorkot		Mirpur	
	Sibi		Muzaffarabad	
	Sujawal		Narowa 1	
	Sukkur		Noshera	
	Toba Tek Sing		Pasrur	
	Vihari		Peshawar	
			Rawalpirdi	
			Samundri	
			Sargodha	
			Shakargarh	
			Sialkot	
			Swabi	
			Talagang	
			Tangi	
			Wah	
			Wazirabad	

APPENDIX II

EXTERIOR DESIGN CONDITIONS*

City	Longi- tude East (deg.)	L a t i - tude North (deg.)	Eleva- tion above sea level m)	Summer: Design DB degree C 1%	Summer: Design DB degree C 2.5%	Summer: Design DB degree C 5%	Summer: Daily Range	Summer: Design WB degree C 1%	Summer: Design WB degree C 2.5%	Summer: Design WB degree C 5%	Winter: Design DB degree C 99%	Winter: Design DB degree C 97.5%	Av. Uind Vel. km/hr	Av. Uind Vel. km/hr Winter
Haripur	73	25	538.0	43.3	41.7	40.6	16.5	25.0	23.9	23.3	2.8	4.4	7.0	8.0
Hyderabad	68	33	30.0	45.0	42.2	41.1	15.0	28.3	27.2	26.7	5.6	7.8	16.0	24.0
Islamabad	73		591.0	43.9	41.7	39.4	13.3	28.3	27.2	26.1.	0.6	2.8	16.0	24.0
Jacobabad	68	28	56.0	46.7	44.4	43.3	15.0	28.3	27.2	26.1	7.2	8.9	3.0	10.0
Kalat	67	25	4.0	45.6	43.3	42.2	18.9	27.8	27.2	26.1	1.7	3.3	5.0	8.0
Karachi	74	32	214.0	41.1	40.0	35.0	11.1	29.4	28.3	27.8	6.7	9.4	24.0	24.0
Lahore	71	30	[illegible]	44.4	42.2	40.6	12.2	28.9	27.8	27.2	1.7	2.8	13.0	19.0
Multan	71	34	125.0	46.1	43.9	41.7	15.6	27.8	27.2	26.1	4.4	5.6	13.0	19.0
Peshauar		30	355.0	44.4	42.2	40.0	12.8	28.3	27.8	26.7	(-)0.6	0.6	16.0	24.0
Puetta	67	33	1580.0	37.8	35.0	34.0	12.8	23.3	21.7	20.6	(-)10.0	(-)6.7	13.0	29.0
Rawalpindi	73		508.0	44.4	42.2	40.0	13.3	27.8	27.2	26.1	0.6	2.8	16.0	24.0
Sukkur	69	28	67.0	43.3	41.7	40.6	12.8	28.3	27.2	26.7	7.2	8.9	5.0	7.0

* The terminology used in this Table is in accordance with ASHRAE Handbook For the purpose of calculating OTTV and HVAC system sizing in accordance with the Building Energy Code, the Summer 2.5% and Uinter 97.5% conditions shall be used.

INTERIOR DESIGN CONDITIONS

	COOLING	HEATING
Temperature:	26 C 79 F	21 c 70 F
Relative Humidity:	50%	40%

CONTENTS

Part 4 - HEATING, VENTILATING AIR CONDITIONING (HVAC) SYSTEMS

Part 4 - HEATING, VENTILATING AND AIR CONDITIONING (HVAC) SYSTEMS

4.1 8cope

This section provides the minimum requirements for design, sizing and control of space conditioning by heating, cooling and ventilation equipment. These requirements are in addition to those provided in the Building Code of Pakistan.

4.2 System Design

4.2.1 System sizing

For the purpose of sizing HVAC systems, the heating and cooling design loads shall include sensible and latent heat gain and loss from conduction, solar radiation, infiltration, ventilation and internal loads. The design loads shall be calculated according to the procedure described in the Building Energy Code Compliance Handbook or the procedures in the ASHRAE Handbook 1989 Fundamentals.

Interior and exterior design conditions shall be those shown in Appendix II.

4.2.2 Simultaneous Heating and Coolincr:

Use of simultaneous heating and cooling by reheating or recooling supply air or by concurrent operation of independent heating and cooling system serving a common zone shall be restricted as below:

(a) Recovered energy: Recovered energy in excess of the new energy expended in the recovery process may be used for the control of temperature and humidity.

(b) New energy for humidity control: New energy may be used to prevent relative humidity from rising above 60 percent for comfort control.

(c) New energy for temperature control: New energy may be used for temperature control if minimized in accordance with para 4.2.2.(c).1 through 4.2.2.(c).5.

