Hall Ticket Number:

II/IV B.Tech (Regular\Supplementary) DEGREE EXAMINATION

July/August, 2023 — Mechanical Engineering

Fourth Semester — Applied Thermodynamics

Time: Three Hours — Maximum: 70 Marks

Answer question 1 compulsory. (14X1 = 14Marks)

Answer one question from each unit. (4X14=56 Marks)

Q		Question	CO	BL	M
1	a)	What are saturation states?	CO1	L1	1M
	b)	What do you understand by the degree of superheat?	CO1	L2	1M
	c)	Draw the Rankine cycle on T-S diagram.	CO1	L1	1M
	d)	What is the effect of steam reheat on the cycle efficiency of a steam power plant?	CO1	L2	1M
	e)	Define a boiler.	CO2	L1	1M
	f)	What is the function of a safety valve?	CO2	L1	1M
	g)	List the different types of boiler accessories.	CO2	L1	1M
	h)	What is the basic function of nozzle in steam power plants?	CO2	L1	1M
	i)	List the functions of the steam condenser in a thermal power plant	CO3	L1	1M
	j)	Define condenser efficiency.	CO3	L1	1M
	k)	What is the compounding of a steam turbine?	CO3	L1	1M
	l)	Define COP of a refrigerator	CO4	L1	1M
	m)	Define the Relative humidity and degree of saturation.	CO4	L2	1M
	n)	How to represent dehumidification with heating on Psychometric Chart.	CO4	L2	1M
		Unit-I			
2	a)	Draw the p v diagram of a pure substance and explain how it formed.	CO1	L1	7M
	b)	A rigid vessel of volume 0.86 m^3 contains 1 kg of steam at a constant pressure of 2 bar. Evaluate the specific volume, temperature, dryness fraction, enthalpy, entropy and internal energy of steam.	CO1	L2	7M
		(OR)			
3	a)	Explain the working principle of the Reheat cycle with a suitable neat sketch.	CO1	L1	7M
	b)	A simple Rankine cycle works between pressures 30 bar and 0.08 bar. The initial condition of steam is dry saturated. Calculate the cycle efficiency, work ratio and Specific steam consumption.	CO1	L2	7M
		Unit-II			
4	a)	How are boilers classified?	CO2	L1	7M
	b)	What are the functions of the following in a boiler (i) superheater (ii) Feed check valve (iii) blow-off cock valve.	CO2	L1	7M
		(OR)			
5	a)	Derive the expression for Critical pressure ratio in nozzles.	CO2	L2	7M
	b)	Dry saturated steam expands through a nozzle from a pressure of 13.5 bar to 9.6 bar. Assuming the flow to be frictionless and adiabatic, estimate the velocity of the steam jet.	CO2	L2	7M
		Unit-III			
6	a)	Draw the schematic diagram of the counter flow jet condenser and explain its working.	CO3	L2	7M
	b)	Explain the evaporative condenser with neat sketch.	CO3	L3	7M
		(OR)			
7	a)	Give a comparison between an impulse turbine and a reaction turbine.	CO3	L2	7M
	b)	In a Parson reaction turbine, the angles of receiving tips are 35° and of discharging tips 20°. The blade speed is 100 m/s. Calculate the tangential force, power developed, diagram efficiency and axial thrust of the turbine if its team consumption is 1 kg/min.	CO3	L3	7M
		Unit-IV			
8	a)	Explain the Working principle of the simple vapour absorption refrigeration cycle.	CO4	L1	7M
	b)	A refrigerator works on the Bell-Coleman cycle and operates between pressure limits of 1.05 bar and 8.5 bar. Air is drawn from the cold chamber at 10°C. Air coming out of the compressor is cooled to 30°C before entering the expansion cylinder. Expansion and compression follow the law $pv^{1.35}$=constant. Determine the theoretical COP of the system.	CO4	L3	7M
		(OR)			
9	a)	Calculate: i) Dew point temperature ii) Relative humidity iii) Specific humidity iv) Degree of saturation v) Enthalpy of mixture per kg of air when the dry bulb temperature is 30° C, wet bulb temperature is 20° C and the barometer reads 740 mm of Hg.	CO4	L3	7M
	b)	Explain the difference between winter air conditioning and summer air conditioning.	CO4	L2	7M

DEPARTMENT OF MECHANICAL ENGINEERING

APPLIED THERMODYNAMICS (20ME404)

SCHEME OF EVALUATION

1. a) A saturation state is the point where a phase change begins or ends. For example, the saturated liquid line represents the point where any further addition of energy will cause a small portion of the liquid to convert to vapor.

b) Degree of Super Heat: It is the difference between the temperature of superheated steam and saturation temperature resultant to the given pressure. So, the degree of superheated = $t_{sup} - t_s$.

c)

d) 1) Increases the cycle efficiency. 2) Reduces the turbine speed. 3) Reduces blade erosion.

e) A steam boiler is a power generation device, used for generating steam by applying the heat energy to water.

f) The main function of a safety valve is to relieve pressure. It is located on the boiler steam drum, and will automatically open when the pressure of the inlet side of the valve increases past the preset pressure.

g) Feed Pump, Injector, Economizer, Air Preheater, Super Heater, Steam Separator.

h) 1) The main function of the steam nozzle is to convert heat energy to kinetic energy. 2) To direct the steam at high velocity into blades of turbine at required angle.

i) In a steam power plant, the function of a condenser is i) to maintain pressure below atmospheric to increase work output from the primemover ii) to receive large volumes of steam exhausted from steam prime mover iii) to condense large volumes of steam to water which may be used again in boiler.

j) Condenser Efficiency is the ratio of temperature rise of cooling water and the difference between the temperature of steam and inlet temperature of condenser.

$$\eta_{Cond} = \frac{\text{Rise in Temperature of Cooling water}}{\text{Temp. Corresponding Vacum in Condenser} - \text{Inlet Temp. of Cooling water}}$$

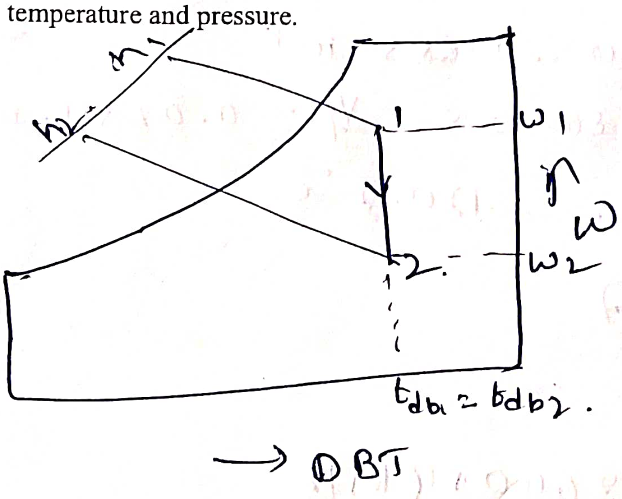
k) The compounding of steam turbine is done to reduce the speed of the rotor by arranging the number of stages of the turbine on a single rotor.

l) The coefficient of performance, COP, of a refrigerator is defined as the heat removed from the cold reservoir Qcold (i.e., inside a refrigerator) divided by the work W done to remove the heat (i.e., the work done by the compressor).

