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Analysis of Cooling Load Estimation By Using Non-Conventional Energy Sources

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ABSTRACT

Cooling load computations are done to appraise the required limit of cooling systems. The motivation behind this venture is to build up an easy to understand program that can without much of a stretch ascertain space-cooling heap of a common classroom taking a portion of the fundamental sources of info like scope, longitude time-zone, building materials and other metrological data of the location. Proposition depends on decreasing cooling heap of room by utilizing reuse plastic as rooftop material in the place of RCC in light of the fact that warm conductivity of plastic is less as contrast with RCC. Which diminishes the cooling load. Cooling load computations are completed to evaluate the required limit of cooling systems.
Keywords : RCC, COP, DBT, WBT

I. INTRODUCTION

In present days the environmental problem is one of the most serious problems. Energy consumption by industries and buildings are responsible for this problem. About 72% of world energy is consumed by infrastructure, industry, commercial buildings, residential houses, and markets. In a large building or complex, which is air-conditioned, about 60% of the total energy requirement in the building is allocated for the air-conditioning plant installed to use the cooling purpose.

In the project, increasing energy consumption associated with space conditioning as identified. A setup has made in which tubes have embedded in the roof of the building through which water is circulated takes away the heat load due to incident solar radiation and internal load due to occupancy, equipment etc. And get cooled by water in the underground tank before getting recirculated in the roof tubes. This reduces the cooling load of air conditioning system and lesser energy consumption.

Terminologies

Commonly used terms relative to cooling load calculation and heat transfer of the buildings according to the ASHRAE reference are given below.

a) Refrigeration: - the term 'Refrigeration' means process of removing heat from a substance or space under the controlled conditions. It also include the process of reducing and maintaining the temperature of a body below the surrounding temperature

b) Unit of refrigeration: - the practical unit of refrigeration is expressed in terms of 'tonne of refrigeration (TR)'. A tonne of refrigeration is defined as the amount of refrigeration effects produced by the melting of 1 ton of ice from and at 0 oC in 24 hours.

c) Coefficient of performance (COP): - the COP is defined as the ratio of heat extracted in the refrigerator to the work done on the refrigerant.

d) Refrigerant: - refrigerant is the fluid used for heat transfer in a refrigerating system that release heat during condensation at a region of higher temperature and pressure, and absorbs heat during evaporation at low temperature and pressure region.

e) Air conditioning: - controlling and maintaining environmental parameters such as temperature, humidity, cleanliness, air movement, sound level, pressure difference between condition space and surrounding within prescribed limit.

g) Humidity: - it is the mass of water vapour present in 1 kg of dry air, and is generally expressed in terms of gram per kg of dry air (g/kg of dry air). It is also called specific humidity or humidity ratio.

h) Relative humidity (RH): - it is a ratio of actual mass of water vapour in a given volume of moist air to the mass of water vapour in the same volume of saturated air at the same temperature and pressure.

i) Dry bulb temperature (DBT): - it is the temperature of air recorded by thermometer, when it is not affected by the moisture present in the air. The dry bulb temperature is generally denoted by td or tdb.

j) Wet bulb temperature (WBT): - it is the temperature of air recorded by a thermometer, when its bulb is surrounded by a wet cloth exposed to the air. The wet bulb temperature is generally denoted by tw or twb.

k) Dew point temperature (DPT): - it is the temperature of the air recorded by the thermometer, when the moisture present it beings to condense.

l) Heat transfer coefficient: - it is the rate of heat transfer through a unit area of building envelope material, including its boundary films, per unit temperature difference between the outside and inside air.

m) Thermal resistance: - it is the reciprocal of the heat transfer coefficient and is expressed in m_2-K/W.

n) Sensible heat gain: - direct addition of heat to the enclosed space, without any change in its specific humidity, is known as sensible heat gain.

o) Latent heat gain: - heat gain of space through addition of moisture, without change in its dry bulb temperature, is known as latent heat gain.

p) Space heat gain: - it is the rate of heat gain, at which heat inter into and generated within the conditioned space.

q) Space cooling load: - it is the rate at which energy must be removed from a space to maintain a desired air temperature of space

Heat exchange of human body with environment

A human body feels comfortable thermodynamically when the heat produced by the metabolism of human body is equal to the sum of the heat dissipated to the surrounding and the heat stored in the human body by raising the temperature of body tissues.