1. Reheat system: Systems employing reheat and servicing multiple zones, other than those employing variable air volume for temperature control, shall be provided with a control that will automatically reset the system cold air supply to the highest temperature level that will satisfy the zone requiring the coolest air. Single zone reheat systems shall be controlled to sequence reheat and cooling.

2. Dual duct and multizone systems: These systems other than those employing variable air volume control, shall be provided with controls that will automatically reset:

   a. The cold deck air 'supply to the highest temperature that will satisfy the zone requiring the coolest air and

   b. The hot deck air supply to the lowest temperature that will satisfy the zone requiring the warmest air.

3. Recooling System: Systems in which heated air is recooled, directly or indirectly, to maintain space temperature shall be provided with control that will automatically reset the temperature to which the supply air is heated to the lowest-level that will satisfy the zone requiring the warmest air.

4. Multiple zones: For systems with multiple zones, one or more zones may be chosen to represent a number of zones with. similar heating/ cooling characteristics. A multiplezone system that employs reheating or recoolingfor control of not more than 2.36 m^3/s (5000 ft^3/min) or 20 percent of the total supply air of the system whichever is less, shall be exempt from the supply air temperature reset requirements of paragraph 4.2.2.(c).l through 4.2.2.(c).3.

5. Concurrent Operations: Concurrent operation of independent heating and cooling systems serving common spaces and requiring the use of new energy for heating and/or cooling shall be minimized by one or both of the following:

a. By providing sequential temperature control of both heating and cooling capacity in each zone.

b. By limiting the heat energy input through automatic reset control of the heating medium temperature (or energy input rate) to only that necessary to offset heat loss due to transmission and infiltration and, where applicable, to heat the ventilation air supply to the space.

4.2.3 Transport Energy:

(a) All air system:

1. The air transport factor for each all-air **HVAC** system shall not be less than 8.0. The factor shall be based on design system air flow for constant volume systems. The factor for variable air volume systems may be based on average conditions of operations. Energy for transfer of air through heat recovery devices shall not be included in determing the factor; however, such energy shall be included in the evaluation of the effectiveness of the heat recovery system.

$$\text{Air transport factor} = \frac{\text{Space ensible Heat Removed*}}{\text{Supply + Return Fan(s) Power Input*}}$$

* Both expressed in **same** units, either **watts** or **Btu/h**

2. For purpose of these calculations, Space Sensible Heat Removed is equivalent to maximum coincident design sensible cooling load of all spaces for which the system provides cooling. Fan Power Input is the rate of energy delivered to the fan prime mover.

(b) Other Systems:

Air and water, all-water and unitary systems employing chilled, hot, dual-temperature or condenser water transport systems to space terminals shall not require greater transport energy (including central and terminal fan power and pump power) than an equivalent all-air system providing the space sensible heat removal and having an air transport factor not less than 8.0.

4.2.4 Balancing:

HVAC system design shall provide means for balancing air and water systems. In doing **so,** the consideration shall include, but not **be** limited to, dampers, temperature and pressure test connections and balancing valves.

4.2.5 Controls

4.2.5.1 Temperature Controls:

Each system shall be provided with at least one adjustable thermostat for the regulation of the temperature. Each thermostat shall be capable of being set by adjustment or selection of sensors as follows:

(a) When used to control heating only: 13 C to 24 C (55 F to 75 F).

(b) When used to control cooling only: 21 C to 29 C (70 F to 85 F).

(c) When used to control both heating and cooling it shall be capable of being set from 13 C to 29 C (55 F to 85 F) and shall be capable of operating the system heating and cooling in sequence. The thermostat and/or control system shall have an adjustable deadband of upto 5.5

C (10 F) or more except as allowed in para **4.2.2.(c).5.** Deadband is defined as the temperature range in which no heating and cooling energy is used.

The recommended internal **dry** bulb temperature shall be 26 °C for summers and 21 °C for winters (see Appendix II).

4.2.5.2 Humidity Controls: If a system is equipped with a means for adding moisture to maintain specific selected relative humidities in space or zones, a humidistat shall be provided. The humidistat shall be capable of being set to prevent new energy from being used to produce space-relative humidity above 30 percent. When a humidistat is used in a system for controlling moisture removal to maintain specific selected relative humidities in spaces or zones, it shall be capable of being set to prevent new energy from being used to produce a space relative humidity less than 60 percent.

4.2.5.3 Zoning:

(a) Multifamily Dwelling: For multifamily dwellings, each individual dwelling unit shall be considered separately and shall have at least one thermostat for regulation of space temperature.

