Cooling load Calculations & design of A/C systems.

Diff heat sources

S.H.L & L.H.L

S.H.L

1) Through walls, ceilings, Floors, windows, doors
2) load due to solar radiation,
   a) Heat transmitted directly by radiation
   b) Heat from sun will be absorbed by walls, roof and later on transmitted to rooms.
3) From occupants
4) equipments
5) infiltrated air through cracks, & frequent openings
6) a) Heat gain by ducts
   b) Heat passed from other Non A/C rooms.

L.H.L

(1) infiltration (2) occupants (3) Cooking Foods
4) Moisture through permeable walls where vap pr is higher.

extra loads

a) Fresh air load
b) Fan load.

Heat Flow due to Conduction

Instead of using formula, U values from Tables are taken

Matl.	Walls Thick in cms	U in W/m² K.
Brick (plain	20	2.45
	30	1.75
	40	1.35

U values for floors, Ceilings

Type	U.
Plain pine floor	2.25
Plaster	1.35 to 1.15

U Values for glass windows & doors

Single brick glass	5.5
double " "	2.2
~~Solid wood door~~	
Solid wood door 2.5 cm brick	3.3

Sun load or load due to Solar radiation through glass.

Solar gain KJ/m²

Type of glass	Solar gain (east exposure)	Solar gain (South west exposure)
Unprotected	1100	1540
White shades	440	550

Window Shading

Type of Shading	effectiveness Factor
Canvas awning	0.35
~~Venetian~~ Venetian blind	0.65

111

Load from occupants

24

Heat loss from human body at different room DBT conditions

Room DBT	Person at rest			Person doing work		
	L H KJ/hr	S.H KJ/hr.	Total KJ/hr	L H	S H	T H
21.1	160	240	400	110	550	660

Heat generation rate for different types of foods.

items	Temp	Heat per Ton/ 24 hr	Composition of water	loss of Moisture	Period for loss
Apple	4.5	1100 to 1800	85.5	0.05 to 3.5	150 days @ 75% RH
oranges	15.5	500	86	—	—

Properties of Materials which are preserved by freezing Method.

Commodity	Freezing Temp	Sp. Ht above Freezing KJ/kgK	Sp ht below Freezing	L.H. of Fusion KJ/kg	% water	Max Storage time
Fish	−2.2	3.2	1.72	214	70	6 Months
Apples	−2	3.4	1.72	230	84	8 M.

equipment load

electric appliance $\Phi = KW \times 3600 \times$ use factor KJ/hr.
(generally taken as 1)

Fan etc, $\Phi = \frac{KW}{\eta_m} \times$ load factor $\times 3600$ KJ/hr

(load factor = Fraction of total load at which motor is working.

level of illumination in lumens/m^2

Conference room	300
Sewing room	700.

Heat output per 1000 lumens.

Type	lumen/w (range)	KJ/hr 1000 lumen
Fluorescent	60-10	14-11.
Tungsten	15-25	50-36

electric light load

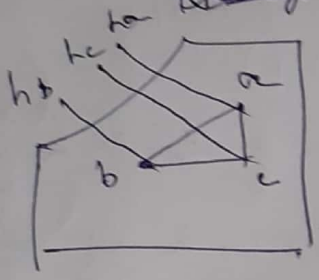
Type	load in KJ/m^2-hr.
Theatre Auditorium	16 to 33
office	132 to 160.
library	160.

equipment load

	SHL	LHL KJ/hr
Fan (Ceiling Sound size	400	
Coffee Maker 15 kg	2500	2500

Infiltration load

use	Revolving door	door with brake
A large	$2.5\ m^3$	$1.75\ m^3$



a = outdoor air
b = air leaving the A/c room.

LH load = $h_a - h_c$
SHL = $h_c - h_b$.

Miscellaneous Heat sources

a) **Duct heat gain.**

$$Q = A_d \cdot U \cdot \left[T_a - \frac{T_i + T_o}{2} \right]$$

A_d = Area of duct
U = overall h.t. coeff
T_a = Temp of ambient, T_i = Temp of air entering duct
T_o = " " " leaving "

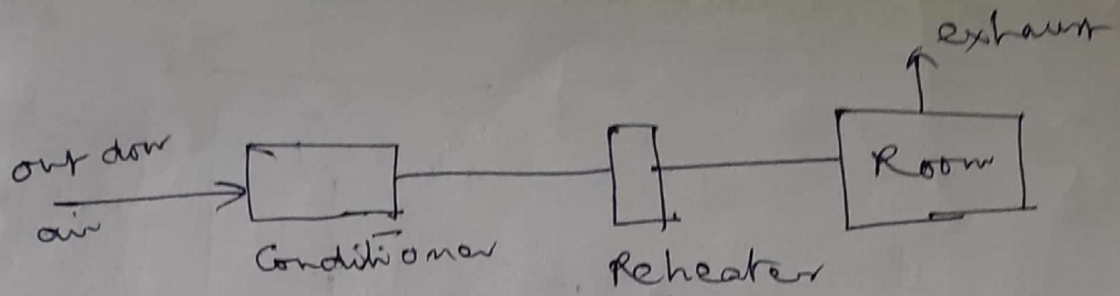
b) Fan load (If fan is located after the A/c, then it is added to RSHL
c) Moisture gain through Permeable walls & ceilings.

