CHAPTER II

THEORITICAL LITERATURE REVIEW

Solar Radiation

Solar radiation has important effects on both the heat gain and heat loss of a building. This effect depends on a great extent from both the location of the sun in the sky and the clearness of the atmosphere as well as on the nature and orientation of the building. It is useful at this point to discuss ways of predicting the variation of the sun's location in the sky during the day and including the seasons for various locations on the earth's surface. It is also useful to know how to predict, for specified weather conditions, the solar irradiation of a surface at any given time and location on the earth, as well as the total radiation striking a surface over a specified period of time.

1. The earth's motion about the sun

The sun 's position in the sky is a major factor in the effect of solar energy on a building. The earth moves in a slightly elliptical orbit about the sun and rotates around the sun approximately once every 365 ¼ days.

As the earth moves it also spins about its own axis at the rate of one revolution each 24 hours. There is an additional motion because of a slow wobble or gyroscopic precession of the earth. The earth's axis of rotation is tilted 23.5 degree with respect to the orbital plane. As a result of this dual motion and tilt, the position of the sun in the sky, as seen by an observer on earth, varies with the observer's location on the earth's surface and with the time of day and year. For practical proposes the sun is so small as seen by an observer on earth that it may be treated as a point source of radiation.

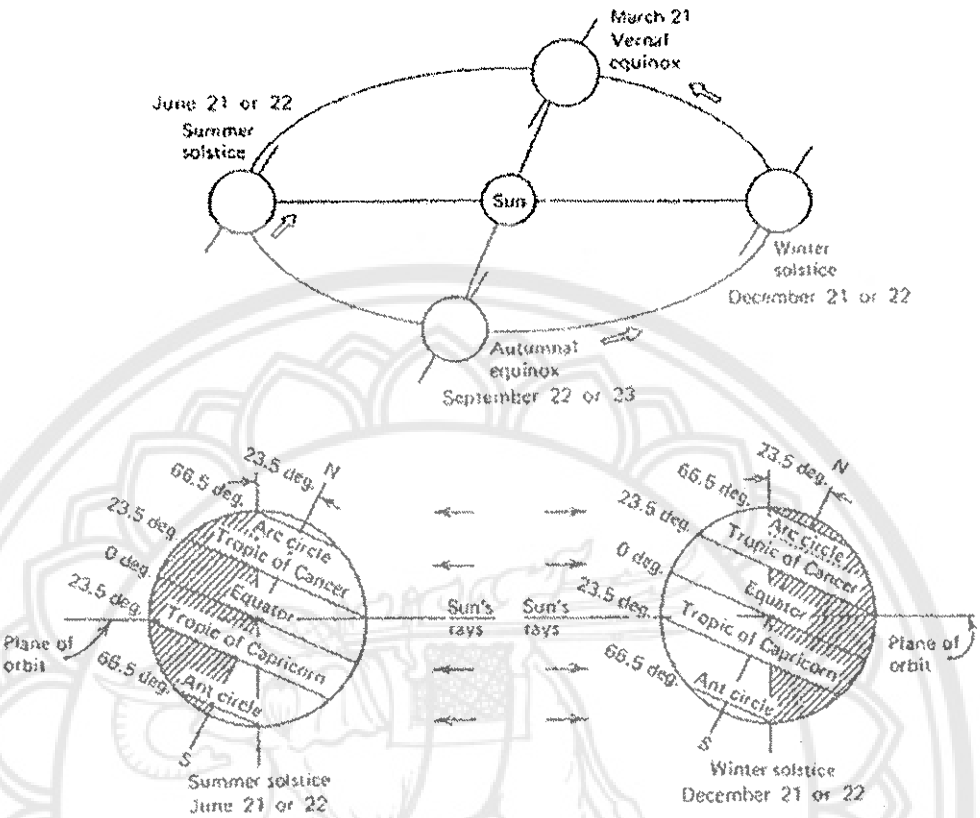

Figure 4 The effect of the earth's tilt and rotation about the sun.

At the time of the vernal equinox (March 21) and of autumnal equinox (September 22 or 23), the sun appears to be directly overhead at the equator and the earth's poles are equidistant from the sun. Equinox means "equal nights" and during the time of the two equinoxes all points to the earth (except the poles) it results to having exactly 12 hours of darkness and 12 hours of daylight.

During the summer solstice (June 21 or 22) the North Pole is inclined 23.5 deg toward the sun. All points on the earth's surface north of 66.5°N latitude (the Arctic Circle) is in continuous daylight, whereas all points south of 66.5°S latitude (Antarctic Circle) is in continuous darkness.

During the summer solstice the sun appear to be directly overhead along the Tropic of Cancer, whereas during the winter solstice (December 21 or 22) it is over head along the Tropic of Capricorn. These were definite in table 1

Table 1 The effect of the earth's tilt and rotation about the sun

During	Result
Vernal equinox (March 21)	Daylight = Darkness
Vernal equinox - Summer solstice	Daylight (upper) > Darkness
Summer solstice (June 21 or 22)	Longest daylight Arctic Circle = Continuous daylight
Summer solstice - Autumnal equinox	Daylight (lower) > Darkness
Autumnal equinox (September 22 or 23)	Darkness = Daylight
Autumnal equinox – Winter solstice	Darkness (upper) > Daylight
Winter solstice (December 21 or 22)	Longest Darkness Arctic Circle = continuous Darkness
Winter solstice - Vernal equinox	Darkness (lower) > Daylight