(b) All other types of buildings or occupancies: At least one thermostat for regulation of space temperature shall be provided for:

1. each separate system

2. each separate zone (see definitions). As a minimum each floor of a building shall be considered as a separate zone. In a multistory building where the perimeter system offsets only the transmission losses of exterior wall, an entire side of uniform exposure may be zoned separately. A readily accessible manual or automatic means shall be provided to balance the heating and/or cooling input to each floor.

c) <u>control Setback and Shut-off</u>

1. Multifamily Dwelling: The thermostat required in para 4.2.5.3(a) or an alternate means including, but not limited to switch or clock, shall provide a readily accessible manual or automatic means for reducing the energy required for heating and cooling during periods of non-use or reduced need including, but not limited to, unoccupied periods and sleeping hours. Lowering thermostat set points to reduce energy consumption of heating systems shall not cause energy to be expended to reach the reduced setting.

2. Other Buildings and Occupancies: Each system shall be equipped with readily accessible means of shutting off or reducing the energy used during periods on non-use or alternate uses of the building spaces or zones served by the system. The following are examples that meet requirement:

   Manually adjustable automatic timing devices

   Manual devices for use by operating personnel

   Automatic Control Systems

4.2.6 <u>Mechanical Ventilation:</u>

4.2.6.1 <u>Switches and **Dampers**</u>

Each mechanical ventilation system (supply and/or exhaust) shall be equipped with a readily accessible switch or other means for shut off or for volume reduction or shutoff when full ventilation is not required. Automatic or gravity dampers that close when the system is not operating shall be provided for outdoor air intake and exhausts. Automatic or manual dampers installed for the purpose of shutting off ventilation systems shall be designed with tight shutoff characteristics to minimize air leakage.

Exceptions: 1. Manual dampers for outdoor intakes may be used in the following cases:

a) For single and Multi-family residential buildings

b) Dampers are not required when ventilation air flow is less than **$0.047 m^3/s$** (100 **ft^3/min**).

4.2.6.2 Non-Residential Kitchen **Space**

a. Non-residential kitchen space must be designed with an exhaust air and make up air balance such that the space is never under a positive pressure, and never under a negative pressure exceeding .02 inch or 0.51 m.m. w.g. relative to all indoor spaces surrounding the kitchen space, during all cooking hours. NOTE: Makeup air in low volume exhaust hoods can be air that is conditioned by a unit dedicated to the hood exhaust system.

b. All exhaust and makeup air system components (fans, dampers, etc.) shall be interlocked in such a way that the balance prescribed in (a) above is maintained throughout all cooking hours, and all variations of cooking operations.

c. Net cooking exhaust from the kitchen space shall be the minimum possible consistent with positive performance, (i.e., capture, containment, and removal of all vapors and smoke produced in the cooking processes). Compensating hoods and reduced exhaust hoods should be listed or certified for lower net levels of exhaust, or have their performance demonstrated to the local authority having jurisdiction, at maximum cooking levels.

4.2.7 Air Duct System:

4.2.7.1 Duct Construction:

All duct constructions shall be in accordance with Part 13 of the Building Code of Pakistan.

4.2.7.2 Duct Insulation

All ducts and plenums installed in or on buildings (except as indicated below) shall be thermally insulated.

(a) All duct systems or portion thereof, shall be insulated to provide a thermal resistance as given in Tables 13.3, and 13.4 of the Building Code of Pakistan (Appendix III & IV).

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

1. Where Δt is 14C (25F) or less.
2. When the heat gain or loss of the ducts, without insulation, will not increase the energy requirements of the buildings.
3. Within HVAC equipment.
4. Exhaust air ducts.
5. Return Ducts installed within conditioned spaces.
6. Ducts used exclusively for evaporative cooling systems.

(b) The thermal resistance in para 4.2.7.2(a) does not consider condensation. Additional insulation with vapour barrier may be required to prevent condensation.

(c) Except where ducts are installed in or beneath concrete slabs in residential buildings, the minimum installed insulation value for ducts in unconditioned space is

$$R=0.74 m^2\ C/W\ (R=4.2\ ft^2.h.F./Btu)$$

4.2.8 **Pipe** Insulation:

All piping installed to serve buildings and within buildings shall be thermally insulated.

4.2.8.1 Insulation Thickness

The minimum pipe insulation thickness shall be as per table 4.0.

