Addis Ababa University
School of Graduate Studies

TRANSINT ANALYSIS OF COOLING LOAD OF A SINGLE ZONE BUILDING

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A thesis submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the Degree of Masters of Science in Mechanical Engineering (Thermal Engineering stream.)

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Abstract

Cooling load calculation is the major work performed in the air-conditioning system design. This should be performed as accurately as possible to reduce over design or under design of the system. Some of the factors that influence results of cooling load are heat gain through wall and glass, infiltration of atmospheric air, ventilation, appliances load, and occupancy.

The objective of this thesis is to develop a user-friendly program that can easily calculate space-cooling load of a single zone system taking some of the basic inputs like latitude, longitude time zone, building materials and other metrological data of the location.

This thesis uses finite difference method for computation of transient heat conduction through the wall and roof. Implicit finite difference method is chosen for its stability.. To make the developed program more friendly, number of commonly used construction materials with their thermal properties are inbuilt in the program. Infiltration effect in the total cooling load is also discussed in detail. Various experimental data and graphs are used for determining the infiltration rate.

Heat gain through window is calculated by taking solar heat gain coefficients (SHGC) of the various combinations of glass used. Various types of glass and glass combination with their thermal properties are also inbuilt in the program.

The components of heat gain are finally categorized under convective and radiant portion. The convective portions are taken as cooling load. The radiant portions are changed to

cooling load by multiplying them with radiant time factors. Beside the project uses number of assumptions proposed by ASHRAE for its calculation of heat gain and cooling load. All the above-mentioned influencing factors of cooling load calculation are dealt in-depth in the thesis in chapter 3 4 5 and 6.

The results found are verified with results found in other literatures. Finally cooling load of an actual building in Gode is computed using the developed program.

CHAPTER 1

INTRODUCTION

The main objective of air conditioning is to maintain the conditions that are

a. conducive to human comfort, or
b. necessary for a product or process within the conditioned space.

Thus, equipment of proper capacity has to be installed and controlled throughout the year. To select a properly sized cooling unit, the peak or maximum load (block load) for each zone must be computed. Because this peak load may vary considerably for different types of buildings each building type has to be considered; the block load for a single family detached house with one central system is the sum of all the room loads. If the house has a separate system for each zone, cooling load for each zone (i.e., the sum of all the loads for all rooms in each zone) is required. When a house is zoned with one central cooling system, the block load must be computed for the complete house as if it were one zone. Apartment buildings with a central cooling system require a block load calculation for the complete structure to size the central system.

For the purpose of estimation, it is essential that comprehensive survey should be made to ascertain as far as possible, the precise evaluation of the components of the load. Economic equipment selection and system design can be made if the actual instantaneous loads within a given mass of a building are carefully determined. Then the operation can be smooth and trouble free.

The actual load is defined as the amount of heat that is instantaneously added or removed by the heating ventilating and air conditioning (HVAC) system. The heat gain or loss is the amount of heat instantaneously coming into or going out of the conditioned space. It may be noted that actual load and the instantaneous heat gain will not be equal due to storage effects or thermal lag of the building structure.

1.1 Building survey

Space characteristics and heat load sources. The very foundation of the heat load estimate depends upon very precise survey of the heat load components of the conditioned space. The complete drawings, mechanical and architectural, and field sketches and some time photographs of important aspects are part of good survey. The following physical aspects are worth considering:

a- Orientation of the building. This aspect defines the location of the conditioned space with respect to

- Compass points for sun and wind effects.
- The adjoining permanent structures for shading effects.
- Reflective surfaces like water, sand etc. for reflective heat loads.

b- Use of conditioned space. It may be used for office, or hospital, or some speciality shop, factory, machine shop, residence, etc.

c- Physical dimension of spaces. Length, width and height is recorded.

d- Ceiling height. The clearance between the false ceiling and the roof, and floor-to-floor height or floor to ceiling height may be noted down.

e- Columns and beams. Size and depth of columns and beams and any other special constructional features may be noted.

f- Construction materials. The materials of construction used, thickness of walls and roofs, ceiling, floors and partitions and their location in the building structure are noted.

g- Surrounding conditions. Whether the adjoining spaces are conditioned or unconditioned and the temperature of un-conditioned adjacent spaces such as furnaces or boiler room or kitchen.Also the outside color of walls and roofs,surface finish and the extent of shaded or sunlit portion has to be recorded.

h- Windows. Size and location of windows, whether wooden or metal sash, whether single or double hung is to be recorded. The type of glass used and whether single or multipane is to be noted. Also the type of shading on it and the dimensions of reveals and overhangs must be noted.

i- Doors. Location, type, size and frequency of the opening must be recorded.

j- People. The number of people, their duration of occupancy, their nature of work activity and any special features like concentration at any place in the conditioned space must be noted.

k- Lighting. The load in watts at peak, the nature of load incandescent, florescent etc must be noted.

l- Motors. Location, name plate and brake power and the usage must be noted.

m- Appliances. Location, rated wattage, steam or gas consumption, or any exhaust air quantity required for the appliances must be considered.

n- Ventilation. Cubic meter per minute (cmm) per person per square meter required, smoking or odor removal needed and the types of exhaust fans with size, speed and cmm delivery may be noted.

o- Thermal storage. System scheduled operation in hours (such as 8,12,16 or 24 hours), permissible temperature swing during design day, the nature of furniture and carpeting and other surface materials in the space must be noted.

p- Continuous and intermittent operation. Whether the plant has to operate every day of the season or only occasionally as in churches and ballrooms.

1.2 Air Conditioning Load Estimation

A cooling load calculation determines total sensible and latent cooling load due to heat gain

a. Through structural components (walls, floors and ceilings);
b. Through windows;
c. Caused by infiltration and ventilation; and
d. Due to occupancy, lighting and equipments.

The above four components will be discussed in detail in the coming four chapters 3, 4, 5 and 6, respectively.

1.3 Literature Review

Cooling load calculations are the major work performed in the air-conditioning system design. This should be performed as accurately as possible to reduce over design or under design of the system. Building heat transfer mechanisms are complex and as unpredictable as the weather and human behavior, both of which strongly influence load calculation results.

Some of the factors that also influence results are heat gain through wall and windows, infiltration of atmospheric air, ventilation, appliances load, and occupancy.

These factors combine to force engineers to develop procedures that minimize the load calculation complexity without compromising accuracy. A combination of measured data and detailed simulations have generated techniques that can be done with a pocket calculator and a one-page form or more complex numerical simulations that take hours to complete using modern computers. However, many assumptions and simplifications must be made for all methods.

To determine cooling load, various softwares have been developed that involve different assumptions. Among the recent and famous ones Energyplus, BLAST, IBLAST, Hourly, DOE-2 are worth mentioning. The above softwares differ each other in the treatment of the heat gain and in the conversion of the heat gain in to cooling load.

Softwares like Energyplus, BLAST, IBLAST and HBFort use heat balance method for their calculation of cooling load [7]. Heat balance method implement the following basic assumptions:

- The air in the thermal zone is well mixed
- Uniform surface temperatures
- Uniform long wave (LW) and short wave (SW) irradiation
- Diffuse radiating surfaces

- One-dimensional heat conduction within the wall.

Within the frame work of the above mentioned assumption heat balance method treat the whole problem by dividing the various heat gains into outside face heat balance, wall conduction process, inside face heat balance and air heat balance [4]. There are various methods for solving heat conduction in the wall. Energy plus uses conduction transfer function for the transient analysis of wall conduction. Windows are described layer by layer as solid panes (glass, plastic film, etc.) separated by gaps containing a gas fill (air, argon, krypton, etc.) in energyplus. Using Fresnel equations and taking inter-reflections between panes into account, the solar absorptance of each pane versus the angle of incidence and the solar and visible transmittance of the glazing system versus the angle of incidence are calculated in a preprocessor and fit to polynomials. In each time step heat balance is made on the effective inside and outside layers of the window as part of the overall heat balance calculation for the zone. The program accounts for the temperature dependence of the conductance of the gas fills, edge effects of glass, the presence of framing elements, and direct and diffuse solar shading by overhangs and other exterior obstructions. In a feature carried over from BLAST, EnergyPlus also tracks where solar radiation transmitted by the windows falls on the inside surfaces of the zone.

Hourly analysis program uses Transfer Function Method for solving heat conduction across the wall. The Transfer Function Method is the culmination of work first published in 1967 by two scientists working for the Canadian National Research Council. The method is based on an idea known as the "Response Factor Principle". This principle states that for a specific room, the thermal response patterns (i.e., how the heat gain is converted to load over a period of time) for each specific type of heat gain will always be the same. The Response Factor Principle is in turn based on three additional principles:

- The Principle of Superposition: The total room load is equal to the sum of loads calculated separately for each heat gain component.
- The Principle of Linearity: The magnitude of the thermal response to a heat gain varies linearly with the size of the heat gain.
- The Principle of Invariability: Two heat gains of equal magnitude occurring at different times will produce the same thermal response in a room.

These principles allow the simplification of the Heat Balance Method analysis for a building [9].

In DOE-2, thermal loads are calculated by applying room weighting factors [11], calculated in a preprocessor, to hourly instantaneous heat gains from solar radiation, conduction, lights and people/equipment. However, because the weighting factor method assumes time-invariant room properties, its accuracy is limited compared to the heat balance method, which allows time-varying properties. Some of the resultant limitations of the weighting factor method are:

- It assumes a constant value for inside air film conductance, which can over- or under-estimate the rapidity with which heat stored in the thermal mass of a zone appears as a load. In contrast, the heat balance method allows this conductance to vary with time depending on surface-to-air temperature difference, direction of heat flow and supply airflow rate.

- It assumes a constant distribution for solar radiation absorbed by inside surfaces [7].

Besides the above methods, previously there were other methods like Cooling Load Temperature Difference/Cooling Load Factor (CLTD/CLF) method. This method was suggested in ASHRAE 1997 handbook. But on the new versions like AHRAE 2001 handbook this methods are not discussed at all and has been replaced by heat balance method and radiant time series (RTS) method which is a simplified version of heat balance method with some limitations.

CHAPTER 2

SOLAR RADIATION

2.1 The Physics of Solar Radiation

The sun radiates energy as a black body having a surface temperature of about 6000^0C mainly over a spectrum of wavelengths 300-470nm. 9% of the energy is in the ultraviolet region but the rest is in the visible (380-780nm) and infrared part of the spectrum. Average radiation of solar radiation reaching upper limit of the atmosphere of the earth is 1370w/m^2, termed as solar constant. The orbit of the earth about the sun is an ellipse and the earth is slightly closer to the sun in January than it is in July. Consequently the solar constant has a maximum value of 1416W/m^2 in January and a minimum of 1323W/m^2 in July.

A total of only about 1025W/m^2 reaches the surface of the earth when the sun is vertically overhead in a cloudless sky. Of this, about 945W/m^2 is by radiation received directly from the sun, termed as beam or direct radiation, and the remainder being the radiation received indirectly from the sky, which is termed as diffused or scattered radiation.

The atmospheric losses in the direct radiation stem from:

i. Scattering which occurs when the radiation encounters the molecules of nitrogen and oxygen in the atmosphere. The effect is more pronounced for the short wave lengths, and accounts for the blue appearance of the sky.
ii. Scattering caused by molecules of water vapor and dust particles.
iii. Selective absorption by the molecules of ozone, carbon dioxide, water vapor etc.

The atmospheric losses in direct radiation produce the diffuse or sky radiation. There is a loss of direct radiation by reflection from upper surface of clouds. Some diffusion of the direct sunlight also occurs when direct or indirect radiation encounters cloud. A part of scattered radiation is lost of the space. However, a good deal of this radiation reaches the surface of the earth in a scattered form. This radiation cannot, however be assigned a specific direction, and hence, it casts no directional shadows outdoors.

The amount of scattered radiation varies with the time of the day, the variations of the moisture content, the cloud cover, the earth sun distance, the portion of the sky from which it is received, the angular relation of the receiving surface with respect to the surroundings, and the reflectance of the relevant surfaces [1].

2.2 Definitions of Terms

There are certain basic terms to describe the attributes of the solar radiation. These are defined below.

Wall solar azimuth (n)

This is the angle the horizontal component of the sun's ray makes with the direction normal to the wall, Fig 2.1. It can have a value between 0 and $\pm 90^o$. When the wall is in shadow the value of wall solar azimuth has no meaning.

Declination (δ)

This is the angular displacement of the sun north or south from the plane of the earth's equator, i.e. the angle between the sun earth center-to-center line and the projection of this line on the equatorial plane. The value of the declination will vary throughout the year between + 23 1/2^0 at the summer solstice to -23 1/2^0 at the winter solstice because the axis of the earth is tilted at an angle of about + 23 1/2^0 to the axis of the plane in which it orbits the sun.

Declination can be determined by

$$\delta = 23.45 \sin\left[360\left(\frac{(284+N)}{365}\right)\right] \tag{2.1}$$

where N is the day number, starting from January 1.

Longitude (LON)

Longitude is the angle that the semi-plane through the poles, and a particular place on the surface, makes with a similar semi-plane through Greenwich. The semi plane through greenwich is an arbitrary zero, and the line it makes in cutting the earth's surface is termed the Greenwich meridian. It is measured east or west of Greenwich and its value lies between 0^0 and 180^0.

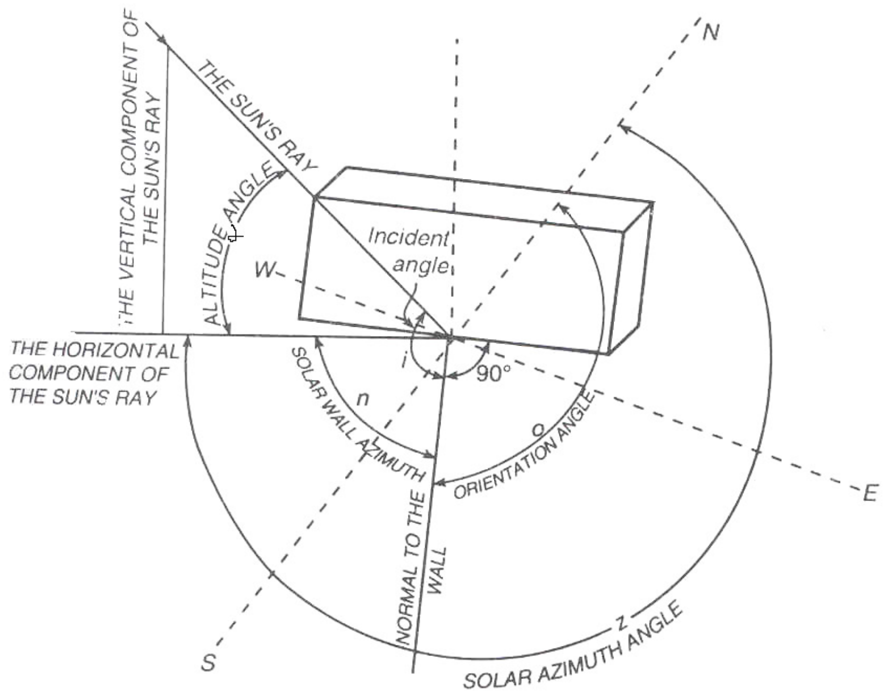

Fig 0-1 Angles related to solar radiation

Hour angle (H)

This is the angular displacement of the sun from noon.

$$H = 15(AST - 12) \tag{2.2}$$

$$AST = LST + ET/60 + \frac{(LSM - LON)}{15} \tag{2.3}$$

where AST- Apparent solar time

ET- equation of time, a factor which accounts for the difference between LSM and AST due to earths orbital effects and the values are given in Table 2.1.

LON- Local longitude

LSM- Local standard time meridian, computed by multiplying the number of hours difference between local time and Greenwich mean time by 15degrees/hour.

LST- Local standard time

Sun time is time in hours before or after noon. Noon being defined as the time when the sun is highest in the sky.

The sun time for any longitude does not always exactly equal the local mean time for that longitude.This is because the orbital velocity of the earth in its path about the sun is not constant, since the orbit is elliptical, not circular. The variation is the amount by which the sun time is different from the local mean time and varies from nearly -14 minutes to just over +15 minutes, depending on the month.

Solar altitude (α)

This is the angle a direct ray from the sun makes with the horizontal at a particular place on the surface of the earth, Fig 2.1**.**

The general expression for the altitude at any time of the day is

$$\sin\alpha = \sin\delta \sin L + \cos\delta \cos L \cos H \qquad (2.4)$$

where L- latitude of the location.

Azimuth of the sun (ϕ)

This is the angle the horizontal component of a direct ray from the sun makes with the true north–south axis. It may be expressed in degrees west or east of south in the northern hemisphere. But it is more commonly given as an angular displacement from south.

The equation for calculation of the azimuth of the sun is

$$\tan\phi = \frac{\sin H}{\sin L \cos H - \cos L \tan\delta} \qquad (2.5)$$

Incident angle (i) The sun angle of incidence (i) on the wall is the angle between the sun rays and the normal to the wall.

$$\cos i = \cos\alpha \cos n \sin\beta + \sin\alpha \cos\beta \qquad (2.6)$$

2.3 The Numerical Value of Direct Radiation

In order to evaluate the amount of solar radiation normally incident up on a surface, it is first necessary to know the value of the intensity, I, which is normally incident on a surface that is held at right angle to the path of the rays. The value of I can be established only by referring to experimental results for different places over the surface of the earth. These data seems to suggest that I_o is independent of the place and it only depends on the altitude of the sun. Intensity of direct radiation can be determined using:

$$I_o = \left[\frac{A}{\exp\left(\frac{B}{\sin\alpha} \right)} \right]^2 \qquad (2.7)$$

where

I_o - radiation in KW/m^2

A -the apparent solar radiation in the absence of an atmosphere and

B -an atmospheric correction factor.

A and B depends on seasonal variations in the earth sun distance, the atmospheric moisture content and dust pollution. The equation does not give the maximum intensity but the value likely on an average cloudless day: the maximum intensity of direct radiation on a very clear day can be 15% higher. Table 2.2 gives correction factor that accounts for the increased intensity with ascending altitude. On an average the direct radiation increases by about 2.5% for each 300m of height above sea level[1].

Table 0-1 Constants for determining the values of direct and scattered radiation at sea level

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
C(-)	0.058	0.06	0.071	0.097	0.121	0.13	0.136	0.122	0.09	0.07	0.06	0.057
A(W/m^2)	1230	1213	1186	1136	1104	1088	1085	1107	1152	1192	1220	1233
B(-)	0.142	0.144	0.156	0.18	0.196	0.21	0.207	0.201	0.18	0.16	0.15	0.142
ET(in deg)	-11.2	-13.9	-7.5	1.1	3.3	-1.4	-6.2	-2.4	7.5	15.4	13.8	1.6

2.4 Estimation of Average Solar Radiation

Radiation data are the best source of information for estimating average incident radiation. Lacking these or data from nearby location of similar climate, it is possible to use empirical relationships to estimate radiation from hours of sunshine or cloudiness. Data on average hours of sunshine or average percentage of possible sunshine hours are widely available from many stations and are usually taken with Campbell-Stokes instruments[12].

The measured and calculated solar radiation values can be related by the following simple empirical formula

$$I/I_o = a + b\left(\bar{n}/\bar{N}\right) \quad (2.8)$$

where I_o- the extraterrestrial radiation for the location,calculated

I- average hourly radition on a horizontal surface, measured

a and b- empirical climatic constants

$\bar{n}$- monthly average daily hours of bright sunshine

$\bar{N}$- maximum possible daily hours of bright sunshine and is given by

$$\overline{N} = \frac{2}{15}\cos^{-1}(-\tan L \tan \delta) \quad (2.9)$$

2.5 The Intensity of Direct Radiation on A Surface

If I is the intensity of direct solar radiation incident on a surface normal to the rays of the sun, then the component of this intensity in any direction can be calculated as illustrated below.

Case 1 The component of direct radiation normal to a horizontal surface (I_h) is, Fig 2.2 (a),

$$I_h = I \sin \alpha \quad (2.10)$$

where α is the angle of altitude of the sun.

Case 2 The component of the direct radiation normal to a vertical surface, I_v, as illustrated in Fig 2.2 (b).

The horizontal component I cosα is resolved in the direction at right angle to the vertical surface which has a particular orientation; that is the wall–solar azimuth angle of n. The component is

$$I_v = I \cos\alpha \cos n \tag{2.11}$$

Table 0-2 Percentage increase in direct solar radiation at varying heights above sea level[1]

Height above sea level	solar altitude in degree									
	10	20	25	30	35	40	50	60	70	80
1000	32	22	18	16	14	16	12	11	10	10
1500	50	31	26	23	21	18	16	15	14	14
2000	65	40	33	29	27	24	21	19	18	18
3000	89	52	43	37	34	31	27	24	23	22

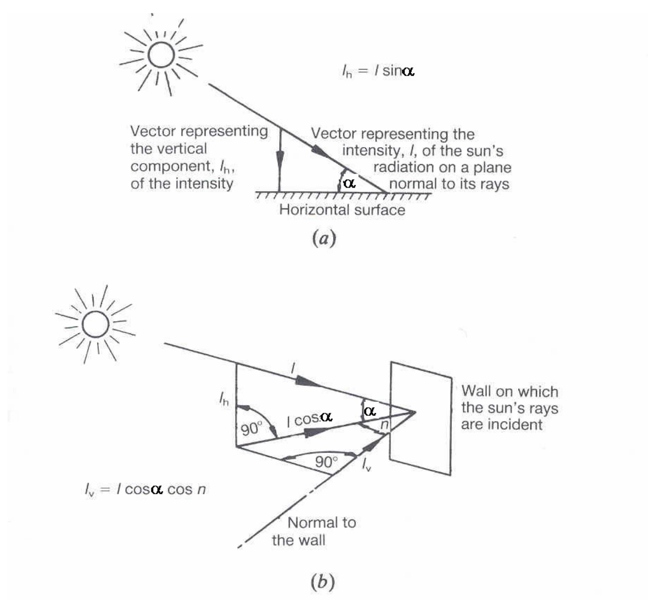

Fig 0-2 Components of solar radiation on horizontal and vertical surfaces

Case3 The component of direct radiation normal to a tilted surface (I_β)

[1] *Note: sky radiation decreases by approximately 30% at 1000m and by 60%at 1500m above sea level[1].*

The surface is tilted at an angle β, Fig 2.3, with the horizontal and has an orientation that gives it a wall solar azimuth angle of n.

Resolution of I in horizontal and vertical components is Icosα and Isinα. Further, the resolution of Icosα normal to a vertical surface is Icosαcosn. It follows that the rays normally incident on the tilted surface have a vector sum of Isinα and Icosαcosn in an appropriate direction. These components are Isinαcosβ and Icosα(cosn)(sinβ). Their sum is the total value of the intensity of radiation normally incident on the tilted surface.

$$I_{\beta} = I \sin\alpha \cos\beta \pm I \cos\alpha \cos n \sin\beta \qquad (2.12)$$

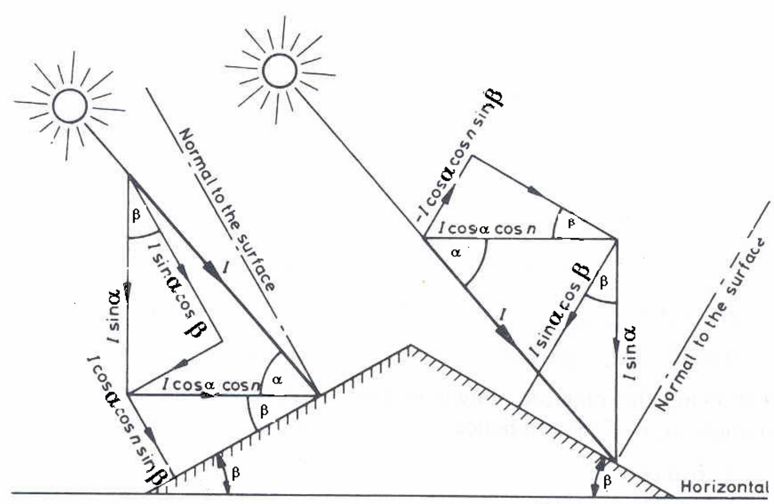

Fig 0-3 Resolution of direct radiation on an inclined surface

2.6 Numerical Values of Scattered Radiation

The ASHRAE Guide Book evaluates sky radiation reflected from surrounding surfaces under diffuse irradiance, I_d

$$I_d = CxYxI \text{, for vertical surface}$$

$$= CxIx\left(\frac{1+\cos\beta}{2}\right) \text{, for surfaces other than vertical} \qquad (2.13)$$

Ratio Y of sky diffuse on vertical surface to sky diffuse on horizontal surface is

for cos(i) > -0.2 $\quad Y = 0.55 + 0.437\cos i + 0.3013\cos^2 i \qquad (2.14)$

otherwise $\quad$ Y=0.45

Ground-reflected irradiance, I_r, is given by

$$I_r = I(C + \sin\alpha)\rho_g \frac{(1-\cos\beta)}{2} \qquad (2.15)$$

The value of constant C varies through the year and is given in table 2.1.

The reflectivity, ρ_g, of the ground depends on solar altitude and on the type of surface. Over the range of solar altitudes from 300 to 600 it has values of about 0.32 for new concrete, 0.22 for old concrete, 0.23 for green grass and 0.1 for asphalt.

2.7 Numerical Values of Total Solar Radiation on A Surface

The total amount of solar radiation, I_t, normally incident on an inclined surface is given by

$$I_t = I_\beta + I_d + I_r \qquad (2.16)$$

Effect Of Atmospheric Haze

This is most noticeable in industrial areas. It results from industrial contaminants carried aloft by thermal up-currents and is more pronounced in afternoon owing to the build up of ground surface temperatures. Haze can reduce the direct radiation so much that the radiation I may decrease by 15%.

2.8 Diurnal Temperature Variation

The energy received from the sun is the source of heat to the atmosphere and so the balance of heat exchanges by radiation between the earth and its environment, which is reflected in changes of air temperature, must vary according to the position of the sun in the sky. That is to say, there will be a variation of temperature against time [1].

On the average basis it is assumed that the dry bulb temperature follows a sinusoidal relationship with sun time. If we assume that the outside temperature, T_a, varies sinusoidally with time, θ, and its maximum value, Ta_{15} , occurs at 15h sun time we can write:

$$Ta_{\theta} = Ta_{15} - \frac{D}{2}\left[1 - \sin\frac{(\theta\pi - 9\pi)}{12}\right] \tag{2.17}$$

where D is the difference between the mean daily max and min temperatures, other wise termed diurnal range.

Symbols

n -wall solar azimuth
δ - declination
LON - longitude
H - hour angle
AST - apparent solar time
ET - equation of time
LON - local time
LSM - local standard meridian
LST - local standard time
α - altitude of the sun
L - latitude
ϕ - azimuth of the sun

i -incidence angle
I -direct irradiance
A -apparent solar radiation in the absence of the atmosphere
B - atmospheric correction factor
I_h - direct radiation normal to horizontal surface
I_v -direct radiation normal to vertical surface
I_β - direct radiation normal to any inclined surface
I_d - diffuse irradiance
I_r - ground reflected irradiance
I_t - total amount of solar radiation
T_a -hourly dry bulb temperature

CHAPTER 3

HEAT GAIN THROUGH STRUCTURES

Basically any building is composed of structures like walls, roofs, and floor. The heat transfer through wall and roof is similar as both structures are of the same nature and exposed to the same type of boundary conditions. For floors directly in contact with ground or over an underground basement that is neither ventilated nor conditioned, heat transfer may be neglected for cooling load estimates [1].

3.1 Heat Gain Through Wall

Wall and roof transmission loads account for heat transferred due to solar radiation striking the exterior surface of the wall, and due to the temperature difference between indoor and outdoor air.

Calculation of heat transfer through a wall section with a variable temperature in the outdoor environment and with a variable solar radiation input on the outside surface requires the heat conduction equation with non-linear, time dependent boundary conditions. The governing differential equation for this kind of conduction is

$$\frac{\partial T}{\partial \tau} = \frac{k}{\rho c}\left(\frac{\partial^2 T}{\partial x^2}\right) \tag{3.1}$$

where T- local temperature at a point in the slab

τ- time in second

$\frac{k}{\rho c}$-thermal diffusivity of the slab, m^2/sec

x- length in m.

At x=0, outside surface, the boundary condition is

$$-k_w A\left(\frac{\partial T}{\partial x}\right)_{x=0} = h_0 A\left(T_{a(\tau)} - T_{WO}\right) + Q_{r(\tau)} \quad (3.2)$$

where $Q_{r(\tau)}$ is the net solar radiation heat transfer to the exterior at a particular time.

In the above equation both T_o and Q_r are functions of time.

At x=L, the inside surface, the boundary condition is

$$-k_w A\left(\frac{\partial T}{\partial x}\right)_{x=L} = h_i A\left(T_{wi} - T_r\right) \quad (3.3)$$

The initial conditions for equations (3.1)-(3.3) are specified temperature distribution in the wall at time τ=0.

The non-linear, time dependent boundary condition at the outside surface is the primary obstacle in obtaining a solution to equation (3.2). To circumvent this difficulty the concept of the *sol-air* temperature is introduced [4]. The sol-air temperature is the fictious temperature that in the absence of all radiation exchanges gives the same rate of heat transfer to the exterior surface as actually occurs by solar radiation and convection. In terms of sol-air temperature the heat transfer to the outer surface is

$$Q_o = h_o A(T_e - T_{wo}) \quad (3.4)$$

In terms of the actual outdoor temperature T_a the heat transfer rate is

$$Q_o = h_0 A(T_a - T_{w0}) + \alpha A I_t - \varepsilon \Delta R A \qquad (3.5)$$

where ε -Emissivity of the surface

ΔR -Difference between long wave radiation incident on the surface from the sky and the radiation emitted from a black body at outdoor air temperature,W/m^2

α -Absorptance of the wall surface

I_t -Total incident solar radiation upon the surface, W/m^2

A-surface area.

Equations (3.4) and (3.5) may be combined to obtain

$$T_e = T_a + \frac{\alpha I_t}{h_o} - \varepsilon \Delta R / h_o \qquad (3.6)$$

The term $\varepsilon \Delta R / h_o$ varies from about zero for a vertical surface to about 4^{o}C for horizontal surface.

The ratio α / h_o varies from 0.026(m^2-^{0}C/W) for a light colored surface to a maximum of about 0.053m^2-^{0}C/W for a dark-colored surface or any surface for which the permanent lightness cannot be anticipated[4].

Horizontal surface

For horizontal surface that receive long-wave radiation from sky only an appropriate value of $\Delta R = 63 W/m^2$ is used.

Vertical surface

Because, the vertical surface receives long-wave radiation from the ground, surrounding buildings as well as the sky, ΔR can not be accurately evaluated. When solar radiation intensity is high, surfaces of terresterial objects usually have higher temperature than the outdoor air; thus, their long-wave radiation compensate to some extent, the sky's low long-wave radiation. Therefore common practice is to assume ΔR=0.

