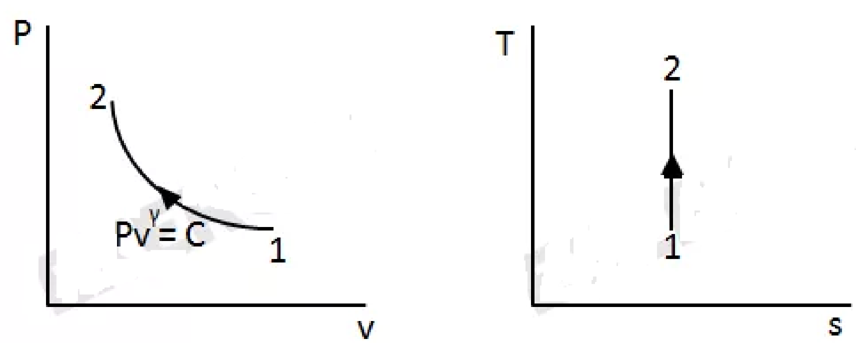
WINTER– 18 EXAMINATION

Subject Name: Thermal Engineering **Model Answer** **22337**

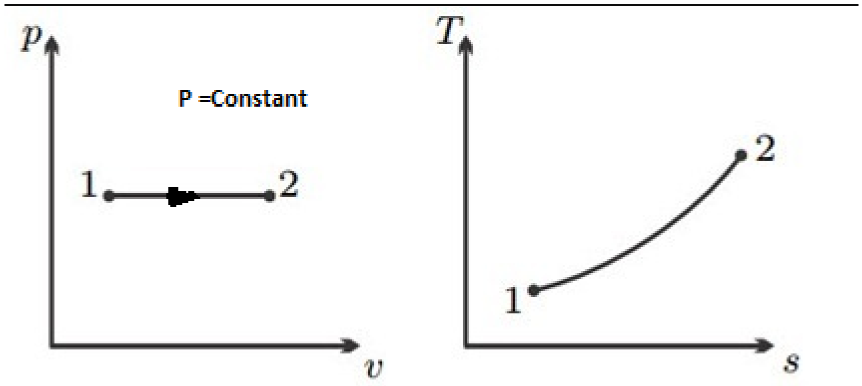
Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q. N.	Answer	Marking Scheme
1	a	Attempt any Five (i) Gray body :- A grey body is defined as a body with constant emissivity over all wavelengths and temperatures. It absorbs a definite percentage of incident energy irrespective of their wavelengths.	2
	b	Write functions of (i) Fusible plug-The function of the fusible plug is to put-off the fire in the furnace of the boiler when the water level falls below an unsafe level and thus avoids the explosion which may take place due to overhearing of the tubes and the shell. (ii) Economizer :- Function of economizers in steam power plants is to capture the waste heat from boiler flue gases and transfer it to the boiler feed water. This raises the temperature of the boiler feed water, lowering the needed energy input, in turn increase in boiler efficiency.	1 1
	c	Define- (ii) Boiler efficiency :-It is the ratio of heat actually used in producing the steam to the heat liberated in the furnace. It is also known as thermal efficiency of boiler. (iii) Latent heat:-It is energy absorbed or released by a substance during a change in its physical state (phase) that occurs without changing its temperature .e.g. latent heat of fusion and latent heat of vaporization .	1 1
	d	Dalton's law of partial pressure:- Dalton's law of partial pressures states that in a mixture of non-reacting gases, the total pressure exerted is equal to the sum of the partial pressures of the individual gases. • or	2

