Designing of Air Conditioner System for College Laboratory

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Abstract—

The use of air conditioning systems for residential/office buildings were very minimum in the earlier days of 1980's. Due to the technology advancement and industrial growth buildings were started construction in a closed area and construction of apartment also increased after 1980's with increased population. Also ambient temperatures are changed drastically due to pollution and concrete structure. Hence air conditioning has become an essential commodity for residential/office building. The increased demand of air conditioners has made scope for new innovations and technology developments in this field and hence there is lot of scope to study and learn this subject therefore the topic was chosen at most interest to develop our skills in this growing field. The necessity of design of air conditioning system for residential/office buildings is increasing day by day and lot of professionals have been developed in this field and adapted themselves into this field as consultants/designers due to the increased requirement. Hence we also felt necessity to learn this subject and upgrade our knowledge in this field of air conditioning. As a mechanical engineer we will do justification to this subject by putting our dedicated efforts using the project period and we will develop our technical skills in the field of air conditioning. The scope of work involved in this project is mainly divided into part A and part B. In part A–we will learn about the basic principles of thermodynamics which consists of thermodynamic processes, second law of thermodynamics from which subject of air conditioning is evolved. Also we will learn about principles of air conditioning which includes properties of gases and vapors, psychometric processes, properties of refrigerants, etc., In part B –we will learn the cooling load calculations, design calculations involved in selection of air conditioning systems and types of equipments and material of construction. This project has given opportunity for enrichment of our technical knowledge in the area of refrigeration and air conditioning and exposure to the practical field to learn the latest trends of air conditioning field and built our confidence to develop ourselves as a professional air conditioning engineer.

Keywords— air conditioning, design, sensible heat, solar heat gain factor.

I. INTRODUCTION

Air conditioning (often referred to as air on, AC or A/C) is the process of altering the properties of air (primarily humidity and temperature) to favorable conditions, typically with the aim of distributing the conditioned air to an occupied space is to improve comfort. In the most general sense, air conditioning can refer to any form of technology humidification, de-humidification, heating, cooling, cleaning, ventilation, or air movement that modifies the condition of air.

In general, the air conditioner is a device (most commonly a home appliance or automobile system) that lowers the air temperature. The cooling is most done using a simple refrigeration cycle, but sometimes the evaporation is used, commonly for the comfort of cooling in -buildings and motor vehicles. In construction, a complete system of heating, ventilation and air conditioning is referred to as "HVAC".

Air conditioning can also be provided by the simple process called free cooling which uses pumps to circulate a coolant (typically or a glycol mix) from a cold source, which in turn acts as a heat sink for the energy that is removed from the cooled space. The free cooling systems can have very high efficiencies and are sometimes combined with seasonal thermal energy storage (STES), so that the cold of winter can be used for summer air conditioning. Common storage media are the deep aquifers/a natural underground rock mass accessed via heat exchanger equipped boreholes with a cluster of small-diameter. Some systems with small storage are hybrids, using free cooling early in the cooling season, and later employing a heat pump to cool the circulation coming from the storage. During the cooling season the temperature of the storage gradually increases, so the heat pump is added-in, thereby declining in effectiveness. Free cooling and hybrid systems are mature technology.

II. DESIGN OF AIR CONDITIONING SYSTEMS

A. Introduction

The total heat required is to be removed from the space in order to bring it at the desired temperature by the air conditioning and refrigeration equipments known as cooling load. The purpose of load estimation is to determine the size of the refrigeration and air conditioning equipment that is required to maintain inside design conditions.

The design load of air conditioning system is based on inside and outside design conditions and its air conditioning and refrigeration equipment capacity to produce and maintain satisfactory inside conditions.

B. Components of a cooling load

The two main components of a cooling load imposed on an air conditioning plant operating during hot weather are as follows:

Sensible heat gain: When there is a direct addition of heat to the enclosed space, a gain in the sensible heat is said to occur.

The sensible heat gain may occur due to the following reasons:

(a) The heat flowing into the building by conduction through exterior walls, doors, windows, floors and ceiling are due to temperature difference on their two sides.
(b) The heat received from solar radiation. It consists of
  - The heat transmitted directly through the glass of windows and
  - The heat absorbed by walls and roofs exposed to solar radiation and later on transferred to the room by conduction.