Note that the sol-air temperature given by equation (3.6) is time dependent because of variation of ambient temperature and solar radiation on the surface. However, the variation is approximately harmonic. The boundary equation given by equation (3.2) is greatly simplified by the sol-air temperature concept and becomes

$$-k_w\left(\frac{\partial T}{\partial x}\right)_{x=0} = h_0\left(T_{e(\tau)} - T_{WO}\right) \tag{3.7}$$

3.1.1 Numerical Analysis of the Basic Heat Equation

There are various methods to treat the basic heat equations numerically. Some of the famous methods are finite element method, finite difference method, transform methods and time series method[6]. From a computational standpoint; two methods that have been used widely are a finite difference procedure and conduction transfer function method. Besides giving surface temperatures, finite difference method gives the temperature distribution across the wall and this is one special advantage of it over conduction transfer function method. For the above-mentioned reason finite difference method is selected in this project.

The finite difference method involves discrete approximations of first derivative as follows

$$\frac{\partial \phi}{\partial x} \approx \frac{\phi_{i+1} - \phi_i}{\Delta x} \tag{3.8}$$

where the quantities at the right hand side are defined on the finite difference mesh. Approximations to the governing differential equations are obtained by replacing all continuous derivatives by discrete formulas such as those in equation (3.8). The relation between the continuous, exact, solution and the discrete approximation is shown in Fig 3.1 [2].

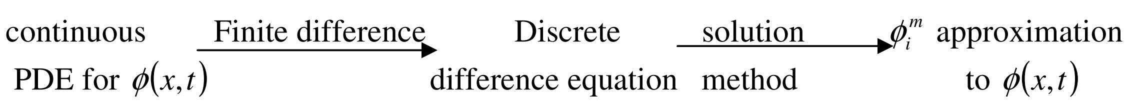

Fig 0-1 Relationship between continuous and discrete problems

Finite difference equations will be developed with the dependent variable ϕ as a function of only one independent variable, x, i.e $\phi = \phi(x)$. The resulting formulas will then be used to approximate derivatives with respect to time or space.

It is possible to solve the above heat conduction equation together with its boundary equations using methods like forward difference, backward difference and Crank-Nicolson.

Due to numerical instabilities of forward difference method and numerical oscillation of Crank-Nickolson methodm, the backward difference method is used in this work.. using backward difference, the PDE of heat conduction is discretized as follows.

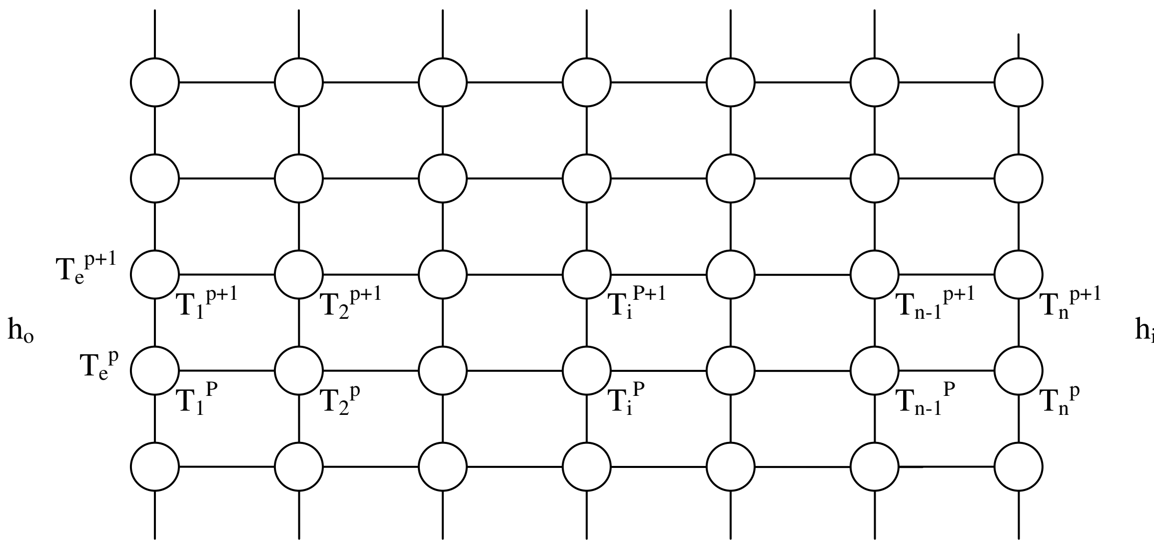

Fig 0-2 Wall descretization

For all interior nodes $\frac{\partial T}{\partial \tau} = \frac{k}{\rho c}\left(\frac{\partial^2 T}{\partial x^2}\right)$ can be descretized, Fig 3.2, using implicit method as

$$\frac{T_i^{p+1} - T_i^{p}}{\Delta \tau} = \alpha \frac{\left(T_{i+1}^{p+1} - 2T_i^{p+1} + T_{i-1}^{p+1}\right)}{(\Delta x)^2}$$

$$T_i^{p+1}\left(1 + 2F_o\right) - F_o\left(T_{i+1}^{p+1} + T_{i-1}^{p+1}\right) = T_i^{p} \qquad (3.9)$$

where $F_o = \frac{\alpha \Delta \tau}{\left(\Delta x\right)^2}$

Applying energy balance for surface node at the exterior portion, the following discrete equation is obtained.

$$h_o A(T_e^{p+1} - T_1^{p+1}) + \frac{KA}{\Delta x}(T_2^{p+1} - T_1^{p+1}) = \frac{\rho c A \Delta x}{2}\left(\frac{T_1^{p+1} - T_1^{p}}{\Delta \tau}\right)$$

where T^p -current temperature

T^{p+1}- temperature in the next time interval

Rearranging the above equation gives

$$(2FoBi + 2Fo + 1)T_1^{p+1} - 2FoT_2^{P+1} = 2FoBiT_e^{p+1} + T_1^{p} \quad (3.10)$$

where $Bi = \frac{h_o \Delta x}{K}$

For interior surface node

$$h_i A(T_r - T_n^{p+1}) + \frac{KA}{\Delta x}(T_{n-1}^{p+1} - T_n^{p+1}) = \frac{\rho C A \Delta x}{2}\left(\frac{T_n^{p+1} - T_n^{p}}{\Delta \tau}\right)$$

Rearranging the above equation we can get the following equation for interior surface node.

$$(2FoBi + 2Fo + 1)T_n^{p+1} - 2FoT_{n-1}^{P+1} = 2FoBiT_r + T_n^{p} \quad (3.11)$$

After arranging the above equations we will have a tri-diagonal matrix and a vector matrix. So solving the above matrix equation will give us the hourly temperature distribution across the layer of the wall.

3.2 Heat Gain Through Roof

Roof used for buildings can be of two types. One with no air gap and the other with air gap in between.. The first type can be treated as a pure wall with some inclination and can be solved using procedures listed in section 3.1. The second case is similar to a natural convection effect in a body of fluid enclosed by surfaces of non-uniform temperature.

For horizontal surfaces there are two different cases

- If the upper plate is at a higher temperature, no convection effects will arise, except possibly at the edges, and heat transfer will be entirely by conduction. The convection coefficient is merely k/s, where s is the distance between the enclosing surfaces. Therefore, the Nusselt number is 1.0.

  $$h/(k/s) = Nu = 1.0$$

- If the lower plate is warmer, an unstable condition results. Lighter layers of fluid are overlaid by denser layers. For a Grashof number based on S, less than 1700, no motion results, and the simple conduction rate pertains. For greater values natural convection pertains [3]. [So we can approximate the condition as a pure conduction and we can treat it in a similar manner to that of wall[4]].

3.3 General Procedures for Calculating Cooling Load Due to Heat Gain Through the Wall.

1. Define the location, wall orientation and construction feature of the wall in detail.
2. From the given inputs determine the direct and diffuse beam radiation.
3. Calculate sol-air temperature from the calculated radiation together with surface heat transfer coefficients.

4. Apply finite difference method to determine the inside surface temperature of the wall.
5. Determine the heat gain due to temperature difference between the wall surface and room temperature. Since this heat gain have both radiation and convection component split the heat gain accordingly. For heat gain through wall and roof the convention is to take 37% as the radiation component and the rest as convection component.
6. Take the convection component directly as a cooling load and apply radiant time series factor for the radiation component, which will be dealt in depth in chapter 4.
7. Summing up results of number 6 will give the cooling load.

Symbols

T - local temperature at a point on a slab
θ - time in sec
K - thermal conductivity
ρ -density of material
c - specific heat of a material
X - layer thickness
T_{wo} - out side wall surface temperature
T_o - outside dry bulb temperature
Q_r -net solar radiation heat transfer
h_o -outside heat transfer coefficient
L -wall thickness
A -wall area
ε -emissivity of the surface
ΔR -difference between long wave radiation incident on the surface from the sky and the radiation emitted from a black body at outdoor air temperature, W/m^2
α -absorptance of the wall surface
I_t - total incident solar radiation up on the surface, W/m^2
T_e - sol-air temperature
$\Delta\tau$ - change in time
Fo - Furrier number
Bi - Biot number
Nu - Nusselt number
T_r -room temperature

CHAPTER 4

SOLAR HEAT GAIN THROUGH GLASS

Glass, being the major cladding material of most building, provides the most direct route for entry of solar radiation. For this reason, the proper estimation of heat gain through glass is imperative. Glass may be considered opaque to radiation for sources of surface temperature less than 200^0C.

4.1 The Transmission of Solar Radiation Through Glass and Heat Absorption

Of the energy that is incident upon the glass, some is reflected and lost, some is transmitted through the glass, and some is absorbed by the glass as the energy passes through it. This small amount of energy raises the temperature of the glass, and the glass eventually transmits this heat by convection partly to the room and partly to the exterior.

Table 4.1 gives figures for transmissibility and absorptivity of glass. For angles of incidence between 60^o and 0^o, ordinary single window glass transmits about 85% of the energy incident up on it. About 6% is absorbed and the remaining 9% is reflected. As the angle of incidence increases beyond 60^0, the transmitted radiation falls off to zero, the reflected amount increases. The absorption figure remains fairly constant at about 6% for angles of incidence up to $80^{0.}$

For double-glazing, only about 90% of what passes through a single glazing is transmitted. Thus, the transmitted percentage for double-glazing is about 76% of the incident energy.

Table 0-1 Transmissivity and absorptivity of glasses with respect to angle of incidence[2]

	angle of incidence in degree						
	0	20	40	50	60	70	80
4mm ordinary, clear glass							
transmissivity	0.87	0.87	0.86	0.84	0.79	0.67	0.42
absorptivity	0.05	0.05	0.06	0.06	0.06	0.06	0.06
6mm ordinary, clear glass							
transmissivity	0.84	0.84	0.83	0.8	0.74	0.62	0.38
absorptivity	0.08	0.08	0.08	0.08	0.1	0.09	0.09

Ordinary glass does not have a very large coefficient of absorption, but certain specially made glasses absorb a good deal of heat[1].

4.2 External Shading

This is the best way of excluding the entry of direct solar radiation into a building. If the shade is completely opaque, all the direct radiation is prevented from entering through the window, although scattered radiation from the ground and the sky can still enter and must be taken into account.

The geometry of the shadow is best illustrated by considering the dimensions of the shadow cast on a vertical window by a reveal and an overhanging support, Fig 4.1.

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[2] *Note: The absorptivity for indirect radiation is taken as 0.06 regardless of the angle of incidence. The transmissivity for diffuse radiation is taken as 0.79 regardless of the angle of incidence.*

: Properties used for the other types of glasses included in the program can be obtained from 2001 ASHRAE fundamental handbook.

Fig 4.1(a) is the prospective view of a window that is recessed from the wall surface by an amount R. The front elevation of the window; Fig 4.1(b) shows the pattern of the shadow cast by the sunlight on the glass. If the coordinate X and Y of the point P' in Fig 4.1(b) can be worked out as under, then the dimensions of the shaded area are known. Fig 4.1(c) shows the plan of the window. If n is the wall solar azimuth angle, then coordinate x is given by

$$X = R\tan(n) \tag{4.1}$$

Where *X*-dimension of shadow casted in the horizontal direction

To see the true angle of altitude of the sun, we must take the section in the plane of the suns rays; that is, along A-A, as shown in Fig 4.1(d). Value of coordinate y can be obtained from

$$Y = m\tan(\alpha).$$

$$= R\sec(n)\tan(\alpha). \tag{4.2}$$

where *Y*- dimension of shadow casted in the horizontal direction

So if we have a window with an area *(xx) x (yy)*, applying external shading will reduce area for direct transmission through window from *A=(xx) x (yy)* to *A=(xx-X) x (yy-Y)* and this area is commonly known as sunlit area.

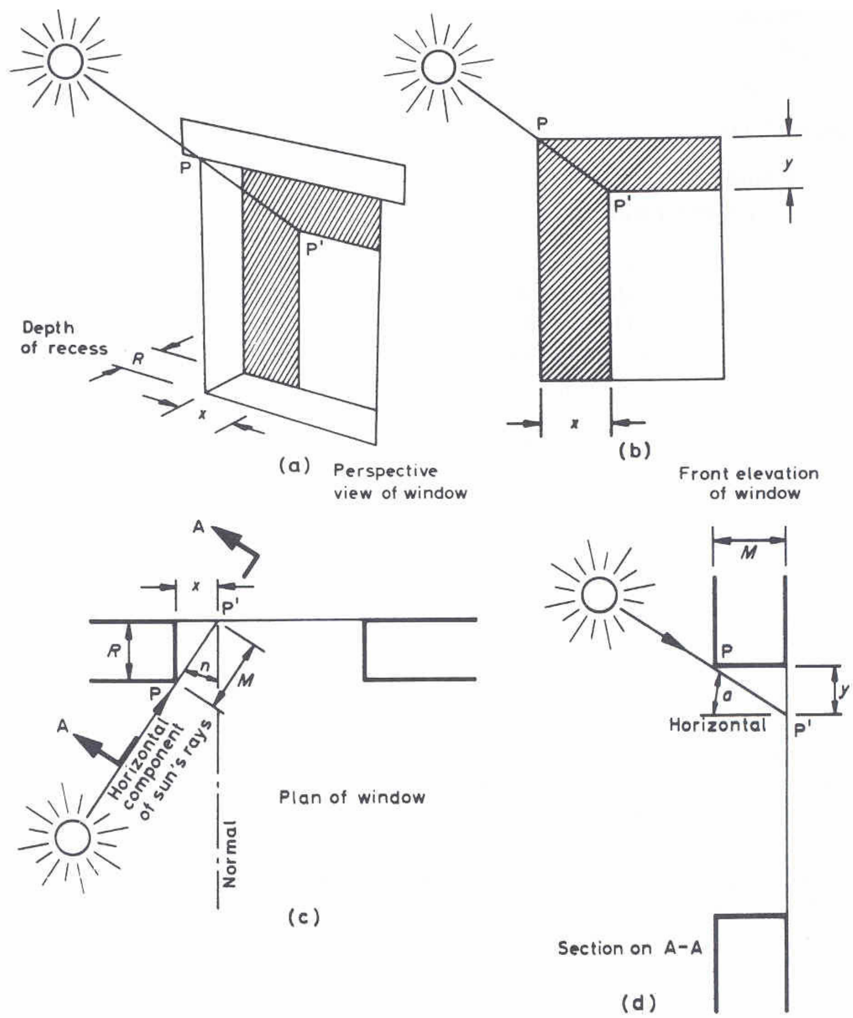


Fig 0-3 Formation of shadow due to external shading or recessing of window

4.3 Internal Shading and Double-Glazing

In tropical and subtropical climates, fixed, horizontal and external shades are effective because the sun is high in the sky for most of the day but in the temperate zone the lower solar altitudes that prevail for the majority of the time make them as much less used. For this reason, internal shading is much adopted and is essential for sunlit windows if air conditioning is to be satisfactory.

Internal shades are often of the Venetian blind type and for these to give most benefit, they should be of a white or aluminum color and should have polished surfaces. They should be adjusted so that they reflect the rays of the sun back to the outside and so that no direct rays pass between the slots. The blinds absorb some radiation, warm up, and convect and radiate heat into the room. Blinds are most effective when fitted between sheets of double-glazing. The effectiveness of various combinations of shades and glazing is expressed in terms of a solar heat gain coefficient

4.4 Solar Heat Gain Coefficient

The total heat gain through fenestration consists of the directly transmitted solar radiation plus the in-ward flowing fraction of the solar radiation that is absorbed in the glazing system. Both parts contain beam and diffuse contributions. The transmitted portion goes directly on the surfaces within the zone and should be reradiated back before considering it as a cooling load. The second part, the inward flowing fraction of the absorbed solar radiation, gets involved in an interaction with other surfaces through long wave radiation exchange and with the zone air through convective heat transfer. The solar heat gain coefficient (SHGC) combines the transmitted solar radiation and the inward-flowing fraction of the absorbed radiation[4]. The SHGC is defined as

$$SHGC = \tau + \sum_{k=1}^{nl} N_k \alpha_k \tag{4.3}$$

where τ - solar transmittance of glazing

α_k -Solar absorptance of the K^{th} layer of the glazing system

nl -Number of layers

N_k -inward flowing fraction of absorbed radiation in the k^{th} layer

SHGC values for various types of glass and glass combinations are given in ASHRAE 2001 Handbook [4]

4.5 Space Cooling Load Due to Solar Gain Through Fenestration

The solar radiation, which passes through a sheet of window glazing, does not constitute an immediate load on the air conditioning system for the following two reasons

- Air is transparent to radiation of this kind, and
- A change of load on the air conditioning system is only coused by variation of the air temperature within the room.

For the temperature of the air in the room to rise, the solar radiation entering through the window must first warm up the solid surfaces around the zone. These surfaces are then in a position to liberate some of the heat to the air by convection. Not all the heat will be librated immediately, because some of the energy is stored within the depth of the solid materials. The situation is analogues to that considered for heat gain through walls. There is, thus, a decrement factor to be applied to the value of the instantaneous solar transmission through glass, and there is also a time lag to be considered.

Fig 4.2 illustrates that, in the long run, all the energy received is returned to room, but because of the diminution of the peak values, the maximum load on the air conditioning system is reduced.

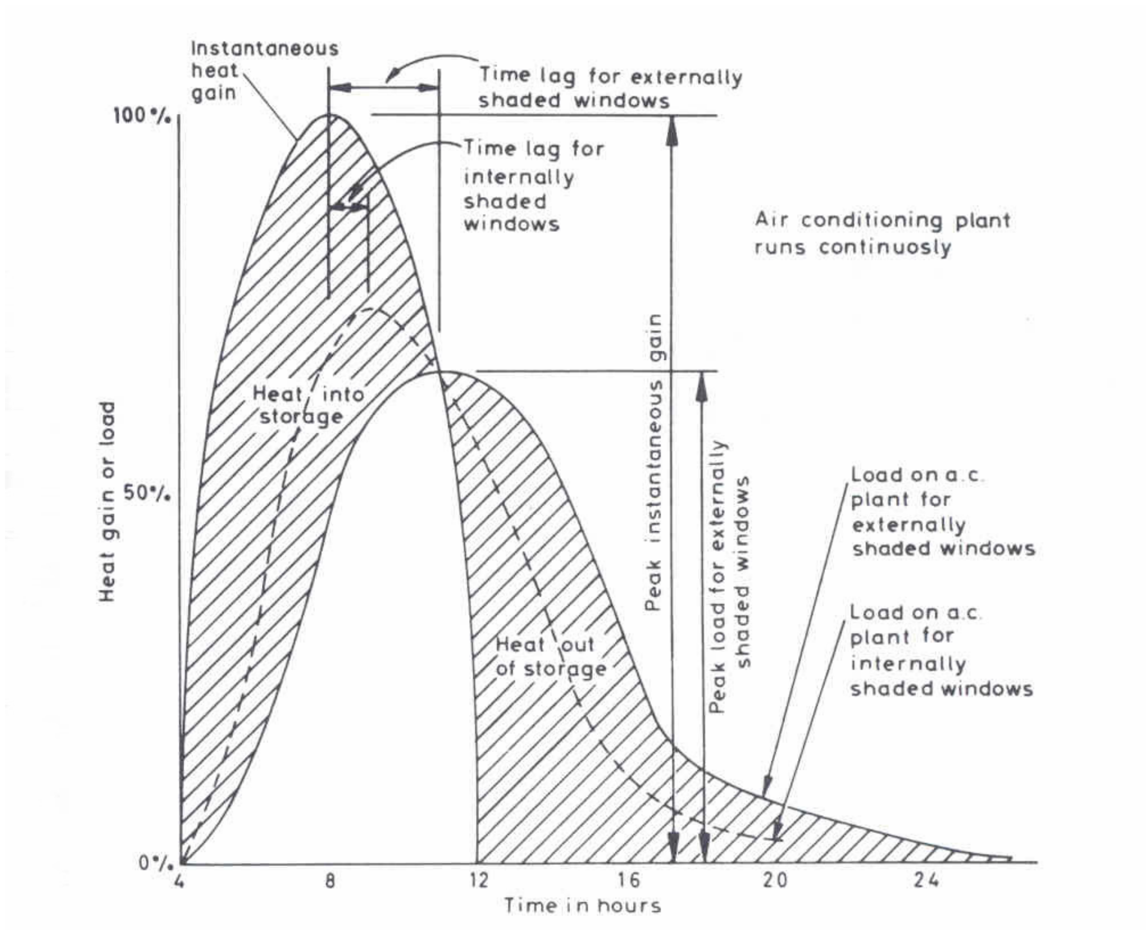


Fig 0-4 Time lag between instantaneous heat gain and air conditioning load [5]

Modern buildings have most of their mass concentrated in the floor slab, which will therefore, have a big effect on the values of the decrement factor and the time lag. Most of the solar radiation strike the floor slab and got absorbed. But the presence of furniture and floor coverings, particularly carpeting, reduces the influence of the slab. Wooden furniture has a small mass; hence any radiation received by it and absorbed will be subjected to only a small time lag and will be convected back to the room quite soon. To account this time lag and decrement there is a radiant time factor (RTF), which is derived from heat balance method, to multiply the transmitted heat. This RTF varies accordingly with the type of construction as well the covering of the floor; i.e. floor with carpet and with no carpet. We have two types of RTF one for solar and the other for non-solar component. The diffuse portion of solar heat gain falls under the non-solar group. The RTFs are given in [4] in detail.

RTFs used to calculate the cooling load on the basis of current and past heat gains. The series shows the portion of the radiant portion that is convected to the zone air for each hour. The radiant time series convert the radiant portion of heat gain according to the following equation (4.4).

$$Q_{r,\theta} = r_o q_{r,\theta} + r_1 q_{r,\theta-1} + r_2 q_{r,\theta-2} + \dots\dots + r_{23} q_{r,\theta-23} \qquad (4.4)$$

where $Q_{r,\theta}$ - radiant cooling load (Q_r) for the current hour θ, W

$q_{r,\theta}$ - radiant heat gain for the current hour,W

$q_{r,\theta-n}$ - radiant heat gain n hours ago, n=1…23, W

r_o, r_1.. r_{23}- radiant time factors.

The radiant cooling load for the current hour, which is calculated using the above equation, will be added with the convective portion to determine the total cooling load for that hour.

4.6 Procedures to Calculate the Cooling Load Due to Solar Gain Through Window

The procedures to be followed while calculating contribution of heat gain through glass in the whole space-cooling load are summarized below.

1. Calculate the values of direct, diffuse and sky radiation on the surface.
2. Define the properties of the glass like emittance, absorptance and sensible heat gain coefficient.
3. Determine the sunlit area
4. Determine the direct radiation transmitted by multiplying direct radiation on the surface by sensible heat gain coefficient, SHGC, of the glass. If there is no internal blind the whole amount will be taken as radiant. In the presence of internal blinds take 63% as radiant and the rest as convective.
5. Determine scattered radiation transmitted by multiplying the summation of diffuse and sky radiation values with hemispherical sensible heat gain coefficient.
6. Multiply the direct radiation transmitted by sunlit area and scattered radiation transmitted by total area of the window. Adding these two values will give instantaneous heat gain through window.

   But this value does not contribute any thing to the cooling load immediately as we already assume air to be completely transparent for radiation.

   So the heat gain through window should be first absorbed by components like furniture, floor etc and should be reradiated back to the room for it to be considered as a cooling load. To take this in to account we have a storage factor to multiply the instantaneous heat gain.

7. Determine the heat gain due to conduction through glass.
8. Add the convective heat gain with the scattered portion and split the summation in to radiative and convective component. The normal trend is to take 37% as convective and the rest as radiative.
9. Multiply the direct radiation by RTF for solar radiations and obtain the cooling load using equation (4.5).
10. Multiply the radiative component of (8) by RTF given for non-solar radiation according to equation (4.5)
11. summation of the results of number 9, 10, and convective component of number 8 will give hourly cooling load due to window heat gain.

Symbols

X	- shaded portion of window in the x-direction
Y	-shaded portion of window in the y-direction
n	-solar azimuth angle
R	-depth of recessing
xx	-width of window
yy	-height of window
$SHGC$	-solar heat gain coefficient
τ	-solar transmittance of glazing
α_k	-solar absorptance of the K^{th} layer of the glazing system
n	-number of layers
N_k	-inward flowing fraction of absorbed radiation in the kth layer
$Q_{r,\theta}$	-radiant cooling load (Q_r) for the current hour θ, W
$q_{r,\theta}$	- radiant heat gain for the current hour,W
$q_{r,\theta-n}$	- radiant heat gain n hours ago, W
r_o, r_1..	- radiant time factors.

CHAPTER 5

INFILTRATION AND VENTILATION

Outdoor air that flows through a building is often used to dilute and remove indoor air contaminants. However, the energy required to condition this outdoor air could be a significant portion of the total space-conditioning load. The magnitude of the outdoor airflow into the building must be known for proper sizing of the HVAC equipment and evaluation of energy consumption. For buildings without mechanical cooling and dehumidification, proper ventilation and infiltration airflows are important for providing comfort for occupants[11].

Air exchange of outdoor air with the air already in a building can be divided into two broad classifications: infiltration and ventilation

5.1 Infiltration

Infiltration is uncontrolled flow of air through unintentional openings such as cracks in the walls and ceilings and through perimeter gaps of windows and doors driven by wind, temperature difference and internally induced pressures. It is caused by a greater air pressure on the outside of the building than the inside. The amount of infiltered air depends on the pressure difference, the number, size and the shape of cracks involved; the number, the length and width of the perimeter gaps of the windows and doors; and the nature of the flow in the crack or gap (laminar or turbulent). The relation connecting these quantities are given by reference [6] as

$$\dot{V}_i = C(\Delta p)^n \tag{5.1}$$

where V_i- flow rate of leaking air

Δp- pressure difference, if outside is greater than inside it is positive.

n- flow exponent

if flow in the crack is laminar, n=1

if turbulent, n=0.5

Usually flow will be transitional thus n will be between 0.5 and 1.

C- flow coefficient, determined experimentally and includes the crack or opening size.

$$\Delta p = \Delta p_{st} + \Delta p_w + \Delta p_p \tag{5.2}$$

where Δp_{st}-pressure difference caused by stack effect

Δp_w-pressure difference caused by wind effect

Δp_p-pressure difference caused by pressurizing the building

5.1.1.1 Pressure Difference Due to Stack Effect

Temperature differences between indoors and outdoors cause density differences and therefore pressure differences that drive infiltration. During the heating season, the warmer inside air rises and flows out of the building at the top. It is replaced by colder outside air that enters the building near its base. During cooling season, the flow direction will be reversed and generally lower because, the indoor-outdoor temperature differences are smaller. Qualitatively the pressure distribution over the building during the cooling season takes the form as shown in Fig 5.1.

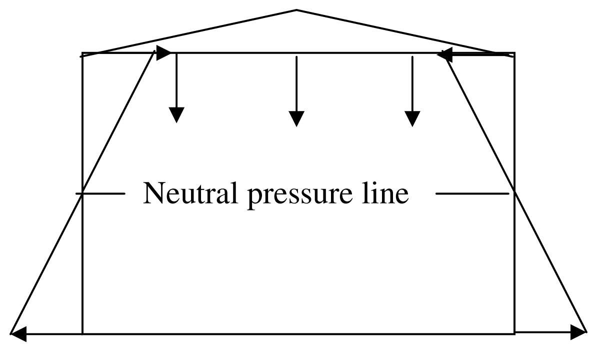


Fig 0-5 Position of neutral pressure line

Under the influence of stack effect there will be a vertical location in the building where the inside pressure equals the outside pressure. This location is defined as the neutral pressure level of the building. If cracks and other openings are uniformly distributed vertically, the neutral pressure level will be exactly at the mid height of the building. If larger openings predominate in the upper portion of the building, this will tend to raise the neutral pressure level and like wise large openings in the lower part will lower the neutral pressure level. Unless there is information to the contrary it is assumed that the neutral pressure level is at the building mid height when under the influence of the stack effect acting alone.

The theoretical pressure difference due to stack effect can be found using [6]

$$\begin{aligned}\Delta p_{st} &= (\rho_o - \rho_i)gh \\ &= \rho_o\left(\frac{T_o - T_i}{T_i}\right)gh\end{aligned} \qquad (5.3)$$

where h-height above or below the neutral pressure line in m

ρ_o -density of outdoor air in kg/m^3

ρ_i -density of room air in kg/m^3

Δp_{st}- theoretical pressure difference between the inside and outside air due to stack effect in pa.

The above formula is valid only for buildings with no vertical separation, that is, no floor as, for example, with an atrium, auditorium, or fire stair towers. Floors in conventional buildings offer a resistance to the vertical flow of air caused by the stack effect. There are pressure drops from one story to the next. If these resistances such as doors can be assumed uniform for every floor, then a single correction, called the thermal draft coefficient, C_d, can be used to relate Δp_{st} and Δp_s, the actual pressure difference.

$$\Delta p_s = C_d \Delta p_{st} \tag{5.4}$$

The value of C_d depends on the resistance to the vertical flow of air, that is, the tightness of stair doors, etc, and to the quantity of vertical airflow. The larger the vertical flow, larger pressure drops per floor and thus a smaller value of C_d. With no doors in the stairwells C_d has a value of 1. Values of C_d determined experimentally for a few modern buildings ranged from 0.63 to 0.82 [6].

5.1.1.2 Pressure Difference Due to Wind Effect

The pressure associated with wind velocity, called velocity pressure is

$$p_v = 0.5 \rho v_w^2 \tag{5.5}$$

Assuming all the velocity pressure is converted in to static pressure, the pressure caused by the wind is given by

$$\Delta p_{wt} = 0.5 \rho v_w^2 \quad (5.6)$$

where Δp_{wt} -max theoretical pressure difference caused by wind, Pa.

ρ - density of air, kg/m^3

V_w - wind velocity, m/s

It is impossible for the wind velocity to become zero as it strikes a building and even on the windward side the air maintains some velocity in order to pass around the building. To account for this there is wind pressure coefficient that is defined by

$$C_p = \left(\frac{\Delta p_w}{\Delta p_{wt}} \right) \quad (5.7)$$

where C_p -pressure coefficient, dimensionless

Δp_w - actual pressure coefficient caused by wind, Pa.