The phenomena of heat loss from the body can be expressed by

$Q_m - W = Q_E \pm Q_S \pm Q_R \pm Q_C$ ……............... (1.1)

Where

QM = metabolic heat produced within the body.

W = useful rate of working.

QS = heat stored in the body.

QE = heat loss by evaporation.

QR = heat loss and gain by radiation.

QC = heat loss and gain by conduction and convection.

[redacted] metabolic heat production depends upon the food consumption in the body.

Convection Heat Loss

The convective heat loss from the body is given by the Eqn. 1.2.

$QC = UA\ (Tb-Ts)$ …………….. (1.2)

Where

U = heat transfer coefficient on body surface.

A = body surface area.

Tb, Ts = temperature of the body and surrounding respectively.

The heat will be gained by the body if the temperature of the surrounding is greater than the body temperature and this will increase with increase in U which is function of air velocity. Higher velocities impart more uncomfort when surrounding temperature is higher than body temperature.

Factor governing optimum effective temperature

The optimum effective temperature is affected by the following important factors.

a) **Climatic and seasonal difference:-** it is known fact that people living in colder climates feel comfortable at a lower effective temperature than those living in warmer regions. There is a relationship between the optimum indoor effective temperature and the optimum outdoor temperature, which change with seasons. It can be see from comfort chart that in winter, the optimum effective temperature is 19 oC where in summer this temperature is 22 oC.

b) **Clothing:-**it is another important factor which affects the optimum effective temperature. It may be noted that the person with light clothings need less optimum temperature than person with heavy clothings.

c) **Age and sex:-**we have already discussed that the women of all ages required higher effective temperature (about 0.5 oC) than men. Similar is the case of old and young people.

The children also need higher effective temperature than adult.

d) **Activity:-**when the activity of the person is heavy such as people working on the factory, dancing hall, then low effective temperature is needed than for the people sitting in cinema hall or auditorium.

e) **Latitude:** - the effective temperature is increases by about 0.5 with every 5˚ reduction in latitude.

II. PROPOSED METHODOLOGY

COOLING LOAD:

Cooling load is the total heat required to be removed from the space in order to bring it at the desired temperature by the air conditioning and refrigeration equipment.

1) The objectives of cooling load calculation are as follows:

i. To determine be the optimum rate at which heat needs to be removed from space to establish thermal equilibrium & maintain a pre-determined inside conditions
ii. To calculate peak design loads (cooling/heating).
iii. To estimate capacity or size of plant/equipment.
iv. To form the basis for building energy analysis

COMPONENT OF COOLING LOAD:

The total building cooling load consists of heat transferred through the building envelope (walls, roof, floor, windows, doors etc.) and heat generated by occupants, equipment, and lights. The load due to heat transfer through the envelope is called as external load, while all other loads are called as internal loads. The percentage of external versus internal load varies with building type, site climate, and building design. The total cooling load on any building consists of both sensible well as latent load components. The sensible load affects the dry bulb temperature, while the latent load affects the moisture content of the conditioned space.

HEAT GAIN THROUGHT BUILDING BY CONDUCTION:

Heat gain through building structure such roof, walls, ceiling, doors and windows constitutes the major portion of the sensible heat load. A little consideration will show that the heat passing through a wall is first receive at the wall surface expose to the region of higher air temperature by radiation convection and conduction. It then flows through the material of the wall to the surface exposed at the region of lower air temperature. Thus, the heat transferred or gained through a wall under steady state condition is

$$Q=U\times A\times (To-Ti) \quad \text{……. (1)}$$

Q=heat gain
A=outside area of roof
U=overall coefficient of heat transmission of the wall
X=thickness of the wall

$$U=\frac{1}{\frac{1}{f}+\frac{X}{K}+\frac{1}{F}} \quad \text{……. (2)}$$

f=outside film or surface conductance
F=inside film or surface conductance

Table 1. Film or surface conductance for air film.