(c) The heat conducted through interior partition from rooms in the same building which are not conditioned.
(d) The heat given off by lights, motors, cooking operations, etc.,
(e) The heat liberated by the occupants.
(f) The heat gain from the fan work.

Latent heat gain: When there is an addition of water vapor to the air of enclosed space, a gain in latent heat is said to occur.

The latent heat gain may occur due to the following reasons:

(a) The heat gain due to the moisture in the outside air entering by infiltration.
(b) The heat gain due to condensation of moisture from occupants.
(c) The heat gain due to condensation of moisture from any process such as cooking foods which takes place within the conditioned space.
(d) The heat gain due to moisture passing directly into the conditioned space through partitions or permeable walls from the outside.

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III. PROBLEM AND RESULT

A laboratory 30 m × 20 m × 4 m high is to be air conditioned. The 30m wall faces north. The north wall has two doors of 2.5 m × 3 m each. The south wall has four glass windows of 2 m × 1.5 m each. The east and west walls also have four windows of the same size. The lighting load is 15 W fluorescent per m^2 floor area. The infiltration is one air change. The solar heat gain factors (SHGF) for south, east and west glass are 150, 50 and 350 W/m^2 respectively. The overall heat transfer coefficients for roof, floor, walls, door and windows are 2.5, 2, 3, 1.5 and 6 W/m^2 K respectively. The corrected equivalent temperature differences for north, south, east, west walls, roof and floor are 12, 15, 12, 17, 20 and 2.5^0C respectively. There are 100 persons with sensible and latent heat loads of 75W and 55W each respectively. The ventilation requirement is 0.3 m^3/min per person. The outdoor condition is 43^0C dry bulb temperature and 0.0277 kg/kg of dry air of humidity ratio. The indoor condition is 25^0C dry bulb temperature and 0.01 kg/kg of dry air of humidity ratio. Use a factor of 1.25 for fluorescent light.

Determine room sensible heat load and room latent heat load with 5% safety factor, 5% for fan power, 1% heat leakage of supply air and 0.5% heat leakage to supply air duct.

Solution: Given : L = 30 m ; B = 20 m ; H = 4 m; Door size = 2.5 m × 3 m ; Window size =2 m ×1.5 m ; QSL = 15 W/m^2 floor area ; No. of air changes(A_c) = 1 ; SHGF for south glass = 150 W/m^2 ; SHGF for east glass = 50 W/m^2 ; SHGF for west glass = 350 W/m^2 ; U_{walls} = 2.5 W/m^2 K ; U_{roof} = 2 W/m^2 K ; U_{floor} = 3 W/m^2 K ; U_{door} = 1.5 W/m^2 K ; U windows = 6 W/m^2 K ; t_e for north wall = 12^0C ; t_e for south wall = 15^0C ; t_e for east wall = 12^0C ; t_e for west wall = 17^0C ; t_e for roof = 20^0C ; t_e for floor = 2.5^0 C ; No.of persons = 100 ; Q_s per person = 75W ; Q_L per person = 55W ; v_1 = 0.3 m^3/ min per person ; t_{d1} = 43^0C ; W_1 = 0.0277 kg/kg of dry air ; t_{d2} = 25^0C ; W_2 = 0.01 kg/kg of dry air ; Allowance factor of the fluorescent light = 1.25 ; safety factor = 5%; Factor for fan power = 5% ; Factor for leakage of supply air = 1%; Factor for heat leakage to supply air duct = 0.5%

The plan of a laboratory room is shown in figure. The sensible heat gain from various sources is given in the following table.