C_p has values less than one and can be negative when the wind causes outdoor pressure below atmospheric pressure on some surfaces of a building. C_p depends on wind direction, the building height, the building shape, and the location of the other building. Buildings are divided as low rise and high-rise, where high-rise is defined as those with a height greater than three times the crosswind width (H>3W).

$$\Delta p_{wt} = \frac{\Delta p_w}{C_p} = 0.5 \rho v_w^2 \quad (5.8)$$

5.1.1.3 Pressure Difference Due to Building Pressurization

A building can be pressurized by bringing in more out door air through the air handling system than is allowed to exhaust. This results a negative pressure difference and a reduction in infiltration from wind and stack effect. On the other hand design on the air handling system may be such that more air is exhausted than supplied from out doors. This generally results in a lower pressure inside the building, a positive pressure difference, and increased infiltration from wind and stack effect. The latter case is usually undesirable.

While building pressurization is often desired and assumed to occur, it is emphasized that the air circulation must be carefully designed and adjusted to achieve this effect.

5.1.2 Curtain Wall Infiltration Per Floor or Room

The flow coefficient ,*C*, in equation (5.1) has a particular value for each crack and each window and door perimeter gap. To determine the value of flow coefficient for each crack would be impractical. However, an overall leakage coefficient suggested in reference [6] can be used by changing equation (5.1) to the following form

$$\dot{V}_i = kA(\Delta p)^n \qquad (5.9)$$

Where k- leakage coefficient ($C=KA$)

A- wall area in m^2

When the above formula is applied to wall area having cracks, the leakage coefficient can be determined experimentally. If very large area is used in the test, the averaging effect of large number of cracks is taken advantage of. Tests have been made on entire buildings by pressurizing them with fans. Air leakage through doors and other openings is not included in the wall leakage. The results of these tests are summarized in Table 5.1 and Fig 5.2 [6].

Table 0-2 Curtain wall classifications

Leakage coefficient	**Description**	**Curtain wall construction**
k=0.22	Tight fitting wall	Constructed under close supervision of workmanship on wall joints. When joints seals appear inadequate, they must be redone
k=0.66	Average-fitting wall	Conventional construction procedures are used
k=1.3	Loose-fitting wall	Poor construction quality control or an older building having separated joints

The pressure difference Δp needed in order to use Fig 5.2 is found using equation (5.2).

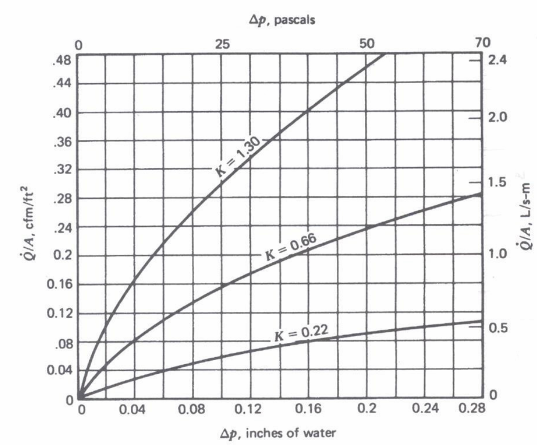
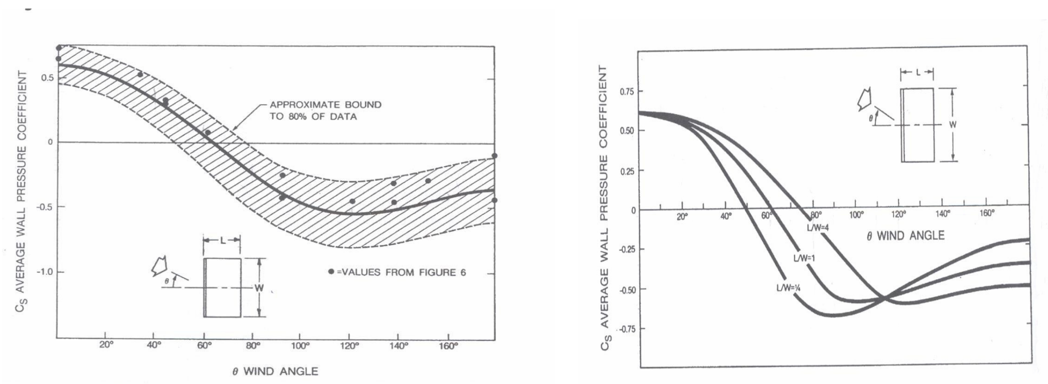


Fig 0-6 Curtain wall infiltrations for one room or one floor

Average wall pressure coefficients for low-rise buildings and high- rise buildings are given in Fig 5.3 (a) and (b) respectively.



(a) (b)

Fig 0-7 Wall average pressure coefficient for low-rise and high-rise buildings

5.1.3 Crack Infiltration for Doors And Movable Windows

Infiltration through windows and all types of doors can be determined by altering equation (5.1) to the form

$$\dot{V}_i = kP(\Delta p)^n \qquad (5.10)$$

where P - perimeter of the windows or door, in m

k - Perimeter leakage coefficient (C=kxP).

n -0.65

5.1.3.1 Infiltration Through Commercial-Type Doors

Commercial type doors differ from residential type doors in that they have larger cracks and they are used more often. Therefore different data are required. Commercial type doors can be broadly divided into swinging and revolving type.

Table 0-3 Window classification

	Wood Double-hung (locked)	**Other types**
Tight fitting window *k=1*	Weathers striped average gap (0.4mm crack)	Wood casement and awning windows; weather-stripped. Metal casement windows; weather-stripped
Average fitting window *k=2*	Non –weather stripped average gap (0.4mm crack) or weather stripped large gap (2.4mmcrack)	All types of vertical and sliding windows; weather-stripped. Note: if average gap (0.4mm1/64 in crack) this would be tight fitting window
Loose fitting window *k*=6.0	Non-weather-stripped large gap (2.4mmCrack)	vertical and horizontal sliding windows, nonweatherstripped

Swinging doors

Data for swinging doors are given in Fig (5.6) where $\dot{V}/P = k(\Delta p)^{0.50}$ for *k*=20,40,80,and 160. The corresponding crack width is given opposite each value of *k*. Note also that for these large cracks the exponent *n*=0.5.

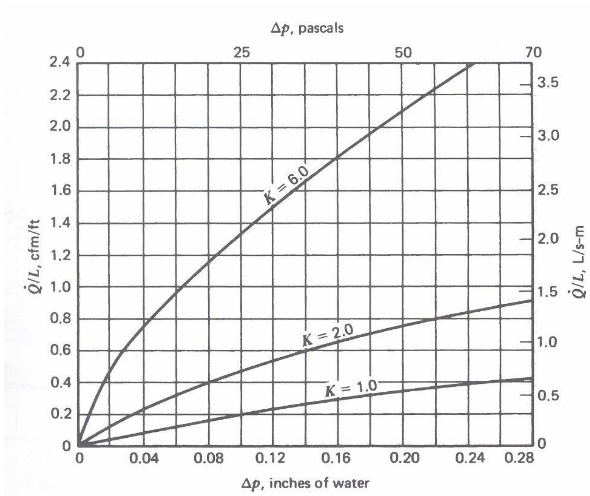


Fig 0-8 Window and door infiltration characteristics

Table 0-4 Door classifications

Tight fitting door *k*=1.0	Very small perimeter gap and perfect fit weathrstripping - often characteristic of new doors
Average fitting door *k*=2	Small perimeter gap having stop trim fitting properly around door and weathrstripped
Loose fitting door k=6.0	Large perimeter gap having poor fitting stop trim and weatherstripped or small perimeter gap with no weather stripping

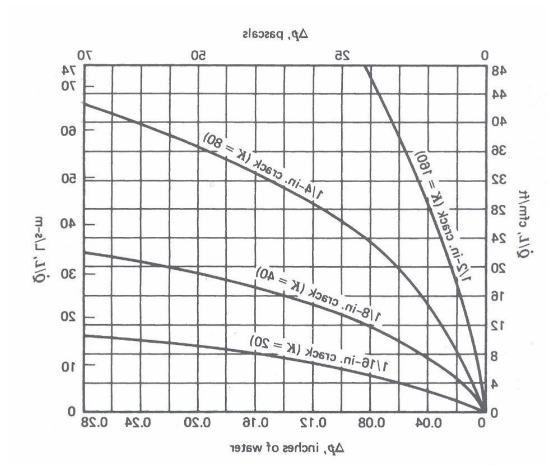
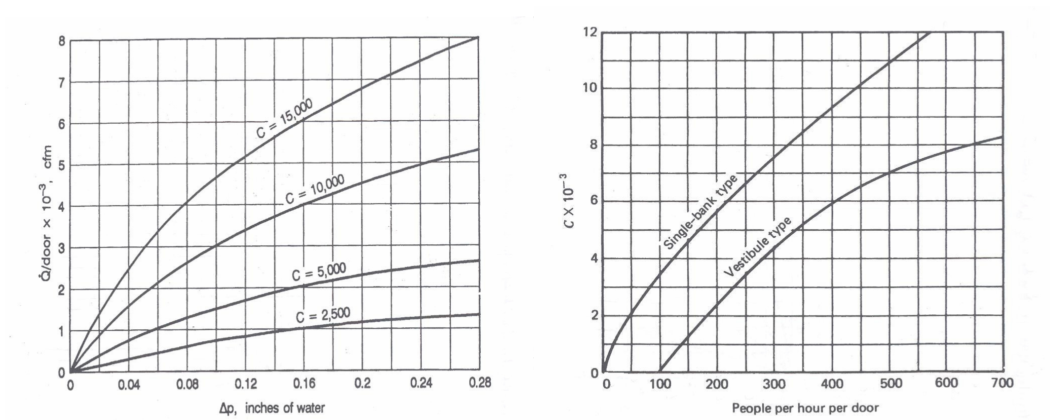


Fig 0-9 Infiltration through closed swinging door cracks

Commercial buildings often have a large number of people entering and leaving, which can increase infiltration significantly. Fig 5.6(a) and (b) have been developed to estimate this kind of infiltration for swinging doors. The infiltration rate per door is given in Fig 5.6 (a) as a function of pressure difference and a traffic coefficient that depends on traffic rate and the door arrangement. Fig 5.6 (b) gives the traffic coefficients as a function of the traffic rate and two door types. Single bank doors open directly in to space; however there may be two or more doors at one location. Vestibule- type doors are best characterized as two doors in series so as to form an air lock between them

The equation for the four curves in Fig 5.6 (a) is $\dot{V} = C(\Delta p)^{0.50}$ for flow coefficients of C=2500,5000,10000 and 15000. This is the same equation as would be used for flow through a sharp edged orifice. These values of *C* in Fig 5.6 (a) and (b) were obtained from model tests and observing traffic under actual conditions. Care must be taken not to overestimate the traffic rate. The traffic may be extremely high for short periods of time and not representative of most of the day.



(a) (b)

Fig 0-10 Swinging door infiltration characterstics

(a)Swinging door infiltration characteristics with traffic

(b) Flow coefficient dependence on traffic rate.

There is no published information on automatically operated doors, but automatic doors do stay open two to four times longer than manually operated doors. A reasonable estimate would be to multiply the infiltration from traffic for the single bank doors by a factor based on the increased time the automatic door will be open.

The total infiltration is the infiltration through the cracks when the door is closed plus the infiltration due to traffic.

Revolving doors

Fig 5.7 shows the infiltration due to a pressure difference across the door seals of a standard sized revolving door. The results are for seals that are typically worn but have good contact with adjacent surfaces.

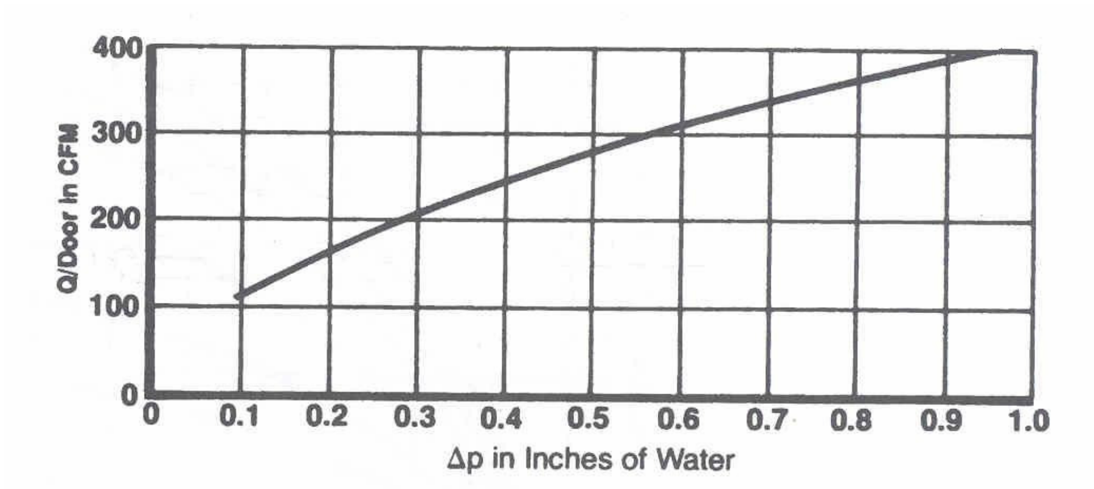
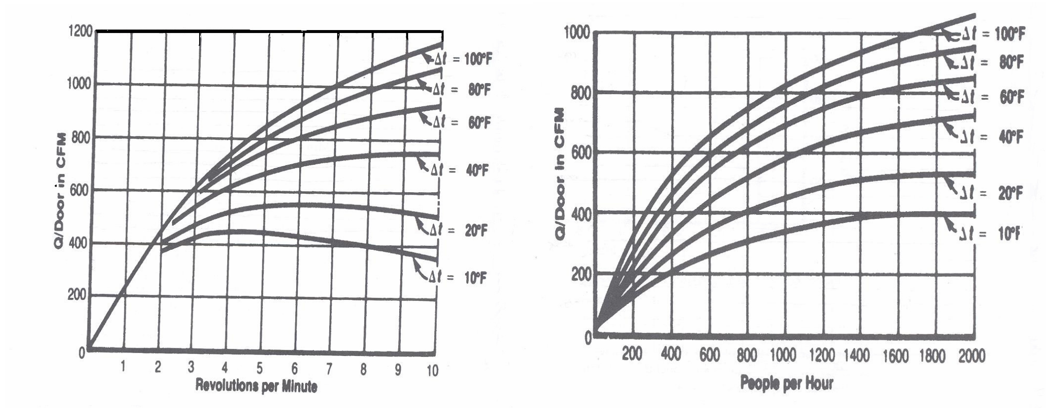


Fig 0-11 Infiltrations through seals of revolving doors not revolving

Fig 5.8 (a) and (b) account for infiltration due to a mechanical interchange of air caused by the rotation of standard sized door.The amount of air interchanged depends on the inside-outside temperature difference and the rotational speed of the door.

The total infiltration is the infiltration due to leakage through the door seals plus the infiltration due to mechanical interchange of air due to the rotation of the door.



(a) (b)

Fig 0-12 Infiltration for motor-operated and manually operated revolving door

5.1.4 Infiltrations for Low-Rise Buildings

Low-rise buildings do not often utilize curtain wall construction. This is especially true of light commercial structures where frame or masonry construction is prevalent. These structures often have movable windows, have cracks or other openings in the ceiling, and generally resemble residential construction. Stack effect although present, is much less important than the wind in producing infiltration. Therefore the stack effect can be neglected in most cases.

5.2 Ventilation

Ventilation is the intentional introduction of air from the outside into a building; it is further subdivided into natural ventilation and forced ventilation. Natural ventilation is the intentional flow of air through open windows, doors, grilles, and other planned building envelope penetrations, and it is driven by natural and/or artificially produced pressure differentials. Forced ventilation is the intentional movement of air into and out of a building using fans and intake and exhaust vents; it is also called mechanical ventilation.

Most of the time the air introduced in to the building by ventilation is expressed in terms of air exchange per hour (ACH). Given ACH the mass flow rate in m^3/s can be calculated by

$$\dot{V}_v = n*(v)/3600 \tag{5.11}$$

where n - number of air exchange per hour

v - volume of the room

So both infiltration and ventilation have the same effect of introducing some amount of air in to the room that has a direct contribution to the overall cooling load of the room.

5.3 Space Cooling Load Due to Infiltered And Ventilated Air

Total heat gain q_t corresponding to the change of a given standard flow rate Q_s, summation of Q_v and Q_i, through an enthalpy difference Δh is

$$q_t = 1.2\dot{V}_s\,\Delta h \tag{5.12}$$

where air density =1.2kg/m^3

Sensible heat gain q_s corresponding to the change of dry bulb temperature Δt for a given air flow (standard conditions) Qs is

$$q_s = \dot{V}_s\,\rho c_p \Delta T$$

$$q_s = 1.2(1.006 + 1.84W)\dot{V}_s\,\Delta T \tag{5.13}$$

Where 1.006 - specific heat of dry air, kJ/kg.K

W - humidity ratio, kg (water)/kg (air)

1.84 - specific heat of water vapor, kJ/(kg.K).

The specific heats are for a range of about –75 to 90^0C. Because a value of W=0.01 approximates conditions found in many air conditioning problems, the sensible heat change in watt can normally be found as

$$q_s = 1.23\dot{V}_s \,\Delta T \tag{5.14}$$

Latent heat gain q_l corresponding to the change of humidity ratio ΔW for given air flow (standard conditions) *Qs* is

$$\begin{aligned} q_l &= 1.2(2500\dot{V}_s \,\Delta W) \\ &= 3010\dot{V}_s \,\Delta W \end{aligned} \tag{5.15}$$

Where 2500 is the approximate heat content of 50% relative humidity vapor at 24^oc less the heat content of water at 10^oc. 50% relative humidity at 24^oC is a common design conditions for the space.

5.4 Procedures for Calculating Cooling Load Due to Infiltration And Ventilation

1. Determine the total pressure difference between indoor and outdoor, which is the summation of pressure differences caused due to stack effect, pressurization and wind.

2. Determine airflow rate into the building due to the above pressure difference through cracks of wall, window and door. Also determine flow rates of air through door and window openings depending on their nature and means of operation.
3. Calculate the airflow rate due to ventilation and add it with air flow rate due to infiltration to find the total air flow rate.
4. After determining the total flow rate calculate the sensible and latent heat gain using equations (5.13) and (5.14).
5. As the infiltered air directly combines with the zone the sensible as well latent heat gains are taken directly as a cooling load with out applying any type of modifications.

Symbols

Q_i - airflow rate due to infiltration
C - Flow coefficient
Δp - change in pressure
Δp_{st} - pressure difference caused by stack effect
Δp_w - pressure difference caused by wind
Δp_p - pressure difference caused by pressurization
C_d - draft coefficient
p_b - outside absolute pressure
h - height above or below the neutral pressure line
Δp_s -actual pressure difference due to stack
T_o - ambient temperature
T_i - room temperature
C_p -pressure coefficient
ΔP_{wt} - theoretical pressure difference due to wind
K - leakage coefficient
A - wall area

CHAPTER 6

INTERNAL HEAT GAIN

6.1 Electric Lighting

As lighting is often the major space load component, a precise account of this heat gain is required. The computation of this heat load is often very difficult due to the rate of heat gain at any given time being quite different from the heat equivalent of the power supplied instantaneously to these lights.

Only part of the energy from light is in the form of convective heat that is picked up instantaneously by the air conditioning apparatus. The remaining portion is in the form of radiation which affects the conditioned space only after having been absorbed and re-released by walls, floors, furniture, etc. This absorbed energy contributes to the space cooling load only after a time lag, with some part of energy still present and reradiating after the lights are switched off.

Instantaneous heat gain from lighting The primary source or heat from lighting comes from light-emitting elements, or lamps, although significant additional heat may be generated from associated appurtenances in the light fixture that house such lumps. Generally, the instantaneous heat gain from electric lighting may be computed from[4].

$$Q_L = W F_{UL} F_{SA} \tag{6.1}$$

where Q_L -heat gain, W

W -total light wattage

F_{UL} -lighting use factor

F_{SA} -lighting special allowance factor

The total light wattage is obtained from the ratings of all lamps installed, both for general illumination and for display use.

The use factor is the ratio of the wattage in use, for the condition under which the load estimate is being made, to the total installed wattage. For commercial applications, such as stores, the use factor is unity.

The special allowance factor is for fluorescent fixtures that are either ventilated or installed so that only part of the heat goes to the conditioned space. For fluorescent fixtures, the special allowance factor primarily accounts for ballast losses and can be as high as 2.19 for 32W single–lump high-output fixtures on 227V circuits. Rapid–start, 40W lamp fixtures have special allowance factors varying from a low of 1.18 for two lamps at 277V to a high of 1.3 for one lamp at 118V, with a recommended value of 1.2 for general applications. Industrial fixtures other than fluorescent, such as sodium lamps, may have special allowance factors varying from 1.04 to 1.37, depending on the manufacturer, and should be dealt with individually.

6.2 Heat Gain from Occupants

Human beings give off heat at a metabolic rate, which depends on their rate of working. The sensible and latent heat proportion of the heat librated for any given activity depends on the value of the ambient dry bulb temperature; the lower the dry bulb temperature the larger the proportion of sensible heat dissipated. Typical values of sensible and latent heat librations of heat are given in Table 6.1

Table 0-5 Sensible and latent heat gain based on activity[3]

	Total heat,W			
Degree of activity	**Adult male**	**adjusted M/F**	**sensible heat,W**	**latent heat,W**
Seated at theatre	115	95	65	30
Seated at theatre,at night	115	105	70	35
Seated, very light work	130	115	70	45
Moderately active office work	140	130	75	55
Standing, light work; walking	160	130	75	55
Walking, standing	160	145	75	70
Sedentary work	145	160	80	80
Light bench work	235	220	80	140
Moderate dancing	265	250	90	160
Walking 4.8km/h; light machine work	295	295	110	185
Bowling	440	425	170	255
Heavy work	440	425	170	255
Heavy machine work; lifting	470	470	185	285
Athletics	585	525	210	315

[3] *Notes*

1- *Tabulated values are based on 24^0C room dry bulb temperature. For 27^oC room dry bulb temperature , the total heat remains the same, but the sensible heat values should be decreased by approximately 20%, and the latent heat values increased accordingly*
2- *All values are rounded to the nearest 5W.*

Deciding on the density of occupation is usually a problem for the designer. A normal density for an office block is $9m^2$ per person, as an average for the whole conditioned floor area. The density of occupation may be as high as $20m^2$ per person in executive offices or as low as $6m^2$ per person in open office areas.

For restaurants, 2m2 per person is reasonable. For departmental stores, densities may reach 4.3 to 1.7m2 per person at certain time of the year. In concert halls, cinema and theaters, the seating arrangement provides the necessary information but in dancing halls and nightclubs estimate are pen to conjecture. Occupation may be very dense but a figure of 0.5m2 per person is suggested tentatively.

6.3 Electric Motors

Instantaneous heat gain from equipment operated by electric motors within a conditioned space is calculated as

$$Q_{em} = \left(P/E_M \right) F_{UM} F_{LM} \tag{6.2}$$

Where Q_{em} -heat equivalent of equipment operation, W

P -motor power rating, W

EM -motor efficiency, decimal fraction<1.0

FUM - motor use factor, 1.0 or decimal fraction<1.0

FLM -motor load factor, 1.0 or decimal fraction<1.0

The motor use factor may be applied when motor use is known to be intermittent with significant nonuse during all hour of operation (e.g., overhead door operator). For conventional applications, its value would be 1.0.

The motor load factor is the fraction of the rated load being delivered under the condition of the cooling load estimate. In equation (6.2), it is assumed that both the motor and the driven equipment are in the conditioned space. If the motor is outside the space or air stream,

$$Q_{em} = PF_{UM}F_{LM} \tag{6.3}$$

When the motor is inside the conditioned space or air stream but the driven machine is outside,

$$Q_{em} = P\left(\frac{1.0 - E_M}{E_M}\right)F_{UM}F_{LM} \tag{6.4}$$

Equation (6.3) also applies to a fan or pump in the conditioned space that exhausts air or pumps fluid outside that space.

6.4 Space Cooling Load Due to Internal Heat Gain

The whole portion of instantaneous heat gain from internal loads will not take part in zone cooling load directly as it has both convective and radiant nature. So before starting to calculate the cooling load we have to split the total heat gain in to convective and radiant component. Table 6.2 summarizes the components in percentage form [4,5].

Since the radiant portion has to be absorbed and reradiated back to the zone before being considered as a cooling load it will be exposed to some decrement and time lag. To take this into consideration just as before we have to multiply the radiant component by RT factor according to equation (4.5) of chapter 4. Adding this component with the convective portion gives the cooling load contribution of internal heat gain on the total zone-cooling load.

Table 0-6 Convective and radiant percentage of internal sensible heat gain

Heat gain source	**Radiant heat**	**Convective heat**
Fluorescent lights, suspended, unvented	67	33
Fluorescent lights, recessed, vented to return air	59	41
Fluorescent lights, recessed, vented to return air and supply air	19	81
Incandescent lights	80	20
People	33	67
Machinery appliances	20	80

Symbol

Q_L -heat gain from lighting, W
W -total light wattage
FUL -lighting use factor
FSA -lighting special allowance factor
qem -heat equivalent of equipment operation, W
P -motor power rating, W
EM -motor efficiency
FUM - motor use factor
FLM - motor load factor

CHAPTER 7

THE COMPUTER PROGRAM

In the previous chapters various formulas and methods, for calculating hourly cooling load of a building, are discussed in detail. To make the computation friendly and time effective a computer program is developed using Matlab. The program developed can be broadly classified in to four major parts

1- A program for calculating heat gain through wall and roof
2- A program for calculating heat gain through window and door
3- A program for calculating heat gain through infiltration.
4- A program for calculating internal heat gain.
5- A program for calculating space cooling load from heat gain

The details of these programs with their algorithm developed will be discussed in this chapter. For the heat gain through wall and roof the algorithms are shown in Fig 7.1 and Fig 7.2. Algorithm for heat gain through window and door is shown in Fig 7.3. In a similar manner algorithms for heat gain through infiltration and internal heat gain are shown in Fig 7.4 and Fig 7.5. Finally algorithm for changing the heat gains in to cooling load is shown in Fig 7.6.

To make the programs developed user-friendly type GUI (graphic user interface) is developed. So any person with out knowing the detail of the program can run and have the hourly cooling load of the building.

Based on the above six algorithms, six programs are developed as shown in appendix. Each program is associated with graphical interface that deals with various inputs.