Material	**Surface position**	**Thermal conductance (f) in W/m^2k**
Still air (f) heat flowing up	Horizontal	9.25
Still air (f) heat flowing down	Horizontal	6.13
Still air (f) heat flowing horizontal	Vertical	8.3
Wind, 24km/h (F)	Any position	34.0
Wind, 12km/h (F)	Any position	22.7

HEAT GAIN DUE TO INFILTRATION:-

The infiltration air is the air that enters a conditioned space through window cracks and opening of doors. The amount of infiltrated air through windows and walls is

$$= \frac{L \times W \times H \times Ac}{60} \text{ cubic meter per min.} \qquad \ldots\ldots\ldots\ldots (3)$$

Where:-

L=room length in meters

W=room width in meters

H=room height in meters

Ac=air changes per hours

HEAT GAIN FROM LIGHTINING EQUIPMENTS:-

The heat gain by electric light depends upon the rating of light in watt,use factor and allowance factor. The heat gain from electric light is given by

=total wattage of light × use factor × allowance factor

Generally use factor is taken below 0.5 and allowance factor is usually taken as 1.25

HEAT GAIN THROUGH VENTILATION:

The ventilation (i.e. supply of outside air) is provided to the conditioned space in order to minimise odour ,concentration of smoke , carbon dioxide and other undesirable gases so that freshness of air could be maintained. The outside air adds sensible as well as latent heat.

HEAT GAIN FROM OCCUPANTS:-

The heat gain from occupants is based on the average no. of people that are expected to be present in the conditioned space.

HEAT GAIN FROM APPLIANCES:-

The appliances frequently used in air conditioned spaces may be electrical, gas fired or steam heated. Following table gives most of the commonly used appliances together with approximate values of sensible heat and latent heat.

Table 2. Heat gain from appliances without hoods(in watt).

Appliances	Electrical		gas	
	Sensible	Latent	Sensible	Latent
Coffee brewer,5/4	264	64	396	103
Coffee brewer with tank, 20 litres	1406	352	2110	528
Egg boiler, 2 cups	352	234	1143	1143
Hair drier, blower type	674	117	1930	733

Climatic condition

In Raipur, the summers are short and sweltering, the winters are short and cool, and it is dry and mostly clear round. Over the course of the year, the temperature typically varies from
51˚F to 104˚F and is rarely below 46˚F to 109˚F.

The hot season lasts for 2.5 months, from April 12 to June 27, with an average daily high temperature above 98˚ F. The hottest day of the year is May 22, with an average high of the year 104˚ F and low of 83˚ F.

The cool season lasts for 2.2 months, from December 7 to February 15, with an average daily high temperature below 80˚ F. The coldest day of the year is January 7, with an average low of 51˚ F and high of 75˚ F.

Heat gain through roof of the building structure:-

2) (without arrangement)

Heat gain through building structure such roof, walls, ceiling, doors and windows constitutes the major portion of the sensible heat load. A little consideration will show that the heat passing through a wall is first receive at the wall surface expose to the region of higher air temperature by radiation convection and conduction. It then flows through the material of the wall to the surface exposed at the region of lower air temperature.

Thus, the heat transferred or gained through a wall under steady state condition is

$$Q=U\times A\times (T_o-T_i) \qquad \text{……………} (4)$$

Q=heat gain (J)

A=outside area of roof (m^2)

U=overall coefficient of heat transmission of the wall (w/m^2k)

X=thickness of the wall (m)

$$U=\frac{1}{\frac{1}{f}+\frac{X}{K}+\frac{1}{F}} \qquad \text{…………..} (5)$$

f= outside film or surface conductance (w/m^2k)

F=inside film or surface conductance (w/m^2k)

HEAT CARRIED AWAY BY WATER FLOWING THROUGH PIPE

3) EMBEDDEBD IN ROOF OF THE BUILDING

Let inlet and outlet temperature of water through pipe are T_c and T_h

Mass flow rate of water = $\dot{m}$
Specific heat of the water at constant pressure = C
Heat carried away by water

$Q' = \dot{m} \times C \times (T_h - T_c)$ ………….. (6) Also, heat taken up by water

$Q' = h \times A \times (Ts - Tb)$ …………… (7)

h=heat transfer coefficient of water (w/m^2k)
A=surface area of the pipe = ($3.14 \times d \times l$) m^2 d= diameter of pipe (m) l= total length of pipe (m)
Ts=surface temperature of the pipe (˚C)
Tb=bulk mean temperature (˚C)