Table 4.0

Minimum Pipe Insulation Thickness

Piping System Types	Pluid Temperature Range °C	F	Insulation Thickness for Pipe Sizes* — Runouts 51 m.m. (2 in.**) m.m. in.	25 m.m. (1 in.) and Less m.m. in.	32/51 m.m. (1 1/4-2 in.) m.m. in.	64/102 □ .m. (2 1/2-4 in.1 m.m. in.	172/152 □ .m (5&6 in.) m.m. in.	(8 in.)and Larger m.m. in
Heating Systems								
Steam **& Hot** Water								
High **Pressure/Temp**	152-230	**306-450**	38 (1.5)	64 (2.5)	64 (2.5)	76 (3.0)	89 (3.5)	89 (3.5
Medium **Pressure/Temp**	122-151	**251-305**	38 (1.5)	51 (2.0)	64 (2.5)	64 (2.5)	76 (3.0)	76 (3.0
Low **Pressure/Temp**	94-121	201-250	25 (1.0)	38 (1.5)	38 (1.5)	51 (2.0)	51 (2.0)	51 (2.0
Low Temperature	49-93	120-200	13 (0.5)	25 (1.0)	25 (1.0)	38 (1.5)	38 (1.5)	38 (1.5
Steam Condensate (for Peed Water)	**Any**	**Any**	25 **(1.0)**	25 **(1.0)**	38 (1.5)	51 (2.0)	51 2.0	51 (2.0
Cooling Systems								
Chilled Water,	4.5-13	**40-55**	13 (0.5)	13 (0.5)	19 (0.75)	25 (1.0)	25 1.0	25 (1.0
Refrigerant, or **Brine**	**Below** 4.5	Below 40	25 (1.0)	25 (1.0)	**38** (1.5)	38 (1.5)	38 1.5	38 (1.5

*Pipe sizes are nominal dimensions. For piping exposed to ambient temperature, **increase** thickness by 0.5 in. or 13 **m.m.** In S.I. Units the pipes **manufactured** to **sizes indicated** or nearest size shall be used.

****Runouts** to Individual Terminal Units **(not** exceeding 12 ft or 3.9 **m.** in length)

Exceptions: Piping insulation is not required in the following cases:

(a) Piping installed within HVAC equipment

(b) Piping at fluid temperatures between 13C to 49C (55F to 120F) in condition spaces. In unconditioned spaces or outdoors, insulation shall be required.

(c) When the heat loss and/or heat gain of the piping, without insulation, does not increase the energy requirement of the buildings.

4.2.8.2 Other Insulation Thicknesses: Insulation thicknesses in Table 4.0 are based on insulation having thermal resistance in the range of 0.028 to 0.032 m^2 C/W.mm (4.0 to 4.6 ft^2.h.F/ Btu.in) on a flat surface at a mean temperature of 24C (75F). Minimum insulation thickness shall be increased for materials haling R values less than 0.028 m^2.C/W.mm (4 ft^2.h.F/Btu.in) or may be reduced for materials having R-values greater than 0.032 m^2 C/W.mm (4.6 ft^2.h.F.Btu.in).

(a) For materials with thermal resistivity greater than 0.032 M^2.C/W.mm (4.6 ft2.h.F/But.in) the minimum insulation thickness may be reduced as follows:

$$\text{New Minimum Thickness} = \frac{0.032 \times \text{Thickness in table 3.3.9}}{\text{Actual R}} \quad \text{S.I. Units}$$

$$= \frac{4.6 \times \text{Thickness in table 3.3.9}}{\text{Actual R}} \quad \text{Btu Units}$$

(b) For materials with thermal resistivity less than 0.028 M^2.C/ W.MM (4.0 ft^2.h.F/Btu.in) minimum insulation thickness shall be increased as follows:

$$\text{New Minimum Thickness} = \frac{0.028 \times \text{Thickness in table 3.3.9}}{\text{Actual R}} \quad \text{S.I. Units}$$

$$= \frac{4.0 \times \text{Thickness in table 3.3.9}}{\text{Actual R}} \quad \text{Btu Units}$$

4.2.8.3 Insulation for Condensation

The required minimum thicknesses do not consider condensation. Additional insulation with vapour barriers may be required to prevent condensation.

4.3 System and Component Efficiency

This section deals with the requirements of the equipment and mechanical component performance for heating, ventilating and air conditioning systems. It specifies the equipment and component efficiency levels. Suppliers of HVAC system equipment and components should furnish upon request by the system designers, contractors or prospective purchasers the input(s) and output(s) of all such HVAC products, based on new equipment and AR1 rating conditions, and should cover full load, partial load and standby conditions as required. This shall be used to determine their compliance under this code. The information should also include performance data under other modes of operation and at ambient conditions necessary to make detailed analysis in case of deviation from the specific design criteria under this code.

4.3.1 Electric Packaged Equipment (Cooling Mode)

The requirements in this section apply to, but are not limited to, unitary (central) cooling equipment; packaged systems with air-cooled, water-cooled and evaporatively-cooled condensers: the cooling mode "of unitary and packaged terminal heat pumps; air source and water source heat pumps; packaged terminal air conditioners; and room air conditioners.