7.1 The Algorithm

7.1.1 Algorithm for Calculation of Solar Radiation

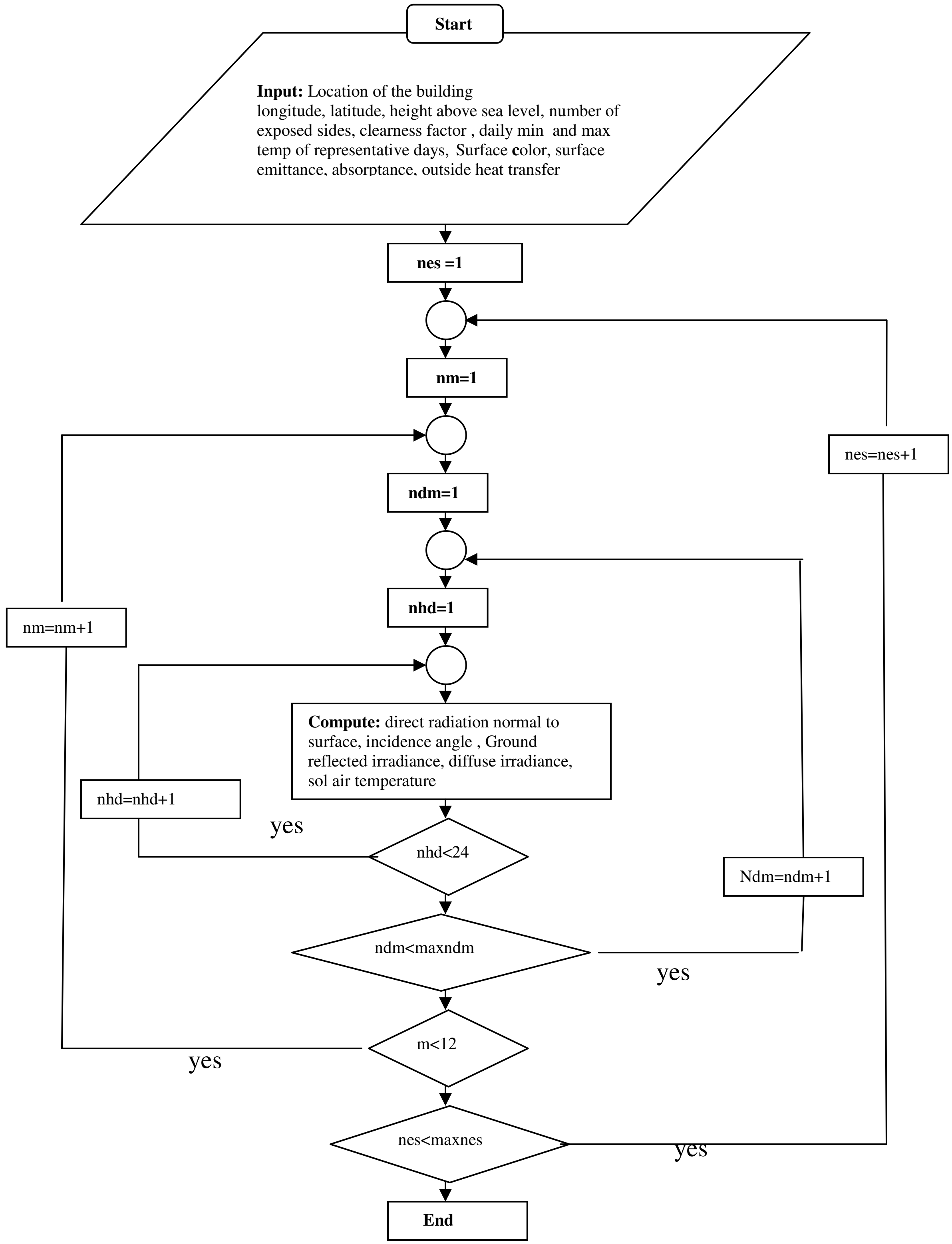
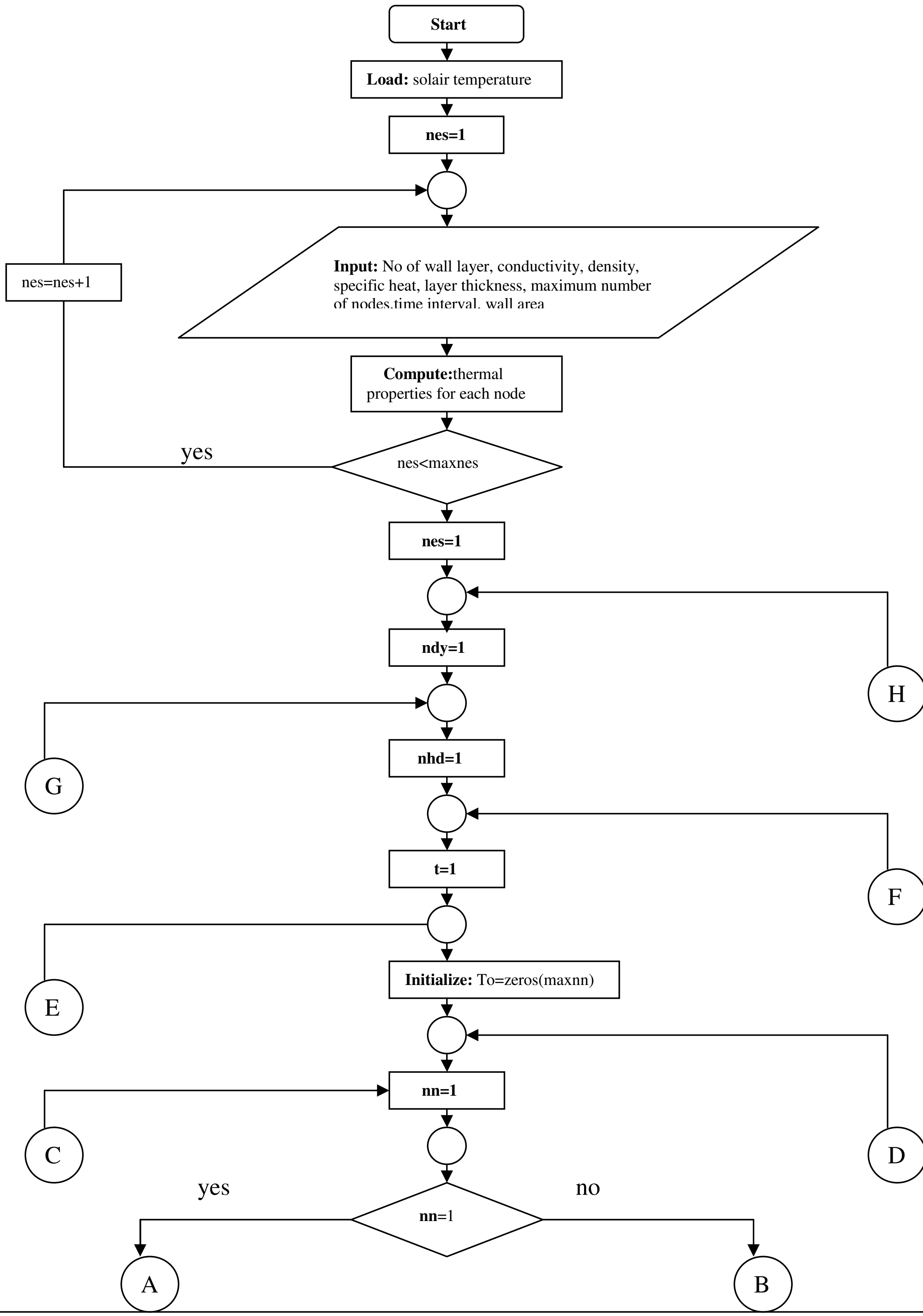


Fig 0-13 Algorithm for calculation of solar radiation

nes-number of exposed sides
nm-number of months
ndm-number of days per month

nhd-number of hours per day
maxndm-maximum number of days per month
maxnes-maximum number of exposed sides

7.1.2 Algorithm for Analysis of Solar Heat Gain Through Wall



ndy- number of days per year
nn-node counter

To-initial nodes temperature distribution
maxnn-maximum number of nodes across the wall

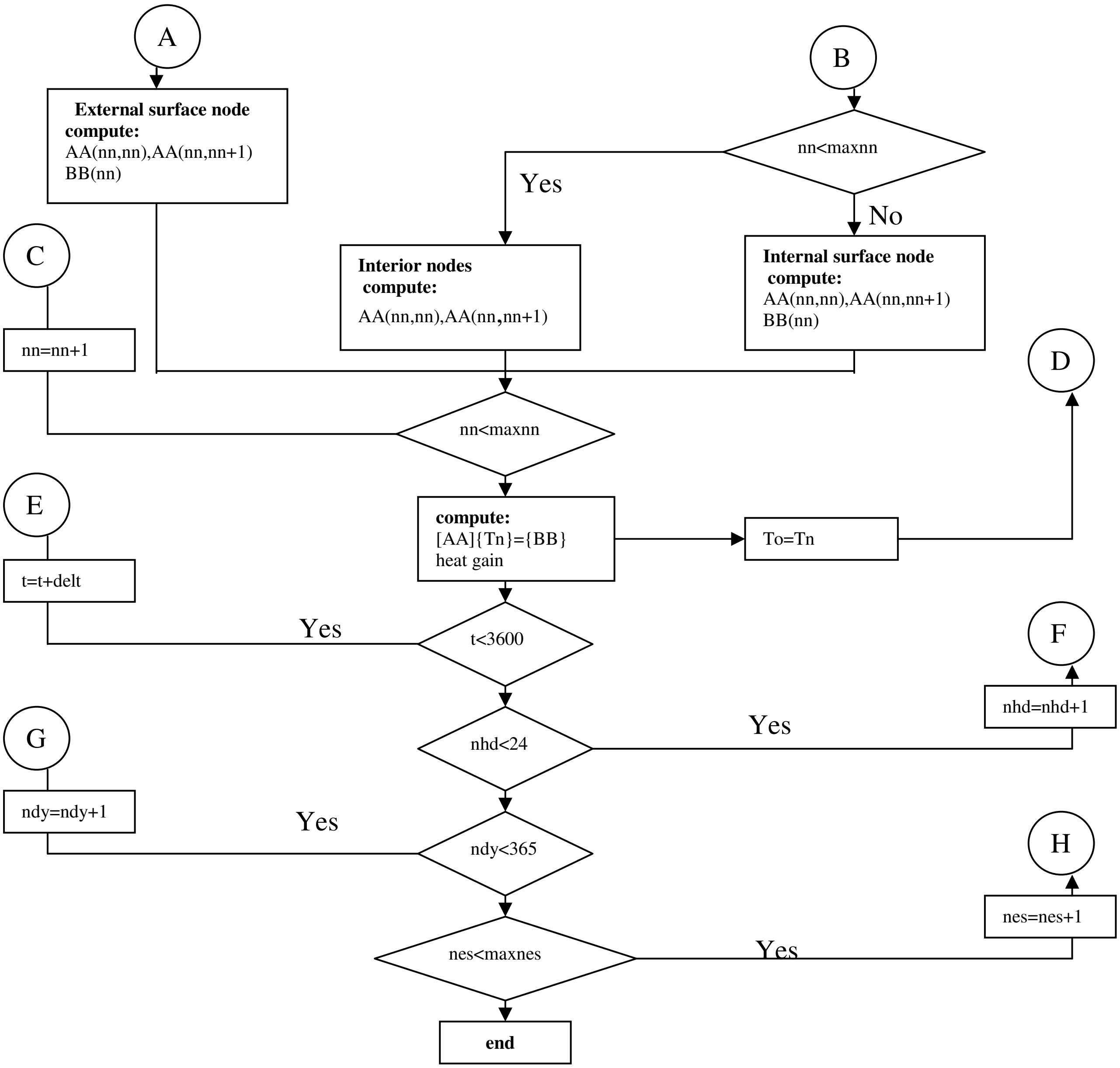


Fig 7.2 Algorithm for analysis of surface temperatures and heat gain through wall

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AA-coefficient for each node temperature
BB-known values for each node
[AA]- Coefficient matrix
{BB}- vector matrix

7.1.3 Algorithm for Calculation of Solar Heat Gain Through Window

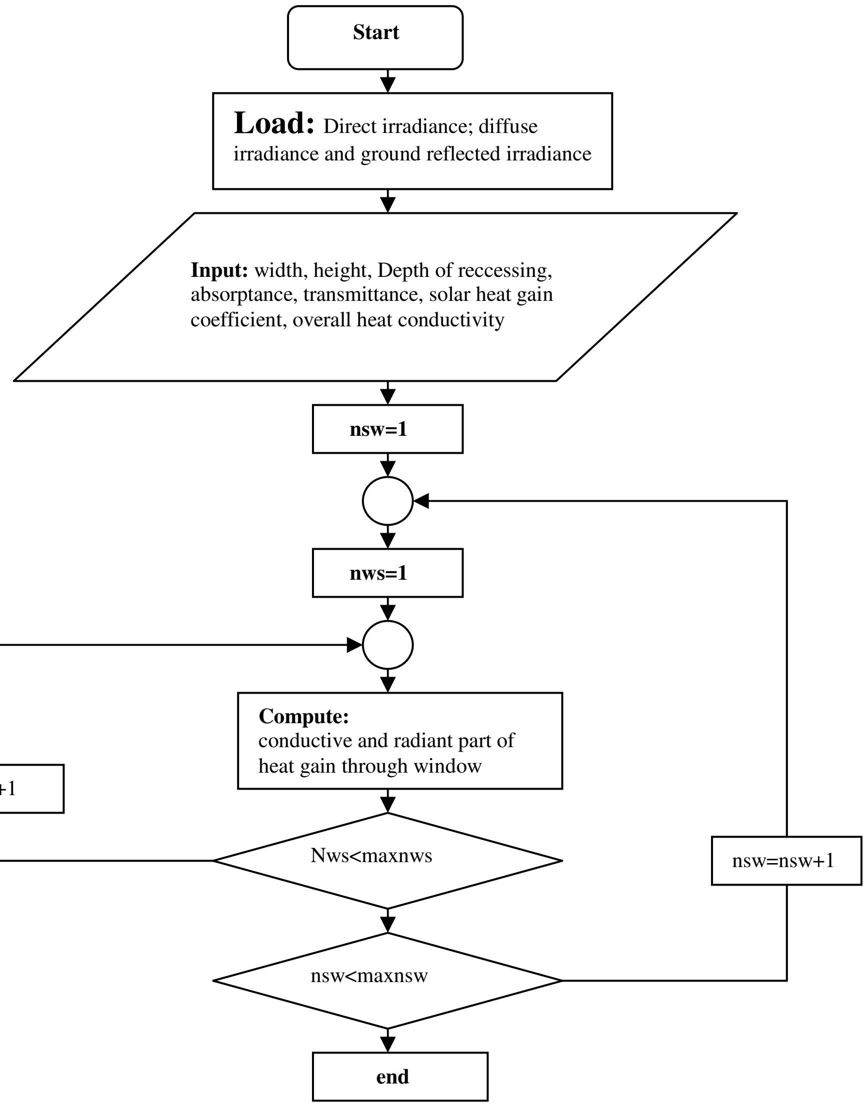

Fig 7-3 Algorithm for solar heat gain through window

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nsw-number of sides with window   maxnws-maximum number of sides with window
nws-number of windows per side   maxnws-maximum number of windows per side

7.1.4 Algorithm for Heat Gain Through Infiltration

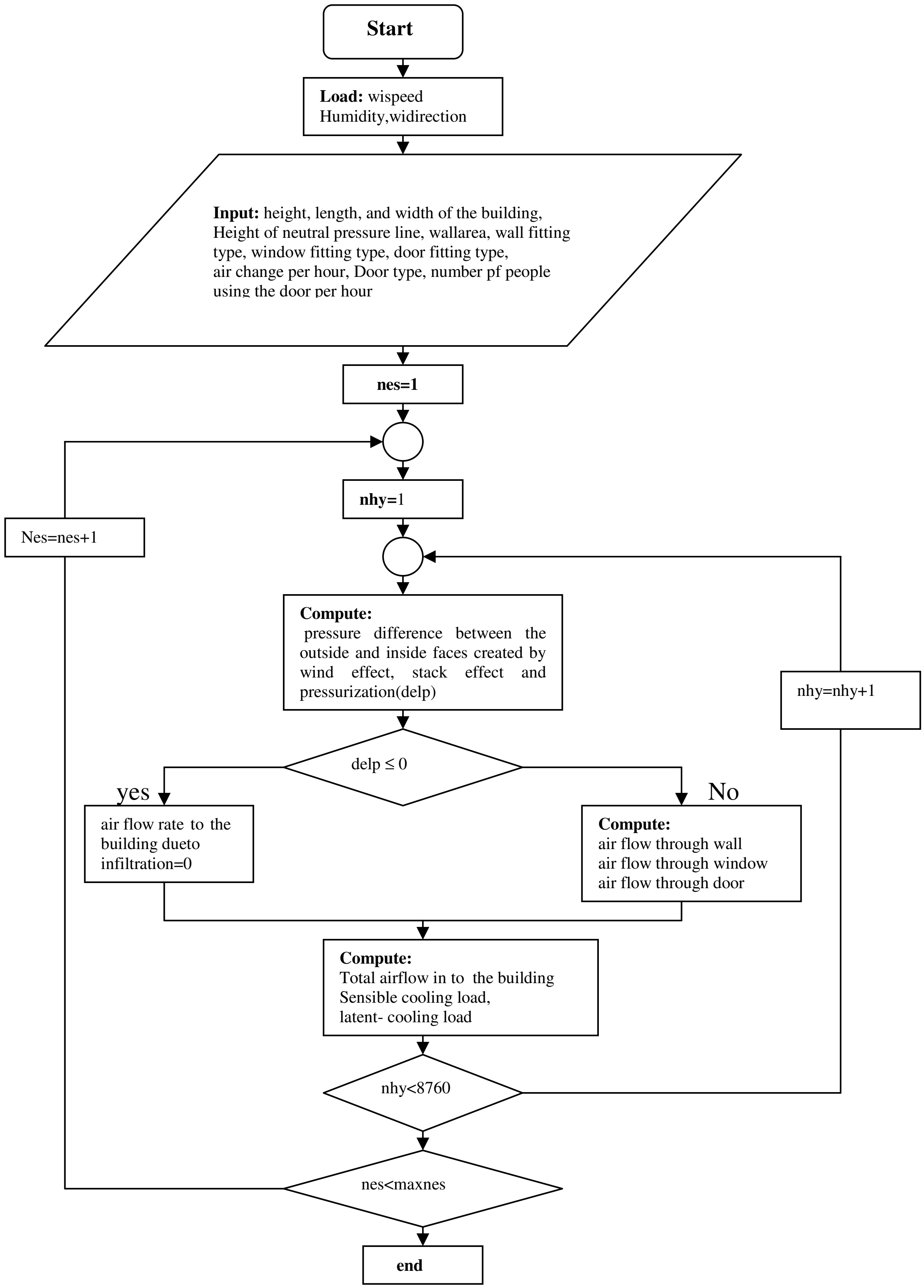

Fig 7-4 Algorithm for heat gain through infiltration

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nhy- number of hours per year

7.1.5 Algorithm for Analysis of Internal Heat Gain

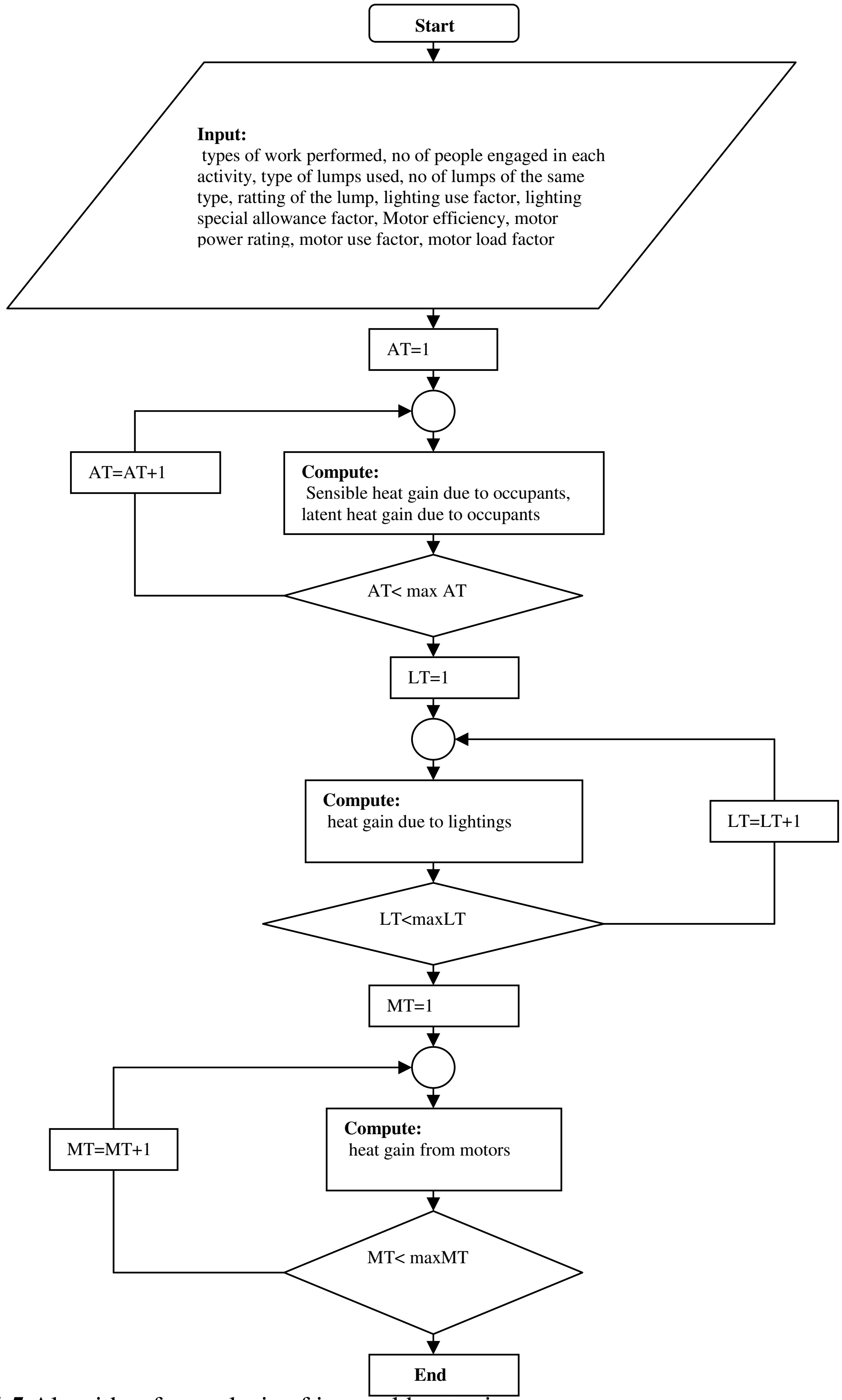

Fig 7-5 Algorithm for analysis of internal heat gain.

AT- activity type	max AT- maximum number of activity type
LT-lump type	max LT- maximum number of lump type
MT-motor type	max MT-maximum number of motor type

7.1.6 Algorithm for Changing Heat Gain in to Space Cooling Load

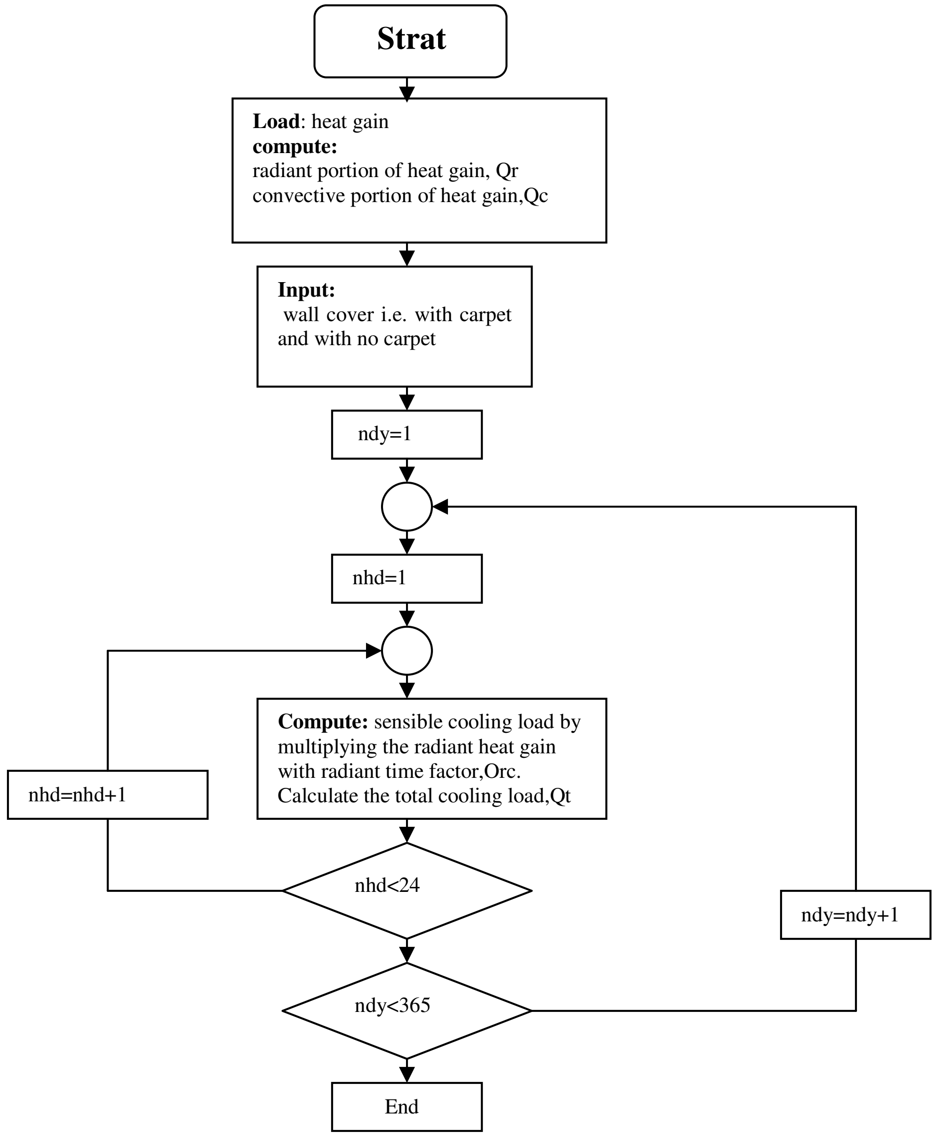

Fig 7-6 Algorithm for changing instantaneous heat gain in to cooling load

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Ndy- number of days per year
Nhd-number of hours per day

7.2 The GUI

There are six main GUI programs developed. The first program "starting window'', Fig 7.7 is used to display the title of the thesis. Besides this feature it has two push buttons, 'Next' and 'Exit'. The Next button leads to the remaining parts of the program and 'Exit' button helps to terminate the program.

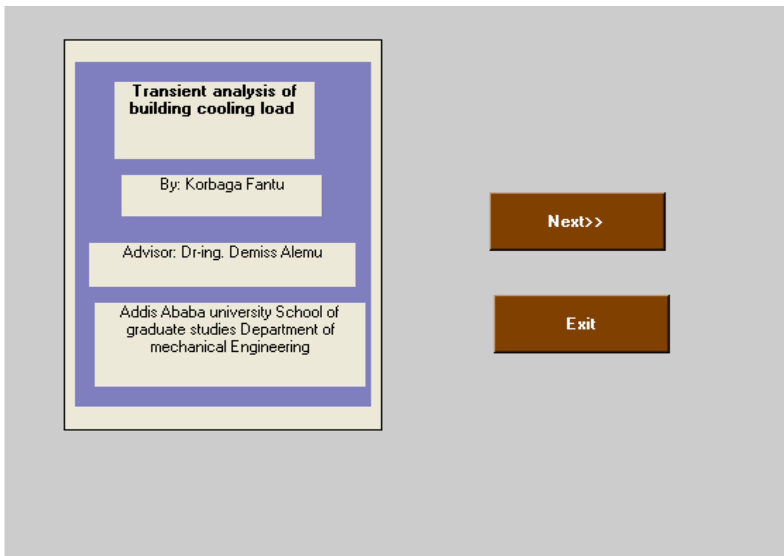

Fig 7-7 Starting window

If the user selects 'Next' button, the module will be automatically shifted to the next part, general input module, Fig 7.8. This module enables the user to define the location and other important features of the building. This module has four push buttons 'Back', 'Reset', 'Next' and 'Exit'. If the user selects 'Next', a module for program selection, Fig 7.9, appears. This module enables the user to choose between programs. It contains six push buttons, 'wall and roof heat gain', 'window heat gain', 'infiltration and ventilation heat gain', 'internal heat gain' and "exit'.

If the user selects one of this buttons the module will be automatically shifted to a module of the selected type. To see the whole feature lets start from the first button, wall heat gain.

The overall structure is divided in to two input modules. So the moment the user selects 'wall heat gain' button the first module, Fig 7.10, appears. This module is designed in such a way that it accepts inputs that are necessary for defining the orientation and surface properties of the wall. There are also four push buttons, Back, Reset, Next and exit with functions similar to their name.

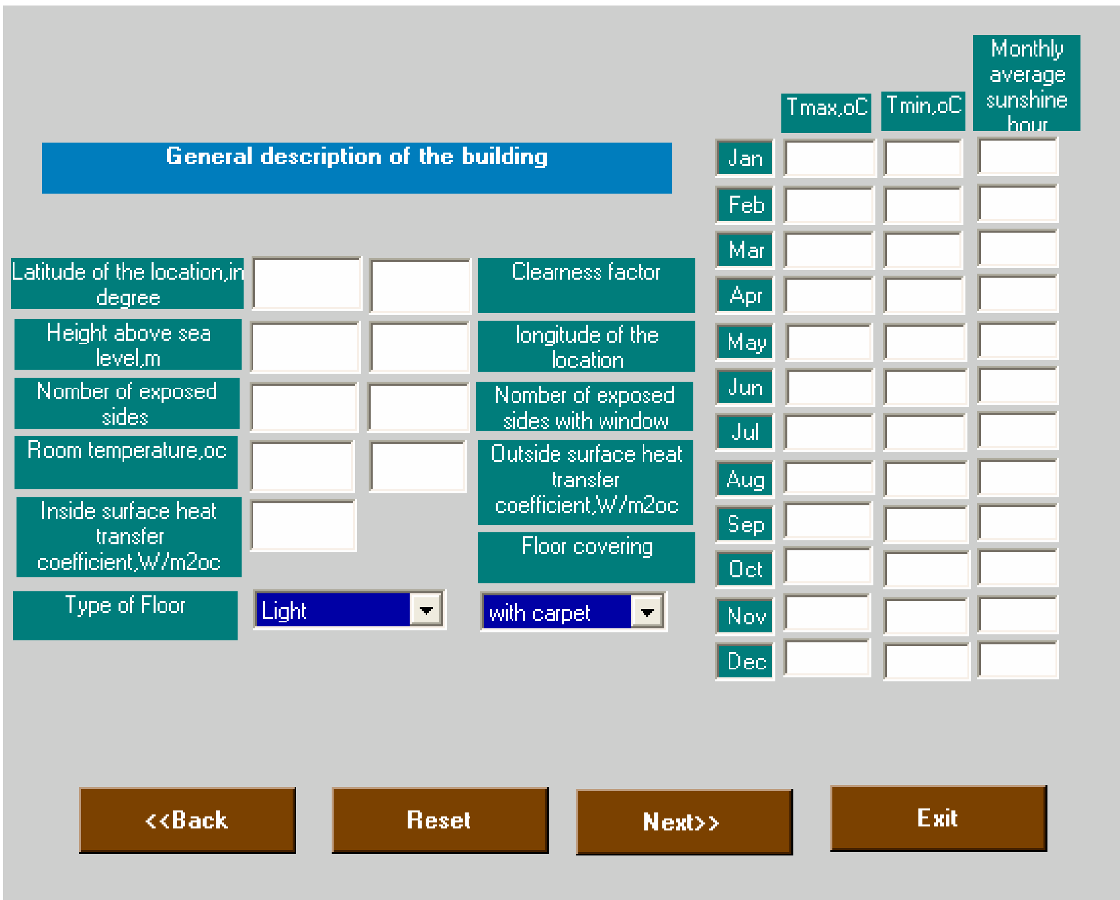

Fig 7-8 Input window for building description

If 'Next' is selected Fig 7.11 will appears. This module is especially designed for accepting thermal properties of the construction materials layer by layer in their order.

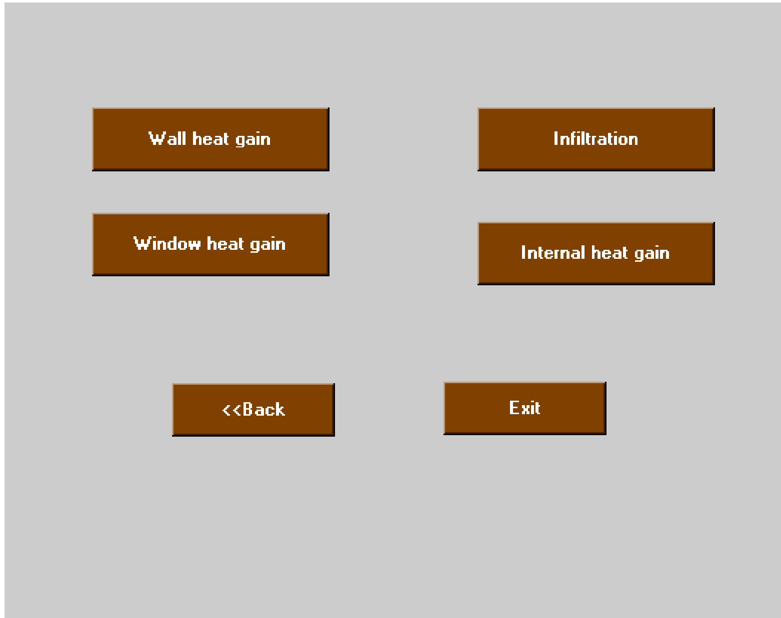

Fig 7-9 Input window for selection of programs

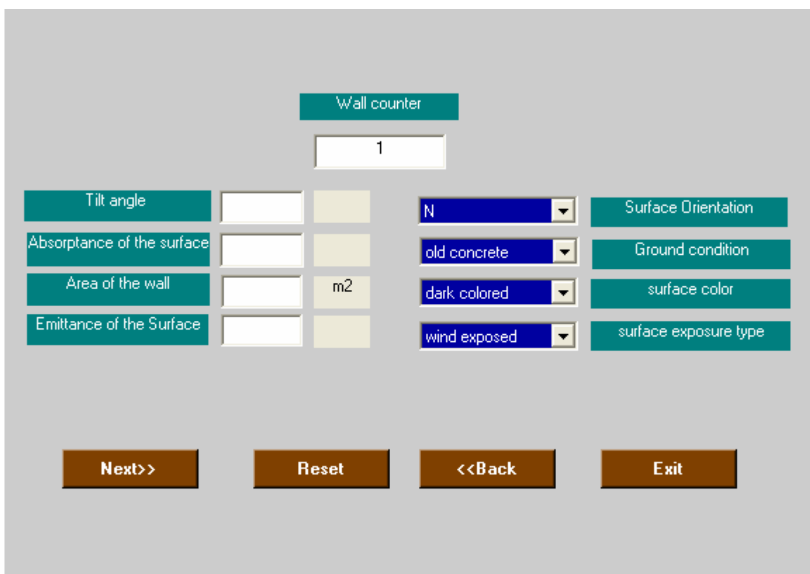

Fig 7-10 Input window for defining the orientation and surface properties of the wall

The module for computing heat gain through window, Fig 7.12, appears when the user selects 'window heat gain' button in the program selection module. This module has different popup buttons that enables the user to choose the desired type of glass from lists provided. If the glass used is not found in the lists given there are editable boxes that accept features of the glass used.