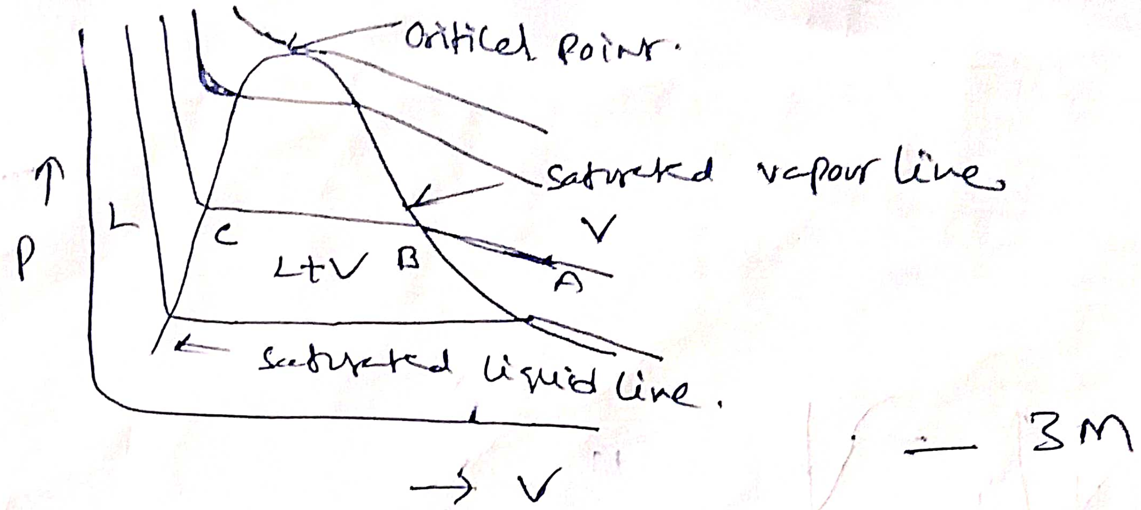
m) Relative humidity (RH) is the amount of moisture present in the air with respect to the maximum moisture-holding capacity and is represented in the percentage of total water-holding capacity.

Degree of Saturation is the ratio of the humidity ratio of moist air - to the humidity ratio of saturated moist air at the same temperature and pressure.

n)



2) (a)



— 3M

→ At point A, working fluid will be in the phase of vapor. by extracting heat energy from vapor with keeping temp - constant. system will having various states and final system i.e. vapor will reach at a point which will be termed as saturated vapor state

Process AB will isothermal process. The saturated state i.e. of state C is called saturated liquid state. — 4M

2) (b) :- Volume $V = 0.86 \, m^3$ $m_g = 1 \, kg$.

$P = 2 \, bar$.

Properties of steam at 2 bar $T_{sat} = 120.2°C$ →

$v_f = 0.001061 \, m^3/kg$ $v_g = 0.88540 \, m^3/kg$ = sp. volume of steam.

$h_f = 504.7 \, kJ/kg$ $h_g = 2706.3 \, kJ/kg$ $h_{fg} = 2201.6 \, kJ/kg$

$s_f = 1.53$ $s_g = 7.127$ $s_{fg} = 5.597 \, kJ/kgK$

∴ $V_g = m_g v_g = 1 \times 0.88540 = 0.8854 \, m^3$ — 2M

∴ $V = V_g + V_f \Rightarrow$ ~~$V_f = 0.86 - 0.8$~~ $V_f = 0.0254 \, m^3$.

Temp. of steam = T_{sat} = 120.2°C.