		In a mixture of perfect gases, total pressure exerted by the mixture is the sum of partial pressures, which each gas would exert if it separately occupied the whole volume and was at the same temperature as the mixture. $P_{total} = p1+p2+p3 +\text{-------}p_n$ where p1, p2, ..., p_n represent the partial pressures of each component.	
	e	Choked flow condition in nozzle :-Choked flow is a fluid dynamic condition associated with the Venturi effect. When a flowing fluid at a given pressure and temperature passes through a constriction (such as the throat of a convergent-divergent nozzle or a valve in a pipe) into a lower pressure environment the fluid velocity increases. Choked flow is a limiting condition where the mass flow will not increase with a further decrease in the downstream pressure environment while upstream pressure is fixed.	2
	f	Universal gas constant :- Universal gas constant or molar constant (denoted by Ru) of a gas is the product of the gas constant and the molecular mass of the gas. Ru is same for all gases. It is 8.314 KJ/Kg-mol K Ru =M X R M = Molecular mass of the gas expressed in kg-mole; R= Gas constant In general, M1, M2,M3 are the Molecular masses of different gases and R1,R2,R3 are their gas constants respectively, then M1R1=M2R2=M3R3 = - - - -= Ru	2
	g	(i) Flow work- This is the work necessary to advance the fluid against the existing pressure, . It is the work required to cause the flow of fluid in any passage. Flow work= PV where P= pressure of fluid, V= volume of fluid.	1
		(ii) Entropy- Entropy is the extensive property of the system (depends on the mass of the system) and its unit of measurement is J/K (Joule per degree Kelvin). Entropy is heat or energy change per degree Kelvin temperature. Entropy is denoted by 'S', while specific entropy is denoted by 's' in all mathematical calculations. Entropy is defined as the property used to measure the quantity of energy or irreversibility of a process.	1
2	a	Attempt any THREE I) Isentropic process 	2

(i) Isobaric process



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b

A process is said to be irreversible if it cannot reach back to its original state without using external work. The spontaneous process will not be a reversible or quasi-static process. It is an irreversible process. There are many factors that make a process irreversible. Four of the most common causes of irreversibility are friction, unrestrained expansion of a fluid, heat transfer through a finite temperature difference, and mixing of two different substances. 2

Irreversibility is classified according their causes:

i) External: The irreversibility caused by external physical factors like friction, resistance, viscosity, surface tension, finite temperature difference, etc. 2

The energy lost due to friction can never be regained. Hence, the direction of the process cannot be reversed without supplying external work.

ii) Internal: Irreversibility caused by properties of the working fluid in a process like throttling or free expansion.

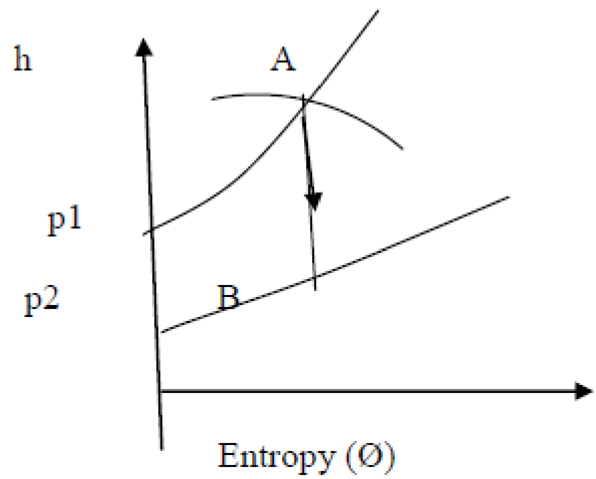
When a gas expands, it uses its internal energy to do so. It cannot contract on its own and reverse the process.

iii) Chemical: Irreversibility caused by internal chemical properties like structure, bonds, etc.

When a chemical reaction occurs in association with absorption or liberation of heat, it cannot reverse spontaneously. Involvement of dissipative effect during the process will also be a cause of irreversibility of a process. There are following various types of dissipative effect during a process -

1. Mechanical friction
2. Magnetic hysteresis
3. Electrical resistance
4. Viscosity or fluid viscosity
5. Inelasticity

	c	Steam supply 15 bar (dry saturated) Condenser pressure 0.4 bar Find dryness fraction and enthalpy of steam. From steam tables, At 15 bar, h_{f1}=844.89 KJ/Kg;h_{fg}1=1947.3; h_{g1}=2792.2KJ/Kg; x1=1(Given); s_{f1}=2.315; s_{fg1}= 4.129 KJ/KgK At 0.4 bar, h_{f2}=317.58;hf_{g2}=2319.2; h_{g2}=2636.8KJ/Kg;; s_{f2}=1.0259; sf_{g2}= 6.645 KJ/KgK Let x_2 =Final dryness fraction Considering steam power cycle as isentropic, Initial Entropy= Final Entropy $S_{f1}+x_1\, s_{fg1}= s_{f2} + x_2\, s_{fg2}$ 2.315+ 1 X 4.129 =1.0259 + x2 X 6.645 x_2 = 0.815 (Dryness fraction) Final Enthalpy = $h_{f2}+ x_2 \times h_{fg2}$=2207.72 KJ/Kg	2 2
	d	Steam turbines may be classified in following ways: (Any four) 1. According to working principle or Action of steam over blade : (a) Impulse Turbine (b) Reaction Turbine (c) Impulse Reaction Turbine 2. According to the stage of expansion of steam: (a) Single stage turbine (b) Multistage turbine 3. According to the position of shaft : (a) Horizontal turbine (b) Vertical turbine 4. According to pressure of steam supplied: (a) High Pressure turbine (b) Low Pressure turbine 5. According to direction of steam flow: (a) Axial flow turbine (b) Radial flow turbine (c) Tangential flow turbine 6. According to exhaust steam pressure (a) Condensing type steam turbine Non-condensing type steam turbine	1 for each