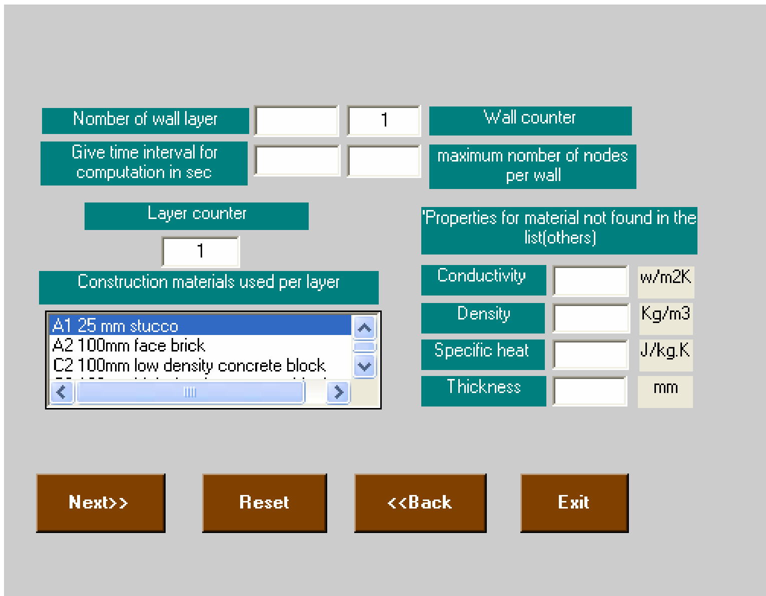

Fig 7-11 Input window for construction material property

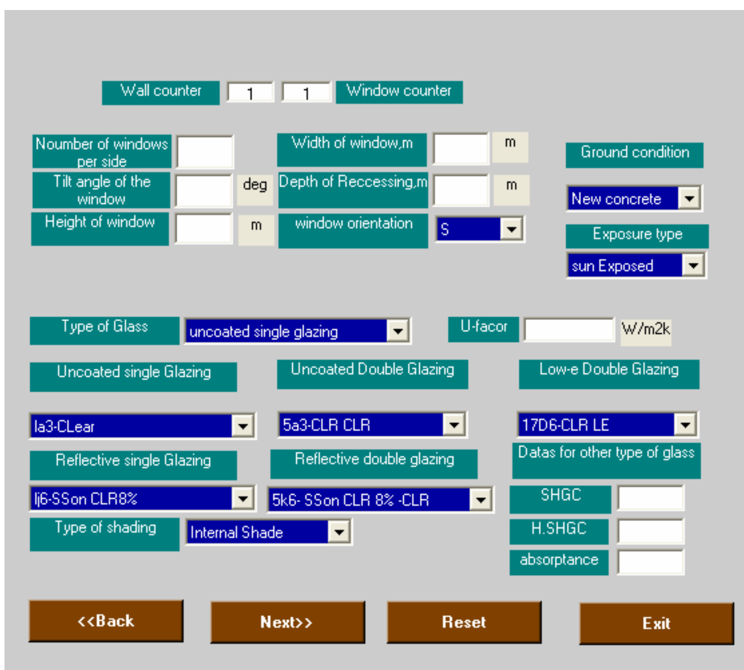

Fig 7-12 Input window for heat gain through window

The module for heat gain through infiltration is composed of three input modules for infiltration through wall, window and door

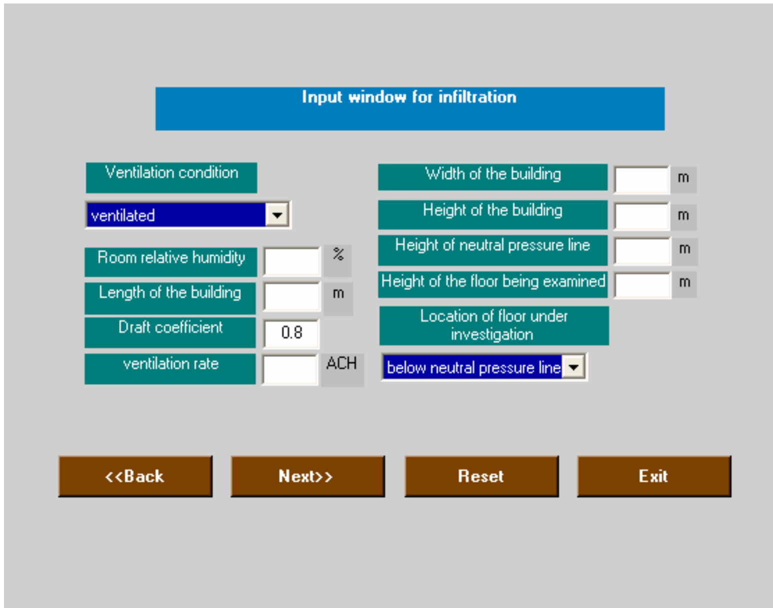

Fig 7-13 Input window for infiltration

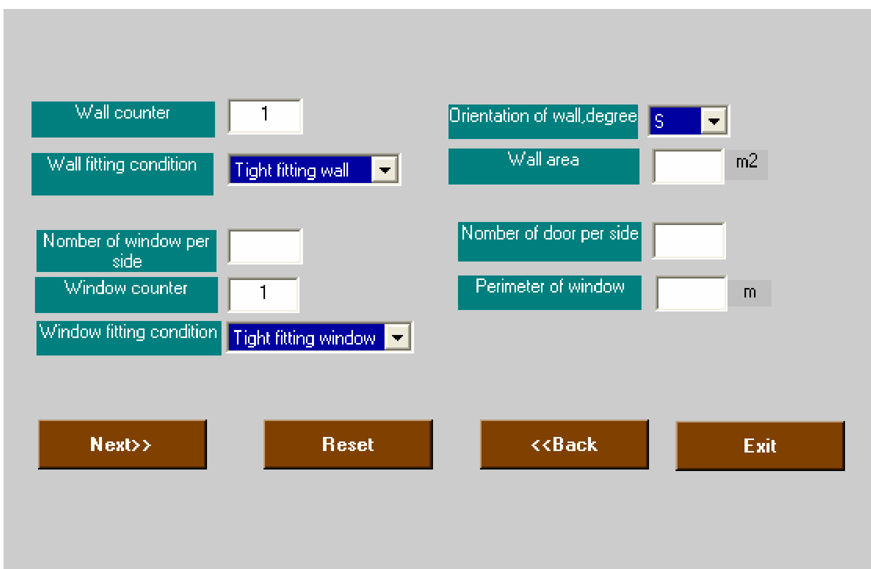

Fig 7-14 Continuation of infiltration heat gain through wall and window

The first module, Fig 7.13, will appear when the user selects 'infiltration heat gain' button. This module enables the user to define wheather the building is ventilated or not, the overall length width and height of the building, relative humidity and height of the neutral pressure line. It also enables to define whether the building is ventilated or not. . If the room is ventilated there will not be infiltration due to the pressurization of the building. So if we choose the building to be ventilated we will not find the next two modules as they are totally dedicated to infiltration. If the building is not ventilated there will be infiltration and pressing 'next' button will lead as to the second module.

The second module, Fig 7.14, is designed for the user to define type of fitting of the wall, wall area, number of window and door per side, perimeter of window etc. selecting continue will shift the module to the third module, Fig 7.15, which enables the user to fully define the type of door used with type of fitting.

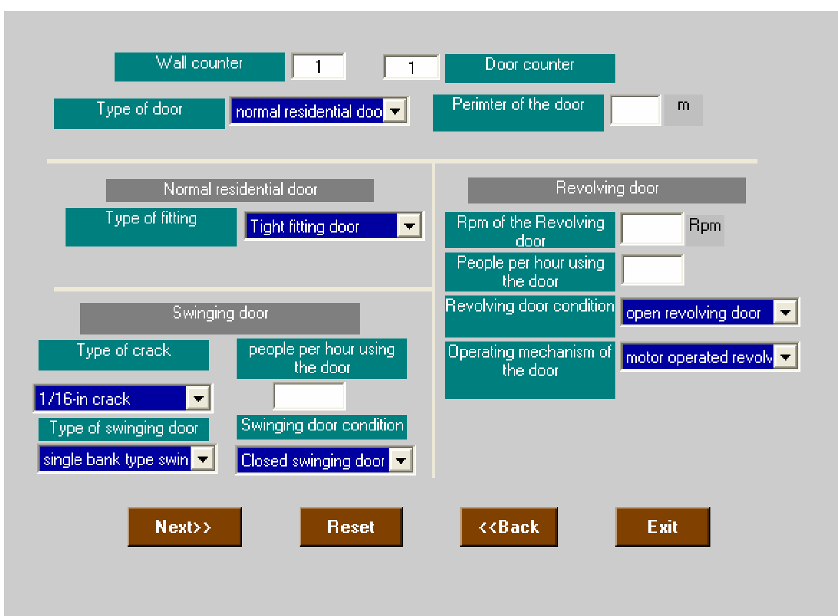

Fig 7-15 Input window for infiltration through door

The last part of the main program, i.e. internal heat gain computing module will be activated when the user choose 'internal heat gain' button of the starting window. Just as before this is also composed of three input modules, one for heat gain through occupancy, Fig 7.16, one for heat gain through lumps, Fig 7.17, and one for heat gain from motors, Fig 7.18.

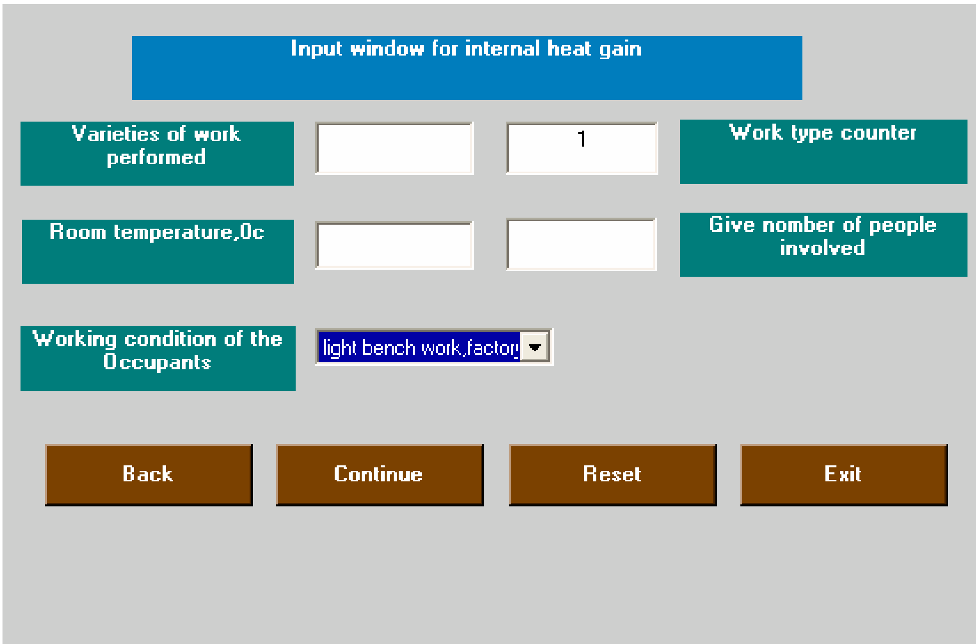

Fig 7-16 Input window for internal heat gain

As stated before the first module, Fig 7.16, enables the user to define the varieties of work performed in the conditioned space together with number of person engaged in each particular activity.

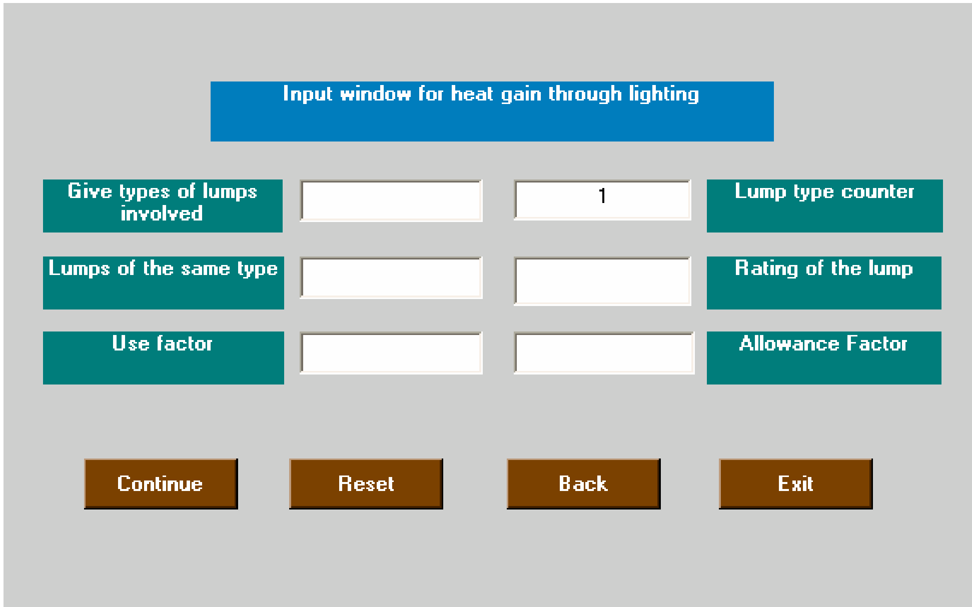

Fig 7-17 Input window for heat gain through lighting

Selecting 'continue' button will shift the module to the second input module, Fig 7.17, and this module is designed to accept type, number and specific features of lumps involved in the conditioned space. The last part of the module is activated by pressing the continue button of the second input module.

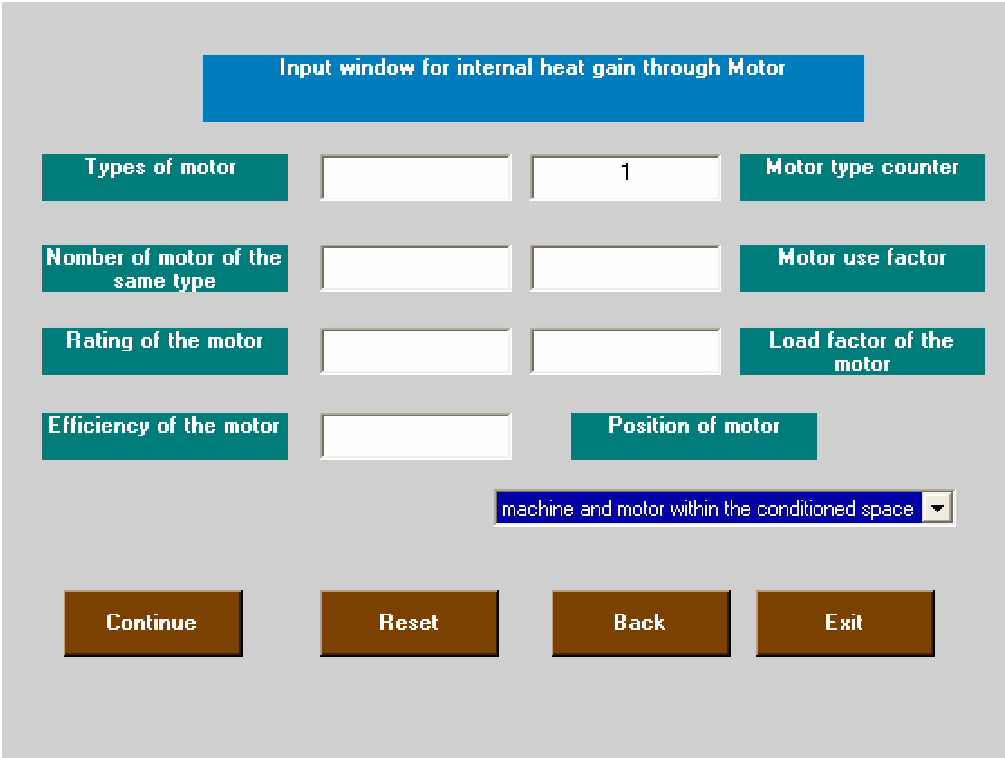

Fig 7-18 Input window for internal heat gain through motor

This module is designed in such a way that the user can put the property, type and number of motors used in the conditioned space.

CHAPTER 8

VERIFICATION AND COMPARISON OF RESULTS

The outputs of the computer program developed are counterchecked with results of varies literatures and the results are summarized below.

8.1 Verification of Sol-Air Temperature

The solair temperature and various variables related to solar radiations are calculated for a particular July day, July 21, for a location in America and the results obtained are counterchecked with the results found for the same day on ASHRAE handbook Fundamentals [4], and it is summarized below in table form.

From the results calculated one can clearly see that the error is almost negligible and we can fully depend on this program for our calculation of sol-air temperature and the like variables related to solar radiation for the need of computation of heat gain due to solar radiation.

Table 0-1 Comparisons of sol air temperature and other solar terms

General input	**Surface input**
Time zone=3	Azimuth=45
Month=7	Tilt=90
Longitude =90	**Sol-air temp input**
Latitude=40	Absorptance=0.45
Clearness=1	h(outside)=17.3
Ground reflectance=0.2	Emittance=1

DIRECT BEAM SOLAR HEAT GAIN						DIFFUSE SOLAR HEAT GAIN					
Direct normal irradiance ASHRAE	Direct normal irradiance Computed	Surface incidence angle ASHRAE	Surface incidence angle Computed	Surface direct irradiance ASHRAE	Surface direct irradiance Computed	Ground diffuse ASHRAE	Ground diffuse Computed	Sky Diffuse ASHRAE	Sky Diffuse Computed	Sol-air temp ASHRAE	Sol-air temp Computed
0	0	139.3	139.32	0	0	0	0	0	0	24.4	24.39
0	0	151.6	151.64	0	0	0	0	0	0	24.4	24.39
0	0	162.7	162.68	0	0	0	0	0	0	23.9	23.89
0	0	167.8	167.76	0	0	0	0	0	0	23.3	23.29
0	0.09	161.1	161.13	0	0	0	0	0	0.01	23.3	23.29
399	398.69	149.7	149.74	0	0	13.7	13.67	24.4	24.4	24.3	24.28
641	640.69	137.3	137.34	0	0	33.9	33.89	39.2	39.21	25.8	25.79
754	753.51	124.7	124.74	0	0	53	53.03	46.1	46.11	27.6	27.57
814	813.67	112.2	112.24	0	0	69.6	69.59	49.8	49.8	29.8	29.79
847	847.33	100	100.04	0	0	82.5	82.46	55.7	55.7	31.9	31.88
865	865.01	88.4	88.36	24.8	24.83	90.8	90.78	66.2	66.21	35.3	35.32
871	871.15	75.4	77.48	220.1	188.88	94	93.99	80.6	78.13	42.5	41.57
867	867.14	67.8	67.84	327	327.05	91.9	91.88	89.6	89.55	47.1	47.11
852	852.09	60.1	60.08	425	425.03	84.6	84.58	98	98.02	50.2	50.19
822	822.32	55	55.01	471.6	471.59	72.6	72.59	101	101.1	51.8	51.76
769	769.02	53.4	53.41	458.4	458.4	56.7	56.7	96.4	96.4	50.4	50.29
671	670.76	55.6	55.59	379	379.03	38	37.99	81.8	81.82	46.9	46.86
467	467.01	61.1	61.15	225.4	225.37	17.8	17.82	53	52.96	40.5	40.49
33	33.21	69.3	69.26	11.8	11.76	0.6	0.65	3.4	3.36	31	31
0	0	79.1	79.12	0	0	0	0	0	0	29.4	29.39
0	0	90.2	90.15	0	0	0	0	0	0	28.3	28.29
0	0	101.9	101.94	0	0	0	0	0	0	27.2	27.19
0	0	114.2	114.2	0	0	0	0	0	0	26.1	26.09
0	0	126.7	126.73	0	0	0	0	0	0	25	24.99

8.2 Verification of Wall Heat Gain And Cooling Load

A simple wall located at 40^0 North latitude and 90^0 longitude, which is facing southwest, is taken for verification purpose. The wall is composed of light colored 100mmbrick, 50mm insulation and 200mm light weight concrete block with air space between the brick and insulation. The results found using finite different method are counterchecked with that obtained by Conduction Transfer Function method (CTF) and presented in table and graph form as follows.

Table 0-2 Cmparisons of heat gain and cooling load through wall

Hour	Sol-air Temp.,°C	Heat gain CTF	Heat gain FDM	Error in %	Cooling load CTF	Cooling laod FDM	Error in %
1	24.4	47.8	46	-3.91	46.7	47.07	0.80
2	24.4	43.8	42.26	-3.62	43.6	44.09	1.14
3	23.9	39.5	38.36	-2.95	40.2	40.84	1.60
4	23.3	35.2	34.48	-2.06	36.7	37.49	2.17
5	23.3	30.8	30.73	-0.19	33.0	34.19	3.60
6	24.3	26.7	27.17	1.73	29.5	30.98	5.04
7	25.8	23.0	23.84	3.55	26.2	27.95	6.701
8	27.6	19.6	20.89	6.20	23.2	25.19	8.611
9	29.8	16.7	18.48	9.63	20.5	22.84	11.44
10	31.9	14.5	16.75	13.45	18.3	21.03	14.92
11	35.3	13.0	15.82	17.85	16.7	19.85	18.88
12	42.5	12.8	15.77	18.85	16.0	19.39	21.20
13	47.1	13.5	16.77	19.50	16.2	19.78	22.14
14	50.2	15.5	19.13	19.00	17.4	21.29	22.4
15	51.8	19.4	23.027	15.75	20.0	24.09	20.47
16	50.4	25.0	28.278	11.59	24.1	28.12	16.70
17	46.9	31.7	34.44	7.97	29.2	33.10	13.37
18	40.5	38.9	40.86	4.80	35.1	38.54	9.81
19	31.0	45.6	46.71	2.39	40.8	43.79	7.33
20	29.4	51.0	51.13	0.27	45.8	48.11	5.04
21	28.3	54.4	53.41	-1.83	49.3	50.83	3.12
22	27.2	55.3	53.53	-3.29	50.9	51.79	1.76
23	26.1	54.0	51.99	-3.85	50.7	51.23	1.06
24	25.0	51.3	49.33	-3.97	49.1	49.54	0.90

The temperature distribution across the wall over 24 hour is shown in Fig 8.1 taking three nodes as representative nodes. From the results we can see that at 1hr the inside surface temperature is less than both outside and interior node for this particular location. The interior node has higher temperature during night as it has heat absorbed during daytime. During daytime the temperature distribution decreases as we go from outside to inside.

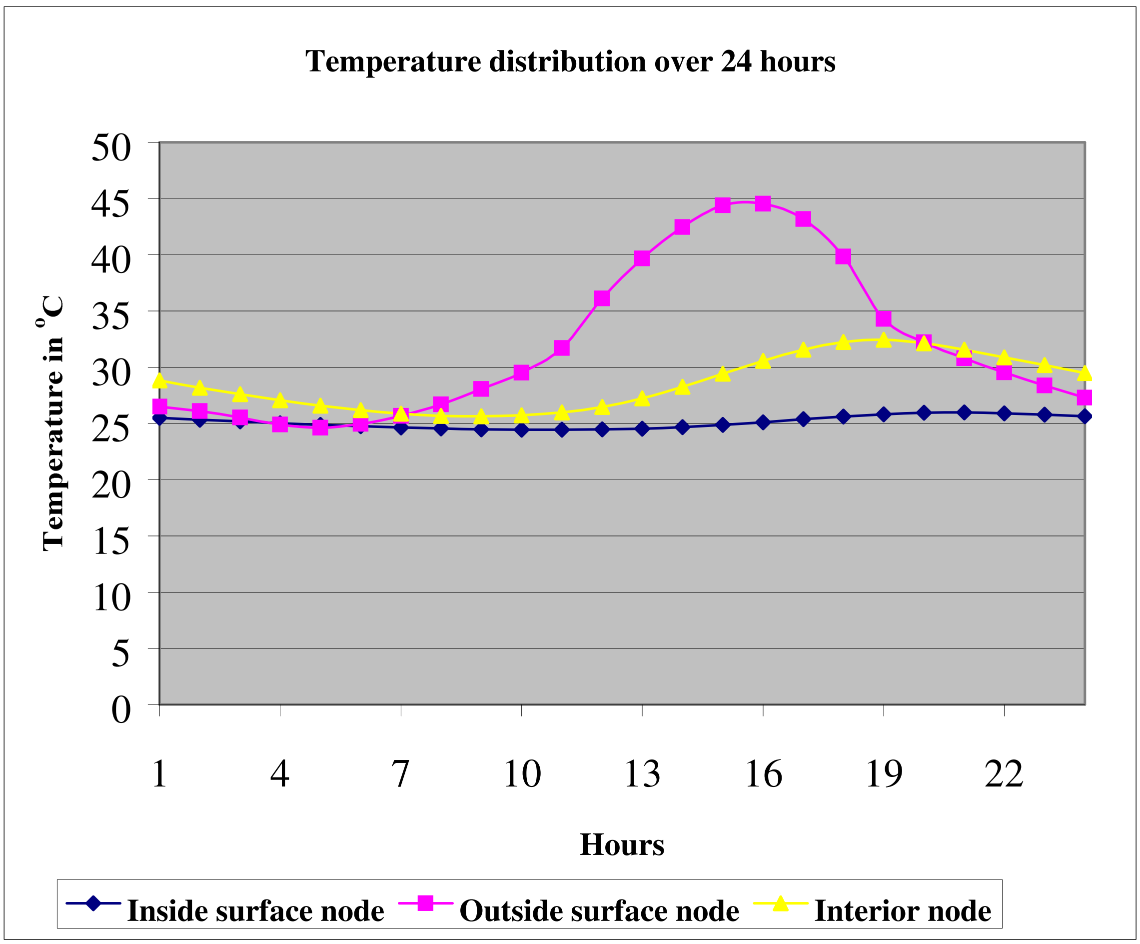

Fig 0-1 Temperature distribution for selected nodes

Heat gain and cooling load variations with sol-air temperature are shown in Fig 8.2 . As we can see there is some time lag between the peak values of the three variables. The heat gain starts to rise after some time lag from the sol- air temperature starts to rise. This is because some time should pass before the heat absorbed in the outside surface reaches to the room. The radiant portion of the heat gain will not create an immediate load, as it has to be absorbed and reradiated back before creating a load. This will create some time gap between the peak values of heat gain and cooling load. Fig 6.2 clearly shows these facts

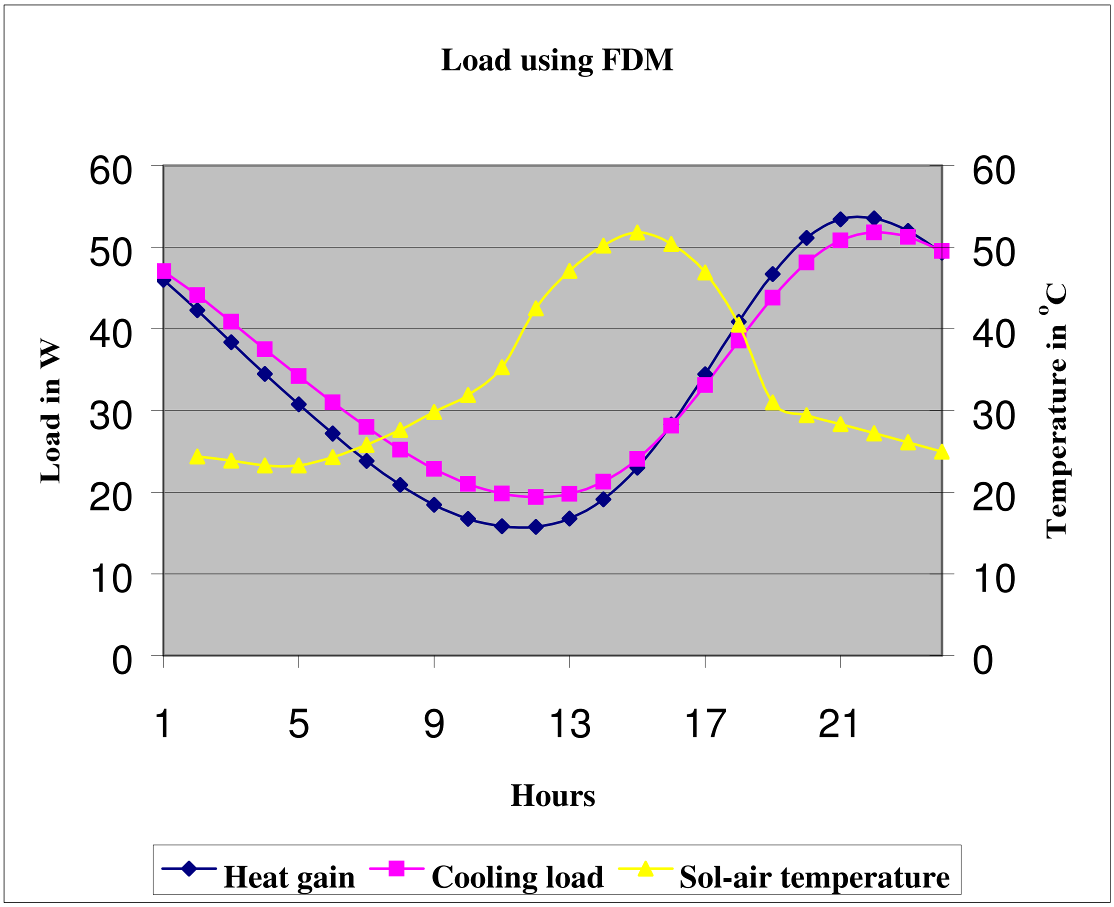

Fig 0-2 wall heat gain, cooling load and sol-air temperature using FDM

The results found using finite difference method (FDM) and conduction transfer function (CTF) are shown in graph form in Fg 6.2 and Fig 6.3