2. Solar Time

Solar time is used in all of the sun–angle relationships. The earth's rate of rotation which affect the time the sun crosses the observer's meridian. The difference in minutes between solar time and standard time is

$$\text{Solar time} - \text{Standard time} = 4(L_{st} - L_{loc}) + E \qquad (2.1)$$

Where

L_{st} Standard meridian for the local time zone, 105°E for Thailand

L_{loc} Longitude of the location in question, 100.28° for Phitsanulok

The equation of time E (in minutes) is determined from figure 5 or Equation 2 (All equation use degrees, not radians)

$$E = 229.2(0.000075 + 0.001868\cos B - 0.032077\sin B - 0.014615\cos 2B - 0.04089\sin 2B) \quad (2.2)$$

Where

$$B = (n-1)\frac{360}{365} \quad (2.3)$$

When

$$n = \text{day of the year};\ (1 \le n \le 365)$$

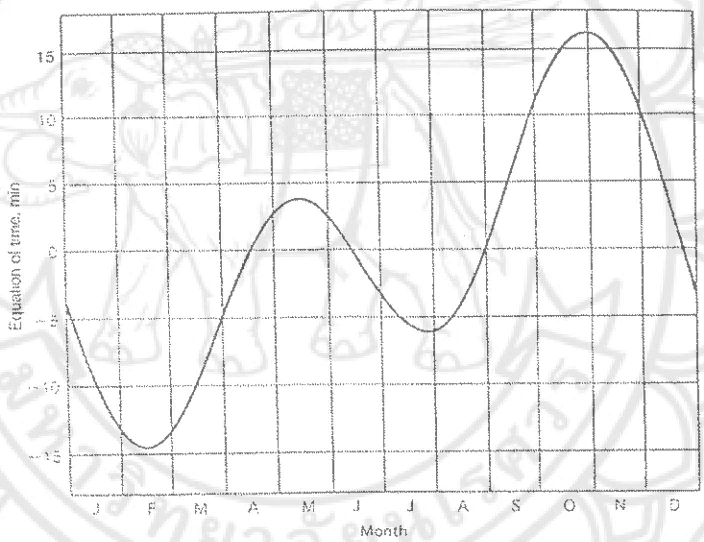

Figure 5 The equation of time E in minutes, as a function of time of year.

The day of the year n can be conveniently obtained with the help of table 2 Note that declination is a continuous function of time. The maximum rate of change of declination is at the equinoxes, when it is about 0.5%/day. For most engineering calculations, the assumption of an integer n to represent a day results in a satisfactory calculation of declination.

Table 2 Reccommended average day for month and value of n by months (Klein, 1997)

Month	n for i^{th} Day of month	For the average day of the month		
		Date	n, Day of year	δ, Declination
January	i	17	17	-20.9
February	31+i	16	47	-13.0
March	59+i	16	75	-2.4
April	90+i	15	105	9.4
May	120+i	15	135	18.8
June	151+i	11	162	23.1
July	181+i	17	198	21.2
August	212+i	16	228	13.5
September	243+i	15	258	2.2
October	273+i	15	288	-9.6
November	304+i	14	318	-18.9
December	334+i	10	344	-23.0

3. Solar Angle

The direction of the sun's rays can be described if three fundamental quantities known as:

3.1 location on the earth's surface

3.2 Time of day

3.3 Day of the year

It is convenient to describe these three quantities by giving the latitude, the hour angle, and the sun's declination, respectively. Figure 6 shows a point P located on the surface of the earth in the northern hemisphere. The latitude l is the angle between the line OP and the projection of OP on the equatorial plane. This is the same latitude that is commonly used on globes and maps to describe the location of a point with respect to the equator.

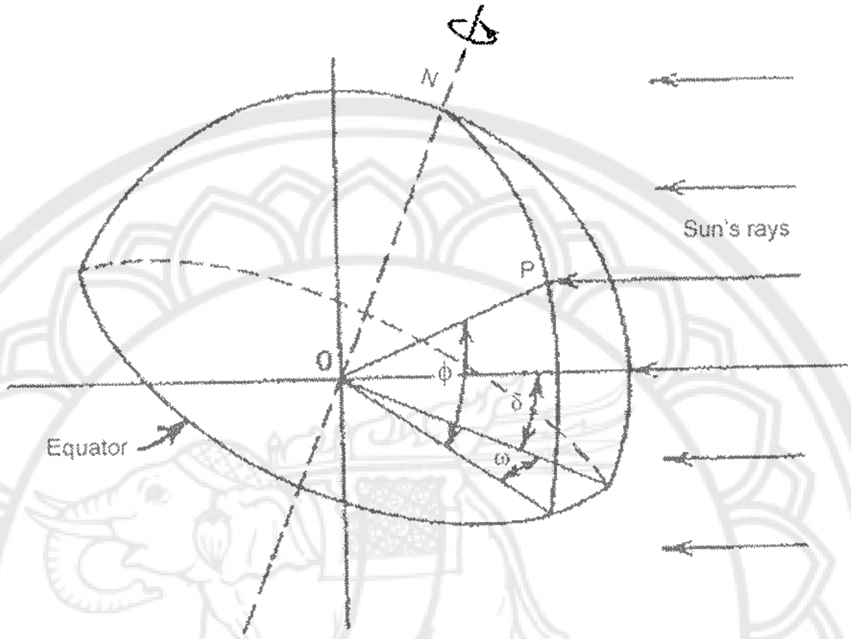

Figure 6 Latitude, hour angle and sun's declination

The hour angle h is the angle between the projection of OP on the equatorial plane and the projection on that plane of a line from the center of the earth. Fifteen degrees of hour angle corresponds to one hour of time. The hour angle varies from zero at local solar noon to a maximum at sunrise or sunset. Solar noon occurs when the sun is at the highest point in the sky, and hour angles are symmetrical with respect to solar noon. Thus, the hour angles of sunrise and sunset on a given day are identical.