Fresh air load

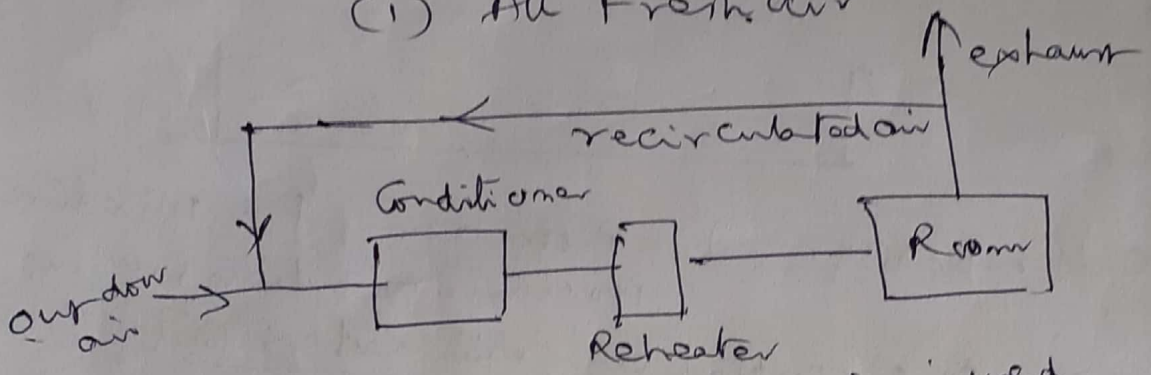
To reduce odours, smoke & to maintain O_2 levels, fresh air is added.

Design of A/c System

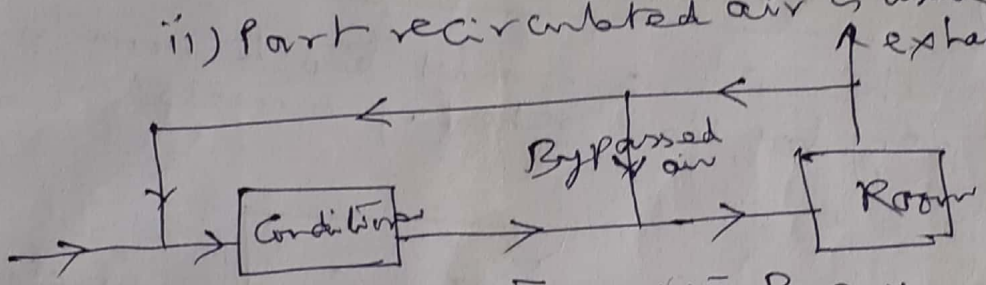
Fresh air & recirculated air



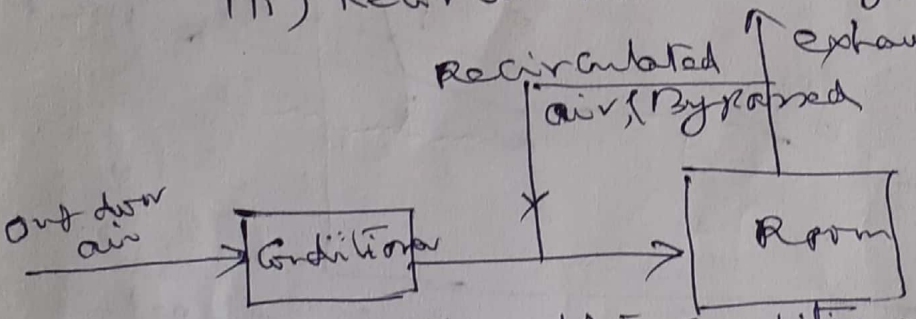
(i) All Fresh air



ii) Part recirculated air is used



iii) Recirculation with Bypass.