$x = \frac{m_g}{m_f + m_g} = 0.97$ — 2M

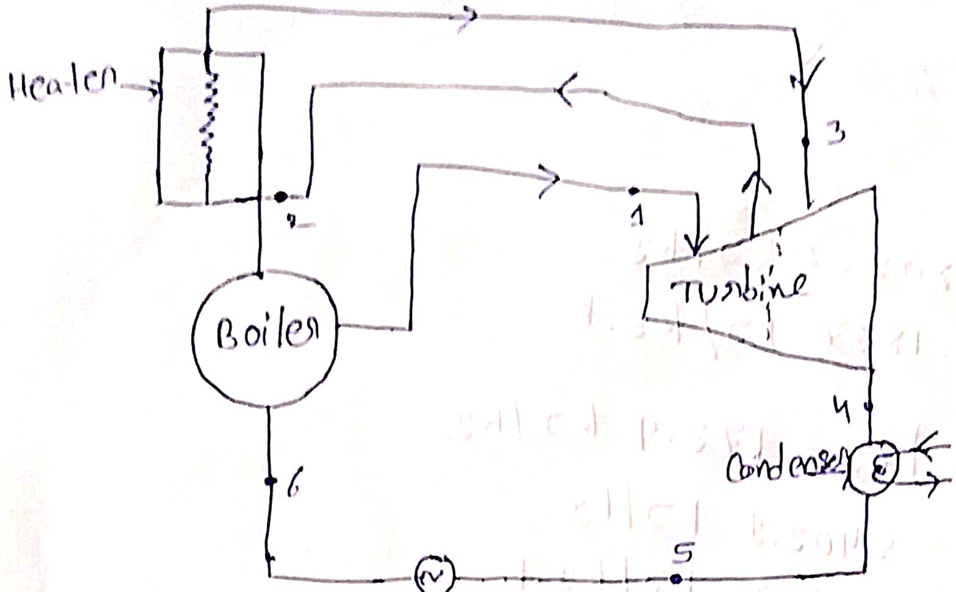
$v = v_f + x \, v_{fg}$

$h = h_f + x \, h_{fg} = 2640.54 \, kJ/kg$

$s = s_f + x \, s_{fg} = 6.9592 \, kJ/kg \, K$

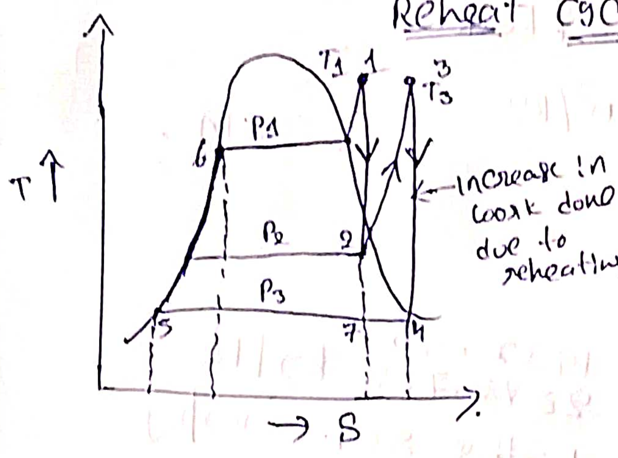
$u = h - pv = 2468.54 \, kJ/kg$. — 4M

3) (a) Reheat Rankine cycle :-

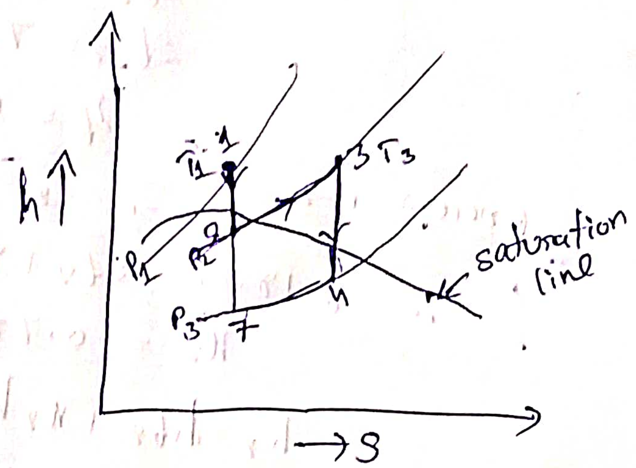


Reheat cycle.

— 2 m



T-S diagram



h-S diagram — 2m

For attaining greater thermal efficiencies when the intial pressure of steam was raised beyond 42 bar it was found that resulting condition of steam after, expansion was increasingly. It, found wetter and exceeded in the safe limit of 12 per cent condensation. It, therefore, became necessary to reheat the steam after part of expansion was over so that the resulting condition after complete expansion fell within the region of permissible wetness.

— 3m

3) (b)

Solution:-

Given data :-

P_1 = 30 bar

P_2 = 0.08 bar.

From steam tables

At 30 bar :- h_1 = 2802.3 kJ/kg.

s_1 = 6.1837 kJ/kg.K

At 0.08 bar $h_{f2} = h_{f3}$ = 173.9 kJ/kg.

h_{fg2} = 2403.1 kJ/kg

s_{f2} = 0.593 kJ/kg.K

s_{fg2} = 7.636 kJ/kg.K

v_f = 0.001 m^3/kg — 2M.

Process 1-2 , $S_1 = S_2$

$6.1837 = s_{f2} + x_2 s_{fg2}$

x_2 = 0.732.

$h_2 = h_{f2} + x_2 h_{fg2}$ = ~~2577.732~~ 1932.96 kJ/kg

$W_{turbine} = h_1 - h_2$ = ~~224.568 kJ/kg~~ 869.33 kJ/kg.

$W_{pump} = h_{f4} - h_{f3} = v_f (P_1 - P_2)$ = 2.992 kJ/kg

$W_{net} = W_t - W_p$ = ~~224.568~~ - ~~2.992~~ = ~~221.576~~ kJ 866.33 kJ/kg

i) cycle efficiency = $\frac{W_{net}}{Q_1} = \frac{866.33 \text{ (~~221.576~~)}}{h_1 - h_{f4}} = \frac{221.576}{2802.3 - 176.69}$ = ~~0.3357~~

= ~~33.57~~ %. ⇒ $\frac{866.33}{2802.3 - 176.69}$ = 32%. — 2M

ii) work ratio = $\frac{W_{net}}{W_{turbine}} = \frac{866.33}{869.33}$ = 0.99.

iii) specific steam consumption = $\frac{3600}{W_{net}}$ = 4.61. — 2M

4. a) Classification of Boilers The different ways to classify the boilers are as follows

1. According to location of boiler shell axis

a) Horizontal b) vertical c) Inclined boilers.

When the axis of the boiler shell is horizontal the boiler is called horizontal boiler. Example: Lancashire boiler, Locomotive boiler, Babcock and Wilcox boiler etc. If the axis is vertical, the boiler is called vertical boiler Example: Cochran boiler. If the axis of the boiler is inclined, it is known as inclined boiler.

2. According to the flow medium inside the tubes

a) Fire tube b) Water tube boilers.

The boiler in which hot flue gases are inside the tubes and water is surrounding the tubes are called fire tube boilers. Example: Lancashire, locomotive, Cochran and Cornish boilers When water is inside the tubes and the hot gases are outside, the boiler is called water tube boiler. Example: Simple vertical boiler, Babcock and Wilcox boiler.

3. According to Boiler Pressure According to pressure of the steam raised the boilers are classified as follows;

a) Low pressure (3.5 - 10 bar) b) Medium pressure (10-25 bar) c) High pressure boilers(> 25 bar)

4. According to the draft used

a) Natural draft b) Artificial draft boilers

Boilers need supply of air for combustion of fuel. If the circulation of air is provided with the help of a chimney, the boiler is known as natural draft boiler. When either a forced draft fan or an induced draft fan or both are used to provide the flow of air the boiler is called artificial draft boiler. Examples Natural draft boiler: Simple vertical boiler, Lancashire boiler. Artificial draft boiler: Babcock and Wilcox boiler, Locomotive boiler.

5. According to Method of water circulation a) Natural circulation b) Forced circulation If the circulation of water takes place due to difference in density caused by temperature of water, the boiler is called natural circulation boiler. When the circulation is done with the help of a pump the boiler is known as forced circulation boiler. Examples Natural circulation: Babcock & Wilcox boiler, Lancashire boiler Forced circulation: Velox boiler, Lamont boiler, Loffler boiler

6. According to Furnace position

a) Internally fired b) Externally fired boilers

When the furnace of the boiler is inside its drum or shell, the boiler is called internally fired boiler. If the furnace is outside the drum the boiler is called externally fired boiler.