Exception. These requirements do not apply to equipment serving areas such as refrigerated food display cases or other equipment contributing a large amount of heat to the area served.

The equipment standard' rating conditions shall be as specified in table 4.1. The energy efficiency ratio (EER) of the equipment and the coefficient of performance (C.0.P) as defined below shall be not less than specified in table 4.2.

Table 4.1

Rating Conditions for Packaged Equipment

		Room air entering equipment C(F)	Condenser Ambient C(F)	Refrigerant water hart exchanger C(F)
Air Cooled	Dry-Bulb	26.7 (80)	35 (95)	
	Wet-Bulb	19.4 (67)	23.9 (75)	
Water Cooled (Water-Source)	Inlet			29.4 (85)
	outlet			35 (95)

Table 4.2 Minimum C.O.P/EER cooling (Performance at sea level)

Standard Rating Capacities		C.O.P.	ERR
19 KW (65,000 Btu/h) and over	Air Cooled	2.40*	8.2*
	Evaporation or Water Cooled	2.69	9.2
Under 19 KW (65,000 Btu/h)	Air Cooled	2.28	7.8
	Evaporative or Water Cooled	2.58	8.8

* This applies when return air fans are not included under the manufacturers model. When return air fans are included the required minimum values are 2.34 (C.O.P); 8 (ERR)

Coefficient of Performance (COP) for packaged equipment in cooling mode is the ratio of the rate of net heat removal to the rate of total on-site energy input to the air conditioner, expressed in consistent units and under designated rating conditions. (Table 4.1)

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

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

4.3.2 Electrically Operated HVAC System Components (Cooling Mode)

HVAC system components where energy input is entirely electric shall have standard rating conditions and energy efficiency ratios and C.O.P. as indicated in .the following tables:

		Tables
(a)	Standard rating conditions for Water Chillers and hydronic system water-source heat pumps	4.3
(b)	Standard rating conditions for Condensing units.	4.4
(c)	Applied HVAC system component efficiency.	4.5

Table 4.3

Rating Conditiona for Reciprocating Chillers and Water-Source Beat Pumps

Conditions		Self Contained Reciprocating Heater-Chilling Package	Condenserless Reciprocating Chilling Package	Hydronic System Water-Source Pump
Leaving Chilled Water Temp		6.7C (44F)	6.7C (44F)	-
Entering Chilled Water Temp		12.2C (54F)	12.2C (54F)	-
Leaving Condenser Water Temp		35c (95F)	-	35.0C (95F)
Entering Condenser Water Temp		29.4C (85F)	-	29.4C (85F)
Fouling Factor Water (i) Non Ferrous Tubes		$9x10^{-5}$ $M.^2K/W$ ($5x10^{-4}$ $ft.^2h.F/But$	$9x10^{-5}$ $M.^2K/W$ ($5x10^{-4}$ $ft.^2h.F/But$	-
(ii) Steel Tubes		$18x10^{-5}$ $M.^2K/W$ $10x10^{-4}$ $ft.^2$ h.F/Btu)	$18x10^{-5}$ $M.^2K/W$ $10x10^{-4}$ $ft.^2$ h.F/Btu)	- -
Fouling Factor Refrigerant		0.0	0.0	-
Condenser Ambient	Air or Evap - Cooled Condenser	3iC (95F) DB 23.9C (75F) WB		
Compressor Saturated Discharge Temperature	Water or Evap - Cooled	-	40.6C (105F)	-
	Air-Cooled		48.9C (120F)	
Refrigerant Liquid Temperature	Water or Evap - Cooled		35C (95F)	
	Air-Cooled		43.4C (110F)	
Air Temperature Surrounding Unit				26.7C (80F)

The rate of net heat removal from the component is defined as the difference in total heat contents of the water or refrigerant entering or leaving the components.

The total on site-energy input to the component shall be determined by combining the energy inputs to all elements and accessories as included in the component including but not limited to compressor(s), internal circulating pump(s), condenser air fan(s), evaporative condenser cooling water pump(s), purge devices, and HVAC system component control circuit.

4.3.3 Heat Operated Equipment (Cooling Mode)

Heat operated cooling equipment shall have a C.0.P for Cooling not less than shown in table 4.6 when tested at standard rating conditions shown in table 4.7. These requirements apply to but are not limited to, absorption equipment, engine driven equipment and turbine driven equipment.

The C.0.P is defined in the foot notes of table 4.6 and excludes electrical auxiliary equipment. However this electrical energy should be included in a calculation of the total HVAC system C.O.P.