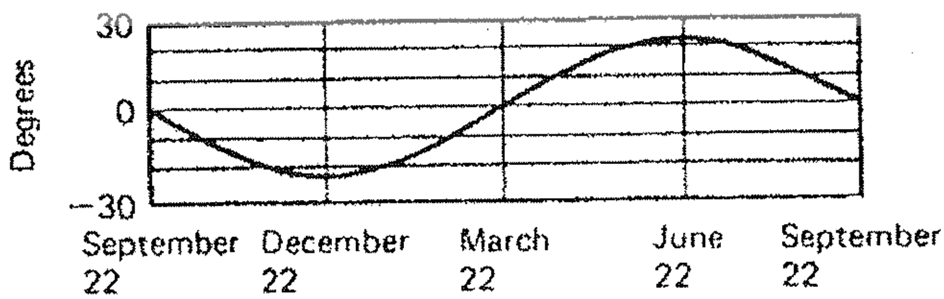

Figure 7 Solar Declination

The solar declination δ is the angle between a line connecting the center of the sun and the earth and the projection of that line on the equatorial plane. The solar declination varies from 23.45° (Summer Solstice) to -23.45° (Winter Solstice). Can be found from the equation of Cooper:

$$\delta = 23.45\sin\left(360\frac{284+n}{365}\right) \tag{2.4}$$

The sun's position in the sky can define in terms of solar altitude angle α_S and the solar azimuth γ_S, which depend on the fundamental quantities ϕ, ω and δ. It can be shown by analytic geometry that the following relationship is true:

$$\sin\alpha_S = \cos\phi\cos\omega\cos\delta + \sin\phi\sin\delta \tag{2.5}$$

where

α_S = solar altitude angle, deg

ϕ = Latitude of Phitsanulok, 16.78°

ω = hour angle, deg

δ = solar declination

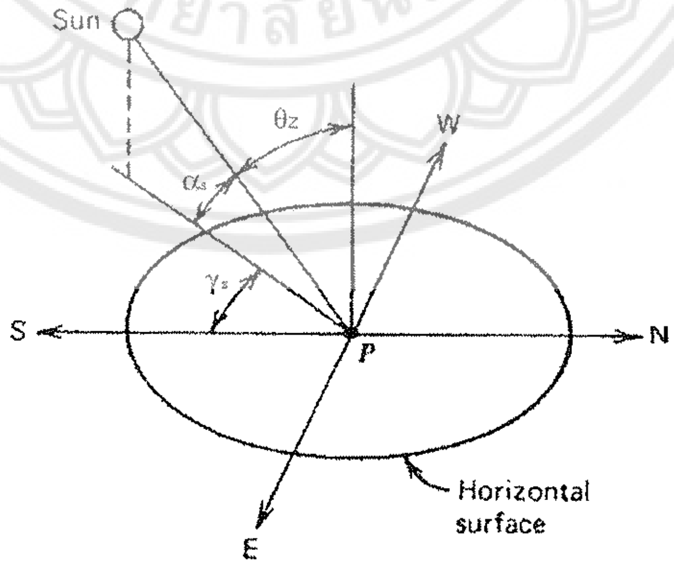

Figure 8 The solar altitude, zenith angle and azimuth angle

Form figure 8

α_S = Solar altitude angle, the angle between the horizontal and the line to the sun, i.e., the complement of the zenith angle

θ_Z = Zenith angle, the angle between the vertical and the line to the sun, i.e., the angle of incidence of beam radiation on a horizontal surface

γ_S = Solar azimuth angle, the angular displacement from south of the projection of beam radiation on the horizontal plane

The daily maximum altitude (solar noon) of the sun at a given location can be shown to be

$$\alpha_S + \theta_Z = 90^\circ \tag{2.6}$$

$$\alpha_{S_{noon}} = 90^\circ - |\phi - \delta| \tag{2.7}$$

$$\cos\gamma_S = \frac{(\sin\alpha_S \sin\phi - \sin\delta)}{(\cos\alpha_S \cos\phi)} \tag{2.8}$$

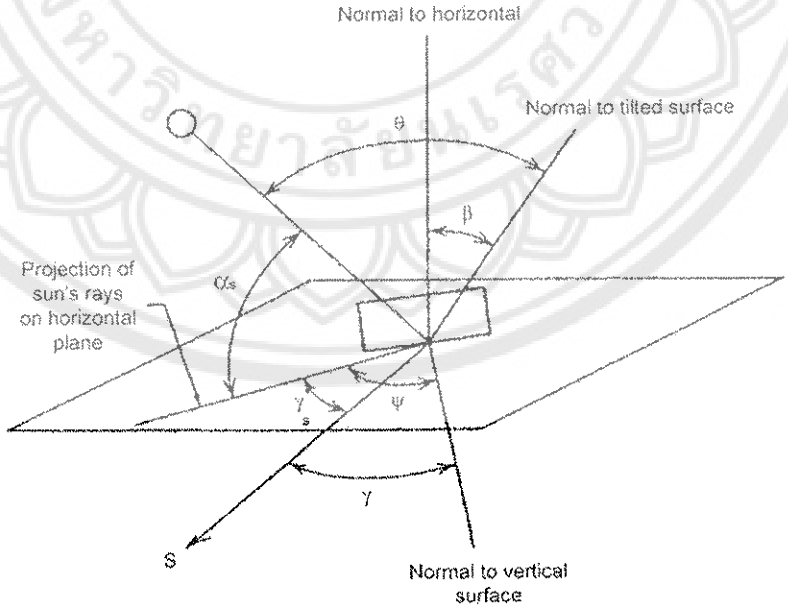

Figure 9 Surface solar azimuth ψ, surface azimuth γ and angle of tilt β for an arbitrary tilted surface

