

## comfort Air conditioning Systems and Requirements

What are the requirements of comfort air conditioning? Explain briefly.

The requirements of comfort air conditioning depends upon the following important factors.

1. Oxygen Supply
2. Air motion
3. Heat removal from occupants body
4. Moisture removal from occupants body
5. Maintenance of air purity.

### 1. Oxygen Supply:

Supply of oxygen is importance for human body to digest food [i.e., combustion] which is quite similar to various machines where conversion of chemical energy to mechanical work takes place and releases carbon-dioxide as exhaust gas. similarly under normal conditions human body requires oxygen content upto  $0.65 \text{ m}^3/\text{hr}$  and dissipates carbon dioxide upto  $0.2\text{m}^3$

The quantity of  $\text{CO}_2$  should be maintained so that the percentage of it could not exceed minimum value (i.e., 2%) Beyond 2% of  $\text{CO}_2$  content in air the person starts breathing problems and if the content increases to 10% the person will in unconscious state.

## 2. Air motion.

Air motion comprises air velocity and air distribution increase in air velocity results in following factors, i.e.,

- (a) Increases the heat transfer from the body.
- (b) Helps for evaporation from the body.
- (c) Decreases the layer thickness of the saturated vapour close to body surface

Generally the comfortable range of air velocity and humidities are considered with respect to room air temperature. The air velocity in air conditioned room should not exceed 6-9 m/min at  $20^\circ\text{C}$  room temperature and at  $22^\circ\text{C}$  it should be within 9-12 m/min. Air distribution

is a constant air supply phenomenon to an air conditioned space. The term "draft" refers to air motion with no uniform distribution of air that results in local cooling sensation. usually velocities less than 8 m/min has 1°C temperature differential with no drafts, whereas velocities greater than 12 m/min has 1.5°C temperature differential that leads to uncomfortable conditions of draft.

### 3. Heat Removal from Occupant's Body:

About 80% of total amount of heat is dissipated from the human body to the atmosphere. If the person fails to dissipate the energy, he feels discomfort. Even though a person does not do any external work but a lot of work is done internally through blood circulation and work carried out by respiration process.

A ventilation system is employed for occupants to live and work comfortably in a good atmosphere and to decrease the temperature of the conditioned room.

#### 4. Moisture removal from occupants Body.

The moisture removal through evaporation from occupants body decreases when there is increase in air humidity. The air or relative humidity should be below 70%. If the air humidity increases then there will be difficulty for heat removal from body and reduction in freshness of air in an enclosed conditioned room. Generally moisture loss from the body per hour is 50 grams.

#### 5. Maintenance of Air purity.

Purity of air is referred with respect to odour toxic gases bacteria and dust. They can be various odours in air conditioned room like odour from human's body through evaporation cloth chemical etc. Toxic gases results in heavy irritation to humans and should be essentially removed. The bacteria should be removed by air essentially removed. The bacteria should be removed by air sterilization to prevent from diseases. The smoke is too unpleasant as it effects human's heart, nose and eyes.

outdoor and indoor conditions are known and are to be located as shown in the following Psychrometric chart.