7. According to type of fuel used

a) Solid b) Liquid c) Gaseous d) Electrical e) Nuclear energy fuel boilers

The boiler in which heat energy is obtained by the combustion of solid fuel like coal or lignite is known as solid fuel boiler. A boiler using liquid or gaseous fuel for burning is known as liquid or gaseous fuel boiler. Boilers in which electrical or nuclear energy is used for generation of heat are respectively called as electrical energy headed boilers and nuclear energy heated boiler.

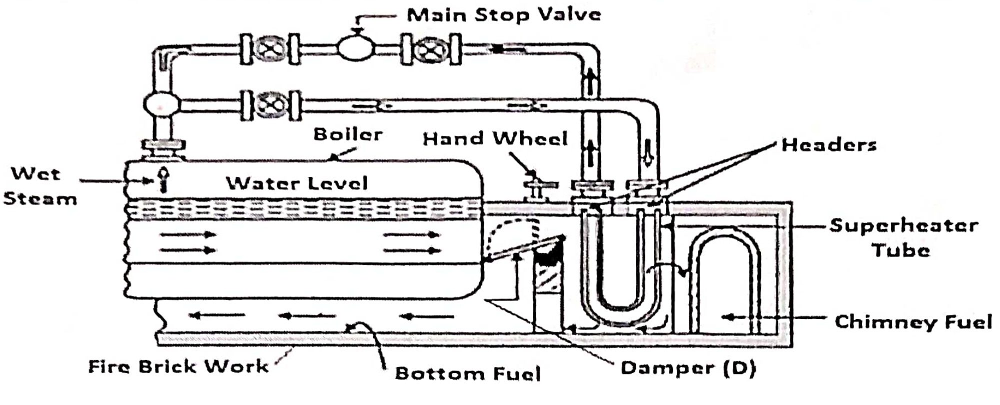
8. According to number of Tubes

a) Single-tube b) Multi-tube boiler

A boiler having only one fire tube or water tube is called a single tube boiler. The boiler having two or more, fire or water tubes is called multi tube boiler.

— 7M

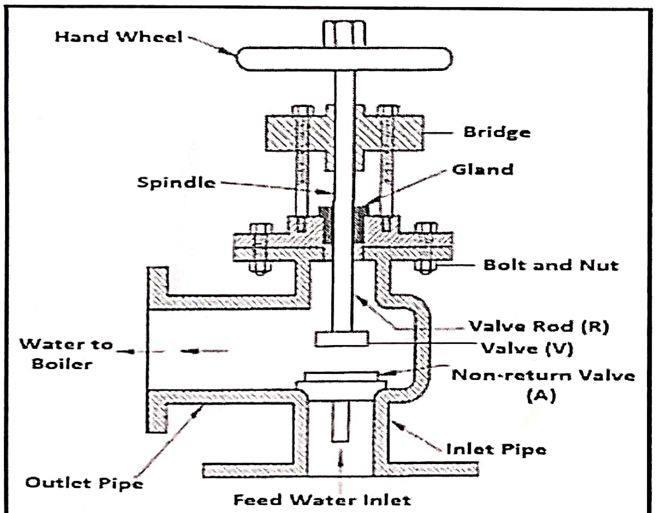
4) (b)



Superheater

The Steam Superheater is a coil-type heat exchanger which is used to produce superheated steam or to convert the wet steam to dry steam, generated by a boiler. The superheater is typically located in the flue gas path of the boiler, where it is heated by the hot flue gases. The superheater can be made of a variety of materials, including steel, copper, and stainless steel. It is different from a boiler in a way that a boiler utilizes both sensible heat as well as latent heat to convert water into steam while a superheater utilizes only sensible heat to superheat the steam in order to increase its enthalpy. Therefore, a superheater is a type of heat exchanger that is used to increase the temperature of steam without changing its pressure.
Benefits of Superheaters in Boilers: Increase in efficiency of the steam power plant Minimized erosion of turbine blade Less steam consumption Reduction of condensation loss in the boiler steam pipes Increases the temperature of saturated steam by removing entrained water particles from turbines steam.

— 2M

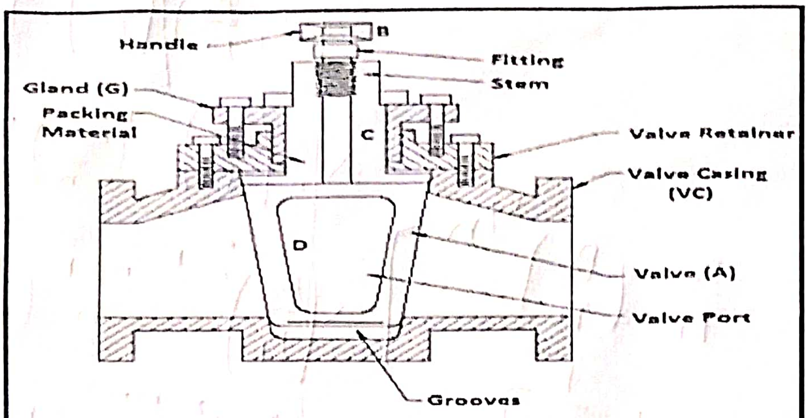


Feed Check Valve

When the level of water in the boiler falls, it is brought back to the specified level by supplying the additional water called feed water. The pressure inside the boiler will be high therefore the pressure of the feed water has to be raised by a pump before it is fed into the boiler. The feed water under high pressure is fed into the boiler through the feed check valve. The function of a feed check valve is to control the flow of

— 3M

water from the feed pump to the boiler and to prevent the backflow of water from the boiler to the pump when the pump pressure is less than the pressure or when the feed pump ceases to work. Evidently feed check valve is placed at the boiler end of the delivery pipe of the feed pump.



Blow off Valve or Cock

The function of a blow-off valve is to remove periodically the sediments deposited at the bottom of the boiler while the boiler is in operation and to empty the boiler while it is being cleaned or inspected. When the blow-off valve is opened the water which is under the pressure of steam, rushes out with tremendous velocity thus carrying out the sediments along with it.

— 2M

5) (a) Critical Pressure ratio in Nozzles :-

Let P_1 = initial pressure

v_1 = initial volume.

P_2 = steam pressure at the throat

v_2 = volume at pressure (P_2).

A = cross sectional Area.

c = velocity of steam.

Pv^n = Constant.

n = 1.135 for saturated.

= 1.3 for super heated.

n = 1.035 + 0.1x, x is the initial dryness fraction.