For a surface in figure 9

ψ = Surface solar azimuth, the angle measured in the horizontal plane between the projection of the sun's ray on that plane and normal to the vertical surface

γ = Surface azimuth angle, the deviation of the projection on horizontal plane of the normal on the surface from the local meridian, measured east (-) or west (+) from south; $-180^{\circ} \leq \gamma \leq 180^{\circ}$

θ = Angle of incidence, the angle between the sun's rays and the normal to the surface

β = Angle of tilt, the angle between the normal to the surface and the normal to the horizontal surface

Then obviously

$$\psi = |\gamma_S \pm \gamma| \tag{2.9}$$

$$\cos\theta = \cos\alpha_S \cos\psi \sin\beta + \sin\alpha_S \cos\beta \tag{2.10}$$

then for a vertical surface ($\beta = 90^{\circ}$)

$$\cos\theta = \cos\alpha_S \cos\psi \tag{2.11}$$

and for a horizontal surface ($\beta = 0^{\circ}$)

$$\cos\theta = \sin\alpha_S \tag{2.12}$$

4. **Shading**

Shading of fenestrations is effective in reducing solar heat gain to a space and may produce reductions of up to 80%. The shading coefficient SC discussed above is not appropriate to use in determining the effect of external shade since its propose is to account only for the effect of the fenestration and its internal shading devices. The SC will be used in heat gain calculation weather the fenestration is externally shaded or not. What is needed in considering heat gains affected by external shade are the areas of the fenestration that are externally shaded. These areas on which external shade falls can be calculated from the geometry of the external object creating the shade and from knowledge of the sun angle for that particular time and location.

Figure 10 illustrates a window that is set back into the structure where shading may occur on the side and top depending on the time of day and the direction the window faces. It can be shown that the dimensions S_H and S_W given by

$$S_w = P_w \tan\psi \tag{2.13}$$

$$S_h = P_h \tan\Omega \tag{2.14}$$

where

$$\tan\Omega = \frac{\tan\alpha_S}{\cos\psi} \tag{2.15}$$

and

α_S	=	Sun's altitude angle from Eq. 2.5
ψ	=	Wall solar azimuth angle $(\gamma_S \pm \gamma)$
γ_S	=	Solar azimuth from Eq. 2.8
γ	=	Wall azimuth measured east or west from the south

The following rules aid in he computation of the wall solar azimuth angle ψ.

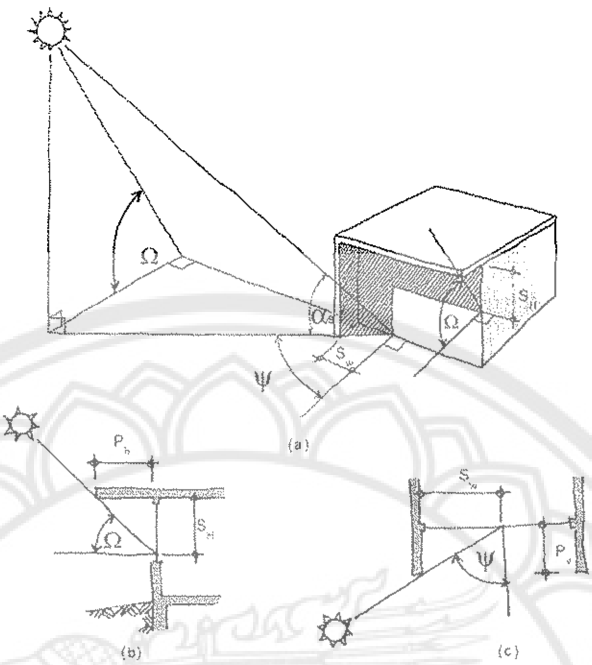

Figure 10 Shading of window set back from the plane of a building surface

For morning hour with walls facing east of south and afternoon hour with walls facing west of south:

$$\psi = |\gamma_S - \gamma| \tag{2.16}$$

For afternoon hours with the walls facing east of south and morning hour with walls facing west of south:

$$\psi = |\gamma_S + \gamma| \tag{2.17}$$

If ψ is greater than 90°, the surface is in the shade. Equation 14 can be used for an overhang at the top and perpendicular to the window provided that the overhang is wide enough for the shadow to extend completely across the window.