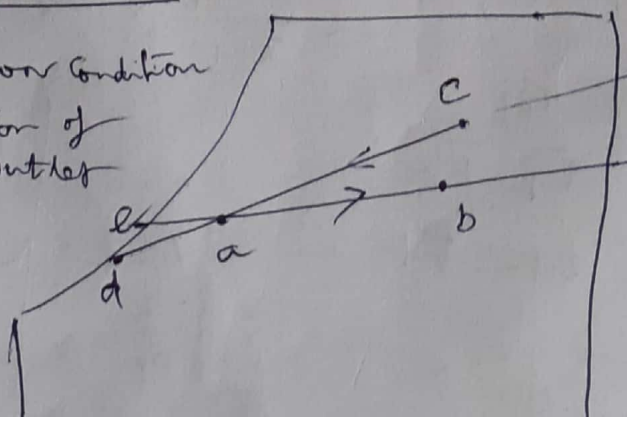
Recirculation after Conditioner.

(Conditioner :- Cooling Coil (Cooling & dehumidification))

(1) All fresh air

C = out door condition

b = Condition of Room outlet air



Coil Condition curve

Room SHR line

Draw SHR Join Cd.

a = Condition of air entering the room.

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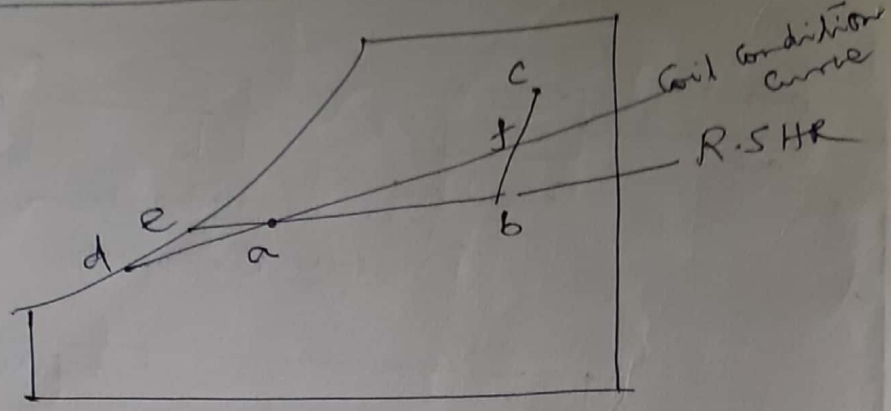
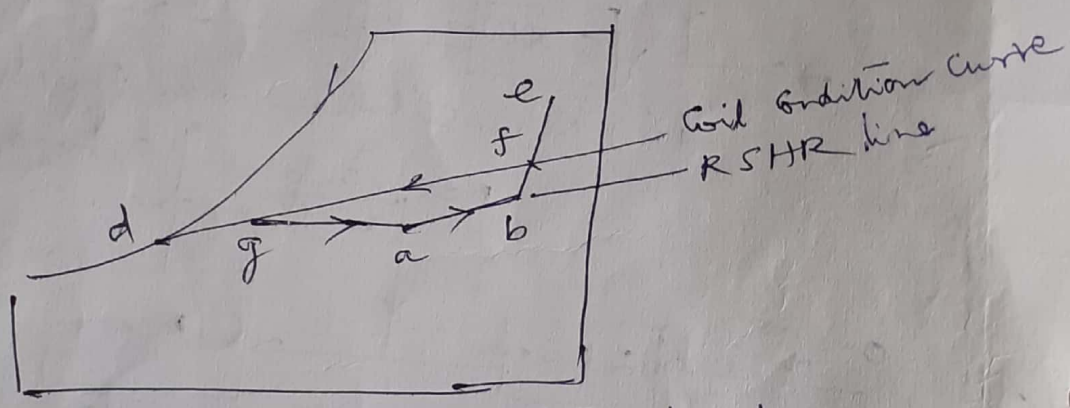
2) Recirculated air



c = Fresh air, b = Room air, f = Mixture.
Procedure is similar to previous one.

3) Recirculated air with Reheat Coil.

When the air inlet temp to room is very low, then reheating is needed.



recirculation with reheat

Conditioner → Bypass factor = $\frac{dg}{df}$

Refg Capacity = $\frac{h_f - h_g}{3.5} \times m_a \cdot TR$

$m_a = \frac{Q_t}{h_b - h_a}$.

Q_t = total ht in KJ/sec

Mark 'a' such that $T_b - T_a$ = 5 to 10°C. locate g by drawing horizontal line.