W/D per kg of steam.

$$\frac{n}{n-1}(P_1v_1 - P_2v_2)$$

Gain in kinetic energy = Adiabatic heat drop = W/D during cycle.

$$\frac{c^2}{2} = \frac{n}{n-1}(P_1v_1 - P_2v_2)$$

$$= \frac{n}{n-1}\left(P_1v_1\left(1 - \frac{P_2v_2}{P_1v_1}\right)\right)$$

$$P_1 v_1^n = P_2 v_2^n$$

$$\frac{v_2}{v_1} = \left(\frac{P_1}{P_2}\right)^{1/n}$$

$$\Rightarrow v_2 = v_1 \left(\frac{P_1}{P_2}\right)^{1/n}$$

$$\Rightarrow \frac{c^2}{2} = \frac{n}{n-1} P_1 v_1 \left[1 - \frac{P_2}{P_1}\left(\frac{P_1}{P_2}\right)^{1/n}\right]$$

$$\Rightarrow \frac{c^2}{2} = \frac{n}{n-1} P_1 v_1 \left[1 - \left(\frac{P_2}{P_1}\right)^{1-\frac{1}{n}}\right]$$

$$\Rightarrow \frac{c^2}{2} = \frac{n}{n-1} P_1 v_1 \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}\right]$$

$$\Rightarrow c^2 = 2\left(\frac{n}{n-1}\right) P_1 v_1 \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}\right]$$

$$\therefore c = \sqrt{2\left(\frac{n}{n-1}\right) P_1 v_1 \left\{1 - \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}\right\}}$$

— 3m

$$M = \frac{Ac}{v_2}$$

Sub 'v_2' in above eq.

$$m = \frac{Ac}{v_1 \left(\frac{P_1}{P_2}\right)^{1/n}}$$

$$= \frac{A}{v_1} \sqrt{\left[2\left(\frac{n}{n-1}\right) P_1 v_1 \left\{\left(\frac{P_2}{P_1}\right)^{2/n} - \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} \left(\frac{P_2}{P_1}\right)^{2/n}\right\}\right]}$$

$$= \frac{A}{v_1} \sqrt{\left[2\left(\frac{n}{n-1}\right) P_1 v_1 \left\{\left(\frac{P_2}{P_1}\right)^{2/n} - \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}\right\}\right]}$$

If $\frac{P_2}{P_1}$ is constant

$$\therefore \frac{d}{d\left(\frac{P_2}{P_1}\right)}\left[\left(\frac{P_2}{P_1}\right)^{2/n} - \left(\frac{P_2}{P_1}\right)^{\frac{n+1}{n}}\right]$$

$$\Rightarrow \frac{2}{n}\left(\frac{P_2}{P_1}\right)^{\frac{2}{n}-1} - \left(\frac{n+1}{n}\right)\left(\frac{P_2}{P_1}\right)^{\frac{n+1}{n}-1} = 0$$

$$\Rightarrow \left(\frac{P_2}{P_1}\right)^{\frac{2}{n}-1} = \frac{n+1}{n}\left(\frac{P_2}{P_1}\right)$$

$$\Rightarrow \left(\frac{P_2}{P_1}\right)^{2-n-1} = \left(\frac{n+1}{2}\right)^n$$

$$\Rightarrow \boxed{\frac{P_2}{P_1} = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}}$$

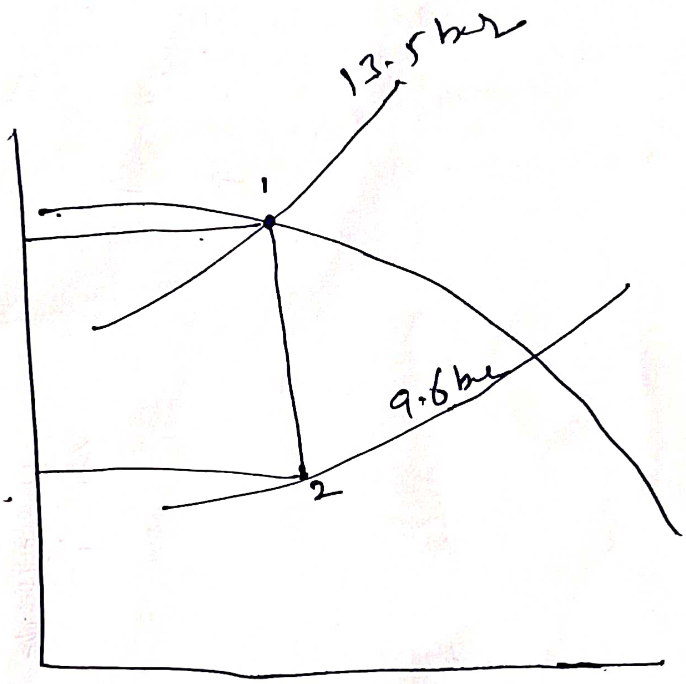
— 4m

5) b)

Given datas,

$P_1 = 13.5$ bar

$P_2 = 9.6$ bar.



$C_1 = \sqrt{2(h_1 - h_2)}$

$h_1 =$ ~~2600 kJ/kg.~~ 2760 kJ/kg

$h_2 = 2700$ kJ/kg

$c_1 = \sqrt{2(2760 - 2700)}$

$= \sqrt{2(60)}$.

$c_1 = \sqrt{120}$

$c_1 = 10.95$ m/sec

— 1m.

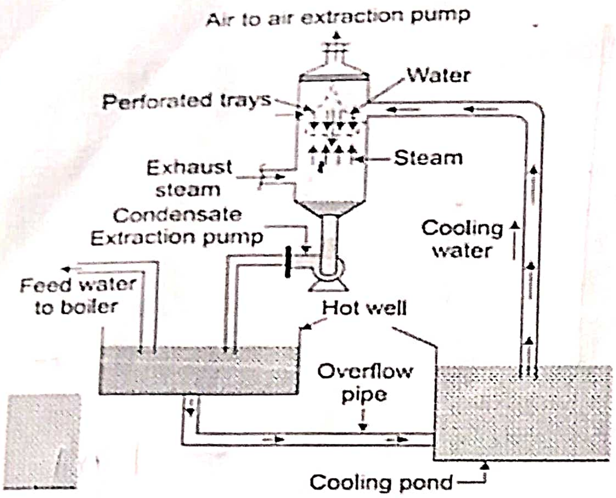
— 4m.