5. The Solar Radiation for a Clear Sky

The total or global radiation on a horizontal surface I_G (W/m^2), can be calculated as

$$I_G = I_{BH} + I_{DH} = I_B(C + \sin\alpha_s) \qquad (2.18)$$

Where

$$C = 0.95 + 0.04\sin\left[\frac{360}{365}(n-100)\right] \qquad (2.19)$$

and

I_{BH} = Direct-beam radiation on a horizontal surface, W/m^2

I_{DH} = Diffuse radiation on a horizontal surface, W/m^2

I_B = Direct-beam radiation, W/m^2

The total intensity of solar radiation, I_t (W/m^2), falling on a tilt surface at a direction normal to the surface on clear days, is given by

$$I_t = I_{BT} + I_{DT} + I_{RT} \qquad (2.20)$$

Where

$$I_{BT} = I_B\cos\theta \qquad (2.21)$$

$$I_{DT} = CI_B\left(\frac{1+\cos\beta}{2}\right) \qquad (2.22)$$

$$I_{RT} = \rho I_B(C + \sin\alpha_s)\left(\frac{1-\cos\beta}{2}\right) = \rho I_G\left(\frac{1-\cos\beta}{2}\right) \qquad (2.23)$$

and

I_{BT}	=	Direct-beam radiation on a tilt surface, W/m^2
I_{DT}	=	Diffuse radiation on a tilt surface, W/m^2
I_{RT}	=	Reflected radiation on a tilt surface, W/m^2
ρ	=	Ground reflectance
	=	0.2 for ordinary ground or grass

6. Clearness Index and Diffuse Fraction

From Duffie and Beckman (1991), a daily clearness index K_T as the ratio of a particular day's radiation to the extraterrestrial radiation for that day. In equation from,

$$K_T = \frac{H}{H_0} \tag{2.24}$$

Where

$$H_0 = \frac{24 \times 3600 G_{sc}}{\pi}\left(1 + 0.033\cos\frac{360n}{365}\right) \times \left(\cos\phi\cos\delta\sin\omega_s + \frac{\pi\omega_s}{180}\sin\phi\sin\delta\right) \tag{2.25}$$

$$\cos\omega_s = -\frac{\sin\phi\sin\delta}{\cos\phi\cos\delta} = -\tan\phi\tan\delta \tag{2.26}$$

and

K_T	=	Daily clearness index
H	=	Daily total radiation, J/m^2
H_0	=	Daily extraterrestrial radiation on a horizontal surface, J/m^2
G_{sc}	=	The solar constant; 1367 W/m^2
ω_s	=	The sunset hour angle ($\theta_z = 90^\circ$), degree

The diffuse fraction, H/H_d, can show available daily radiation data or weather condition. Correlations of daily diffuse fraction with K_T are as follows:

For $\omega_s \leq 81.4°$

$$\frac{H}{H_d} = \begin{cases} 1 - 0.2727K_T + 2.4495K_T^2 - 11.9514K_T^3 + 9.3879K_T^4 & \text{for } K_T < 0.715 \\ 0.143 & \text{for } K_T \geq 0.715 \end{cases} \quad (2.27)$$

and for $\omega_s > 81.4°$

$$\frac{H}{H_d} = \begin{cases} 1 + 0.2832K_T - 2.5557K_T^2 + 0.8448K_T^3 & \text{for } K_T < 0.715 \\ 0.175 & \text{for } K_T \geq 0.715 \end{cases} \quad (2.28)$$

Table 3 Radiation intensity for various weather conditions (Robert Kaiser, 1995. p. 57)

Weather	Clear blue sky	Hazy/Cloudy	Overcast sky dull day
Global Radiation	600-1000 W/m^2	200-400 W/m^2	50-150W/m^2
Diffuse fraction	10-20%	20-80%	80-100%

Hazy or Cloudy is sun visible as whitish yellow disc.

Solar Absorption Cooling System

Most cooling systems in use today are based on electricity-powered, vapor-compression-cycle technologies, there are heat-driven alternatives that make especially good sense a part of a cogeneration system. The most developed of these systems is based on the absorption cooling cycle shown in figure 11

In absorption cooling system, the mechanical compressor in a conventional vapor compression system is replaced with components that perform the same function, but do so thermochemically. In figure 11, everything outside of the dot-ted box is conventional; that is, it has the same components as would be found in a compressive refrigeration system. A refrigerant, in this case water vapor, leaves the thermochemical compressor under pressure. As it passes through the condenser, it changes state, releasing heat to the environment, and emerges as pressurized liquid water. When its pressure is released in the expansion value, it flashes back to the vapor state in the evaporator, drawing heat from the refrigerated space. The refrigerant then must be compressed to start another pass around the loop.

The key to the dotted box on the right of the figure is the method by which the vaporized refrigerant leaving the evaporator is re-pressurized using heat rather than a compressor. The system show in figure 11 uses water vapor as the refrigerant and use lithium bromine (LiBr) as the absorbent into which the water vapor dissolves. A vary small pump shuttles the water-LiBr solution from the dissolved water vapor and drives it out of solution. The pressurized water vapor leaving the generator is ready to pass trough the condenser and the rest of the conventional refrigeration system. Meanwhile, the LiBr returns to the absorber, never having left the system. The absorption of refrigerant into the absorbent is an exothermic reaction, so waste heat is released from the absorber as wall as the condensor. (Gilbert M. Master, 2004. p. 277-8)