3	a	 From Mollier Chart H_2 = 2510 at point B and H_1 = 3130 at point A Heat drop = H_1 - H_2 = 3130 - 2510 = **620 kJ/kg** Final condition of steam From Mollier chart at point B dryness fraction is **0.90**	2 2
	b	**steady flow equation can be expressed as:** Internal Energy at 1 + Potential Energy at 1 + Kinetic Energy at 1 + Flow work at 1 + Heat supplied = Internal Energy at 2 + Potential Energy at 2 + Kinetic Energy at 2 + Flow work at 2 + Work done Hence the steady flow energy equation is,	

$$h_1 + \frac{c_1^2}{2} + Z_1 g + Q = h_2 + \frac{c_2^2}{2} + Z_2 g + W$$ 1

Where,

h_1& h_2 = Enthalpy at inlet and outlet in J /kg

C_1& C_2 = velocity at inlet and out of fluid---- m/s

Z_1 and Z_2 = height of inlet & outlet above datum

Q = heat supplied per ---------------Joule 1

W = work done by 1 kg of fluid----Joule

PV = Flow work---------N-m or Joule

Application :

Steam Condenser :- It is a device to condensed the exhaust steam
Heat- is lost hence q is **– ve**

Applying SFEE

$$q + h_1 + gZ_1 + \frac{1}{2}c_1^{\,2} = w + h_2 + gZ + \frac{1}{2}C_2^{\,2}$$

$$-q + h_1 + 0+0 = 0 + h_2 + 0 + 0$$

$$q = h_1 - h_2$$

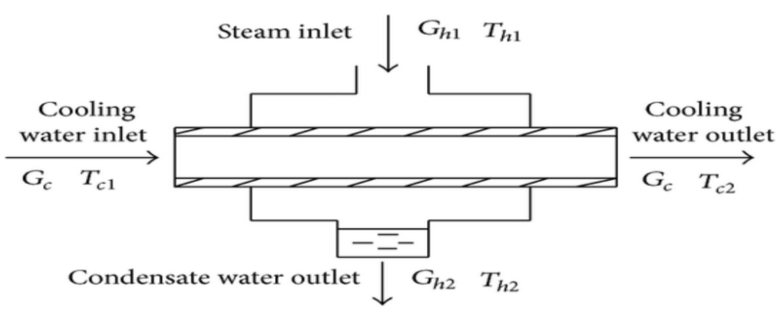


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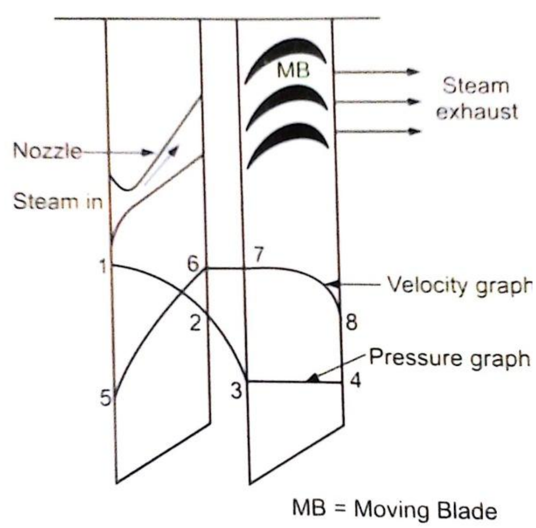
Fig: Steam condenser