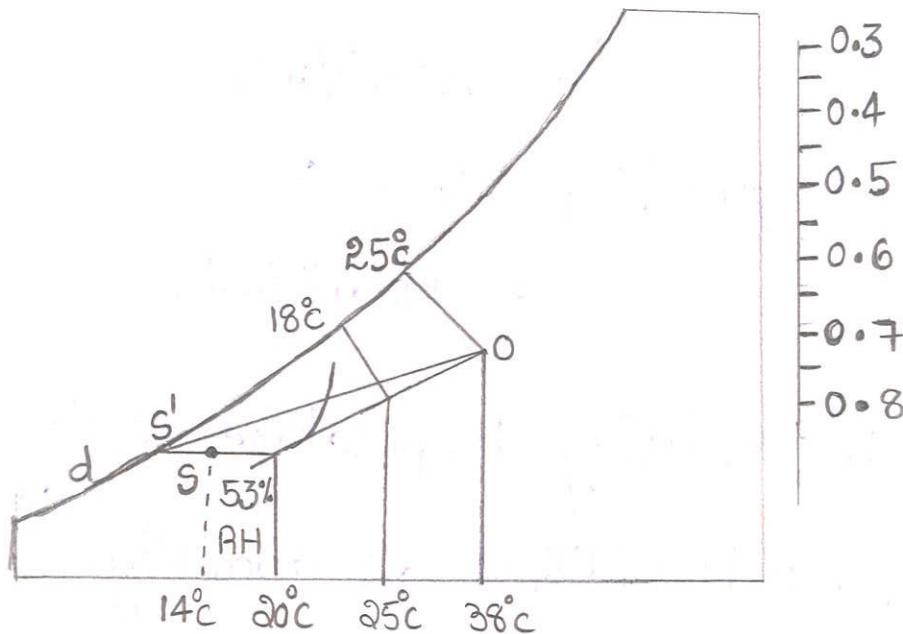


Figure: Psychrometric chart.

Drawing a line id' from i parallel to  $\text{ESHF} = 0.53$  gives very low ADP which is not desirables. Hence, we choose  $8^\circ\text{C}$  as ADP and solve the problems.

ESHF corresponding to  $\text{ADP} = 8^\circ\text{C}$  is 0.71

$$\text{a) Modified ESHF} = \frac{\text{ERSH} + \text{Reheat}}{\text{ERSH} + \text{ERLH} + \text{Reheat}}$$

$$0.71 = \frac{28.67 + \text{Reheat}}{28.67 + 25.05 + \text{Reheat}}$$

$$\Rightarrow 38.14 + 0.71 \text{ Reheat} = 28.67 + \text{Reheat}$$

$$0.29 \text{ Reheat} = 9.47$$

$$\text{Reheat} = 32.65 \text{ kW}$$

$$\begin{aligned}
 b) \text{ supply air quantity} &= \frac{\text{ERSH} + \text{Reheat}}{0.0204 [T_i - T_{\text{APP}}] (1 - Bpf)} \\
 &= \frac{28.67 + 32.65}{(0.0204)(20-8)(1-0.06)} \\
 &= 266 \text{ m}^3/\text{min}
 \end{aligned}$$

$$\begin{aligned}
 \text{Return air quantity} &= 266 - 76 \\
 &= 190 \text{ m}^3/\text{min}
 \end{aligned}$$

c) To find the entering temperature to the cooling coil

$T_d \times \text{Dehumidified air quantity}$

$$= T_{\text{outside}} \times (\text{ventilation air quantity}) +$$

$$T_{\text{inside}} \times (\text{return air quantity})$$

$$\Rightarrow T_d = \frac{38 \times 76 + 20 \times (190)}{266}$$

$$= \frac{2888 + 3800}{266} = 25.14^\circ\text{C}$$

Locate  $T_d = 25.14^\circ\text{C}$  on the line io at point r which gives.

$T_w = 18^\circ\text{C}$  for entry air join sd and set  $\frac{ds}{dx} = 0.06$

s' gives the leaving air condition from the cooling coil which can be observed in the psychometric chart.

$$\therefore T_s = 9^\circ\text{C}, T_w = 8^\circ\text{C}$$

d) After leaving the cooling coil, air is reheated to  $s$  froms, draw a line froms' to intersect RSHF line which gives supply air condition.

At S,

$$T_s = 14^\circ\text{C}$$

$$T_w = 11^\circ\text{C}$$

Hot water at  $80^\circ\text{C}$  from the boiler is supplied to a building by a 25 meter long pipe of 6cm inside diameter. Assume the following data.

Thickness of pipe material = 4 mm

$$k \text{ [pipe material]} = 50 \text{ W/MK}$$

$$h_i \text{ [inside heat transfer coefficient]} = 80 \text{ W/m}^{20}\text{C}$$

$$h_o \text{ [outside heat transfer coefficient]} = 20 \text{ W/m}^{20}\text{C}$$