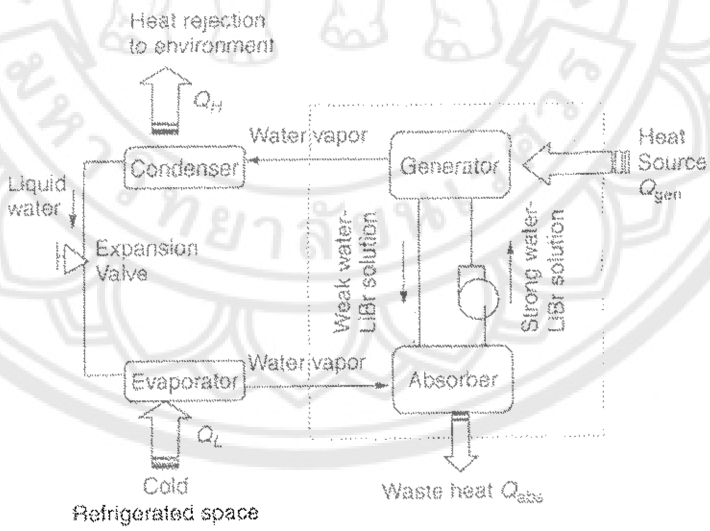

Figure 11 LiBr asorption chiller schematic. The compressor in a standard compressive refrigeration system has been replaced with a generator and absorber that perform the same function but do so with heat in stead of mechanical power.

The COP of and absorption cooling system is given by

$$COP_R = \frac{\text{Desired output (Cooling)}}{\text{Required input (heat + vary little electricity)}} \approx \frac{Q_L}{Q_{gen}} \qquad (2.29)$$

The SACS, in Testing building SERT Nareasuan University, compose two terms that are heat source or energy supply term, and the air condition term.

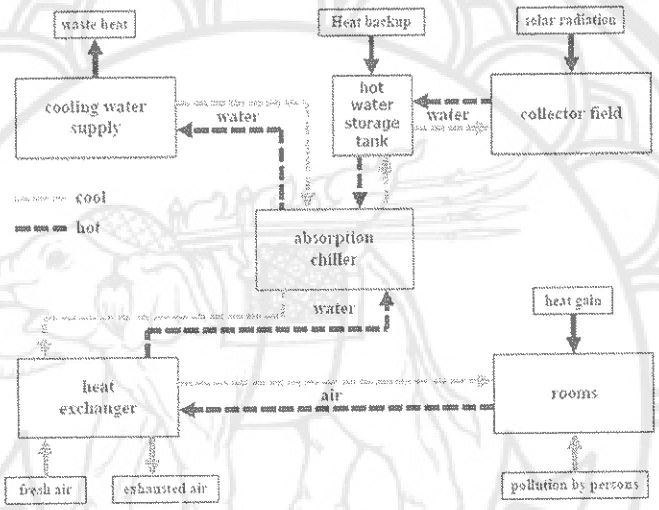

Figure 12 The solar cooling system in Testing Building

(Nipon Ketjoy, May 1st 2005.)

2. Heat source (Energy supply)

This term composes the solar collector field absorber area 72 m^2 (Net aperture area 81.78 m^2 from 84.6 m^2 because of shading of building), a hot water storage tank 500 L (400 L net capacity) and an auxiliary heat from LPG water heater.

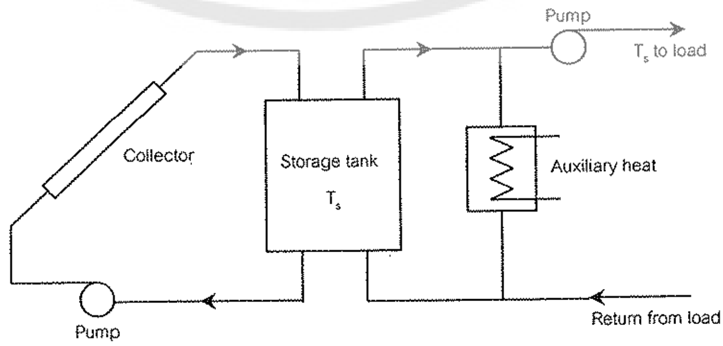

Figure 13 The solar thermal term

Solar collector converts solar energy into thermal energy for heating up the working fluid flowing inside the collector. the rate of useful energy gain from collector and the efficiency of collector can be written as:

$$q_C = \dot{m} C_p (T_o - T_i) \tag{2.30}$$

$$\eta_C = \frac{q_C}{I_T A_C} \tag{2.31}$$

Where

q_C	=	Rate of useful energy gain from collector, MJ/hr
$\dot{m}$	=	Require water flow rate, kg/h
C_p	=	specific heat water; 4,190J/kg $^{\circ}$C
η_C	=	Collector efficiency
A_C	=	Area of solar collector, m^2
I_T	=	Solar radiation on tilted surface, MJ/m^2 hr
T_i	=	Inlet water temperature into the collector, $^{\circ}$C
T_o	=	Outlet water temperature from the collector, $^{\circ}$C

3. Air condition term

This term compose with an absorption chiller capacity 10 tons of refrigeration (range hot water for energized at 70°C to 95°C), cooling water supply from a cooling tower capacity 40 tons and heat exchanger from fan coil unit capacity 32,000 Btu h.