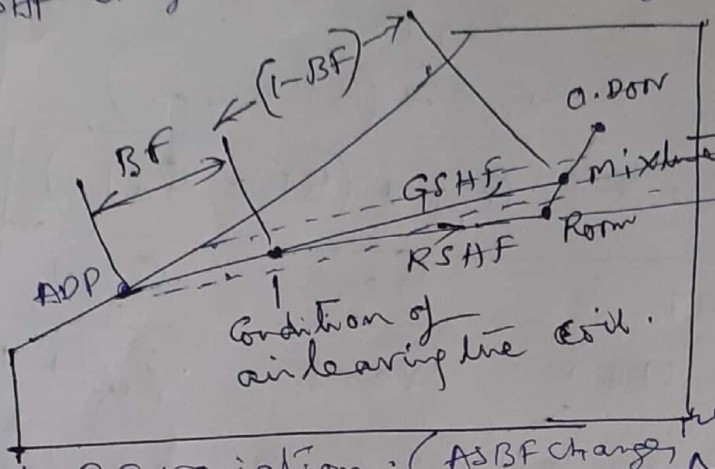
See page 118 for (4)

P.T.O for (4)

By Bypass Factor consideration

There is a Psychrometric relationship of BF to GSHF & RSHF lines

BF ; GSHF changes *



Conditioner Coil line
RSHF line.

GSHF = Gross
RSHF = Room

relative position of GSHF & RSHF changes (dotted lines)

Effect of BF variation : (As BF changes)

BF	Type of Application	ex
0.3 to 0.5	Small total load	Residence
0.1 to 0.2	Typical Comfort Condition	Store, Bank.
0.05 to 0.1	More ventilation (large outdoor air)	Restaurant
0 to 0.1	All outdoor air.	Hospital operating theatre

—x—

ESHF :-

$$RSHF = \frac{Q_{rs}}{Q_{rs} + Q_{rl}} = \frac{Q_{rs}}{Q_{rt}}$$

(Condition of air moving in room)

Q_{rs} = room sensible heat load
Q_{rl} = " latent "

$$GSHF = \frac{\text{Gross Sensible Heat Factor}}{\text{(Mixture to ADP) line}}$$

(Condition of air moving through coil)

Q_{os} = S.H.L of outside air
Q_{ol} = L.H.L of "

Q_{ers} = effective room Sensible heat
Q_{erl} = " " " latent "
Q_{ert} = " " " Total "

P.T.O for (4)

RSHF = related to room
GSHF = related to air moving through coil.

Simplified Approach

ESHF Concept simplifies the Calculations.
(It relates BF, ADP)

$$ESHF = \frac{Q_{ers}}{Q_{ert}}$$

$$Q_{ers} = Q_{rs} + (BF \times Q_{o.s})$$

$$Q_{ert} = Q_{rt} + (BF \times Q_{o.l})$$

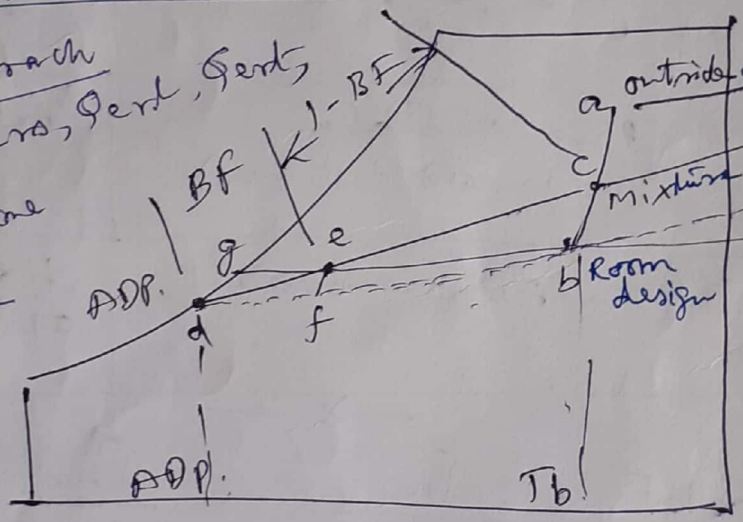
$Q_{ert} = Q_{rt} + BF(Q_{os} + Q_{ol})$

$$ESHF \text{ (effective SHF)} = \frac{Q_{ers}}{Q_{ert}} = \frac{Q_{rs} + BF \cdot Q_{os}}{Q_{rt} + BF(Q_{os} + Q_{ol})}$$

[By Passed outdoor air loads are similar to infiltration loads).

Joining ADP & room design condition represents ESHF line

Simplified approach
Calculate Q_{ers}, Q_{ert}, Q_{rs}, Q_{rt}
ESHF.
Draw ESHF line to get ADP.



RSHF line, GSHF are essential to calculate air qty. Now a simplified approach is by ESHF Method.