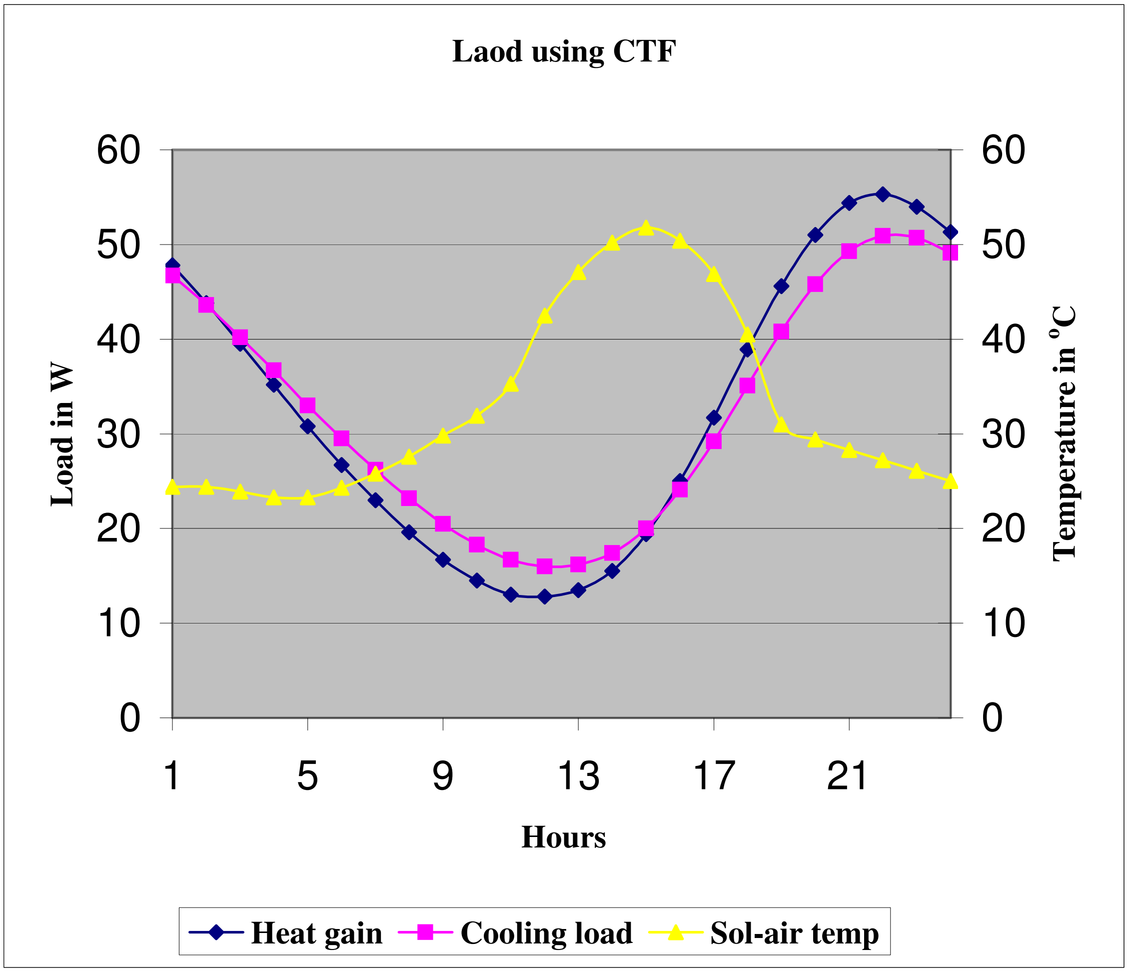

Fig 0-3 Wall heat gain, cooling load and sol-air temperature using CTF

8.3 Verification of Fenestration Heat Gain And Cooling Load

For the same July day the heat gain as well as cooing load due to solar heat gain through window with the following specification are calculated and checked with results found in ASHRAE fundamental handbook [4]. The results found are summarized as follows

Glass specification
Double glazed bronze
low-e,17f
Area=1.858
U-factor=3.18

T Outside	Direct Normal Irradiance,W, Computed	Surface Incident Angle Computed	Direct Solar Heat Gain, W Computed	Direct solar Heat Gain, W ASHRAE	Total Diffuse, W Computed	hshgc	Diffuse Solar Heat Gain,W Computed	Diffuse Solar Heat Gain, W ASHRAE	Conduction Heat Gain,W Computed	Conduction Heat Gain,W ASHRAE	Total Heat Gain, W Computed	Total Heat Gain,W ASHRAE	Window Cooling Load,W Computed	Window Cooling Load,W ASHRAE
24.4	0	139.32	0	0	0	0.38	0	0	2.954	3.3	2.9542	3	32.1019	32
24.4	0	151.64	0	0	0	0.38	0	0	2.954	3.3	2.9542	3	30.9395	31
23.9	0	162.68	0	0	0	0.38	0	0	0	0	0	0	28.1217	28
23.3	0	167.76	0	0	0	0.38	0	0	-3.54	3.3	-3.54	3	24.6828	25
23.3	0.09	161.13	0	0	0.01	0.38	0.0071	0	-3.54	3.3	-3.5329	3	23.3956	24
23.3	398.69	149.74	0	0	38.07	0.38	26.879	26.9	-3.54	3.3	23.338	3	40.5165	41
23.9	640.69	137.34	0	0	73.1	0.38	51.612	51.6	0	0	51.611	52	60.7988	61
25	753.51	124.74	0	0	99.14	0.38	69.997	70	6.69	6.6	76.686	72	79.2946	79
26.7	813.67	112.24	0	0	119.4	0.38	84.294	84.3	16.54	16.4	100.83	101	96.9086	97
28.36	847.33	100.04	0	0	138.2	0.38	97.546	97.5	25.99	26.3	123.53	124	113.1566	113
30.6	865.01	88.36	0	1.1	157	0.38	110.84	110.8	39.59	39.4	150.42	151	132.3626	133
32.2	871.15	77.48	67.07	81.9	172.1	0.38	121.52	123.3	49.04	49.2	237.63	254	184.5959	194
33.9	867.14	67.84	178.81	174.6	181.4	0.38	128.1	128.1	59.08	59.1	365.99	362	270.2678	271
34.4	852.09	60.08	277.75	275.9	182.6	0.38	128.92	128.9	62.04	62.4	468.71	467	353.9409	354
35	822.32	55.01	333.22	328.6	173.6	0.38	122.6	122.6	65.58	65.6	521.4	517	412.7517	410
34.4	769.02	53.41	330.19	326.2	153.1	0.38	108.09	108.1	62.04	62.4	500.32	497	424.0194	422
33.9	670.76	55.59	265.77	262	119.8	0.38	84.591	84.6	59.08	59.1	409.44	406	383.4266	381
32.8	467.01	61.15	144.36	142.7	70.78	0.38	49.974	50	52.59	52.5	246.91	245	284.9167	283
30.6	33.21	69.26	6.16	6	4.01	0.38	2.8312	2.8	39.59	39.4	48.577	48	144.9287	144
29.4	0	79.12	0	0	0	0.38	0	0	32.5	32.8	32.496	33	95.4659	95
28.3	0	90.15	0	0	0	0.38	0	0	26	26.3	25.997	26	69.4567	70
27.2	0	101.94	0	0	0	0.38	0	0	19.5	19.7	19.497	20	54.7649	55
26.1	0	114.2	0	0	0	0.38	0	0	13	13.1	12.999	13	43.8976	44
25	0	126.73	0	0	0	0.38	0	0	6.479	6.6	6.4793	7	35.4365	36

Table0-3 ComparisonofFenestrationcooling*load*

8.4 Verification of Airflow Rate Due to Infiltration

A 12- story office building with plan dimensions of 36.57m x 9.143m(120ft x 30ft) and 3.04m(10ft) floor height with other descriptions listed in Table 8.3 is used for verifying the result. The results obtained are also summarized in the same table .

Table 0-4 Comparison of airflow due to infiltration

Indoor-outdoor temperature difference =21^{0}c 6.7m/s wind speed normal to one of the long side	Two vestibule type doors in the windward side, each handling 250 people per hour			
		Computed result	**ASHRAE Result[6]**	**Error in %**
Change in pressure due to stack effect (in m of water)		0.00254	0.002235	3.6
Change in pressure due to wind effect (in m of water)				
	Windward side=0.0665	0.001689	0.001676	0.77
	Sides=-0.0785	-0.00199	-0.00185	7.56
	Leeward side=-0.03	-0.00076	-0.00071	7.04
Total pressure difference (in m of water)	Windward side	0.004229	0.003912	8.10
	Sides	0.000546	0.000381	43.3
	Leeward side	0.001778	0.001524	16.66
Infiltration rate through wall crack (in m3/sec)				
	windward side	0.1166	0.113282	2.92
	sides	0.0064	0.005664	12.9
	leeward side	0.0665	0.062305	6.7
Total infiltration rate through wall		0.1959	0.186915	4.8
Total infiltration through door		1.396	1.364	**2.34**

8.5 Verification of Light Heat Gain

Suspended fluorescent lights with a total load of 2000W are taken for verification. The lights are 50% on at 7A.M., 100% on from 8A.M. to 6 P.M., then off for the remainder of the time. The sensible cooling load is calculated for the whole day and checked with the results given for 10A.M. in ASHRAE Handbook

Table8.4 Comparison of cooling load due to lighting heat gain.

Construction type- average commercial construction
Surface type- surface covered with carpet
Suspended fluorescent light

Hour	1	2	3	4	5	6	7	8	9	10	11	12
Computed	154.1	154.1	147.4	134	121	107	752	1511	1672	1752	1792	1812
ASHRAE										1752		
Hour	13	14	15	16	17	18	19	20	21	22	23	24
Computed	1826	1833	1846	1859	1873	1886	583	369	261	208	181	168

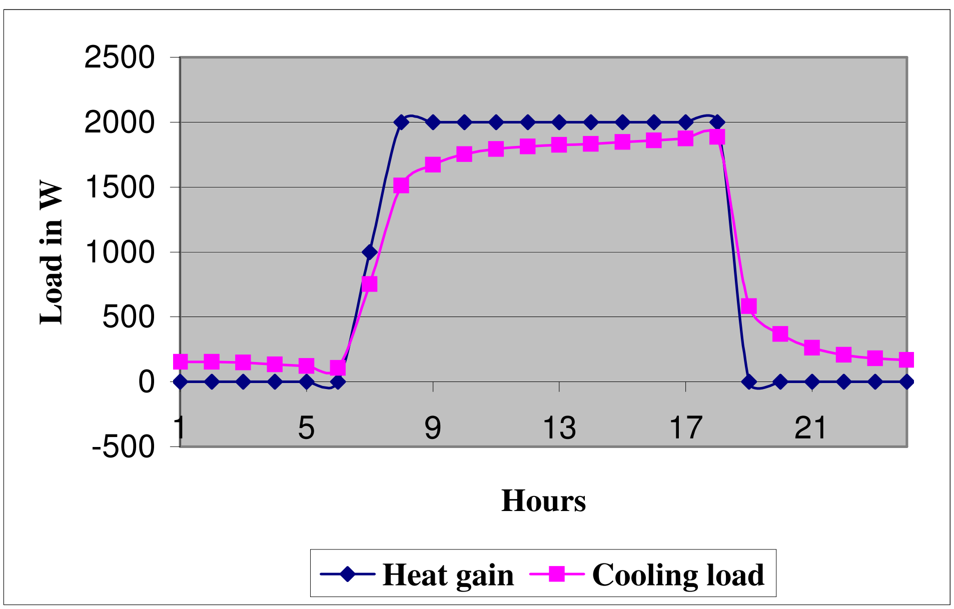

Fig 0-4 Heat gain versus cooling load for lighting

8.6 Analysis of Cooling Load of an Auditorium in Gode

Finally hourly analysis of sensible and latent cooling load analysis of an actual Auditorium building found in Gode is done. The location and other details of the building are given in Table 8.5 to Table 8.9.

Table 0-5 Location detail

Latitude	5.86
Longitude	43.7
Time zone	3

Table 0-6 Monthly minimum temperature, monthly maximum temperature and average sunshine hours

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp max	35.5	36.6	37.3	35	34.4	33.4	32.5	33.9	35.3	34.6	34.5	35.1
Temp min	22	23.2	24.9	24	24	23.5	22.8	22.9	23.6	22.9	22	21.8
Average sunshine hours	10.2	10.2	9.2	8.2	8.5	7.7	9.2	7.7	8.7	7.3	9.2	10.2

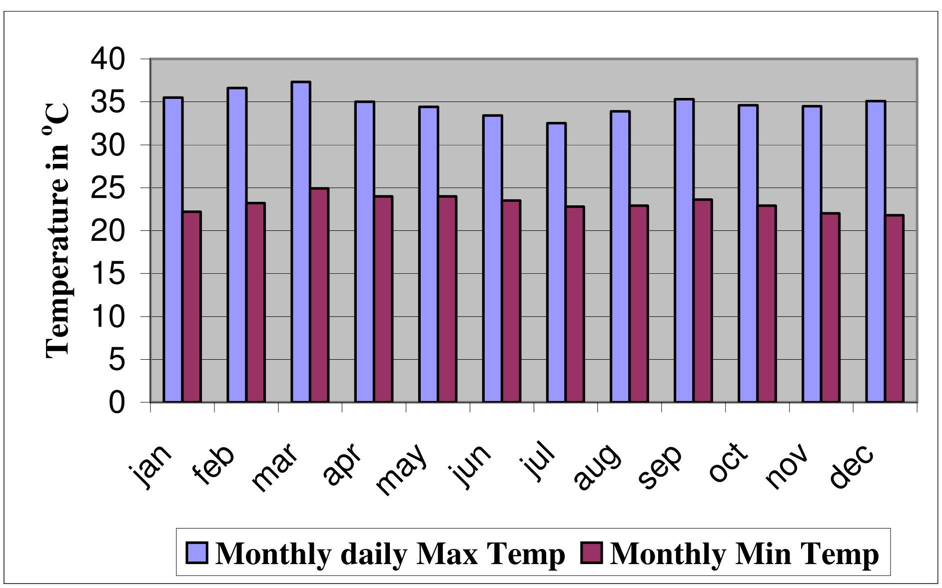

Fig 0-5 Monthly average daily min and max temperatures

Table 0-7 Building detail

	Overall wall area	Number of window [4]	Number of door[5]
South facing wall	174	3(2x 4),1(1.45x4)	1(1.7x 2),1(1x2)
West facing wall	120	-----	------
North facing wall	174	4(2x4),1(1.45x4)	1(1.7x 2)
East racing wall	120	2(2.55x 4), 2(1.15x4), 2(1.2x4)	1(4.8x 2)

Table 0-8 Construction material

	Layer1	Layer 2	Layer 3	Layer 4
Wall	C7-8 in hollow block	Concrete ¾ in stucco	----------	---------------
Roof	Galvanized steel	Ceiling air space	B4-3 in insulation	Soft wood ¾ in

Using the above-mentioned features of the building the results found are summarized in table and graph form as follows.

Table 0-9 Summary of cooling load

	Monthly sensible cooling load in KW-hr	Monthly latent cooling load KW-hr	Total cooling load KW-hr
Jan	64096.69	2089654	66186.34
February	60992.24	1918730	62910.97
March	68020.46	2211307	70231.77
April	54502.14	2078794	56580.93
May	55963.83	2350771	58314.6
June	49130.95	2136494	51267.44
July	56620.13	2066848	58686.98
August	52044.33	2191719	54236.05
September	59431.94	2127370	61559.31
October	53270.91	2179783	55450.69
November	57970.81	2083315	60054.13
December	63727.86	1972710	65700.57

[4] Single 4mm ordinary glass with Venetian blind is used for window
[5] single 4mm ordinary glass with no blind is used for door

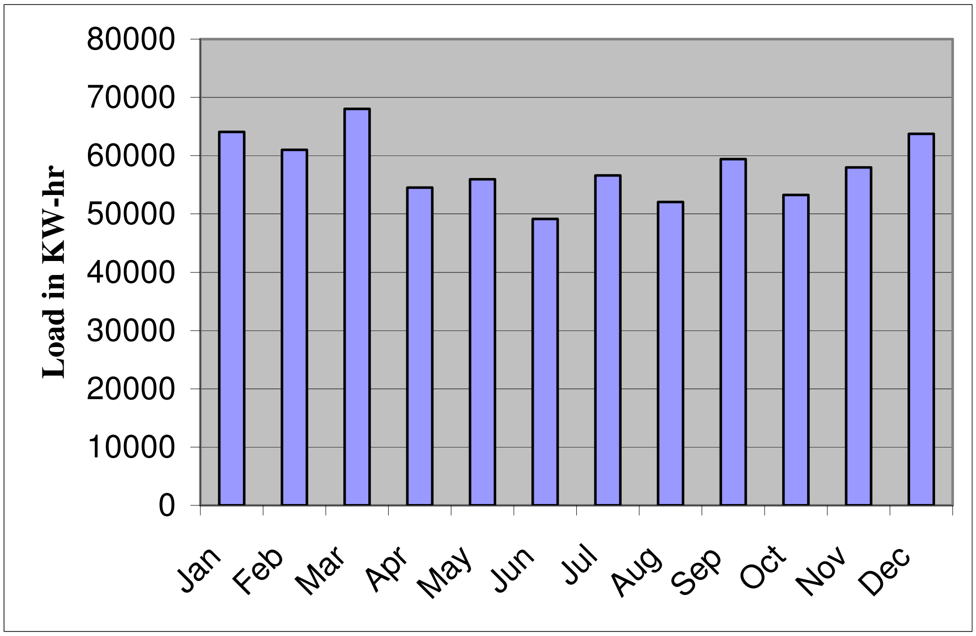

Fig 0-6 Monthly sensible cooling load

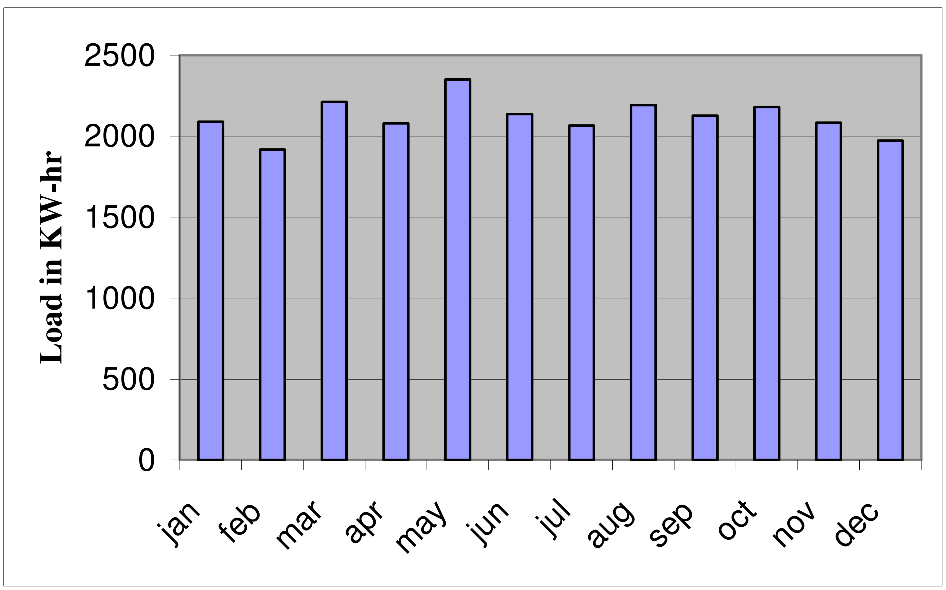

Fig 0-7 Monthly Latent heat gain

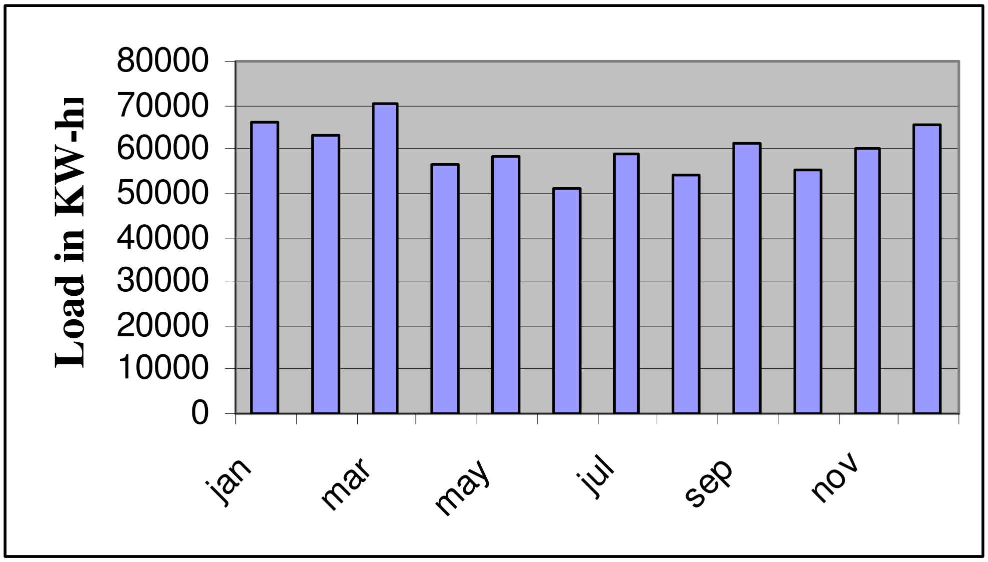

Fig 0-8 Monthly total cooling load

As we can see from the above graphs maximum cooling load occurs in march and minimum in june. Solar radiations for these two months are plotted against time in Fig 8.9 and Fig 8.10

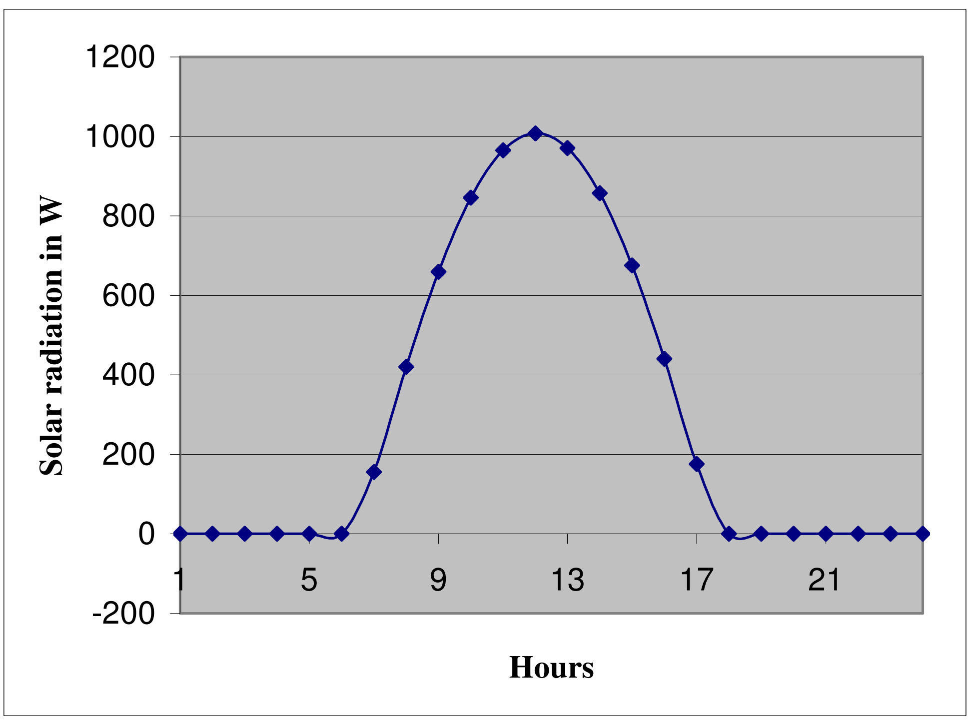

Fig 0-9 Solar radiation for March 21

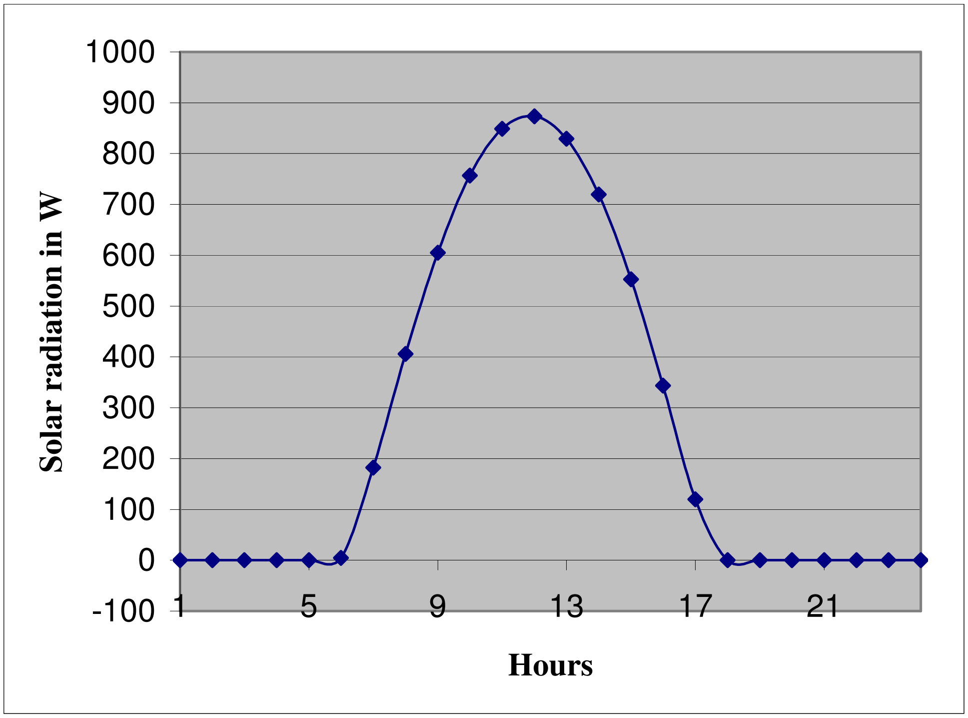

Fig 0-10 Solar radiation for June 21

Hourly variations of cooling loads for the peak load day, March 21, is given in Fig-----

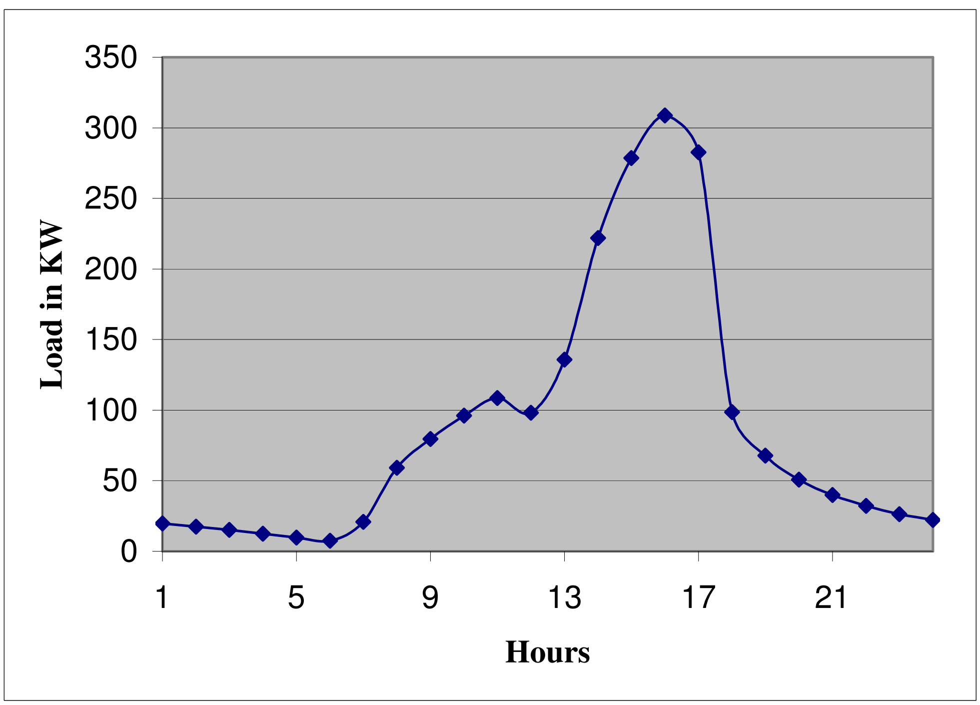

Fig 0-11 Sensible load variation with time for March 21

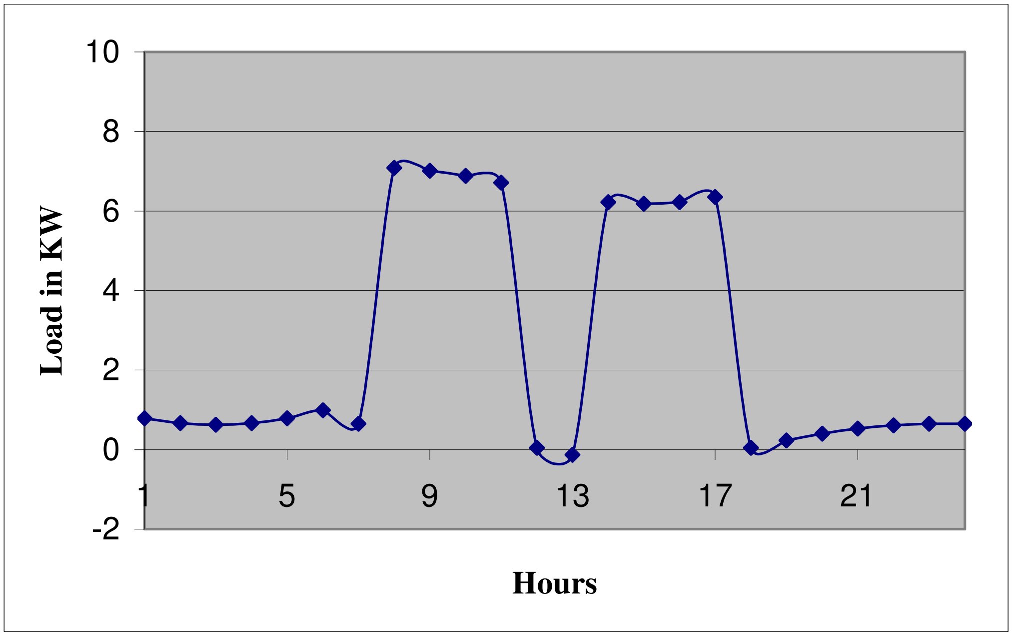

Fig 0-12 Hourly variation of Latent cooling load for March 21

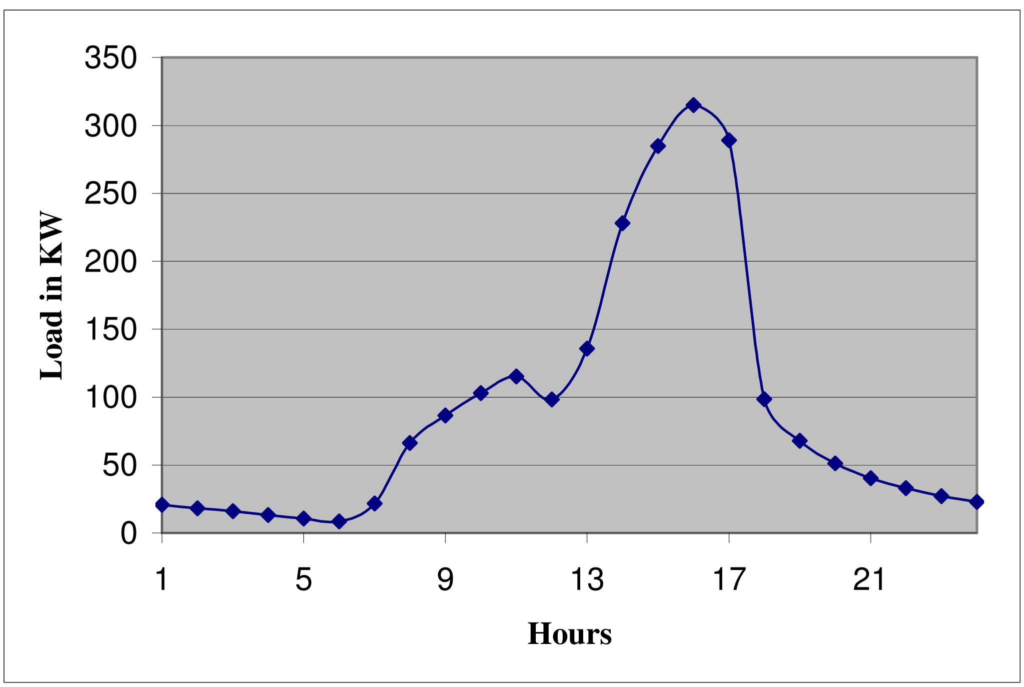

Fig 0-13 Hourly variation of cooling load for March 21

Electrical power consumption estimation

The electrical consumption that is needed for conditioning the given Auditorium can be calculated by

$$\text{Electrical energy} = \text{Thermal energy/COP}$$

Where COP- Coefficient of performance of the airconditioining system.