- Properties from steam tables

— 2m

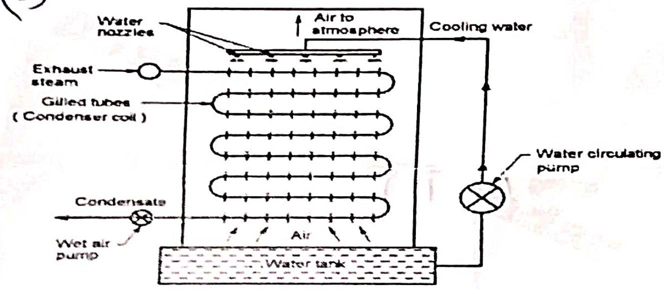
6. a) In counterflow or low-level jet condenser, exhaust steam enters lower side and cooling water comes upper-side of the condenser chamber, see in the diagram.The direction of exhaust steam is upper-side and cooling water is downwards.Air pump has created a vacuum and it is placed at the top of the condenser shell.The vacuum draws the supply of the cooling water which falls a large number of jets.A perforated conical plate stores this falling water, from which it escapes in second series of jets and meets the exhaust steam entering at the bottom.Condensate and cooling water released for this rapid condensation to discharge the hot well through a vertical pipe by condensate pump.

— 3m



— 4m

6) (b)



— 3m

Evaporating Condenser

Evaporative condenser is another type of surface condenser. When the supply of cooling water is limited, evaporating the circulating water under small partial pressure can reduce its quantity required for condensing the steam. This principle is employed in evaporative condensers. The exhaust steam from the steam engine or steam turbine enters at the top of a series of pipes outside of which a film of cold water is falling. At the same time, a stream of air rotates above the water film, causing rapid evaporation of some of the cooled water. As a result of this, the steam circulating inside the pipe is condensed. The coolant pump draws water from a cooling pond and forces it to a horizontal header. The header is provided with a number of spray nozzles. Hence the cooling water is sprayed over the finned pipes. A portion of cooling water is evaporated as it flows over the finned tubes by taking its latent heat from the steam. The remaining water drips back to the cooling pond.

— 4m

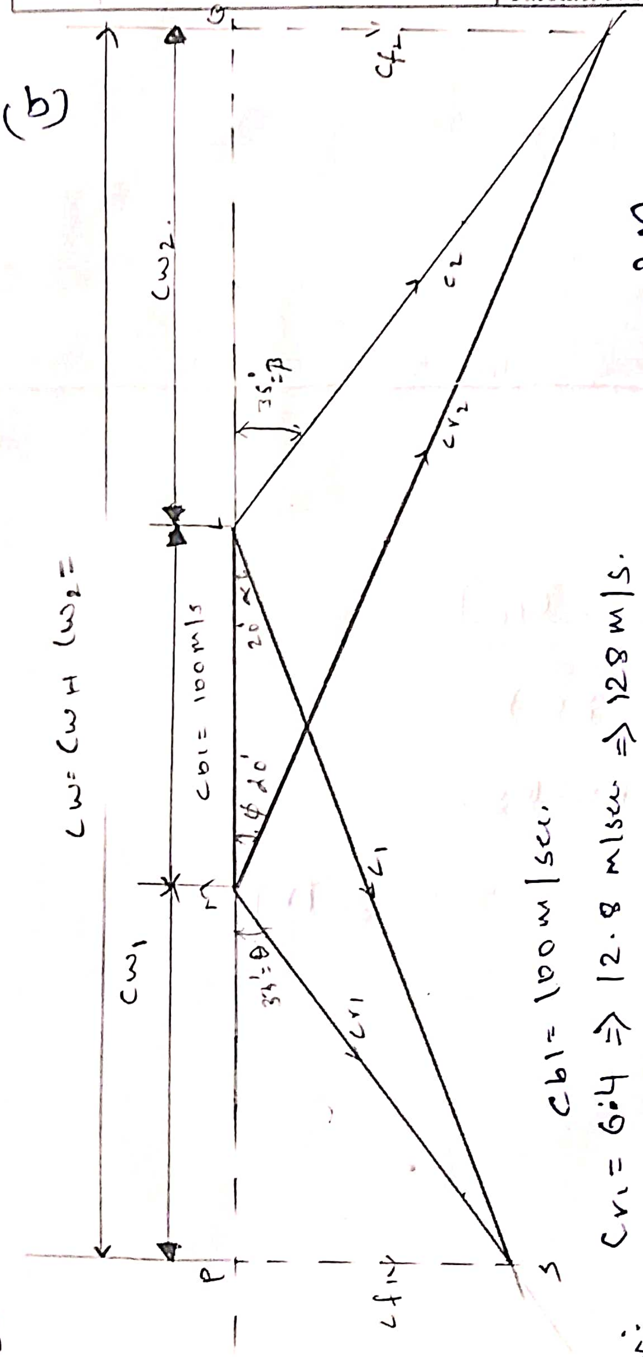
7) (a)

Impulse turbine	Reaction Turbine
The entire available energy of the water is first converted into kinetic energy.	The available energy of the water is not converted from one form to another.
The water flows through the nozzles and impings on the buckets, which are fixed to the outer periphery of the wheel.	The water is guided by the glide blades to flow over the moving vane.
The water impings on the buckets with KE	The water glides over the moving vanes with PE.
The pressure of the flowing water remains unchanged and is equal to the atmospheric pressure.	The pressure of the flowing water is reduced after gliding over the vane.
It is not essential that the wheel should run full.	It is essential that the wheel should always run full and kept full of water.
It is possible to regulate the flow without loss.	It is not possible to regulate the flow without loss.
Impulse Turbine has more hydraulic efficiency.	Reaction Turbine has relatively less efficiency.
Impulse Turbine operates at high water heads.	Reaction turbine operates at low and medium heads.
Example of Impulse turbine is Pelton wheel.	Examples of Reaction Turbine are Francis turbine, Kaplan and Propeller Turbine, Deriaz Turbine, Tubuler Turbine, etc.

— 7M

7) (b)

scale – 1:2



— 2M

from figure:

Cb1 = 100 m/sec.

$C_{r1} = 6.4 \Rightarrow 12.8$ m/sec $\Rightarrow 128$ m/s.

$C_{r2} = 12.7 \Rightarrow 127 + 127 \Rightarrow 254$ m/s.

$C_1 = 10.9 \Rightarrow 109 + 109 \Rightarrow 218$ m/sec.

$C_2 = 8.5 \Rightarrow 85 + 85 \Rightarrow 170$ m/sec.

$C_{w1} = 10.3 \Rightarrow 103 + 103 \Rightarrow 206$ m/sec.

$C_{w2} = 7.0 \Rightarrow 70 + 70 \Rightarrow 140$ m/sec.