CALCULATION OF HEAT TRANSFER COEFFICIENT "h":-

Reynolds no.= $\frac{\rho \times v \times d}{\mu}$ ……………(8)

V=velocity of water flowing through pipe (m/s) d=diameter of pipe (m) μ= dynamic viscosity (Ns/m^2)

The properties like coefficient of viscosity, thermal conductivity, specific heat ,prandtl number can be calculated at mean bulb temperature from heat and mass transfer design databook (C.P. KOTHANDRAMAN AND S. SUBHRAMANYAN)

For pipe, flow is laminar when

$Re < 2300$

And turbulant when

$Re > 2300$

Nusselt number Nu= $\frac{h \times l}{k}$ ……….. (9)

h= heat transfer coefficient (w/m^2k) l=total length of pipe (m) k=thermal conductivity of water (w/mk)

Therefore, reduction in heat gain through roof of building is given by

$= Q - Q'$

CALCULATION OF POWER TO DRIVE THE PUPM

Power to drive the pump is given by

$P = \dot{m} \times g \times H$ (w) .... (10) where

$H = hs + hd + hfs + hfd + hb$ .... (11)

Where, h_s= suction head h_d= delivery head h_{fs} and h_{fd} = loss of head due to friction in suction and delivery pipe.

h_b = loss of head due to bending

Loss of head in pipe due to friction is calculated from Darcy-Weisbach equation

$h_{fd} = \frac{4\times f\times l\times v2}{d\times 2\times g}$ .... (3.12) f=coefficient of friction

Losses of head due to bending of pipe

$h_b = \frac{k\times v2}{2\times g}$ K= coefficient of bending

CALCULATIONS AND RESULTS

For calculation we have taken the dimensions of seminar hall of academic building of our college whose all dimensions.

CALCULATION OF PUMP WORK:

The power to drive the pump is given by

Power(P)= $m \times g \times H$

Where

$H = hs + hd + hfs + hfd + hb$ .... (1) These values are:

hs =1.5 (assumed)

hd=18m (as seminar hall roof is 18m above the ground) The value of loss of head due to friction delivery pipe is given by $hfd = \frac{4\times f\times l\times v2}{d\times 2\times g}$ =2.363m here, f = 0.01 (taken from fluid mechanics book) l = 18 + length of pipe = 18 + 221.47=239.47 m

(length of the pipe is according to the dimension of seminar hall)

d = 0.0125m, v = 0.246m/s, g = 9.81 m/s^2 similarly, the value of loss of head due to friction in suction pipe is given by

$\frac{4\times f\times l\times v2}{d\times 2\times g}$ hfs==0.7896m

[l = 80m (length of suction pipe assumed 80m)] and

hb= $\frac{k\times v2}{2\times g}$ =0.00154m

[here, k = 0.5 from fluid mechanic book] after putting the above values on the equation (1), we get total head, H=240.26m

Then, the power of pump is given by

$P = \dot{m}\times g\times H$

Where m = 0.12 kg/s

P=282.83 W

III. RESULTS:

1. As per above calculations the following results have obtained which are-
2. Heat gain through roof to the room without setup =Q=16.58Kw
3. Here heat taken up by the water= Q'=4.01 kw
4. power require to drive the pump, P = 0.28283 kw
5. Heat gain through roof to the room with setup=Q- Q'=12.57 kw
6. This will constitute lower load of air conditioning system which will reduce the power consumption of the air conditioning system.

IV. CONCLUSION

As per the above methodologies and calculations, the following conclusion can be drawn which are as follows-

1. Heat gain through roof of the building without the setup, Q = 16.58 kw
2. Heat carried away by water flowing through pipe, Q'=4.01 kw
3. Power require to drive the pump is calculated as P = 0.28283 kw
4. Therefore, the reduction in heat gain through roof is given as Q- Q'=12.57 kw

   This reduction in heat gain will reduce the total heat gain in the cooling space which will reduce the cooling load of the air conditioning system which will ultimately reduce the power consumption of the air conditioning system.

5. As this system using water as a working fluid and electricity to drive the pump, this one is eco-friendly and energy efficient system (project) which does not harm the environment.

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