Ambient air temperature =  $11^\circ\text{C}$

(a) Find the heat loss per hour from the pipe

(b) Also find the percentage decrease in heat

loss if the pipe is lagged with an insulation

having  $k = 0.06 \text{ W/mK}$  and thickness = 4 cm

a) Heat loss / hr from pipe

Hot water temperature  $T_g = 80^\circ\text{C}$

Length of the pipe = 25 m

Inside diameter = 6 cm

$$\therefore R_1 = 3 \text{ cm}$$

$$= 0.03 \text{ m}$$

Thickness of pipe material  $t_1 = 4 \text{ mm} = 0.004 \text{ m}$

$\therefore$  outer diameter  $R_2 = R_1 + t_1 = 0.34 \text{ m}$

$$K_1 = 50 \text{ W/mK}$$

$$K_2 = 0.06 \text{ W/mK}$$

$$h_i = 82 \text{ W/m}^2\text{K}$$

$$h_o = 20 \text{ W/m}^2\text{K}$$

Ambient air temperature =  $T_d = 11^\circ\text{C}$

Given condition is.

$$Q = \frac{2\pi(T_g - T_d)}{\frac{1}{R_1 h_i} + \frac{1}{K_1} \log_e \left( \frac{R_2}{R_1} \right) + \frac{1}{R_2 h_o}}$$

$$= \frac{2\pi(80 - 11)}{0.03 \times 82 + \frac{1}{50} \log \left( \frac{0.034}{0.03} \right) + \frac{1}{0.034 \times 20}}$$

$$= \frac{2\pi \times 69}{0.4065 + 0.00250 + 1.4705} = \frac{138\pi}{1.8795}$$

$$= 230.66 \text{ Watts/meter}$$

$\therefore$  Heat loss per hour from the pipe.

$$= \frac{230.66 \times 3600}{1000} \text{ KJ/h}\delta\text{.m} = 830.37 \text{ KJ/h}\delta\text{.m}$$

$$= 830.37 \times 25 = 20759.25 \text{ KJ/h}\delta$$

b) Heat loss if the pipe is lagged with an insulation for this condition is given as,

$$\therefore Q = \frac{2\pi(80-11)}{\frac{1}{0.03 \times 82} + \frac{1}{50} \log_{e} \left[ \frac{0.034}{0.03} \right] + \frac{1}{0.06} \log_{e} \left[ \frac{0.074}{0.034} \right] + \frac{1}{20 \times 0.074}} \quad [ \because \text{Length of pipe} = 25 \text{ m} ]$$

$$Q = \frac{2\pi \times 69}{0.4065 + 0.00250 + 12.96 + 0.675} = \frac{138\pi}{14.0446}$$

$$= 30.86 \text{ watts/m}$$

$$\text{Heat loss by } 25 \text{ m length} = 30.86 \times 25$$

$$= 771.7 \text{ Watts}$$

$$= \frac{771.7 \times 3600}{1000}$$

$$= 2778.12 \text{ KJ/h}\delta$$

$$\text{Decrease in heat loss} = 20759.25 - 2778.12$$

$$= 17981.13 \text{ KJ/h}\delta$$

$$\therefore \% \text{ Decrease in heat loss} = \frac{17981.13 \times 100}{20759.25}$$

$$= 86.6 \%$$

What do you understand by the term load characterization.

The term load characterization is similar to the load classification of an air conditioning system. Therefore the different types of load classifications are as follows.

a) Based on season, the air conditioning load may be classified as,

1. summer cooling load

2. winter heating load

Summer cooling load is the amount of heat removed per hour to produce and maintain the design conditions within the space or room.

Winter heating load is the amount of heat supplied per hour to produce and maintain the design conditions within the space or room.

b) Based on the types of loads, they are classified as:

1. sensible heat load.

2. latent heat load.

Any heat source that raises the DBT of the air in the conditioned room, causes a sensible heat gain which also includes.

- i) Heat transmission through the building as a result of conduction, convection and radiation through walls, roof, ceiling, door, floor, glass partition etc.
- ii) outside air due to occur infiltration
- iii) Heat produced by occupants.
- iv) Heat produced from electric lights, fans
- v) Heat produced from materials or products brought in at higher temperature than the room temperature
- vi) Heat produced from integral sources such as motors etc.

Any heat source that adds water vapour to the air in a conditioned room causes latent heat gain which also includes.