	c	**Given :** $V_1 = 3\ m^3$ $T_1 = 30\ ^OC$, $P_2 = 1$ bar For isothermal process PV = C $P_1V_1 = P_2V_2$ $5 \times 10^5 \times 3 = 1 \times 10^5 \times V_2$ $V_2 = 15 X 10^5$ Work done : $dW = P_1V_1 \log_e (V_2/V_1)$ $= 5 \times 10^5 \times 3 \log_e (15/3)$ dW = $\mathbf{2.41 \times 10^6}$ **kJ/kg** **For Isothermal process dW = dQ and dU = 0**	1 2 1
	d	Features of Indian Boiler regulation : (**Any Four points 1 mark each**) 1. A boiler cannot be put to use unless it has been registered with the Chief Inspector of Boilers. 2. The maximum working pressure of the boiler has to be determined by Boiler Inspector who will issue certificate for this. Owner cannot exceed this pressure limit in any case. 3. In case of accident, it should be reported by owner within 24 hours with full details. 4. The rules, regulations and bye-laws governing the upkeep and maintenance of boilers, procedure of registration, inspection and certification of maximum pressure, safety conditions etc. are subject to a revision by a Central Board under control of Govt. of India. 5. The boiler house plan, chimney design (Max height 30.48 m from floor) should be approved by boiler inspector. 6. Owner should apply for registration in prescribed format, inspector should fix date of inspection within 30 days, conduct inspection/examination of boiler, Issue the certificate of registration not exceeding 12 months period. 7. Following inspections are carried out by Boiler Inspector at various stages/ levels /need->Inspection for registration, Hydraulic test, steam test, annual inspection, Inspection under steam, Internal inspection, Accident inspection, Casual inspection 8. Violation of law is liable to prosecution and punishment with fine.	01 for each

4	a	Given : Initial Volume of air $=V_1 : 0.12\ m^3$ Initial pressure of air $= P_1: 1$ bar Initial temperature of air $= T_1 : 90 + 273 = 360$ K Final Volume of air $= V_2 : 0.03 m^3$ Final Pressure of air $= P_2 : 6$ bar $P_1V_1 = mRT_1$ 1 x 105 x 0.12 = m x 289 x 360 m = 1.15 kg Assume compression to be polytrophic $P_1/ P_2 = (V_2/V_1)^n$ $1/6 = (0.03/0.12)^n$ **n = 1.29** We know that $P_1V_1/T_1 = P_2V_2/T_2$ $(1 \times 0.12) / 360 = (6 \times 0.03) / T_2$ $T_2 = 540$ K Increase in internal energy $= m\ Cv\ (T_2 - T_1)$ = 1.15 x 0.72 x (540 – 360) **= 149.04 kJ**	2 2
	b	Energy losses in steam turbines **[Any four points with explanation 01 mark each]** (i) Residual velocity loss- The steam leaves the turbine with a certain absolute velocity which results in loss of KE. This loss is about 10 to 12% .It can be reduced by multistaging. (ii) Losses in regulating valves-Due to throttling action in valve , steam pressure drop occurs. Hence steam pressure at entry to turbine is less than the boiler pressure. (iii) Losses due to friction in nozzle-Friction occurs both in nozzle and turbine blades. In nozzle, nozzle efficiency is considered, whereas in turbines, blade velocity coefficient is taken into account. This loss is about 10% (iv) Loss due to leakage-The leakage occurs between the shaft, bearings and stationary diaphragms carrying the nozzles in case of impulse turbines. In reaction turbine the leakage occurs at blade tips. This is about 1-2%. (v) Loss due to mechanical friction-This occurs in bearings and may be reduced by lubrication (vi) Loss due to wetness of steam-In multistage turbine, condensation occurs at last stage ,so in dragging water particles with steam, some KE of stem is lost (vii) Radiation loss-As turbines are heavily insulated to reduce the heat loss to surroundings by radiation and so these losses are negligible	01 for each

	c	**State : (1 Mark for each definition)** **i) Fourier's law:** "Fourier's law states that the rate of heat flow, dQ/dt, through a homogeneous solid is directly proportional to the area, A, of the section at right angles to the direction of heat flow, and to the temperature difference along the path of heat flow, dT/dx. **ii) Newtons Law of cooling :** "The rate of cooling of a body is directly proportional to the difference in temperature of the body (T) and surrounding (T_o), provided difference in temperature should not be exceed by 30 ^OC **iii) Radiation** – It is process of heat transfer between two bodies without any carrying medium through different kind of electro-magnetic wave. **iv) Thermal Conductivity :** It is defined as amount of energy flow through a body of unit area and unit thickness in unit time when the difference in temperature between the faces carrying the heat flow is 1 ^0C . Thermal conductivity depends on molecular structure, specific gravity etc .	01 for each
	d	**Advantages of feed heating: (1 mark each)** 1.The thermal efficiency of boiler increases as heat input decreases. 2. Capacity of Condenser changes 3. Reduce fuel consumption. 4. Thermal stress in the boiler reduces as temperature difference is decrease due to hot feed water is supplied 5. Overall efficiency of the plant increase.	01 for each
	e	Volume of balloon = $\frac{4}{3}\pi r^3$ $V = \frac{4}{3}\pi (5)^3 = 523.6\ m^3$ MR = 8.3143 R = 8.3143/2 = 4.15715 kJ/kg K Pressure of hydrogen in the balloon = Atmospheric pressure = 101.325 kN / m^2 Applying gas equation , PV = mRT	2