ESHF can be calculated without knowing ADP. Afterwards ADP can be determined by drawing ESHF line

Air qty calculation Using BF, ADP.

$$Q_{ers} = \frac{V_{air}}{v_{sa}} C_{pa} (1 - BF)(T_b - T_{adp})$$

where $Q_{ers} = [Q_{rs} + Q_{o.s}(1 - BF)]$

V_{air} = Vol of air circulated through room

v_{sa} = Sp. Vol of air at pt 'e'.

C_{pa} = Spht of air.
T_b = room design Temp.
T_{adp} = DBT at ADP pt.

$$V_{air} = \frac{Q_{ers} \cdot v_{sa}}{c_{pa}(1-BF)(T_b - T_{adp})}$$

(This air qty is the regd air to offset room loads + out door air loads & supplementary loads).

$$BF = \frac{de}{dc} = \frac{df}{db} = \frac{fe}{bc}.$$

where ef is parallel to ab.
f is located. draw bf & extend to get ADP.

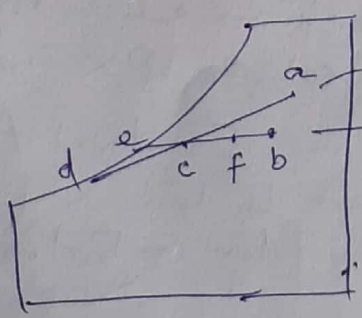
Fan load & Fan Position:

Fan before Coil: heat load is to be taken.
(Generally not added in Problems, unless it is specified clearly)

19.6, 19.7, 19.8, 19.9, 19.11, 19.21,

—— x ——

4) Recirculated air used for heating the air coming out of conditioner



Conditioner curve
RSHR

c = Condition of air leaving the coil.
f = resulting condition after mixing with return air.

m_a = Mass of air passed through room

$$m_a = \frac{Q_t}{h_b - h_f}, \quad Q_t = \text{Total room load}$$

A/C Systems

It is an assembly of different parts of system to get required air conditions.

Classification:-

1) Central A/C system 2) Unitary A/C
3) District A/C " 4) Self Contained A/C units

Another Method of classification based on type of fluid is

1) Direct Expansion 2) All water system
3) All air syst 4) Combined system.
5) Heat pump system.

I) Central A/C:-

Following components are assembled at site.

1) Cooling & dehumidifying Coils 2) Heating Coils
3) Blower with Motor 4) Sprays for Cooling, humidifying or washing 5) Air cleaning
Expt 6) Control devices.

Extensive duct work is with individual Controls.

i) Air is conditioned in central A/C room & is supplied to required rooms with controlled air discharge to each room

ii) Individual evaporator in each room with thermostatic control or DX system

(iii) water is chilled in Central A/C room & is supplied to the required rooms with individual flow control.

Advantages

i) Capital cost & running cost per unit is less
ii) Can be located away from A/C space
iii) Noise & vibration is less for people in A/C space
iv) Maintenance is easily accessible

II) Unitary A/C Systems

All the components are assembled at Factory itself. The assembled units are installed at A/C rooms. Small capacity around 15 TR are preferred for this

Classified as

i) Remote A/C unit System:— Condensing unit & heating unit are separated.
ii) Self Contained A/C unit:— All the components are assembled in one cabinet.
iii) Unitary System in Multistorey bldg:— It is a combination of unitary & Central A/C Systems. A/cs in each room are supplied with Chilled water from Central A/C plant.

Adv

i) Installation is easy
ii) extensive duct work eliminated
iii) flexibility in using the units in each room
iv) individual room temp control is specific feature

III) District A/c Systems

District heating systems are popular. Pipe line costs are to be evaluated before unit is selected.

Adv. i) Initial cost of equipt is less.
ii) Central plant can be located away
iii) Capacity of plant is less
iv) less operating cost
v) Noise is eliminated

disadv: i) Protection of underground pipes is necessary
ii) Pipe cost is more
iii) chilled water pumping costs are higher.

IV) Self Contained A/c units:-

i) Room Coolers (A/C) :- 0.25 to 1.5 TR, Mounted on windows or Split A/c, air cooled. Condr.

ii) Show Coolers — Self Contained units Floor mounted. 3 to 20 TR, ~~Air cooled~~ or water cooled Condr. Short duct work for bigger units

iii) Residential A/c unit:-
1) Self Contained unit.
ii) DX system
iii) chilled water supplied to cooling coil.

Systems classified as per fluid used

i) ~~Direct~~ Direct Expansion

ii) All water :-
Cooled water or brine is supplied to line coils fixed in room. (Fan coil units)

iii) All air syst:-

A/c plant is outside, Cold air is sent through ducts & distributed to A/c space.