Taking the COP of the system to be 3, we can calculate the electrical energy needed per year as

$$\text{Electrical energy}=\frac{\text{Total thermal energy per year}}{3}$$

$$=\frac{721179.8}{3}$$

=240393.3KW-hr/year

The total amount of money required for running Air conditioning plant is estimated to be

Amount of money =Electrical energy X cost per unit

=240393.3 X 0.48

*=**<u>115,388.784birr</u>***

where 0.48 is EELPA's charge for KW-hr energy consumption

CHAPTER 9

CONCLUSION AND FUTURE WORK

The main objective of this thesis was developing a program that is capable of computing the sensible and latent cooling loads of a single zone building taking all the influential factors in to consideration. This thesis uses FDM which replaces the CTF method which is mostly used by other commercial softwares. It also analyses infiltration effects deeply unlike other softwares and this makes it more appropriate for cooling load estimation of structures that need precision analysis like cold rooms. One can also use this thesis for cooling load estimation of other single zone structures like Auditorium buildings..

Values obtained can be taken for modifying the building orientation and construction material accordingly with the resulting cooling load at the design stage or can also be used for approximation of energy requirement of actual buildings.

To make the program more powerful the following things are suggested as a future work.

- The program developed has a capacity of determining single zone-cooling load. But to select the required type of air conditioning equipment having only zone cooling load is not enough. So as a future work one can expand this project to calculate system-cooling load taking other influencing factor like supply air temperature, supply system heat gain, extraction system heat gain etc in to consideration.

- It is known that the surrounding buildings can affect cooling load by blocking some of the direct radiation coming and changing wind direction. To get more accurate results one can incorporate this shading effect of surrounding buildings as a future work.
- Finally it is also possible to upgrade this program in such a way that it can be interfaced with AutoCAD. This interface enables it to accept drawings directly from AutoCAD and calculate the cooling load accordingly rather than giving the orientation of each wall as done in this program.

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www.H:\koffe\Application Center Application Heat Transfer Through a Multilayer Wall.htm

Appendix A

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%MATLAB PROGRAMMING FOR COMPUTING HOURLY DRY BULB TEMPERATURE TAKING
%DAILY MAX AND MIN OF REPRESENTATIVE DAYS
Ta=zeros(8760,1);
rt=0;
for wq=1:365
     rt=rt+1;
     if wq<32
        tmax(wq)=tmaj;
        tmin(wq)=tmij;
     elseif wq<60
        tmax(wq)=tmaf;
        tmin(wq)=tmif;
     elseif wq<91
        tmax(wq)=tmam;
        tmin(wq)=tmim;
     elseif wq<121
        tmax(wq)=tmaa;
        tmin(wq)=tmia;
     elseif wq<152
        tmax(wq)=tmama;
        tmin(wq)=tmima;
     elseif wq<182
        tmax(wq)=tmaju;
        tmin(wq)=tmiju;
     elseif wq<213
        tmax(wq)=tmajul;
        tmin(wq)=tmijul;
     elseif wq<244
        tmax(wq)=tmaau;
        tmin(wq)=tmiau;
     elseif wq<274
        tmax(wq)=tmas;
        tmin(wq)=tmis;
     elseif wq<305
        tmax(wq)=tmao;
        tmin(wq)=tmio;
     elseif wq<335
        tmax(wq)=tmano;
        tmin(wq)=tmino;
     else
        tmax(wq)=tmad;
        tmin(wq)=tmid;
      end
   end
   ii=0;
   rt1=0;
   for dy=1:365
    rt1=rt1+1;
      for hd=1:24
         ii=ii+1;
         md=((hd*pi)-(9*pi))/12;
         Ta(ii)=tmax(rt1)-((tmax(rt1)-tmin(rt1))/2)*(1-sin(md));
      end
   end
```

Appendix B

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%MATLAB PROGRAM FOR COMPUTATION OF SOLAR RADIATION AND      %
%SOLAIR TEMPERATURE                                         %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clc
abc=[1230 0.142 0.058 -11.2;
     1215 0.144 0.06  -13.9;
     1186 0.156 0.071  -7.5;
     1136 0.18  0.097   1.1;
     1104 0.196 0.121   3.3;
     1088 0.205 0.134  -1.4;
     1085 0.207 0.136  -6.2;
     1107 0.201 0.122  -2.4;
     1151 0.177 0.092   7.5;
     1192 0.16  0.073  15.4;
     1221 0.149 0.063  13.8;
     1233 0.142 0.057  1.6];
  a=0.29;
  b=0.41;
for i=1:ns
    n=0;
    ii=0;
    for m=1:12
       if m==1
            shh=shj;
            ndm=31;
       elseif m==2
            shh=shf
            ndm=28;
       elseif m==3
           ndm=31;
           shh=shm;
       elseif m==4
           ndm=30;
           shh=sha;
       elseif m==5
           ndm=31;
           shh=shma;
       elseif m==6
           ndm=30;
           shh=shju;
       elseif m==7
           ndm=31;
           shh=shjl;
       elseif m==8
           ndm=31;
           shh=shau;
       elseif m==9
           ndm=30;
           shh=shs;
       elseif m==10
           ndm=31;
           shh=sho;
```

```
        elseif m==11
            ndm=30;
            shh=shn;
        elseif m==12
            ndm=31;
            shh=shd;
        end

     for d=1:ndm
          n=n+1;
          dec=(pi/180)*23.45*sin(pi*(360*(284+n))/(365*180));% declination
     for LST=1:24
          ii=ii+1;
          LSM=90;
          ET=abc(m,4);
          AST=LST+(ET/60)+((LSM-LON)/15);
          H=15*(AST-12);% hour angle
alti=asin((cos(pi*L/180)*cos(dec)*cos(pi*H/180))+(sin(pi*L/180)*sin(dec)))
;%altitudei
solazb=acos(((sin(alti)*sin(L*pi/180))-
sin(dec)))/(cos(L*pi/180)*cos(alti)));
   if AST<=12
     solazb=-solazb;
   else solazb=solazb;
   end
    if surfazg(i)==1
       surfaz(i)=0;
    elseif surfazg(i)==2
       surfaz(i)=22.5;
    elseif surfazg(i)==3
       surfaz(i)=45;
    elseif surfazg(i)==4
       surfaz(i)=67.5;
    elseif surfazg(i)==5
       surfaz(i)=90;
    elseif surfazg(i)==6
       surfaz(i)=112.5;
    elseif surfazg(i)==7
       surfaz(i)=135;
    elseif surfazg(i)==8
       surfaz(i)=157.5;
    elseif surfazg(i)==9
       surfaz(i)=180;
    elseif surfazg(i)==10
       surfaz(i)=202.5;
    elseif surfazg(i)==11
       surfaz(i)=225;
    elseif surfazg(i)==12
       surfaz(i)=247.5;
    elseif surfazg(i)==13
       surfaz(i)=270;
    elseif surfazg(i)==14
       surfaz(i)=292.5;
    elseif surfazg(i)==15
       surfaz(i)=315;
    else surfazg(i)==16
       surfaz(i)=337.5;
```

```
    end
    solaz=real(solazb*180/pi);%solar azimuth in angle
    if surfaz(i)<=180
      surfazz=surfaz(i);
    else surfazz=-(360-surfaz(i));
    end
    surfsolaz=(solaz-surfazz);
    C=abc(m,3);
    if alti>0
    A=abc(m,1);
    B=abc(m,2);
    Edn=A/(exp(B/sin(alti))); % in W/m2
    else
    Edn=0;
    End
    Nsh=2/15*acos(-tan(pi*L/180)*tan(dec));%day length
    Edn=Edn*(a+(b*(shh/Nsh));

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%                  %percentage increase in direct radiation due to varying
height above sea level, y percentage increment

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
 if hh==0
    Edn=Edn;
 elseif hh==1000
    y = 2.2e-006*(alti*180/pi)^4 - 0.00055*(alti*180/pi)^3 +
      0.052*(alti*180/pi)^2 - 2.3*(alti*180/pi) + 50;
    Edn=Edn+(0.01*y)*Edn;
 elseif hh==1500
    y = 5.7e-006*(alti*180/pi)^4 - 0.0013*(alti*180/pi)^3 +
      0.11*(alti*180/pi)^2 - 4.3*(alti*180/pi) + 83;
    Edn=Edn+(0.01*y)*Edn;
 elseif hh==2000
    y = 9.1e-006*(alti*180/pi)^4 - 0.002*(alti*180/pi)^3 +
      0.16*(alti*180/pi)^2 - 6*(alti*180/pi) + 1.1e+002;
    Edn=Edn+(0.01*y)*Edn;
 else
    y = 1.4e-005*(alti*180/pi)^4 - 0.003*(alti*180/pi)^3 +
      0.25*(alti*180/pi)^2 - 9.1*(alti*180/pi) + 1.6e+002;
    Edn=Edn+(0.01*y)*Edn;
 end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
decreament due to haze factor
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
 Edn=cf*Edn
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
 if surfsolaz > 90 |  surfsolaz <-90
    Ednn=0;
 else
    Ednn=Edn;
 end
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
if beta(i)>90
   beta(i)=180-beta(i);
   phi=acos(((sin(alti)*cos(beta(i)*pi/180)))-
      (cos(alti)*cos(surfsolaz*pi/180)*sin(beta(i)*pi/180)));%incident
angle in rad
else
phi=acos(((sin(alti)*cos(beta(i)*pi/180)))+(cos(alti)*cos(surfsolaz*pi/
      180)*sin(beta(i)*pi/180))); %incident angle in rad
end
Edns=Ednn*cos(phi);;%direct radiation intensity on a surface
if cos(phi)>-0.2
  Y=0.55+(0.437*cos(phi))+(0.313*(cos(phi))^2);%the ratio of sky diffuse
radiation on a vertical surface to on a horizontal surface.
else
  Y=0.45;
end
 if beta(i)==90
    Ed=C*Y*Edn;          % diffuse irradiance
 else
    Ed=C*Edn*((1+cos(beta(i)*pi/180 ))/2);
 end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
   %%decreament of sky radiation with height,de decreament in fraction
 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
 de = 2e-007*hh^2 + 0.0001*hh + 3.3e-017 ;
 Edf=Ed-(Ed*de) ;   %sky diffuse
 phii=phi*180/pi; % incidence angle in degree
 if alti <0
    phiig=0;
 else phiig=alti*180/pi;
 end

 if gc(i)==1;%1=nc  % ground condition , new concrete
    roug = 2.5e-009*phiig^5 - 7.5e-007*phiig^4 + 8.7e-005*phiig^3 -
0.0049*phiig^2 + 0.13*phiig - 1.1;
 elseif gc(i)==2;%2=oc% gc,  old concrete
   roug = 3.7e-007*phiig^3 - 3.2e-005*phiig^2 + 0.001*phiig + 0.21;
 elseif gc(i)==3;%3=bgg; % gc,bright green grass
   roug = 3.2e-005*phiig^2 - 0.00089*phiig + 0.22;
 elseif gc(i)==4;%4=cr;%gc,crushed rock
   roug=0.2;
 elseif gc(i)==5;%5=bgr;% bitumn and gravel roof
   roug=0.14;
 elseif gc(i)==6%6=bpl;% bitiminous parking lot
   roug= 8.9e-006*phiig^2 - 0.0002*phiig + 0.09;
 else roug=0.2;
 end
   delr = - 0.22*beta(i)+ 20;
 if sc(i)==1
   aoho=0.026;%aoho=absorp/ho
 else
   aoho=0.052;
 end
```

```
  Er=Edn*(C+sin(alti))*roug*((1-cos(beta(i)*pi/180))/2); % ground
reflected irradiance
 if wec(i)==1
    Etot(ii,i)=(Edf+Er+Edns); %store(Etot(ii,ns));%
 else
    Etot(ii,i)=Edf+Er;
 end
   Te(ii,i)=Ta(ii) + aoho*Etot(ii,i)-(emitt(i)*delr/ho);
 end
 end
 end
 end
```

Appendix C

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%MATLAB PROGRAMING FOR DETERMINING SURFACE TEMPERATURE AND HEAT GAIN
THROUGH WALL
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clc
wwe=zeros(8760,w);
wxwx=zeros(8760,w);
qwallsol=zeros(8760,w);
qwallsolout=zeros(8760,w);

for w=1:ns
x=0
it=0
 if nwl(w)==1
    Le(w)=sum(X(w));
    delxa(w)=Le(w)/(nno(w)-1);
    for xx=x:delxa(w):L
         it=it+1;
         KK(it,w)=K(i,w);
         alpp(it,w)=alp(i,w);
   end
else
   Le(w)=sum(X(:,w));
   delxa(w)=Le(w)/(nno(w)-1);
   for i=1:(nwl(w)-1);
    for xx=x:delxa(w):sum(X((1:i),w));
        it=it+1;
        if xx <sum(X((1:i),w));
            KK(it,w)=K(i,w);
            alpp(it,w)=alp(i,w);
         else xx==sum(X((1:i),w))
            KK(it,w)=(K(i,w)+K(i+1,w))/2;
            alpp(it)=(alp(i,w)+alp(i+1,w))/2;
        end
     end
    a=fix(sum(X((1:i),w))/delxa(w));
    x=(a*delxa(w))+delxa(w);
   end
 for i=nwl(w)
    for xx=x:delxa(w):sum(X(1:(nwl(w))))
        it=it+1;
        KK(it,w)=K(nwl(w),w);
        alpp(it,w)=alp(nwl(w),w);
    end
end
end
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
for w=1:ns
```

```
   ii=0;
   ee=zeros(nno(w),1);
   ee(:,1)=20;
   for d=1:1:365
      for t=1:1:24
         ii=ii+1;
         for de=1:delt:3600
            for ix=1:nno(w)
               if ix==1;
                  Bi=ho*delxa(w)/KK(ix,w);
                  Fo=(alpp(ix,w)*delt)/delxa(w)^2;
                  AA(ix,ix)=(1+(2*Fo)+(2*Fo*Bi));
                  AA(ix,ix+1)=-2*Fo;
                  BB(ix)=(2*Fo*Bi*Te(ii,w))+ee(ix);
               elseif ix < nno(w)
                  Fo=(alpp(ix,w)*delt)/delxa(w)^2;
                  AA(ix,ix)=(1+(2*Fo));
                  AA(ix,ix+1)=-Fo;
                  AA(ix,ix-1)=-Fo;
                  BB(ix)=ee(ix);
               else
                  Bi=hi*delxa(w)/KK(ix,w);
                  Fo=(alpp(ix,w)*delt)/delxa(w)^2;
                  AA(ix,ix)=(1+(2*Fo)+(2*Fo*Bi));
                  AA(ix,ix-1)=-2*Fo;
                  BB(ix)=(2*Fo*Bi*Tr)+ee(ix);
               end
            end
         ww=AA;
         ez=BB';
         Tn=inv(ww)*ez;
         ee= Tn;
      end
      wwe(ii,w)=Tn(nno(w));
      wxwx(ii,w)=Tn(1);
      wde(ii,w)=Tn(11);
      qwallsol(ii,w)=Aw(i)*hi*(wwe(ii,w)-Tr);
   end
end
end
if w==1
   walltotal=qwallsol;
else
wallt=qwallsol';
wa=sum(wallt);
walltotal=wa';
end
```

Appendix D

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%MATLAB PROGRAMMING FOR DETERMINING HEAT GAIN THROUGH WINDOW
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
qgwinsensT= zeros(8760,ns);
qgwinsens= zeros(8760,nw(i));
abc=[1230 0.142 0.058 -11.2;
     1215 0.144 0.06  -13.9;
     1186 0.156 0.071  -7.5;
     1136 0.18  0.097   1.1;
     1104 0.196 0.121   3.3;
     1088 0.205 0.134  -1.4;
     1085 0.207 0.136  -6.2;
     1107 0.201 0.122  -2.4;
     1151 0.177 0.092   7.5;
     1192 0.16  0.073  15.4;
     1221 0.149 0.063  13.8;
     1233 0.142 0.057  1.6];
  a=0.29;
  b=0.41;
for i=1:nsw
for ix=1:nw(i)
    n=0;
    ii=0;
    load Ta1.m; To=Ta1;
    load hiid.m; hiw=hiid;
    load hood.m; how=hood;
    for m=1:12
       if m==1
            shh=shj;
            ndm=31;
       elseif m==2
            shh=shf
            ndm=28;
       elseif m==3
           ndm=31;
           shh=shm;
       elseif m==4
           ndm=30;
           shh=sha;
       elseif m==5
           ndm=31;
           shh=shma;
       elseif m==6
           ndm=30;
           shh=shju;
       elseif m==7
           ndm=31;
           shh=shjl;
       elseif m==8
           ndm=31;
           shh=shau;
       elseif m==9
           ndm=30;
```

```
            shh=shs;
        elseif m==10
            ndm=31;
            shh=sho;
        elseif m==11
            ndm=30;
            shh=shn;
        elseif m==12
            ndm=31;
            shh=shd;
        end
        for d=1:ndm
             n=n+1;
           dec=(pi/180)*23.45*sin(pi*(360*(284+n))/(365*180));% Declination
             for LST=1:24
                 ii=ii+1;
                   LSM=90;
                   ET=abc(m,4);
                 AST=LST+(ET/60)+((LSM-LON)/15);
                 H=15*(AST-12);% hour angle
alti=asin((cos(pi*L/180)*cos(dec)*cos(pi*H/180))+(sin(pi*L/180)*sin(dec)))
;%
solazb=acos(((sin(alti)*sin(L*pi/180))-
        (sin(dec)))/(cos(L*pi/180)*cos(alti)));
        if AST<=12
           solazb=-solazb;
        else solazb=solazb;
        end
        solaz=real(solazb*180/pi);%solar azimuth in angle
        if surfaz(i)<=180
        surfazz=surfaz(i);
        else surfazz=-(360-surfaz(i));
        end
        surfsolaz=(solaz-surfazz);
        C=abc(m,3);
        if alti>0
        A=abc(m,1);
        B=abc(m,2);
        Edn=A/(exp(B/sin(alti))); % in W/m2
        else
        Edn=0;
        End
        Nsh=2/15*acos(-tan(pi*L/180)*tan(dec));%day length
        Edn=Edn*(a+(b*(shh/Nsh));
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%percentage increase in direct radiation due to varying height above sea
%level,y percentage increament
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
      if hh==0
        Edn=Edn;
      elseif hh==1000
         y = 2.2e-006*(alti*180/pi)^4 - 0.00055*(alti*180/pi)^3 +
            0.052*(alti*180/pi)^2 - 2.3*(alti*180/pi) + 50;
       Edn=Edn+(0.01*y)*Edn;
      elseif hh==1500
         y = 5.7e-006*(alti*180/pi)^4 - 0.0013*(alti*180/pi)^3 +
            0.11*(alti*180/pi)^2
```

```
          - 4.3*(alti*180/pi) + 83;
        Edn=Edn+(0.01*y)*Edn;
    elseif hh==2000
        y = 9.1e-006*(alti*180/pi)^4 - 0.002*(alti*180/pi)^3 +
           0.16*(alti*180/pi)^2 - 6*(alti*180/pi) + 1.1e+002;
        Edn=Edn+(0.01*y)*Edn;
    else
        y = 1.4e-005*(alti*180/pi)^4 - 0.003*(alti*180/pi)^3 +
           0.25*(alti*180/pi)^2 - 9.1*(alti*180/pi) + 1.6e+002;
        Edn=Edn+(0.01*y)*Edn;
    end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% decreament due to haze factor
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
                   Edn=cf*Edn;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
     if surfsolaz > 90 |  surfsolaz <-90
         Ednn=0;
     else
         Ednn=Edn;
     end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
%intensity of direct radiation on a surface
%  diffuse and ground radiation,ref ashrae handbook,fundementals,2001
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
if beta(i)>90
       beta(i)=180-beta(i);
phi=acos(((sin(alti)*cos(beta(i)*pi/180)))-
      (cos(alti)*cos(surfsolaz*pi/180)*sin(beta(i)*pi/180))); %incident
angle in rad
else
phi=acos(((sin(alti)*cos(beta(i)*pi/180)))+(cos(alti)*cos(surfsolaz*pi/180
)*
    sin(beta(i)*pi/180))); %incident angle in rad
end
Edns=Ednn*cos(phi);;%direct radiation intensity on a surface

if cos(phi)>-0.2
Y=0.55+(0.437*cos(phi))+(0.313*(cos(phi))^2);% the ratio of sky diffuse
            radiation on a vertical surface to on a horizontal surface.
else
Y=0.45;
end
if beta(i)==90
  Ed=C*Y*Edn;          % diffuse irradiance
else
Ed=C*Edn*((1+cos(beta(i)*pi/180 ))/2);
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
%decreament of sky radiation with height,de decreament in fraction
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
de = 2e-007*hh^2 + 0.0001*hh + 3.3e-017 ;
```

```
Edf=Ed-(Ed*de) ;   %sky diffuse
phii=phi*180/pi; % incidence angle in degree
if alti <0
   phiig=0;
else phiig=alti*180/pi;
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
if gc(i)==1;%1=nc  % ground condition , new concrete
roug = 2.5e-009*phiig^5 - 7.5e-007*phiig^4 + 8.7e-005*phiig^3 -
         0.0049*phiig^2 + 0.13*phiig - 1.1;
elseif gc(i)==2;%2=oc% gc,  old concrete
roug = 3.7e-007*phiig^3 - 3.2e-005*phiig^2 + 0.001*phiig + 0.21;
elseif gc(i)==3;%3=bgg; % gc,bright green grass
roug = 3.2e-005*phiig^2 - 0.00089*phiig + 0.22;
elseif gc(i)==4;%4=cr;%gc,crushed rock
roug=0.2;
elseif gc(i)==5;%5=bgr;% bitumn and gravel roof
 roug=0.14;
 elseif gc(i)==6%6=bpl;% bitiminous parking lot
 roug= 8.9e-006*phiig^2 - 0.0002*phiig + 0.09;
 else roug=0.2;
 end
 Er=Edn*(C+sin(alti))*roug*((1-cos(beta(i)*pi/180))/2); % ground
refl;ected irradiance
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
 if surfsolaz > 90 |  surfsolaz <-90
    sunlit=0;
 else
    surfsolaz= surfsolaz;
    surfss=abs(surfsolaz);
    xw=R(ix,i)*tan(surfss*pi/180);
    yw=R(ix,i)*tan(abs(alti))/cos(surfss*pi/180);
 if xw > xx(ix,i) | yw > yy(ix,i)
    sunlit =0;
 else
    sunlit=(xx(ix,i)-xw)*(yy(ix,i)-yw);
 end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
 end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

if wintype(ix,i)==1
if tydet(ix,i)==1
   shgc = 4.235e-013*phii^7 - 1.082e-010*phii^6 + 9.625e-009*phii^5 -
         3.631e-007*phii^4 +4.653e-006*phii^3 + 0.86;%la3
   hshgc=0.78;
   absorp=0.1;
elseif tydet(ix,i)==2
   shgc= - 9.601e-014*phii^7 + 2.003e-011*phii^6 - 1.787e-009*phii^5 +
         6.575e-008*phii^4 -9.624e-007*phii^3 + 0.81;%lb6
   hshgc=0.73;
   absorp=0.18;
elseif tydet(ix,i)==3
   shgc= 5.204e-013*phii^7 - 1.415e-010*phii^6 + 1.373e-008*phii^5 -
5.728e-
         007*phii^4 +8.363e-006*phii^3 + 0.73;%lc3
```

```
   hshgc=0.65;
   absorp=0.31;
elseif tydet(ix,i)==4
   shgc = - 1.282e-013*phii^7 + 3.206e-011*phii^6 - 3.3e-009*phii^5 +
         1.556e-007*phii^4 -3.137e-006*phii^3 + 0.62;%ld6
   hshgc=0.54;
   absorp=0.49;
elseif tydet(ix,i)==5
   shgc= 2.137e-014*phii^7 - 1.004e-011*phii^6 + 9.686e-010*phii^5 -
3.458e-
         008*phii^4 +1.086e-007*phii^3 + 0.7;%le3
   hshgc=0.63;
   absorp=0.34;
elseif tydet(ix,i)==6
  shgc= - 4.622e-013*phii^7 + 1.061e-010*phii^6 - 9.144e-009*phii^5 +
         3.458e-007*phii^4 -5.119e-006*phii^3 + 0.6;%lf6
  hshgc=0.54;
  absorp=0.48;
 elseif tydet(ix,i)==7
    shgc= - 1.136e-012*phii^7 + 2.677e-010*phii^6 - 2.345e-008*phii^5 +
         8.96e-007*phii^4 -1.285e-005*phii^3 + 0.7;%lg3
    hshgc=0.63;
    absorp=0.37;
 elseif tydet(ix,i)==8
    shgc= - 4.622e-013*phii^7 + 1.061e-010*phii^6 - 9.144e-009*phii^5 +
         3.458e-007*phii^4 -5.119e-006*phii^3 + 0.59;%lh6
    hshgc=0.52;
    absorp=0.52;
 else
    shgc= 6.247e-013*phii^7 - 1.519e-010*phii^6 + 1.315e-008*phii^5 -
         4.809e-007*phii^4 +5.844e-006*phii^3 + 0.62;%li6
    hshgc=0.55;
    absorp=0.49;
 end
 elseif wintype(ix,i)==2
 if tydet(ix,i)==1
    shgc= - 4.321e-013*phii^7 + 1.036e-010*phii^6 - 9.252e-009*phii^5 +
         3.599e-007*phii^4 -5.121e-006*phii^3 + 0.19;%lj6
    hshgc=0.18;
    absorp= - 2.921e-013*phii^7 + 6.325e-011*phii^6 - 5.008e-009*phii^5
      +1.578e-007*phii^4 -1.13e-006*phii^3 + 0.45;
 else
   shgc= 6.7e-014*phii^7 - 2.8e-011*phii^6 + 3.5e-009*phii^5 - 1.8e-
         007*phii^4 +3.1e-006*phii^3 + 0.25;%lm6
   hshgc=0.23;
   absorp= 1.264e-012*phii^7 - 3.237e-010*phii^6 + 3.015e-008*phii^5 -
         1.221e-006*phii^4 +1.809e-005*phii^3 + 0.8;%lm6absorp
 end
 elseif wintype(ix,i)==3
 if tydet(ix,i)==1
   shgc= 4.031e-014*phii^7 - 5.343e-012*phii^6 - 1.475e-010*phii^5 +
         2.224e-008*phii^4 -7.274e-007*phii^3 + 0.76;%w5a3
   hshgc=0.66;
   absorp=0.1587;
 elseif tydet(ix,i)==2
   shgc= 4.808e-013*phii^7 - 1.114e-010*phii^6 + 9.122e-009*phii^5 -
      3.202e-007*phii^4 +3.641e-006*phii^3 + 0.7;%w5b6
```

```
   hshgc=0.60;
   absorp=0.296;
 elseif tydet(ix,i)==3
   shgc= - 7.183e-013*phii^7 + 1.802e-010*phii^6 - 1.684e-008*phii^5 +
         6.883e-007*phii^4 -1.075e-005*phii^3 + 0.49;%w5d6
   hshgc=0.41;
   absorp=0.5536;
 else
   shgc= - 7.183e-013*phii^7 + 1.802e-010*phii^6 - 1.684e-008*phii^5 +
         6.883e-007*phii^4 -1.075e-005*phii^3 + 0.49;%w5f6
   hshgc=0.41;
   absorp=0.525;
 end
 elseif wintype(ix,i)==4
 if tydet(ix,i)==1
   shgc= - 7.445e-013*phii^7 + 1.815e-010*phii^6 - 1.643e-008*phii^5 +
         6.54e-007*phii^4 -9.734e-006*phii^3 + 0.13;%w5k6
   hshgc=0.11;
absorp=0.5842;
elseif  tydet(ix,i)==2
   shgc= - 9.324e-013*phii^7 + 2.315e-010*phii^6 - 2.132e-008*phii^5 +
         8.582e-007*phii^4 -1.28e-005*phii^3 + 0.22;%w5n6
   hshgc=0.14;
   absorp=0.7264;
else
   shgc= 2.6e-012*phii^7 - 6.6e-010*phii^6 + 6.3e-008*phii^5 - 2.6e-
         006*phii^4 +3.9e-005*phii^3 + 0.21;%w5o6
   hshgc=0.18;
   absorp=0.6374;
end
elseif wintype(ix,i)==5
if tydet(ix,i)==1
   shgc= 2.283e-013*phii^7 - 5.527e-011*phii^6 + 4.734e-009*phii^5 -
1.819e-007*phii^4 +2.343e-006*phii^3 + 0.65;%w17d6
   hshgc=0.56;
   absorp=0.336;
else
   shgc= - 6.37e-013*phii^7 + 1.623e-010*phii^6 - 1.538e-008*phii^5 +
6.364e-007*phii^4 -1.007e-005*phii^3 + 0.45;%w17f6
   hshgc=0.38;
   absorp=0.568;
end
else
   shgc=shgc;
   hshgc=hshgc;
   absorp=absorp;
   end
if shgc<0
   shgc=0;
   end
 Drad=Edns*shgc;%direct radiation transmitted
 dred(ii,ix)=Drad*sunlit;
 Scat=hshgc*(Edf+Er);% scattered radiation transmitted
 ad(ii,ix)=Scat*(xx(ix,i)*yy(ix,i));
 Dpd=(Drad*sunlit);
 Dpd2=(Scat*(xx(ix,i)*yy(ix,i)));%direct plus scattered radiation
transmitted.
```

```
 qw=(xx(ix,i)*yy(ix,i))*U*(To(ii)-Tr);
if tys(ix,i)==1
 windi(ii,ix)=0;
 windd(ii,ix)=qw+Dpd2+Dpd;
else windi(ii,ix)=Dpd;
 windd(ii,ix)=qw+Dpd2;
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
end
end
end
end
widi=windi';
widd=windd';
if nw(i)==1
widif=widi;
widdf=widd;
else
       widif=sum(widi);
       widdf=(widd);
    end
windif(:,i)=widif';
winddf(:,i)=widdf';
end
```