A feasibility study for cogeneration system may be considered where absorption machines are to be used.

Table 4.6
Efficiency of Heat Operated Equipment

Heat Source	Minimum C.O.P*
Gas Engine Driven	1.25
Direct Fired (Gas, Oil)	0.48
Indirect Fired (Steam, Hot Water)	0.68

*Minimum C.0.P = $\frac{\text{Net Coolina Output}}{\text{Total Heat Input}}$
(Electrical auxiliary inputs excluded)

Table 4.4

Rating Conditions for Condensing Units

	Temperatures			
	DB	WB	Inlet	Outlet
Air entering equipment	26.6C (80F)	19.4C (67F)		
Condenser Ambient (air cooled)	35C (95F)			
Condenser Water (water cooled)			29.4C (85F)	35C (95F)

Table 4.5

System Component Efficiency (at sea level)

		Condensing Means					
	Type of	Air		Water		Evaporative	
Component	Compressor	C.O.P	EER	C.O.P	EER	C.O.P	EER
Self Contained Water Chillers	Centrifugal	2.34	8.0	0.04	13.8		
	Positive Displacement	2.46	8.4	3.51	12.0		
Condenserless Water Chillers	Positive Displacement	2.9	9.9	3.51	12.0		
Compressors and Condenser Units 19 KW (65000 Btu/h) and over	Positive Displacement	2.78	9.5	3.66	12.5	3.66	12.5

Coefficient of Performance (COP) for system components in cooling mode is the ratio of the rate of net heat removal to the rate of on-site energy input, expressed in consistent units and designated rated conditions.

Table 4.7

Rating Conditions for Heat Operated Equipment

Standard Rating Condition	Heat Source: Direct Fired (Gas, Oil)	Heat Source: Indirect Fired (Steam, Hot Water)
Air Conditioners	**Temperatures**	Temperatures
Entering Conditioned Air	26.7C (80F) DB 19.4C (67F) WB	-
Entering Condenser Air	35C (95F) DB 23.9C (75F) WB	-
Water Chillers		
Leaving Chilled Water	7.2C (45F)	6.7C (44F)
Fouling Factor		0.00009 M^2 K/W (0.0005 ft^2.h.F/Btu)
Entering Chilled Water	Per Mfgr. Spcc.	12.2C (54F)
Entering Condenser Water	23.9C (75F)	29.4C (85F)
Fouling Factor		0.00018 M^2.K/W (0.0010 ft^2.h.F/Btu)
Condenser Water Flow Rate	-	per Mfgr. Spcc.

4.3.4 Heat Pumps (Heating Mode&

Heat pumps where energy inputs are entirely electric shall have standard rating conditions indicated in table 4.8 and a coefficient of performance as defined below not less than the values shown in table 4.9.

Table 4.8

Rating Conditions for Heat Pumps (Heat Mode)

Conditions	Air Source		Water Source
Air Entering Equipment	21.1C DB (70F) DB		21.1C DB (70F) WB
Outdoor Unit Ambient	8.3C DB/6.1C WB (47F) DB/(43F) WB	-8.3C DBI-9.4 CWB (17F) DB/(15F) WB	
Entering Water Temperature			15.6C (70F)
Water Flow Rate			As Used in Cooling Mode

Table 4.9

Efficiency of Heat Pumps (Beating Mode)

Source & Outdoor Temperatures	Minimum C.O.P
Air Source 8.3C DB/6.1C WB (47F) DB I (43F) WB	2.7
Packaged Terminal (PTAC)	2.2
Air Source -8.3C DB/-9.4C WB (17F)DB / (15F) WB	1.0
Water Source 15.6C (70F)	3.0

Coefficient of Performance (COP) for heat pumps (heating mode) is the ratio of the rate of net heat output by ,the heat pump to the rate of total on-site energy input to the heat pump, expressed in consistent units and under designated rating conditions.

The rate of net heat output shall be defined as the change in total heat content of the air entering and leaving the equipment (not including supplementary heat).

Total on-site energy input to the heat pump shall be determined by combining the energy inputs to all elements, except supplementary heaters, of the heat pump including, but not limited to, compressor(s), compressor sump heaters, pumps, supply air fan(s), return-air fan(s), out door air fan(s), cooling tower fan(s) and HVAC system equipment control circuit.