- i) outside air due to infiltration or ventilation.
- ii) Heat produced by occupants.
- iii) products brought in the conditioned room outside.

iv) Heat produced from any other internal sources.

c) Based on the position of the load they are classified as.

1. outdoor or external loads.

2. indoor or internal loads.

The loads that are coming from the space which are not air conditioned are outdoor loads and the loads that are produced within the conditioned room are indoor loads.

Draw a neat diagram of air conditioning system required in winter season. Explain the working of different components in the circuit. Is it possible to use steam for such air conditioning system.

The construction and working of the air conditioning system required in winter season is shown in the following schematic diagram.

The main components of winter air-conditioning system are filter, preheating coil, humidifier, eliminator, reheating coil and a fan. The general principle involved in this systems is heating and humidification of air.

In its working the outside air first enters into the dampers and flows through the filters to remove dirt, dust and other impurities. It then passes through a pre-heater coil in order to prevent the possible freezing of water as well as evaporation of water in the humidifier. Humidifier adds certain humidity to air and eliminator is used to separate the condensed water particles. After that, the air is passed through a reheating coil to bring

the air to a desired dry bulb temperature. Then with the help of fan the air is supplied to the room or space which is to be conditioned. Hence recirculation of air can be done.

## The thermodynamics of human body.

Human is considered as a homoexothermic machine and has the ability to maintain a constant internal temperature at different range of climate conditions. To safeguard the body tissues from overheating human body has an extremely improved thermo-regulatory systems.

### Thermodynamics of human body.

A healthy man works best at a body temperature of  $36.9^{\circ}\text{C}$  and if the body temperature is  $40.5^{\circ}\text{C}$ . the person will be in a serious condition. Beyond the body temperature of  $43.5^{\circ}\text{C}$  the person dies.

According to thermodynamic law a human body feels more comfort when the rate of heat produced by metabolism (i.e., rate at which body produces heat) should be equal to the heat dissipated to the environment.

$$\text{i.e., } Q_m - W = Q + Q_s$$

Where

$\dot{Q}_m$  = Metabolic rate of heat generation  
within the body (Watts)

$W$  = useful work rate (Watts)

$\dot{Q}_s$  = Rate of heat stored in human body  
(Watts)

$\dot{Q}$  = Total heat loss (Watts)

The rate of heat loss from human body

to the surroundings is by three processes

namely.

a) Radiation

b) convection and

c) evaporation of moisture

$\therefore$  Total heat loss from the body  $\dot{Q} = \dot{Q}_r + \dot{Q}_c + \dot{Q}_e$

Substituting in equation (1), we get

$$\dot{Q}_m - W = \dot{Q}_r + \dot{Q}_c + \dot{Q}_e + \dot{Q}_s$$

Where

$\dot{Q}_r$  = Heat loss due to radiation

$\dot{Q}_c$  = Heat loss due to convection

$\dot{Q}_e$  = Heat loss due to evaporation of moisture.

### a) Radiation heat loss ( $Q_r$ )

The heat loss by radiation from human body is given as follows.

$$Q_r = \sigma A (T_a^4 - T_i^4)$$

Where

$\sigma$  = stefan boltzmann constant

$$\sigma = 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4$$

A = Body surface area,  $\text{m}^2$

$T_i$  = Atmospheric temperature

$T_a$  = Human body temperature

When  $T_i > T_a$ , human body gains heat from environment and if  $T_i < T_a$  then heat is lost by the body.

### b) convective heat loss ( $Q_c$ )

The convective heat loss from human body is given as follows

$$Q_c = UA(T_a - T_i)$$

Where

$U$  = overall heat transfer coefficient,  $\text{W/m}^2\text{K}$ .

### c) Evaporative heat loss ( $Q_e$ )

It is the heat loss through evaporation of moisture from human body and is given by

$$Q_e = k_d A (P_s - P_v) h_{fg} \times K_c$$

Where

$k_d$  = coefficient of diffusion

$P_s$  = saturation pressure of water vapour at skin temperature ( $N/m^2$ )

$P_v$  = vapour pressure of moisture in air ( $N/m^2$ )

$h_{fg}$  = evaporative latent heat ( $KJ/kg$ )

$K_c$  = clothing factor.

heat or combined. To design air-conditioning system, it is necessary to know the rate of heat given out under different conditions of air and body activity.