In this case study especially consider the absorption chiller. From the first law of thermodynamics; heat input to the generator, heat input to evaporator and heat rejected to cooling tower are expressed in heat balance term of absorption chiller as follow:

$$Q_c = Q_g + Q_e \qquad (2.32)$$

where

$$Q_g = \dot{m} c_p (T_{g_i} - T_{go}) \qquad (2.34)$$

$$Q_e = \dot{m} c_p (T_{ei} - T_{eo}) \qquad (2.35)$$

And

$\dot{Q}_c$	=	Energy rejected to cooling tower, W
$\dot{Q}_g$	=	Energy input to generator, W
$\dot{Q}_e$	=	Energy input to evaporator or cooling capacity, W
$\dot{m}$	=	Require water flow rate, kg/h
T_{gi}	=	Water temperature input to generator, °C
T_{go}	=	Water temperature output to generator, °C
T_{ei}	=	Water temperature input to evaporator, °C
T_{eo}	=	Water temperature output to evaporator, °C

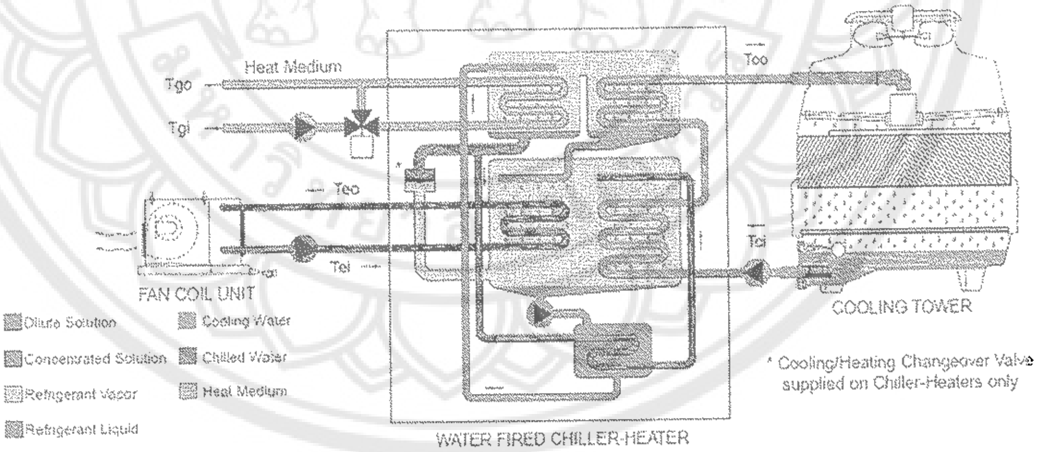

Figure 14 Water fried cooling and heating system for cooling operation

Heat Gain and Cooling Load

The cooling load is the rate at which energy must be removed from a space to maintain the temperature and humidity at the design values. The cooling load will generally differ from the heat gain because the radiation from the inside surface of walls and interior objects as well as the solar radiation coming directly into the space through openings does not heat the air within the space directly. This radiation energy is mostly absorbed by floors, interior wall and furniture, which are then cooled primarily by convection as they attain temperatures higher than that of the room air. Only when the room air receives the energy by convection does this energy become part of the cooling load. Figure 15 illustrates the phenomenon. The heat storage characteristics of the structure and interior object determine the thermal lag and therefore the relationship between heat gain and cooling load. For this reason the thermal mass (product of mass and specific heat) of the structure and its content must be considered in such cases. The reduction in peak cooling load because of the thermal lag can be quite important in sizing the cooling equipment.

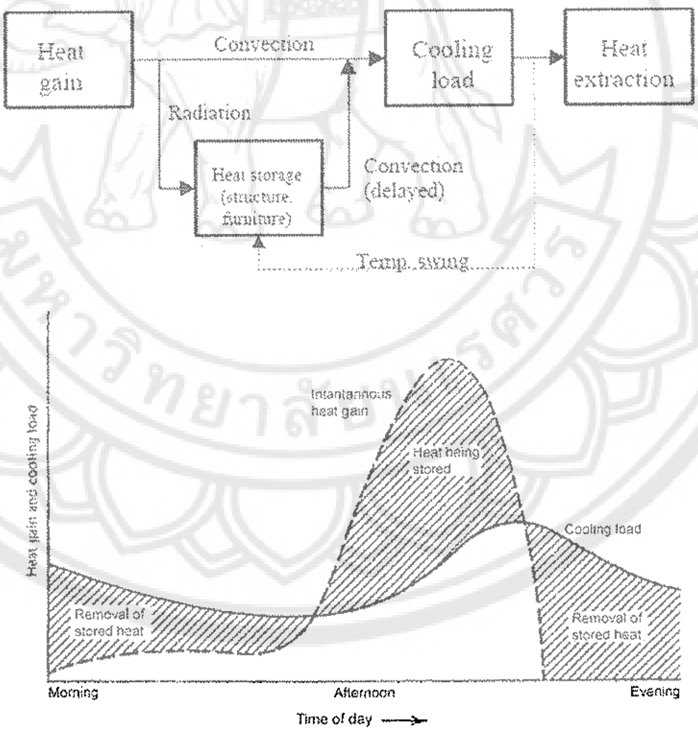

Figure 15 Relation of heat gain to cooling load

Cooling load calculations for air conditioning system design are mainly used to determine the volume flow rate of the air system as well as the coil and refrigeration load of the equipment-to size the HVAC&R equipment and to provide the inputs to the system for energy use calculation in order to select optimal design alternatives. Cooling load usually can be classified into two categories: external and internal.

External cooling load, these loads are formed because of heat gains in the conditioned space from external sources trough the building envelope or building shell and the partition walls. Sources of external loads include the following cooling loads:

1. Heat gain entering from the exterior walls and roofs
2. Solar heat gain transmitted through the fenestrations
3. Conductive heat gain coming through the fenestrations
4. Heat gain entering from the partition walls and interior doors
5. Infiltration of outdoor air into the conditioned space

Internal cooling load, these loads are formed by the release of sensible and latent heat from the heat sources inside the conditioned space. These sources contribute internal cooling loads:

1. People
2. Electric lights
3. Equipment and appliances

1. **Heat transfer Fundamental**

Heat transfer between two bodies, two materials, or two regions is the result of temperature difference. The science of heat transfer has provided calculation analyses to predict rates of heat transfer. The design of and air conditioning system must include estimates of heat transfer between the conditioned space, its contents and surroundings, to determine cooling and heating loads. Heat-transfer analysis can be described in three modes: conduction, convection, and radiation.