Methods

a) Volume Control - variable & load is taken care of by vol of Cooling air. (all air - variable vol - Const temp system).

b) By Pass Control:- Qty of air supplied is kept const, but qty of air passing through Conditioner is varied.

c) Reheat Control - Plant is designed for peak load & reheat Coils are used to adjust the temp.

d) Dual duct System:-

Central A/c is used and warm air through one duct, Cold air through another duct are supplied. Thermostat Controls are used for proper mixing of airs.

e) Multizone System:-

Eight Zones are made. Single Supply duct for each Zone. Temp Control is made by mixing hot & cold air at Central units by using thermostats which sense the Zone temp.

Air water System:-

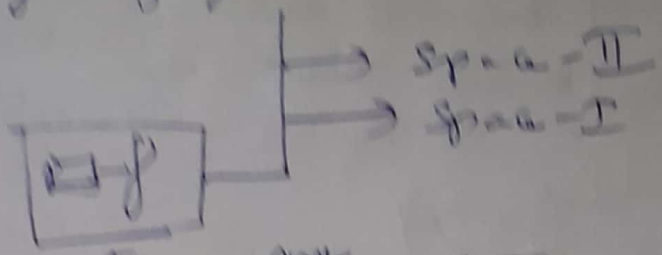
Conditioned air is brought upto Conditioned Space by ducts. Remaining Cooling & heating is done by a Coil in the A/c Space.

Heat pump System

It is used in year round A/C system.

Three practical arrangements

a) constant volume - variable Temp System with the help of Refrigeration control.



b) Control - Variable Temp system with the help of Bypass Control.

Bypass arrangement is as shown.

c) Control, variable Temp. System with the help of air reheat control.

Additional reheat coils are located at supply ducts to the A/C Space/ Zones

d) variable vol, Const Temp System

only vol of air is controlled.

(used in Multizone system)

Equipment

Air filters

1) Dry filters
2) Viscous filters
3) wet filters
4) Electric filters
5) Centrifugal dust collectors.

1) Dry filters :- Bags made of cloth, paper used.

2) Viscous :- glass wool, plastic fibres are rods are used. oily substance Viscosine is put in the rods.

3) wet filters:
water spray Type air washer.

4) electronic filters:-
air is passed through a pair of oppositely charged conductors. As voltage is applied (5000 to 15000V) ionisation occurs.

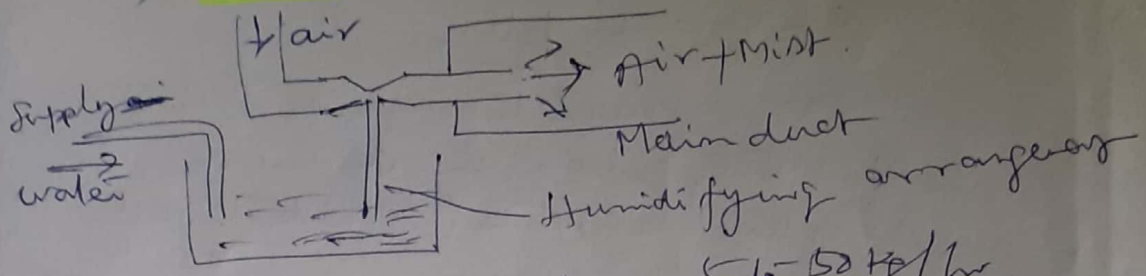
5) Centrifugal dust collector:-
used in Industrial A/C.
removes & collects the dust.
whirling motion is created to collect the dust

6) Activated Carbon (charcoal)
removes odours.

Humidifiers:
Humidification is achieved by 4 Methods
1) injecting the steam 2) Atomizing the water
3) evaporating the water 4) By air washing

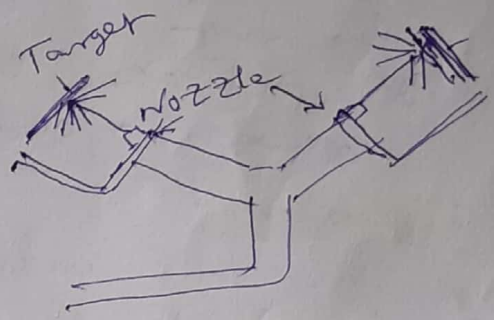
A) Injecting the steam:-
Steam humidifiers are generally located inside the ducts of air handling system. They are available in a wide capacity range from a few kg/hr to several thousand kg/hr.
Initial cost is low if steam is already available. Equipment costs increase if steam generating equipment is also needed.
For complete absorption of steam in air, a minimum length of one metre straight duct is required. Different arrangements can be made for straight horizontal ducts or vertical ducts.