Estimation of sensible
heat gain Area of one
door = 2.5 ×3 = 7.5 m^2
Area of one window =
2 ×1.5 = 3 m^2

Source	***Overall heat transfer coefficient(U) W/m²K***	***Area(A) m²***	***Equivalent temperature difference (t_e)⁰C***	***Sensible heat gain = U.A.t_e***
1.North wall	2.5	30 * 4 – 2*7.5 =105	12	2.5*105*12 = 3150
2.South wall	2.5	30*4 - 4*3 = 108	15	2.5*108*15 = 4050
3.East wall	2.5	20*4 – 4*3 = 68	12	2.5*68*12 = 2040
4.West wall	2.5	20*4 – 4*3 = 68	17	2.5*68*17 = 2890
5.Roof	2	30 * 20 = 600	20	2*600*20 = 24000
6.Floor	3	30 * 20 = 600	2.5	3*600*2.5 = 4500
7.Doors(2 nos.) in north wall	1.5	2 * 7.5 = 15	12(same as north wall)	1.5*15*12 = 270
8.Windows (a)South wall(4 nos)	6	3 * 4 = 12	18	6*12*18 = 1296
(b)East wall(4 nos)	6	3 * 4 = 12	18	6*12*18 = 1296
(c)West wall (4 nos)	6	3 * 4 = 12	18	6*12*18 = 1296
Total = 44788 W = 44.788 kW				

Solar heat gain through south glass
= Area of four glass windows * SHGF for south glass
= (3 * 4) 150 = 1800W
Similarly, solar heat gain through east glass
= area of four glass windows * SHGF for east glass
= (3 * 4) 50 = 600W
and solar heat gain through west glass
= Area of four glass windows * SHGF for west glass
= (3 * 4) 350 = 4200W
Total solar heat gain (sensible) through south, east and west glasses
= 1800 + 600 + 4200 = 6600 W = 6.6 KW
Total sensible heat gain from persons
= Q_S per person * No. of persons
= 75 * 100 = 7500W =7.5KW
Total latent heat gain from persons
= Q_L per person * No. of persons
= 55 * 100 = 5500W =5.5KW
We know that the amount of infiltrated air,
V_1 = (L*W*H*A)/60 = (30*20*4*1)/60 =

40 m^3/min (A_c=1) Sensible heat gain due to infiltration air,

$= 0.02044\ v_1\ (t_{d1} - t_{d2}) = 0.02044 * 40\ (43 – 25) = 14.7KW$

latent heat gain due to infiltration air

$= 50\ v_1\ (W_1 – W_2) = 50 * 40(0.0277 – 0.01) = 35.4KW$

We know that volume of ventilation or outside air

v = 0.3 m^3/min/person = 0.3 * 100 = 30 m^3/min Outside air sensible heat,

OASH = 0.02044 v (td1 – td2) = 0.02044 * 30 (43 - 25) = 11.04KW

and outside air latent heat,

OALH = 50 v (W1 – W2) = 50 * 30 (0.0277 – 0.01) = 26.6KW

Sensible heat gain due to lighting

= Total wattage of lights * Use factor * Allowance factor

= 15 (30 * 20) *1 * 1.25 =11250 W = 11.25KW

Assuming that the fan is placed before the conditioner (i.e. neglecting factor of 5%for fan power), the total room sensible heat (RSH) is to be increased by 6.5% (i.e. 5% for safety factor ; 1% for leakage of supply air and 0.5% for heat leakage to duct).

RSH = 1.065[Heat gain from walls, roof, floor and windows + Solar heat gain through glasses + Sensible heat gain due to ventilation (OASH) + Sensible heat gain due to infiltration air + Sensible heat gain due to lighting]

= 1.065[44.788 +6.6 +7.5 + 14.7 + 11.04 + 11.25]

= 102 kW

The total room latent heat (RLH) is to be increased by 6% (i.e. 5% for safety factor and 1% for leakage of supply air). Total room latent heat, RLH = 1.06[Latent heat gain from persons + Latent heat gain due to infiltration air + Latent heat gain due to ventilation(OALH)]

= 1.06[5.5 + 35.4 + 26.6] = 71.6kW

If the fan is located after the conditioner, then the 5% for fan power should be added to RSH. The RLH will remain unaffected.

RSH = (1.065 + 0.05) (44.788 + 6.6 + 7.5 + 14.7 + 11.04 +11.25) =107KW.

IV. CONCLUSION

This project work has given us opportunity for enrichment of our technical knowledge in area of R&AC and exposure to the practical field to learn the latest trends of AC field and built our confidence to develop ourselves as a professional air conditioning engineer.

Used for calculation, inspection, testing, designing of air conditioning system for room/residential/office building with help of load calculations.

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