The heat pump shall be installed with a control to prevent electric supplementary heater operation when the heating load can be met by the heat pump alone. Electric supplementary heater operation is permitted during transient periods, such as start ups, following room thermostat set point advance, and during defrost. A two stage room thermostat, which controls the supplementary heat on its second stage, shall be accepted as meeting this requirement. The cut-on temperature for the compression heating shall be higher than the cut-on temperature for the supplementary heat and the cut-off temperature of the compression heating shall be higher than the cut-off temperature for the supplementary heat. Supplementary heat may be derived from any source including, but not limited to, electric resistance heating, combustion heating, or solar or stored-energy heating.

4.3.5 Combustion Equipment

4.3.5.1 Efficiency

All gas and oil fired residential furnaces and boilers, all vented home equipment and commercial furnaces and boilers when tested in accordance with applicable U.S DOE furnace test procedures or equivalent accepted procedure, shall have not less than the minimum steady state combustion efficiency specified in table 4.10.

Combustion efficiency of furnaces and boilers is defined as 100 percent minus stack losses in percent of heat input. Stack losses are:

a) **Loss due to sensible heat in dry flue gas**

b) **Loss due to incomplete combustion**

c) **Loss due to sensible heat and latent in moisture formed by combustion of hydrogen in fuel.**

Table 4.10

Efficiency of Combustion Equipment

Type of Equipment	Residential/Commercial Furnaces with inputs 65.9KW (225,000 Btu/h) and less Boilers with inputs 87.8KW (300,000 But/h) and less	All other Commercial & Industrial Furnaces L Boilers
Forced Air Furnaces	75	75
Low Pressure Steam or Hot Water Boilers	80	SO
Gravity Central Furnaces	69	-
All other vented heating equipment	69	-

4.3.5.2 **Adequate** <u>Combustion Air:</u>

a) **For residential and commercial installations with inputs under 117 KW (400,000 Btu/h), it is the system designer's responsibility either to establish that the total minimum calculated infiltration rate will provide sufficient combustion air for full-fired equipment or to provide positive means for introducing adequate outdoor air for that purpose.**

b) For installations with input 117 xw (400,000 Btu/h) and over, a machine room, or boiler or furnace room, or installation outdoors, shall be provided as required to ensure adequate outdoor air supply and to comply with the provisions of Building Code of Pakistan.

4.3.6 Maintenance:

Equipment and Components which require preventive maintenance for efficient operation should have complete maintenance information. Routine maintenance action should also be clearly stated. At least one copy of the information for preventive and routine maintenance should be furnished by the manufacturer to the owner and systems designers upon reguest.

INSULATION OF DUCTS

DUCT LOCATION	DUCT LENGTH (m) 0 to 20	21 to 45	46 and longer
	Type of Insulation*		
2	3	A	5
Roof or exposed to outside air	c+w	c+w	c+w
Between floor spaces, under floor spaces and basements, above false ceilings	A+W**	B+W**	c+w**
Within the conditioned space		None required***	
Encased in concrete		None required	

* For description of insulation types A,B,C & W, see Appendix IV

** W is required only on cooling and cooling/heating applications.

*** When the design dry bulb temperature of fluid inside the duct is below the dewpoint temperature of air surrounding duct then the A+W type of insulation shall be used.

(Table 13.3 of the Building Code of Pakistan)

APPENDIX IV

TYPES OF INSULATION

Type of Insulation		Material	Minimum Density Kg/cu. cm	Minimum Thickness mm
1		2	3	4
A	i)	Fibre glass or rockwool	10.4	12
	ii	Expanded polyestrene*	24	12
B	i)	Fibre glass or rockwool	10.4	25
	ii)	Expanded polyestrene*	24	25
C	i)	Fibre glass or rockwool	12	50
	ii)	Fibre glass or rockwool	24	25
	iii)	Expanded polyestrene*	24	38
W		Approved weather proof vapour barrier		

* Expanded polyestrene shall only be used in spaces where:

(1) Requirement of Part 4 "Fire Safety" of the Building Code of Pakistan would otherwise not prohibit the use of polyestrene for other uses.

(2) Temperature of the fluid in the duct or piping will not exceed 65 degree C.

(3) Temperature of the duct metal will not exceed 65 degree C due to heat generating sources installed in ducting such as electric heaters.

(Table 13.4 of the Building Code of Pakistan)

CONTENTS

Part 5 - LIGHTING

Part 5 - **LIGHTING**

5.1 **Scope**

This section describes recommendations and requirements for interior and exterior electric lighting and recommendations for daylighting within buildings. The requirements of this section are in addition to those given in Part 9 of the Pakistan Building Code.

5.2 General

Lighting not only uses a significant proportion of the electricity consumed in most buildings but also contributes a large portion of the cooling load in air conditioned buildings. As such, lighting installation should be carefully designed so as to achieve the desired illumination level and visual effect with a minimum requirement of energy. This can be achieved by limiting the installed lighting power load through the use of efficient lighting equipment and the maximum utilization of daylight. Where appropriate, return air may be exhausted through the lighting fixture to increase its output.