#### iv) moisture in the air:-

The moisture content of outside air varies in winter and summer duration, while designing in air conditioning system, proper DBT for either winter or summer must be selected. Generally in winter, RH should be around 40% and in summer, it should be around 60%.

#### Quality and quantity of air:-

Air in an occupied space should be free from toxic, unhealthy fumes such as  $\text{CO}_2$ , and free from dust and odour and its concentration in the room.  $1 \text{ m}^3/\text{min}$  air per person of outside air is sufficient to take care of all conditions.

#### vi Air motion:-

Air motion includes distribution and velocity of air. It should not exceed 8 to 12 meter/minute. It is important to maintain uniformity in temperature inside the conditioned space.

#### Hot and cold surfaces:-

The cold or hot objects or surface inside a conditioned space may cause discomfort to occupier. While designing an air conditioning system, temperature of surfaces while exposed to surroundings like glazed ceilings etc. must be given complete consideration.

Define the 'human comfort' and describe the factors which affect the human comfort.

Human comfort:-

According to ASHRAE definition, "human comfort" is that condition of mind, which expresses satisfaction with the thermal environment.

Factors affecting human comfort! -

The important factors which affect human comfort are as follows.

i) Effective Temperature!-

effective temperature is the combined effect of DBT, RH and air velocity. The concept of effective temperature is presented by the comfort chart. The comfort chart is made on different kinds of people with variations in environmental temperature RH and air motion.

ii) Heat production and Regulation!-

The metabolism (process of combustion of food in the human body) produces heat and energy due to oxidation of products in the human body by O<sub>2</sub> obtained from inhaled air. Heat production from normal person is about 60 watt (Joules/sec) 80% of the heat from human body must be ejected to surroundings, otherwise accumulation of heat results discomfort. Human body attempts to maintain its temperature through metabolism.

iii) heat and moisture losses! -

The heat off from the human body is sensible or latent

A laboratory has 27 kW sensible and 23 kW latent heat load. The inside design conditions of air are  $20^\circ\text{C}$  DBT and 53% RH and outside design conditions of air are  $38^\circ\text{C}$  DBT and  $25^\circ\text{C}$  WBT. The ventilation air used is  $76 \text{ m}^3/\text{min}$ . A cooling coil with a bypass factor of 0.06 must be used. An apparatus DPT is  $8^\circ\text{C}$ . Determine

- Amount of reheat required
- Supply air quantity.
- DBT and WBT of air entering and leaving the apparatus.
- Supply air temperature.

Given that,

outdoor conditions =  $38^\circ\text{C}$  DBT,  $25^\circ\text{C}$  WBT

Indoor conditions =  $20^\circ\text{C}$  DBT, 53% RH

ventilation air =  $76 \text{ m}^3/\text{min}$

Bypass factor = 0.06

Apparatus DPT =  $8^\circ\text{C}$

$$RSH = 27 \text{ kW}, RLH = 23 \text{ kW}$$

We know that

outside Air sensible heat (OASH)

$$G_{10} = 0.0204 V_1 (T_0 - T_1) = 0.0204 \times 76 \times (38 - 20)$$

$$= 27.9 \text{ kW}$$

outside Air Latent heat (OALH)

$$F_{10} = 50 V_1 (W_1 - W_2) \text{ kW} = 50 \times 76 \times [0.016 - 0.007]$$

$$= 34.2 \text{ kW}$$

outside Air total heat (OATH)

$$= OASH + OALH = 27.9 + 34.2$$

$$= 62.1 \text{ kW}$$

Effective Room sensible heat (ERSH)

$$= RSH + OASH \times \text{Bypass factor}$$

$$= 27 + 27.9 \times 0.06 = 28.67 \text{ kW}$$

Effective Room latent heat (ERLH)

$$= RLH + OALH \times \text{Bypass factor}$$

$$= 23 + 34.2 \times 0.06 = 25.05 \text{ kW}$$

Effective sensible heat factor (ESHF)

$$= \frac{ERSH}{ERSH + ERLH} = \frac{28.67}{28.67 + 25.05}$$

$$= 0.53$$