B) By atomizing the water into air
i) Atomization type Humidifier.



Capacities a range from 5 to 50 kg/hr.
20 kg/hr is ideal unit size.
Humidifier is noisy due to high velocity of air. Preferred for Industrial buildings.

ii) Impact Type:
This is most practical type.
It makes use of water directed against a hard target with high velocity.
Fine spray is formed. Air picks up water by evaporation. Eliminators remove the water droplets.

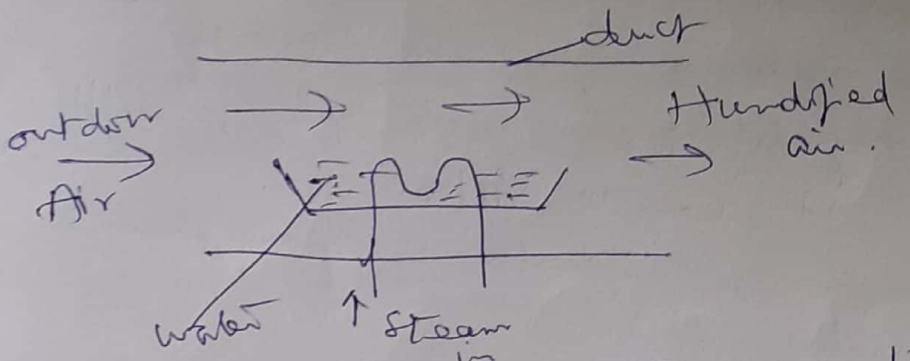


iii) Hydraulic separation Humidifier:-
If the stream of water is caused to rotate the helical slots in nozzle, the stream will breakup into fine spray.
This principle is used in this type.

IV) Mechanical separation Type;-
Water rises from reservoir upto disks; due to rotation of tube. Spray of water is caused due to centrifugal action given to water by discs. Fan blows air through water spray. Some water is evaporated & carried by air.

c) Humidification by evaporating the water into the air.

i) Pan & Coil type humidifier



Humidistat functions with respect to the needs & energises the heating element in the water pan. evaporation of water takes place & the vapour is absorbed by air.

ii) Heated water Type :-

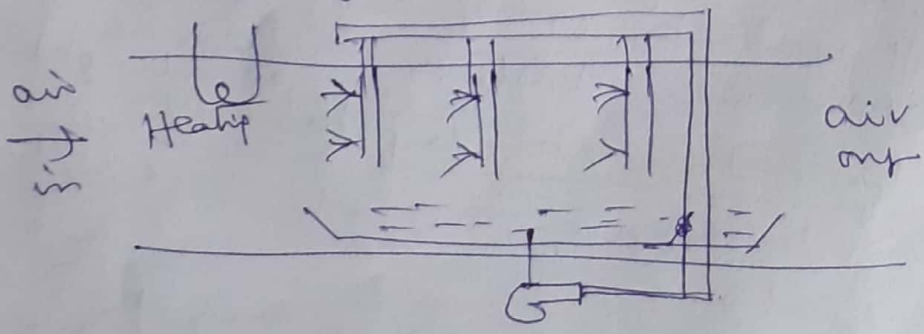
Warm water is supplied to the evaporative media (Pads). Air moving the evaporative media picks up water vapour.

iii) Heated Air Type :-

Rotating evaporative media moves through a reservoir of water. Fan & heating coils are energized. Heated air goes through wetted media & picks up water vapour.

D) Humidification by Air washing :-

i) Spray Type Air washer



(27)

It is most effective & commonly used.
Pump supplied water to spraying nozzles.
unevaporated water is collected & recirculated.
Eliminator removes the droplets of water.
Heater is placed before the sprays.
By regulating the water qty, diff DBT, RH can be obtained.
It is easy in operation & maintenance cost is low.

Dehumidifiers:

Dehumidification (removal of moisture) of air is required in many industrial applications in addition to Comfort A/C.
To protect from corrosion, Rust, oxidation. less RH is preferred.
In ~~Food~~ industry low humidity is required to prevent formation of mold.
In Pharmaceutical tableting operation, moisture is to be controlled for compressing of the powder.

3 Methods of dehumidification

1). By reducing the temp of air below DPT
2) By absorption of moisture (passing air through absorption beds)
3) Adsorption of moisture:-
It is done by passing air through a chemical. Moisture is adsorbed. ex silica gel

1 (A) By reducing air temp below DPT.

i) Air is passed over cold surface (cooling coil).
ii) Air passed through spray of cold water.

(B) Spray Type dehumidifier

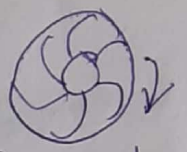
It is similar to Air washer eqpt. except that temp of water sprayed is below DPT of air.