Appendix E

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%MATLAB PROGRAMMING FOR CALCULATION OF HEAT GAIN THROUGH INFILTRATION AND
%VENTILATION
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clc
qinflsens=zeros(8760,ns);
qinfllat=zeros(8760,ns);
delp=zeros(8760,ns);
QwallT=zeros(8760,ns);
QwindowT=zeros(8760,ns);
QdoorT=zeros(8760,ns);
load hum.m; hum=0.01*hum;
load dirw.m; dirw=dirw;
load wispeed.m; U=2.237*wispeed;% u in mph
roui=1.2;
g=9.81;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%pressure difference due to wind
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
vol=Le*Wi*htr;
qvent=ach*vol/3600;
for i=1:ns
    it=0
for ty=1:8760
    it=it+1;
    toox=(9/5*Too)+32;
    tr=(9/5*Tr)+32;
    delT=toox-tr;%conversion to degree faranite
    dist=abs(htr-Hnpl)*3.281;
   if delT<=10;
      delppsc= 0.000268*dist + 0.000702;%10
   elseif delT<=20;
      delppsc= 0.000556*dist+ 0.000352;%20
   elseif delT<=30;
      delppsc= 0.000854*dist - 0.000294;%30
   elseif delT<=40;
      delppsc= 0.00115*dist+ 0.00352;%40
   elseif delT<=50;
      delppsc= 0.00148*dist+ 0.00167;%50
   elseif delT<=60;
      delppsc= 0.00181*dist- 0.000553;%60
   elseif delT<=70;
      delppsc= 0.00214*dist+ 0.00568;%70
   elseif  delT<=80;
      delppsc= 0.0025*dist- 2.92e-016;%80
   elseif delT<=90;
      delppsc= 0.00287*dist+ 0.0055;%90
   else delT<=100;
      delppsc = 0.00327*dist - 0.000262;%100
   end
   delpsin=delppsc*CD;% change in pressure due to stack,in in of water
    if floc==1
```

```
        delpsin=delpsin;
    else
        delpsin= - delpsin;
    end
    delpc(it,i)= - 3.2e-007*U^3 + 0.00049*U^2 + 9.6e-005*U -0.00024;%vel
press vs wind velocity in mph
    if Le/Wi<=0.25
        ratio=1;
    elseif Le/Wi<=1
        ratio=2;
    else ratio=3;
    end
        orw=abs(dirw-orws(i));
    if orw>180
        orw=(360-orw);
    end
        orww(it,i)=orw;
    if H > 3*Le % high rising building
    if ratio==1
        Cp(it,i) = - 4.3261e-014*orw^7 + 2.9565e-011*orw^6 - 7.883e-
                009*orw^5 + 1.0104e-006*orw^4 - 6.0348e-005*orw^3 +
                0.0012741*orw^2- 0.011419*orw + 0.6026;
    elseif ratio==2
        Cp(it,i) = - 5.4503e-016*orw^8 + 3.9161e-013*orw^7 - 1.1173e-
                010*orw^6 +1.5955e-008*orw^5 -1.1842e-006*orw^4 +
                4.4812e- 005*orw^3 - 0.00098477*orw^2 + 0.0070361*orw
                + 0.59686;
    else
       Cp(it,i)= 1.0749e-016*orw^8 - 5.614e-014*orw^7 + 9.4225e-
                012*orw^6 -3.5347e-010*orw^5 - 4.7158e-008*orw^4 +
                4.9994e-006*orw^3- 0.00030562*orw^2 + 0.0039536*orw +
                0.59693;
    end
    else  % low rising building
       Cp(it,i)= 1.1068e-012*orw^6 - 6.3812e-010*orw^5 + 1.326e-
                007*orw^4 - 1.1138e-005*orw^3 +0.00027354*orw^2 -
                0.0062555*orw + 0.60104;
     end
         delpw(it,i)=Cp(it,i)*delpc(it,i);%in in of water
         %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
         delp(it,i)=delpw(it,i) + delpsin;
      if delp(it,i)<0
         QwallT(it,i)=0;
         QwindowT(it,i)=0;
         QdoorT(it,i)=0;
      else
%%%%%%%%%%%%%%%%%%%
% curtain wall infiltration per floor or room
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
      if cwt(i)==1     %1-tight fitting wall;
         QovA(i)= 15*delp(it,i)^3 - 12*delp(it,i)^2 + 4.1*delp(it,i) +
                   0.00047;%Kc=0.22; delp in in qova in L/s-m2
      elseif cwt(i)==2 %2-average fitting wall;
         QovA(i)= 44*delp(it,i)^3 - 31*delp(it,i)^2 + 10*delp(it,i) +
                0.035;%Kc=0.66;
      else          %3-loose fitting;
```

```
        QovA(i)= - 3.6e+003*delp(it,i)^4 + 1.6e+003*delp(it,i)^3 -
               2.7e+002*delp(it,i)^2 + 29*delp(it,i) +0.0042;%Kc=1.3;
     end
     QwallT(it,i)=QovA(i)*Aw(i)*0.001;   %A-area of the wall,im m3/s

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
% crack infiltration through movablewindows
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
if now(i)==0;
QwindowT(it,i)=0;
else
for q=1:now(i)
if wtw(q)==1% 1 -tight fitting window
QoL= -2*delp(it,i)^3 - 2.6*delp(it,i)^2 + 3.3*delp(it,i) - 0.0032;% window
and infiltration characterstics
elseif wtw(q)==2%2-average fitting window
QoL = 40*delp(it,i)^3 - 27*delp(it,i)^2 + 9.6*delp(it,i) + 0.016;% window
and infiltration characterstics
else %3 -loose fittting window
QoL  = -1.6e+003*delp(it,i)^4 + 9.8e+002*delp(it,i)^3 -
            2.3e+002*delp(it,i)^2 + 35*delp(it,i)+ 0.05;% window and
infiltration characterstics
end
Qwindow(q)=QoL*perw(q,i)*0.001;% perw perimetr of the window,in m3/s.
end
QwindowT(it,i)=(sum(Qwindow));
end
if QwindowT(it,i)<0
   QwindowT(it,1)=0;
end
            %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
if nod(i)==0;
   QdoorT(it,i)=0;
else
for do=1:nod(i)
if doty(do,i)==1 %normal residential door
if wt(do,i)==1% 1 -tight fitting door
   QoL= - 2*delp(it,i)^3 - 2.6*delp(it,i)^2 + 3.3*delp(it,i) - 0.0032;%
window and door infiltration characterstics
elseif wt(do,i)==2%2-average fitting door
   QoL = 40*delp(it,i)^3 - 27*delp(it,i)^2 + 9.6*delp(it,i) + 0.016;%
window and door infiltration characterstics
else %3 -loose fittting door
   QoL  = - 1.6e+003*delp(it,i)^4 + 9.8e+002*delp(it,i)^3 -
               2.3e+002*delp(it,i)^2 + 35*delp(it,i)+ 0.05;% window and
door infiltration characterstics
end
  Qdoor(do,i)=QoL*perd(do,i)*.001; % perd perimetr of the door,m3/s.
elseif doty(do,i)==2 % swinging doors
if crack(do,i)==1
  QoL = 6.6e+002*delp(it,i)^3 - 4.4e+002*delp(it,i)^2 +
         1.3e+002*delp(it,i) + 0.0092;% infiltration through closed
swinging door cracks,k=20
elseif crack==2
  QoL = 1.1e+003*delp(it,i)^3 - 8.7e+002*delp(it,i)^2 +
```

```
        2.8e+002*delp(it,i) + 0.82;% infiltration through closed swinging
doo cracks,k=40
elseif crack==3
 QoL = 4.5e+003*delp(it,i)^3 - 2.6e+003*delp(it,i)^2 +
      6.2e+002*delp(it,i) + 0.98;% infiltration through closed swinging
doo cracks,k=80
else
QoL = 1e+005*delp(it,i)^3 - 1.8e+004*delp(it,i)^2 +
      1.6e+003*delp(it,i) + 0.057;% infiltration through closed swinging
doo cracks,k=160
end
Qdoorc(do,i)=QoL*perd(do,i)*0.001; % L perimetr of the door,l/m3.
if sdt(do,i)==1%single bank type
cc(do,i) = - 1.8e-014*ph(do,i)^7 + 3.5e-011*ph(do,i)^6 - 2.5e-
         008*ph(do,i)^5 + 8.5e-006*ph(do,i)^4 -0.0011*ph(do,i)^3 -
         0.044*ph(do,i)^2 + 44*ph(do,i) + 0.25;
else %vestibule type
cc(do,i) = 6.5e-015*ph(do,i)^7 - 1.8e-011*ph(do,i)^6 + 1.9e-
         008*ph(do,i)^5 - 1.1e-005*ph(do,i)^4 +0.0037*ph(do,i)^3
         - 0.69*ph(do,i)^2 + 94*ph(do,i)- 5.2e+003;
end
if cc(do,i) <= 3750
Qpd = - 0.015*delp(it,i)^2 + 0.009*delp(it,i) - 5.3e-005;%for C=2500
elseif cc(do,i) <= 7500
Qpd = - 0.028*delp(it,i)^2 + 0.017*delp(it,i) + 2.7e-005;%for C=5000
elseif cc(do,i) <= 12500
Qpd = 0.18*delp(it,i)^3 - 0.13*delp(it,i)^2 + 0.04*delp(it,i) +
      6.2e-005;%for C=10000
else
Qpd = 0.37*delp(it,i)^3 - 0.24*delp(it,i)^2 + 0.066*delp(it,i) +
      7.1e-005;%for C=15000
end
Qdoorv(do,i)=Qpd*1000*4.72e-4;%  nomber of door,m3/s,4.72e-4 conversion
unit from cfm to m3/s
Qdoor(do,i)=Qdoorv(do,i)+Qdoorc(do,i);
else %revolving door
if rvd(do,i)==1%revolving door not revolving.
Qrevpd = 1.9e+003*delp(it,i)^5 - 6e+003*delp(it,i)^4+
         6.9e+003*delp(it,i)^3 - 3.8e+003*delp(it,i)^2 +
         1.3e+003*delp(it,i) + 1.6; %infiltration through seals of
            revolving doors not revolving.
Qdoor(do,i)=Qrevpd*4.72e-4;
else %open revolving door
if revd(do,i)==1%motor operated
if delT <15 %in degre faranite
Qpdrev = - 0.24*rpm(do,i)^4 + 6.6*rpm(do,i)^3 - 68*rpm(do,i)^2 +
         2.9e+002*rpm(do,i) + 2.1;   %10
elseif delT<30
Qpdrev = - 0.2*rpm(do,i)^4 + 5.6*rpm(do,i)^3 - 59*rpm(do,i)^2 +
         2.9e+002*rpm(do,i) + 2.4;%20
elseif delT<50
Qpdrev = - 0.15*rpm(do,i)^4 + 4.3*rpm(do,i)^3 - 50*rpm(do,i)^2 +
         3e+002*rpm(do,i) - 1.4;%40
elseif delT<70
Qpdrev = - 0.09*rpm(do,i)^4 + 3*rpm(do,i)^3 - 40*rpm(do,i)^2 +
         2.9e+002*rpm(do,i) - 1.9;%60
elseif delt<90
```

```
Qpdrev = - 0.051*rpm(do,i)^4 + 2.2*rpm(do,i)^3 - 35*rpm(do,i)^2
      + 2.9e+002*rpm(do,i) - 4;%80
else
 Qpdrev = - 0.047*rpm(do)^4 + 1.8*rpm(do)^3 - 29*rpm(do)^2 +
         2.8e+002*rpm(do) - 3.5;%100
 end
 Qdoor(do,i)=Qpdrev*4.72e-4;%in m3/sec
 else% manually operated
 if delT<15
 Qpdrev = - 0.06*phr(do,i)^4 + 1.6*phr(do,i)^3 - 18*phr(do,i)^2 +
         1.3e+002*phr(do,i) + 0.1;%10
 elseif delT<30
 Qpdrev = 0.017*phr(do,i)^4 + 0.16*phr(do,i)^3 - 13*phr(do,i)^2 +
         1.5e+002*phr(do,i) - 5;%20
 elseif delT<50
 Qpdrev = - 0.055*phr(do,i)^4 + 1.7*phr(do,i)^3 - 25*phr(do,i)^2 +
         2e+002*phr(do,i) + 0.91;%40
 elseif delT<70
 Qpdrev = - 0.12*phr(do,i)^4 + 3.2*phr(do,i)^3 - 39*phr(do,i)^2 +
         2.7e+002*phr(do,i) - 1.1;%60
 elseif delT<90
 Qpdrev = - 0.24*phr(do,i)^4 + 6*phr(do,i)^3 - 58*phr(do,i)^2 +
         3.2e+002*phr(do,i) - 1.8;%80
 else
 Qpdrev = - 0.15*phr(do,i)^4 + 4.9*phr(do,i)^3 - 59*phr(do,i)^2 +
         3.6e+002*phr(do,i) + 6.8;%100
 end
 Qdoor(do,i)=Qpdrev*4.72e-4;%in m3/sec
 end
 end
 end
 end
 QdoorT(it,i)=(sum(Qdoor(:,i)));
 end
 if QdoorT(it,i)<0
    QdoorT(it,i)=0;
 end
 end
 totQ(it,i)=(QwallT(it,i)+QdoorT(it,i)+QwindowT(it,i));
 end
 end
 if i==1
 totQinf=totQ
 else
 totQinf=(sum(totQ'))';
 end
 vem=zeros(8760,1);
 vem(:,1)=qvent;
 ii=0;
 for to=1:8760
 ii=ii+1;
 qinfvent=vem+totQinf;
qinflsens(ii)=1000*(1.2*(1.006+(1.84*hum(ii)))*qinfvent(ii,i)
         *(Ta(ii)- Tr));% in w
qinfllat(ii)=1000*(3010*qinfvent(it,i)*(hum(ii)-(humr*0.01)));% in w ,humr
room humidity
end
```

Appendix F

%%
%MATLAB PROGRAMMING FOR CALCULATION OF COOLING LOAD DUE TO INTERNAL HEAT
%GAIN
%%%

```
it=0;
for w=1:wv
if wc(w)==1% seated at theater
   shg(w)=65;%in(W)
   lhg(w)=30;
elseif wc(w)==2% seated verylight work
   shg(w)=70;
   lhg(w)=45;
elseif wc(w)==3%moderately  active office work
   shg(w)=75;
   lhg(w)=55;
elseif wc(w)==4% walking standing
   shg(w)=75;
   lhg(w)=70;
elseif wc(w)==5% sedentary work, restourant
   shg(w)=80;
   lhg(w)=80;
elseif wc(w)==6%light bench work, factory
   shg(w)=80;
   lhg(w)=140;
elseif wc(w)==7%moderate dancing
   shg(w)=90;
   lhg(w)=160;
elseif wc(w)==8%light machine work, factory
   shg(w)=110;
   lhg(w)=185;
elseif wc(w)==9%heavy work, factory
   shg(w)=170;
   lhg(w)=255;
elseif wc(w)==10%heavy machine work,factory
   shg(w)=185;
   lhg(w)=285;
else % athletics
   shg(w)=210
   lhg(w)=315
end
   shgslg(w)=shg(w) +lhg(w);
if Tr==24
    shg(w)=shg(w);
    lhg(w)=lhg(w);
else
    shg(w)=shg(w)-(0.2*shg(w));
    lhg(w)=shgslg(w)-shg(w);
end
    Tshg(w)=ni(w)*shg(w);
    Tlhg(w)=ni(w)*lhg(w);
end
```

```
   shgT=sum(Tshg);
   oshgr=0.677*shgT;
   oshgc=0.333*shgT;
   lhgT=sum(Tlhg);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%lighting heat gain
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
 for l=1:nolump
    qel=Watt(l)*Ful(l)*Fsa(l)*slump(l); %Ful is unity for commercial
purpose
 if lcla(l)==1
    qelr(l)=0.67*qel;
    qelc(l)=0.33*qel;
 elseif lcla(l)==2
    qelr(l)=0.59*qel;
    qelc(l)=0.41*qel;
 elseif lclc(l)==3
    qelr(l)=0.19*qel;
    qelc(l)=0.81*qel;
 else
    qelr(l)=0.8*qel;
    qelc(l)=0.2*qel;
 end
 end
   qelrt=sum(qelr);
   qelct=sum(qelr);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%heat gain through electric motors
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
   qem=zeros(nomot,1);
for n=1:nomot
if pmot==1 % machine and motor within the conditioned space
   qem(n)=(P/Em)*Fum*Flm;
elseif pmot==2 %motor outside the conditoned space
   qem(n)=P*Fum*Flm;
else % motor inside and driven machine outside the conditioned space
   qem(n)=P*((1-Em)/Em)*Fum*Flm;
end
end
qemtot=sum(qem);
qmotrt=0.5*qemtot;
qmotct=0.5*qemtot;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%total heat gain from occupants
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
insenr=qmotrt+qelrt+oshgr;
insenc=qmotct+qelct+oshgc;
intrc=zeros(8760,1);
intcc=zeros(8760,1);
intrc(:,1)=insenr;
intcc(:,1)=insenc;
er=1;
rtsn=[0.50  0.43  0.49  0.33  0.38  0.25
      0.18  0.19  0.17  0.16  0.09  0.09
      0.10  0.11  0.09  0.10  0.06  0.06
      0.06  0.07  0.05  0.07  0.04  0.05
      0.04  0.05  0.03  0.05  0.04  0.05
```

```
        0.03   0.03   0.02   0.04   0.03   0.04
        0.02   0.03   0.02   0.03   0.03   0.04
        0.01   0.02   0.01   0.03   0.03   0.04
        0.01   0.01   0.01   0.02   0.03   0.03
        0.01   0.01   0.01   0.02   0.03   0.03
        0.01   0.01   0.01   0.02   0.02   0.03
        0.01   0.01   0.01   0.02   0.02   0.03
        0.01   0.01   0.01   0.01   0.02   0.03
        0.01   0.01   0.01   0.01   0.02   0.03
        0      0.01   0.01   0.01   0.02   0.02
        0      0      0.01   0.01   0.02   0.02
        0      0      0.01   0.01   0.02   0.02
        0      0      0.01   0.01   0.02   0.02
        0      0      0.01   0.01   0.02   0.02
        0      0      0.01   0.01   0.02   0.02
        0      0      0      0.01   0.01   0.02
        0      0      0      0.01   0.01   0.02
        0      0      0      0.01   0.01   0.02
        0      0      0      0      0.01   0.02];

m1=[1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9    8   7   6   5   4   3   2
     2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3
     3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4
     4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5
     5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7   6
     6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7
     7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8
     8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9
     9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10
    10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11
    11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12
    12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13
    13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14
    14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15
    15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16
    16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17
    17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18
    18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19
    19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20
    20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21
    21  21  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22
    22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23
    23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24
    24 23 22 21 20 29 18 17 16 15 14 13 12 11 10  9  8  7  6  5  4  3  2  1 ];

if tyf==1
if fco==1
   xt=1;
else
   xt=2;
end
elseif tyf==2
if fco==1
   xt=3;
else
   xy=4;
end
```

```
else
if fco==1
   xt=5;
else
   xt=6;
end
end


ia=0;
ba=0;
for da=1:365
im=0;
for iw=er:(er+23)
ba=ba+1
im=im+1
intrcrt(ba)=(intrc(m1(im,1) +(ia*24))*rtsn(1,xt)) +(intrc(m1(im,2)
      +(ia*24))*rtsn(2,xt)) +(intrc(m1(im,3) +(ia*24))*rtsn(3,xt))
      + (intrc(m1(im,4)+(ia*24))*rtsn(4,xt)) +(intrc(m1(im,5) +
      (ia*24))*rtsn(5,xt))+ (intrc(m1(im,6)+(ia*24))*rtsn(6,xt))
      +(intrc(m1(im,7) +(ia*24))*rtsn(7,xt)) +(intrc(m1(im,8)
      +(ia*24))*rtsn(8,xt)) +(intrc(m1(im,9) +(ia*24))*rtsn(9,xt))
      +(intrc(m1(im,10)+(ia*24))*rtsn(10,xt))+
      intrc(m1(im,11)+(ia*24))*rtsn(11,xt))+(intrc(m1(im,12)+
      (ia*24))*rtsn(12,xt))+(intrc(m1(im,13)+(ia*24))*rtsn(13,xt))
      +(intrc(m1(im,14)+(ia*24))*rtsn(14,xt))+(intrc(m1(im,15)+
      (ia*24))*rtsn(15,xt))+ (intrc(m1(im,16)+(ia*24))*rtsn(16,xt))
      +(intrc(m1(im,17)+(ia*24))*rtsn(17,xt))+(intrc(m1(im,18)+
      (ia*24))*rtsn(18,xt))+(intrc(m1(im,19)+(ia*24))*rtsn(19,xt))
      +(intrc(m1(im,20)+(ia*24))*rtsn(20,xt))+(intrc(m1(im,21)+
      (ia*24))*rtsn(21,xt))+(intrc(m1(im,22)+(ia*24))
      *rtsn(22,xt))+(intrc(m1(im,23)+(ia*24))*rtsn(23,xt))
      +(intrc(m1(im,24)+(ia*24))*rtsn(24,xt));
 intsecolo(iw)=intrcrt(iw)+intcc(iw);
 end
 ia=ia+1
 er=er+24;
 end
```

Appendix G

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%MATLAB PROGRAMMING FOR CHANGING WINDOW HEAT GAIN TO COOLING LOAD
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clc
er=1;
rts=[0.55 0.45 0.54  0.29  0.49  0.27  0.50  0.43  0.49  0.33  0.38  0.25
     0.17 0.20 0.16  0.15  0.12  0.13  0.18  0.19  0.17  0.16  0.09  0.09
     0.09 0.11 0.08  0.10  0.06  0.07  0.10  0.11  0.09  0.10  0.06  0.06
     0.05 0.07 0.04  0.07  0.04  0.05  0.06  0.07  0.05  0.07  0.04  0.05
     0.03 0.05 0.03  0.06  0.03  0.04  0.04  0.05  0.03  0.05  0.04  0.05
     0.02 0.03 0.02  0.05  0.02  0.04  0.03  0.03  0.02  0.04  0.03  0.04
     0.02 0.02 0.01  0.04  0.02  0.03  0.02  0.03  0.02  0.03  0.03  0.04
     0.01 0.02 0.01  0.03  0.02  0.03  0.01  0.02  0.01  0.03  0.03  0.04
     0.01 0.01 0.01  0.03  0.02  0.03  0.01  0.01  0.01  0.02  0.03  0.03
     0.01 0.01 0.01  0.03  0.02  0.03  0.01  0.01  0.01  0.02  0.03  0.03
     0.01 0.01 0.01  0.02  0.02  0.03  0.01  0.01  0.01  0.02  0.02  0.03
     0.01 0.01 0.01  0.02  0.02  0.03  0.01  0.01  0.01  0.02  0.02  0.03
     0.01 0.01 0.01  0.02  0.01  0.02  0.01  0.01  0.01  0.01  0.02  0.03
     0.01 0.00 0.01  0.02  0.01  0.02  0.01  0.01  0.01  0.01  0.02  0.03
     0.01 0    0.01  0.01  0.01  0.02  0     0.01  0.01  0.01  0.02  0.02
     0    0    0.01  0.01  0.01  0.02  0     0     0.01  0.01  0.02  0.02
     0    0    0.01  0.01  0.01  0.02  0     0     0.01  0.01  0.02  0.02
     0    0    0.01  0.01  0.01  0.02  0     0     0.01  0.01  0.02  0.02
     0    0    0.01  0.01  0.01  0.02  0     0     0.01  0.01  0.02  0.02
     0    0    0     0.01  0.01  0.02  0     0     0.01  0.01  0.02  0.02
     0    0    0     0.01  0.01  0.02  0     0     0     0.01  0.01  0.02
     0    0    0     0     0.01  0.02  0     0     0     0.01  0.01  0.02
     0    0    0     0     0.01  0.01  0     0     0     0.01  0.01  0.02
     0    0    0     0     0.01  0.01  0     0     0     0     0.01  0.02
      ];


m1=[1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10  9   8   7   6   5   4   3   2
     2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3
     3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4
     4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5
     5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7   6
     6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7
     7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8
     8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10   9
     9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11  10
    10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12  11
    11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13  12
    12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14  13
    13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15  14
    14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16  15
    15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17  16
    16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18  17
    17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19  18
    18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20  19
    19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21  20
    20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22  21
    21  21  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23  22
```

```
   22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24  23
   23  22  21  20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1  24
   24  23  22  21  20  29  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1
];

ewin=windif;
ewind=zeros(8760,i);
ewind=0.63*winddf;
difc=0.37*winddf;
if tyf==1
if fco==1
   xt=1;   xv=7;
else
   xt=2;   xv=8;
end
elseif tyf==2
if fco==1
   xt=3;   xv=9;
else
   xy=4;   xv=10;
end
else
if fco==1
   xt=5;  xv=11;
else
   xt=6;  xv=12;
end
end
ia=0;
ba=0;
for da=1:365
  im=0;
for iw=er:(er+23)
  ba=ba+1
  im=im+1
  qwi(ba,i)= (ewin((m1(im,1) +(ia*24)),i)*rts(1,xt)) +(ewin((m1(im,2)
         +(ia*24)),i)*rts(2,xt)) +(ewin((m1(im,3) +(ia*24)),i)
         *rts(3,xt))+ (ewin((m1(im,4)+(ia*24)),i)*rts(4,xt))+
         (ewin((m1(im,5)+(ia*24)),i)*rts(5,xt))+(ewin((m1(im,6)
         +(ia*24)),i)*rts(6,xt)) +(ewin((m1(im,7) +(ia*24)),i)*rts(7,xt))
         +(ewin((m1(im,8) +(ia*24)),i)*rts(8,xt))+(ewin((m1(im,9)+
         (ia*24)),i)*rts(9,xt))+(ewin((m1(im,10)+(ia*24)),i)*
         rts(10,xt))+ (ewin((m1(im,11)+(ia*24)),i)*rts(11,xt))
         +(ewin((m1(im,12)+(ia*24)),i)*rts(12,xt))+(ewin((m1(im,13)+
         (ia*24)),i)*rts(13,xt))+(ewin((m1(im,14)+(ia*24)),i)
         *rts(14,xt))+(ewin((m1(im,15)+(ia*24)),i)*rts(15,xt))+
         (ewin((m1(im,16)+(ia*24)),i)*rts(16,xt))+(ewin((m1(im,17)
         +(ia*24)),i)*rts(17,xt))+(ewin((m1(im,18)+(ia*24)),i)
         *rts(18,xt))+(ewin((m1(im,19)+(ia*24)),i)*rts(19,xt))
         +(ewin((m1(im,20)+(ia*24)),i)*rts(20,xt))+(ewin((m1(im,21)
         +(ia*24)),i)*rts(21,xt))+(ewin((m1(im,22)+(ia*24)),i)*rts(22,xt))
         +(ewin((m1(im,23)+(ia*24)),i)*rts(23,xt))+(ewin((m1(im,24)+
         (ia*24)),i)*rts(24,xt));
   qwid(ba,i)= (ewind((m1(im,1) +(ia*24)),i)*rts(1,xv)) +(ewind((m1(im,2)
         +(ia*24)),i)*rts(2,xv)) +(ewind((m1(im,3) +(ia*24)),i)*rts(3,xv))
         +(ewind((m1(im,4) +(ia*24)),i)*rts(4,xv)) +(ewind((m1(im,5)
         +(ia*24)),i)*rts(5,xv)) +(ewind((m1(im,6) +(ia*24)),i)*rts(6,xv))
```

```
         +(ewind((m1(im,7) +(ia*24)),i)*rts(7,xv)) +(ewind((m1(im,8)
         +(ia*24)),i)*rts(8,xv)) +(ewind((m1(im,9) +(ia*24)),i)*rts(9,xv))
         +(ewind((m1(im,10)+(ia*24)),i)*rts(10,xv))+ ewind((m1(im,11)+

         (ia*24)),i)*rts(11,xv))+(ewind((m1(im,12)+(ia*24)),i)*rts(12,xv))
         +(ewind((m1(im,13)+(ia*24)),i)*rts(13,xv))+(ewind((m1(im,14)
      +(ia*24)),i)*rts(14,xv))+(ewind((m1(im,15)+(ia*24)),i)*rts(15,xv))
         +(ewind((m1(im,16)+(ia*24)),i)*rts(16,xv))+(ewind((m1(im,17)+
         (ia*24)),i)*rts(17,xv))+(ewind((m1(im,18)+(ia*24)),i)*rts(18,xv))
         +(ewind((m1(im,19)+(ia*24)),i)*rts(19,xv))+(ewind((m1(im,20)+
         (ia*24)),i)*rts(20,xv))+(ewind((m1(im,21)+(ia*24)),i)*rts(21,xv))
         +(ewind((m1(im,22)+(ia*24)),i)*rts(22,xv))+(ewind((m1(im,23)
   +(ia*24)),i)*rts(23,xv))+(ewind((m1(im,24)+(ia*24)),i)*rts(24,xv));
 winco(iw,1)=difc(iw,i)+qwid(iw,i)+qwi(iw,i);
end
ia=ia+1
er=er+24;
end
```

ANNEX A.

Guidelines for using the developed program

Introduction

This application note describes how to use the developed program, TASZCL, and how to access the outputs.

Running The Program

Install Matlab 5.3 or 6.1 on your computer.
Initialize the program by double clicking either of the two.
Write 'startingwindow' on the Matlab command window and enter.
This will run the first GUI that contains the title of the thesis and button for continuing into the main programs. Once this module appears one can follow section 7.2 to proceed to the remaining parts.

Accessing Output Data

Just after running the program one can initialize the Microsoft excel and open files in the 'work' folder of Matlab. All the output data will be found there with filenames wallcooling, wincooling, qinflsens, qinfllat, intsencool and intlatcool. The abbreviations are
wallcooling- cooling load due to heat gain through wall .
wincooling- cooling load due to heat gain through window.
qinfilsens- sensible cooling load due to infiltration or ventilation.
qinfilat-latent cooling load due to infiltration or ventilation.
intsencool- sensible cooling load due to internal heat gain
intlatcool-latent cooling load due to internal heat gain