5.2.1 **Light** Source

The choice of light source depends on the nature of the installation and the specific task performed. The designer should be able to make the appropriate choice from the many types of lamps available. High lamp efficiencies are necessary to ensure a low installed lighting load. Recommended minimum lamp efficiencies are given in Table 5.0

Table 5.0

Recommended Minimum Lamp Efficiencies

Type of Lamp	Minimum Efficiency (Lumens per Watt)
1 Fluorescent (above 32W)	60
2 Fluorescent (32W and below)	35
3 Mercury	36
4 Metal Halide	60
5 High Pressure sodium	65

5.2.2 **Luminaires**

While it is essential in the design of an energy efficient lighting system to use the correct type of light sources, it is equally important to select the right type of luminaires that are efficient, have light distribution characteristics appropriate for the tasks and the environment, and not produce discomfort, glare or serious reflection. The most efficient luminaires for fluorescent lamps that at the same time meet the requirements of glare limitation are the mirror reflector or prismatic type, whereas for high-pressure discharge lamps, luminaires should have high quality anodized aluminum reflectors.

In general, only luminaires of high efficiency having a high downward light output ratio should be used. The design of fluorescent luminaires should be such that the tube wall temperature is kept cool through return air flow, in air-conditioned building.

The use of instant-start, low loss, and solid-state ballasts may be considered in fluorescent and other luminaires. All luminaires should be power factor corrected to a value greater than 0.90.

5.3 Exterior Liahting

5.3.1 Incandescent Liahting

Incandescent lighting shall not be used for exterior lighting except for special cases including temporary decorative lighting, places where low lighting levels are needed and other applications that could not be met by other lighting types. Single family residences are excluded from this requirement.

5.3.2 Facade **Liahting**

Facade lighting shall be no greater than 2 percent of the total electrical interior load of the building. Additional exterior security lighting may be added if required.

5.3.3 Automatic Timers and Sensors

All exterior lighting shall be controlled by automatic timers or sensors to assure turnoff during daylight hours. Single family residences are excluded from this requirement.

5.4 Interior Liuhting

Incandescent lighting shail not be used for area lighting. However, localized incandescent lighting may be used in areas for special tasks or for commercial display. All residential units and rooms designed primarily as living area (e.g. hotel rooms, hospital rooms, etc.) are excluded from this requirement.

5.5 Davlighting

5.5.1 Advantaqes

Making adequate use of natural light is one of the most important ways to reduce the building's energy load. Daylight is an efficient and economical light source - its cost being limited to the construction and maintenance of windows. It has additional advantages in that its provision can be combined with windows for natural ventilation and view; and it is generally preferred to artificial lighting because of its better color rendition.

5.5.2 Considerations

In designing a building for daylight, careful consideration should be given to the following factors:

a) Glazing reduces the thermal performance of the wall. If necessary, the thermal performance of the glazing may need to be upgraded by installing sunshading devices and/or double glazing.

b) The availability of daylight varies considerably from day to day and even from minute to minute. This may make it difficult to adjust internal light levels with artificial light. There may thus be a need for automatic switching.

c) Glare problems may be more difficult to deal with, as glare from daylight may come from several sources - direct sun, bright sky, external objects, sunlit translucent glazing panels, interior decor, etc.

5.5.3 Daylight Factor

The quantity of daylight in an interior can be specified by the "Daylight **Factor".** It is the ratio of the illuminance at a point inside to the illuminance on an unobstructed horizontal plane outside under a specified distribution of sky luminance, direct sunlight being excluded from both measurements.

5.6 Switching and Control

Energy used for lighting purposes is a product of the lighting load and the hours of use. Thus, individual switching of small groups is desirable to allow unnecessary lights to be switched off while permitting the others to be used. This will result in lower operating cost. The following points shall be considered in the design of switching to control lighting:

i) Lighting in task areas larger than $10m^2$ shall be provided with controls so that the lighting can be reduced by at least half when the task is not performed or relocated.

ii) Except for enclosed stairways and corridors used by the public, switches should be provided at accessible locations within sight of the light they control.

iii) Where lighting switches are grouped, they should be suitably identified to indicate the area controlled by each switch.

iv) Luminaires should be switched in row parallel to the windows, so that the rows of lights near to the windows can be turned off (manually or automatically) when daylighting is adequate.

v) Where task lighting is installed, such lighting should be provided with switches located adjacent to the work station.

Residential buildings and areas within buildings designed as living space are excluded from this requirement.

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