Lithium Bromide Absorption system, Calcium Chloride system can be used for dehumidification purpose.

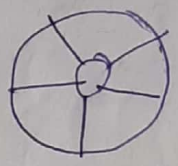
Fans & Blowers

1) Axial flow Fans
   a) Propeller Type b) disc type (more twist)
air flows parallel to axis of fan

2) Centrifugal Fans:


Forward blade


Backward blade


Radial blade

Centrifugal Fans

$H_t = H_p + H_v$

H_t = Total head in cms of water

H_p = static pr head "

H_v = velocity head "

$BP = \frac{W_a H_t}{1000}$ kW.

W_a = wt of air delivered kg/sec

$W_a = \rho_a V$.

ρ_a = density of air at std Atm Condition

V = vol of air

$\eta_f = \frac{\text{Fan output in BP}}{\text{Input BP}} = \frac{\rho_a . V . H_t}{1000} \times \frac{1}{\text{Input BP}}$.

Fan laws

Vol capacity = Q.

$Q = \text{Area} \times \text{vel}$

$= A \times \pi D N$.

$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$

P_v = velocity head $\propto V^2 \propto N^2$

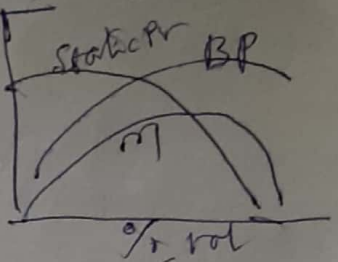
V = Tip speed

$\frac{P_{v_1}}{P_{v_2}} = \left(\frac{N_1}{N_2}\right)^2$

$\frac{BP_1}{BP_2} = \left(\frac{N_1}{N_2}\right)^3$.

BP is ∝ to product of vol & vel prhd.

Fan Curves



Grills & Registers.

A decorative covering for an ~~outlet~~ outlet is grill & grill with damper is Register.

Food Preservation.

The preservation of foods in storage & during transportation is necessary if the life of the food is to be extended.

All types of food contain either Carbohydrates, Proteins or fats. The destruction of ~~these~~ these ingredients causes spoilage of food.

The spoilage Period ~~from~~ ~~to~~ Varies from food to food. The spoilage includes, bad odour, Uncommon colour, bad taste etc.

The result of spoilage of food may be loss of weight, softing, souring, rotting, molding etc.

Fruits & vegetables soften & rotting starts if not protected properly.

Milk gives sour taste

Fatty foods like butter, cheese give sour odour

Eggs ~~&~~ give ~~&~~ bad odour

Slimy coating forms on surface of meat

The spoilage agents are
1) enzymes (2) Micro-organisms
of bacteria
b) yeast c) Molds..

Food Preservation:-

1) **Heat Processing**:- In some cases heating, packing storing below 25°C preserves the food

2) **Dehydration**:- In some cases dehydrating the foods helps in preservation

3) **Chemical preservation**:- Salt, Sugar helps, Vinegar also helps. (Pickles)

4) **Freezing preservation**:- low temp is used. It stops the spoilage

5) **Application of Isotopes**:- Radiation doses are given; by which preservation period increases

Freezing

1) **Slow Freezing**
-15°C to -30°C. Food is stored & cooled. & low rate of cooling.

2) **Quick Freezing**:- Forced circulation of cold air is used.

a) **Freezing by immersion**:- $NaCl_2$ brine, Propylene glycol are used.

b) **Freezing by indirect contact**.
refrigerants cold like metal surface. Food is freezed by contacting the metal surface

c) Air blast Freezing:-

Freezing by contact with cold air.
Widely used. Quality of food remains.

Freezers

i) Contact or Plate Freezers
ii) Inline Freezer
iii) Spiral Freezer.
iv) Air blast Freezer.

Liq N_2 Cooling System.

(Transport Refgn)

Industrial applications:

Ind	operation	Temp °c	RH
Baking	Cake icing	21	50%.
~~Electrical~~ Food	Preparation	15-21	40%.
Foundries	Moulding	15-21	-
Photographic	Cutting	21-24	60-65

Other Industries where Refrigeration is reqd.
Ice Cream Manufacture,
Breweries.
Liquified natural gas (LNG) Industry
Textile Industry
Photographic Industry

Transport Refgn:

Automobile Air Conditioning.
Bus A/c
Railway A/c
Marine A/c (Ships)
~~Air craft A/c~~

Other Applications
Heat Treatment of Metals
liquefaction of gases
Medical Applications
Civil Engg Applications.

Ice rinks.
Ice Factory
Milk & dairy