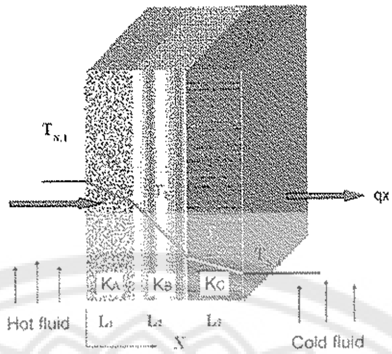

Figure 16 Steady-state one dimensional heat conduction through a composite wall

For one dimensional steady-state heat transfer, the overall heat-transfer rate of the composite wall can be calculated as

$$q = UA(T_i - T_o) \tag{2.36}$$

$$U = \frac{1}{1/h_i + L_1/k_1 + ... + L_n/k_n + 1/h_o} \tag{2.37}$$

where

q	=	The overall heat-transfer rate of the composite wall, W
U	=	Overall heat-transfer coefficient (the U value), W/m^2 °C
A	=	Surface area perpendicular to heat flow, m^2
T_i	=	Indoor temperature, °C
T_o	=	Outdoor temperature, °C
h_i	=	The inside surface heat-transfer coefficient at the liquid-to-solid interface, W/m^2 °C
h_o	=	The outside surface heat-transfer coefficient at the liquid-to-solid interface, W/m^2 °C
L	=	Thickness of layers, respectively, of composite wall, m
k	=	Thermal conductivity, W/m^2 °C

2. **Fenestration**

Fenestration is the term use for assemblies containing glass or light-transmitting plastic, including appurtenances such as framing, mullions, dividers, and internal, external, and between-glass shading devices. The proposes of fenestration are to provide a preview of the outside world, permit entry of daylight, admit solar heat as a heating supplement in winter, act as an emergency exit for single-story buildings and add to aesthetics.

Solar radiation admitted trough a glass or window pane can be an important heat gain for the buildings, with greater energy impact in the sun belt.

Heat gain for single glazing:

Heat admitted through a unit area of the single-glazing window glass is

$$\frac{Q_{wi}}{A_s} = \tau I_t + U\left(\frac{\alpha I_t}{h_o} + T_o - T_i\right)$$

$$= SHGCI_t + U\left(\frac{\alpha I_t}{h_o} + T_o - T_i\right) \qquad (2.38)$$

Solar heat gain coefficient (SHGC) is the ratio of solar heat gain entering the space through the window glass to the incident solar radiation, total short wave irradiance for a single-glazed window is given as

$$SHGC = Q_{ws} / I_t A_s$$

$$= \tau + \frac{U\alpha}{h_o} \qquad (2.39)$$

where

A_s	=	The sunlit area of window, m^2
I_t	=	The total intensity of solar radiation, W/m^2
Q_{wi}	=	Heat gain through the window, W
Q_{ws}	=	The solar heat gain entering the space, W

U = The overall heat-transfer coefficient of the window, W/m^2 °C

T_i = Indoor temperature, °C

T_o = Outdoor temperature, °C

h_o = heat-transfer coefficient for out door surface of window glass, W/m^2 °C

τ = The transmittance of the window glass

α = The absorptance of the window glass

$SHGC$ = Solar heat gain coefficient

In equation (2.41) and (2.42), U indicates the overall heat-transfer coefficient of the window can be calculated as

$$U = \frac{U_{wg}A_{wg} + U_{eg}A_{eg} + U_f A_f}{A_w g + A_{eg} + A_f} \qquad (2.40)$$

where

U = The overall heat-transfer coefficient of the window, W/m^2 °C

A_{wg} = Area of the glass of the window, m^2

A_{eg} = Area of the edge of the glass including the sealer and spacer of the insulating glass, m^2

A_f = Area of the edge of the frame of the window, m^2

U_{wg} = Heat-transfer coefficient of the glass, W/m^2 °C

U_f = Heat-transfer coefficient of the frame of the window, W/m^2 °C

U_{eg} = Heat-transfer coefficient of the edge of the glass including the sealer and spacer of the insulating glass, W/m^2 °C

Shading Coefficients:

The shading coefficient is defined as the ratio of solar heat gain of a glazing assembly of specific construction and shading devices at a summer design solar intensity and outdoor and indoor temperatures, to the solar heat gain of a reference glass as the same solar intensity and outdoor and indoor temperatures. The reference glass is double-strength sheet glass (DSA) with transmittance $\tau = 0.86$, reflectance $\rho = 0.08$, absorptance $\alpha = 0.06$, and $F_{DSA} = 0.87$ under summer design conditions. The shading coefficient SC is an indication of the characteristics of a glazing and the associated shading devices, and it can be expressed as

$$SC = \frac{\text{Solar heat gain of specific type of window glass}}{\text{Solar heat gain of double-strength sheet glass}}$$

$$= \frac{SHGC_w}{SHGC_{DSA}} = \frac{SHGC_w}{0.87} = 1.15 SHGC_{wi} \qquad (2.41)$$

where

$SHGC_w$ = Solar heat gain of specific type of window glass

$SHGC_{DSA}$ = Solar heat gain of standard reference double-strength sheet glass