$C_w = C_{w1} + C_{w2} = 206 + 140 = 346$ m/sec.

tangential force $F = m_s (C_{w1} + C_{w2}) C_{b1}$

$= 1 (206 + 140) 100$

$\Rightarrow 34600$ N-m

$F = 34600$ N-m

— 2M

* power developed $P = \frac{m_s(C_{w1} + C_{w2}) C_{b1}}{1000}$

$\Rightarrow \frac{1(206 + 140) \times 1000}{1000}$

$\Rightarrow \frac{34600}{1000}$

$P = 34.6 \, kW$

$\eta_d = \frac{2 C_{b1} (C_{w1} + C_{w2})}{C_1^2}$

$\Rightarrow \frac{2 \times 100 (206 + 140)}{(218)^2}$

$= \frac{200(346)}{47524}$

$\eta = 1.46 \%$

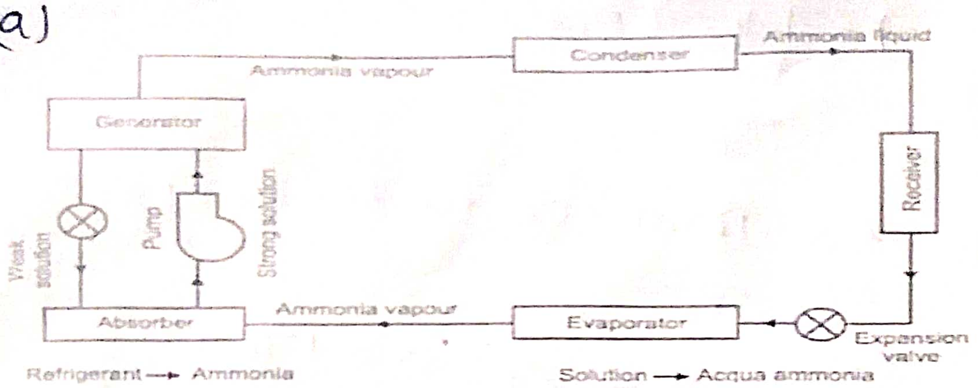
axial thrust $= m_s (C_{f2} - C_{f1})$

$= 1(106 - 85)$

$= 21$ N per kg.

— 3M.

8.) (a)



— 4M

Vapour absorption refrigeration system working: Vapor absorption refrigeration system consists of evaporator, absorber, generator, condenser, expansion valve, pump & reducing valve. In this system ammonia is used as refrigerant and solution is used is aqua ammonia. Strong solution of aqua ammonia contains as much as ammonia as it can and weak solution contains less ammonia. The compressor of vapor compressor system is replaced by an absorber, generator, reducing valve and pump. The heat flow in the system at generator, and work is supplied to pump. Ammonia vapors coming out of evaporator are drawn in absorber. The weak solution containing very little ammonia is spread in absorber. The weak solution absorbs ammonia and gets converted into strong solution. This strong solution from absorber is pumped into generator. The addition of heat liberates ammonia vapor and solution gets converted into weak solution. The released vapor is passed to condenser and weak solution to absorber through a reducing valve. Thus, the function of a compressor is done by absorber, a generator, pump and reducing valve. The simple vapor compressor system is used where there is scarcity of Electricity and it is very useful at partial and full load.

— 3M

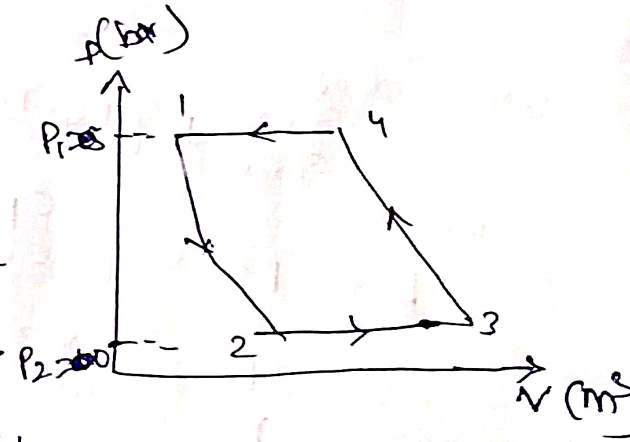
8) (b) $Pv^{1.35} = \text{constant}$

$P_2 = 1.05 \text{ bar}$

$P_1 = 8.5 \text{ bar}$

$T_3 = 10^\circ C = 10+273 = 283 K$

$T_4 = 30^\circ C = 30+273 = 303 K$



— 1M

<u>Process 3-4</u>

$$\frac{T_4}{T_3} = \left(\frac{P_1}{P_2}\right)^{\frac{n-1}{n}} = \left(\frac{8.5}{1.05}\right)^{\frac{1.35-1}{1.35}} = 1.719756$$

$$T_4 = T_3 \times 1.7197 = 283 \times 1.7197 = 486.6751 K$$

<u>Process 1-2</u>

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{n-1}{n}} = \left(\frac{8.5}{1.05}\right)^{\frac{1.35-1}{1.35}} = 1.7197$$

$$T_2 = \frac{T_1}{1.7197} = \frac{303}{1.7197} = 176.193 K$$

— 2M

$C_p = 1.003 \frac{kJ}{kg.K}$ $\gamma = 1.4$ (For air take)

Heat extracted from cold chamber per kg of air

$= C_p (T_3 - T_2) = 1.003 (283 - 176.19)$

$= 107.13$ kJ/kg

Heat rejected in cooling chamber per kg of air

$\Rightarrow C_p (T_4 - T_1) = 1.003 (486.67 - 303)$

$= 184.22$ kJ/kg. — 2M

work done

$= \frac{n}{n-1} R [(T_4 - T_3) - (T_1 - T_2)]$

$R = C_p - C_v$ $\left[\frac{C_p}{C_v} = \gamma\right]$

$C_v = \frac{C_p}{\gamma} = \frac{1.003}{1.4} = 0.716$

$R = 1.003 - 0.716 = 0.287$ kJ/kg

work done

$= \frac{1.35}{1.35-1} \times 0.287 [(486.67 - 283) - (303 - 176.19)]$

$= 85.08$ kJ/kg

$COP = \frac{\text{Heat extracted}}{\text{work done}} = \frac{107.13}{85.08} = 1.259$

— 2M

9) (a)

Given data

Dry bulb temperature $(t_d) = 30°C$

Wet bulb temperature $(t_w) = 20°C$

Barometeric Reading $(P_b) = 740$ mm of Hg

1 mm of Hg = 133.3 N/m²

1 bar = 10^5 N/m²

$P_b = \frac{740 \times 133.3}{10^5} = 0.98642$ bar

① Dew point temperature (t_{dp})

from steam table - ①

Find saturation pressure at wet bulb temperature 20°C

$P_w = 0.02337$ bar

Partial pressure of vapour (P_v)

$= P_w - \frac{(P_b - P_w)(t_d - t_w)}{1547 - 1.44 t_w}$

$= 0.02337 - \frac{(0.98642 - 0.02337)(30-20)}{1547 - 1.44(20)}$

$P_v = 0.01702$ bar

from steam table-2

Dew point temperature (t_{dp}) at pressure 0.01702 bar

$t_{dp} = \frac{13.04 + 17.51}{2}$

$t_{dp} = 15°C$ — 2m

② Relative humidity (ϕ)

from steam table - 1

Find saturation pressure at dry bulb temperature 30°C

$P_s = 0.04242$

$\phi = \frac{P_v}{P_s} = \frac{0.01702}{0.04242}$

$\phi = 0.4012$ (or) 40.12 %

③ Specific humidity (w)

$w = 0.622 \frac{P_v}{P_b - P_v}$

$= 0.622 \left[\frac{0.01702}{0.98642 - 0.01702}\right]$

$w = 0.01092$ kg/kg dry air

④ Degree of saturation (μ) — 2m

$\mu = \frac{w}{w_s}$

$w_s = 0.622 \frac{P_s}{P_b - P_s}$

$= 0.622 \left[\frac{0.04242}{0.98642 - 0.04242}\right]$

$w_s = 0.02795$ kg/kg dry air

$\mu = \frac{0.01092}{0.02795}$

$\mu = 0.3906$ (or) 39 %

⑤ Enthalpy of mixture per kg of air (h)

From steam table - ①

$t_{dp} = 15°C$ $h_{fgdp} = 2466.1$ kJ/kg

$h = 1.022 t_d + w[h_{fgdp} + 2.3 t_{dp}]$

$= 1.022 \times 30 + 0.01092 [2466.1 + 2.3 \times 15]$

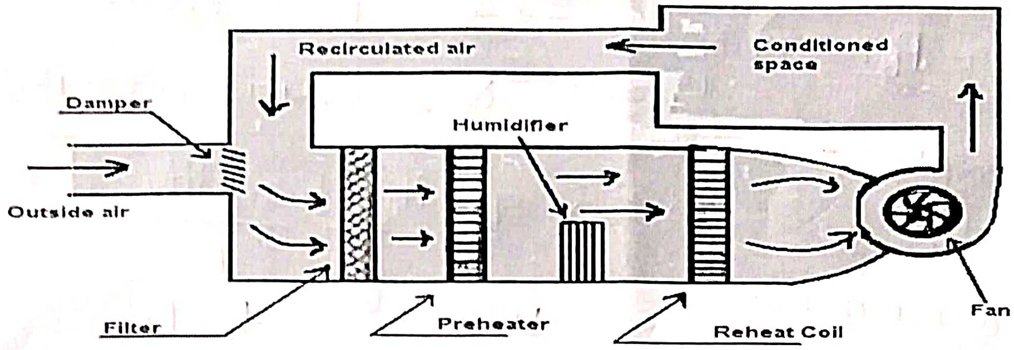
$= 30.66 + 27.13$ — 3m

$h = 57.79$ kJ/kg dry air

9) (b)

Winter Air Conditioning System:

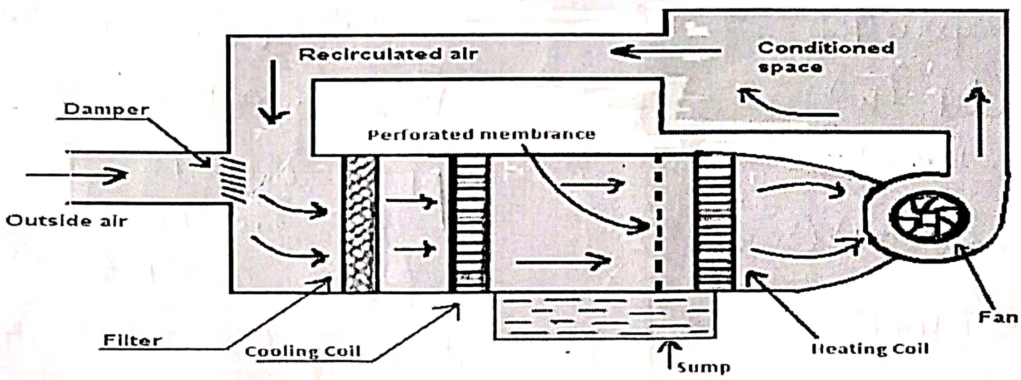
Air conditioner working principle In winter air conditioning system, the air is burnt and heated, which is generally followed by humidification. The outside air flows through a damper and mixes with the recirculated air. The mixed air passes through a filter to remove the dirt, dust, and impurities. The air now passes through a preheat coil to prevent the possible freezing of water and to control the evaporation of water in the humidities. After that, the air is made to pass through a reheat coil to bring the air to the designed dry bulb temperature. Now, the conditioned air is supplied to the conditioned space by a fan. From the conditioned space, a part of the air is exhausted to the atmosphere by the exhaust fans. The remaining part of the used air is again conditioned and this will repeat again and again.



← 4M

Summer Air Conditioning System:

In this system, the air is cooled and generally dehumidified. A Schematic for a typical summer air conditioning system is arranged. The outside air flows through the damper and mixed with recirculated air (which is obtained from the conditioned space). The mixed air passes through a filter to remove the dirt, dust and impurities. The air now passes through a cooling coil. The coil has a temperature much below the required dry bulb temperature of the air in the conditioned space. The cooled air passes through a perforated membrane and loses its moisture in the condensed from which is collected in the sump. After that, the air is made to pass through a heating coil which heats the air slowly. This is done to bring the air to the designed dry bulb temperature and relative humidity. Now the conditioned air is supplied to the conditioned space by a fan. From conditioned space, a part of the used air is rejected to the atmosphere by the exhaust fan. The remaining air is again conditioned and this repeated for again and again. The outside air is sucked and made to mix with recirculated air to make for the loss of conditioned air through exhaust fan from the conditioned space.



← 3M.

Prepared by
Dr. A. Praveen
Asst. Professor.
Dept. of Mechanical Engg.
Ph. No: 8143679931.

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