		Mass of air hydrogen in balloon $= \frac{PV}{RT}$ = 101.325 x 523.6 / 4.15715 x (20 +273) **= 43.56 kg** The volume of air displaced by the balloon = Volume of the balloon m = $\frac{PV}{RT}$ = (101.325 x 523.6) / 0.287 x (20 +273) **= 630 .91 kg** Total load lifted by the balloon = 630.91 - 43.56 = **587.35 kg**	2
5	a(i)	**Throttling:** When fluid or gas flow through the restricted passage like a plate with partially opened valve or suddenly reduce the diameter of the pipe pressure drop occur. The kinetic energy at the inlet and outlet is very small and there is no change in potential energy and there is no work done and there is enough time to appreciate heat transfer. It can show that there is an abrupt change in pressure (high pressure converted into low pressure) between the inlet and outlet at constant enthalpy. It is called throttling process.	1
		Purpose of throttling: **1.** For determining the condition of steam 2. used in refrigeration plant 3. Liquefaction of gas 4. in many cryogenic application	2

	ii	Q.5 a) ii) (1/2) Ans :- Steam pressure = 6.87 bar Steam temp. = 205°c Inlet velocity of steam in Nozzle = 50 m/s outlet velocity of steam = 500 m/s outlet poessure of steam = 1.37 bar find. final enthalpy = h_2 = ? → Inlet enthalpy @ 6.87 bar and 205°c is. $h_{sup} = h_g + C_p \times (t_{sup} - t_s)$ t_s = saturation temp. @ 6.87 bar = 163.8°c t_{sup} = but the given temp. is 205°c it is higher than the saturation temp. so. @ 6.87 bar $h_g = 2760.8$ kJ/kg $C_p = 2.5$ kJ/kgK (Assume) $\therefore h_1 = h_{sup} = 2760.8 + 2.5(205-165)$ $= 2860.8$ kJ/kg.	3
	b	 **Figure: Impulse Turbine**	2

Construction:

Impulse turbine consist of one fixed set of nozzle mounted on a stationary diaphragm that orient the steam flow into high speed jets, which is followed by one set of moving blade ring as shown in Fig. for a single stage impulse turbine. 2

Working:

In impulse turbine power is developed by the impulsive force of high velocity jet or jets which contain significant kinetic energy which is converted in to shaft rotation by the bucket-like shaped rotor blades, as the steam jet changes direction. 2

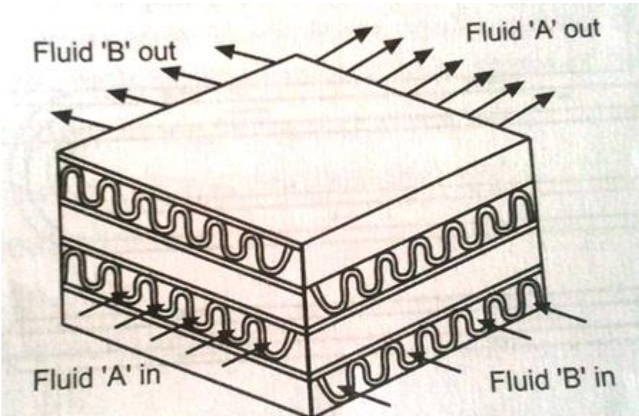
A pressure drop occurs across only the stationary blades, with a net increase in steam velocity across the stage. As the steam flows through the nozzle its pressure falls from inlet pressure to the exit pressure.

The high velocity steam jets are obtained by complete expansion of steam in the stationary nozzles fitted in diaphragm then this velocity steam passes through moving blade with no drop in pressure but a gradual reduction in velocity.

In pure impulse steam turbine the high velocity jet from nozzle strikes on the blades mounted on the wheel attached to the shaft.

Theses blades change the direction of steam and hence momentum of the jet of steam which rotate the shaft.

c



2

Figure: Plate type heat exchanger

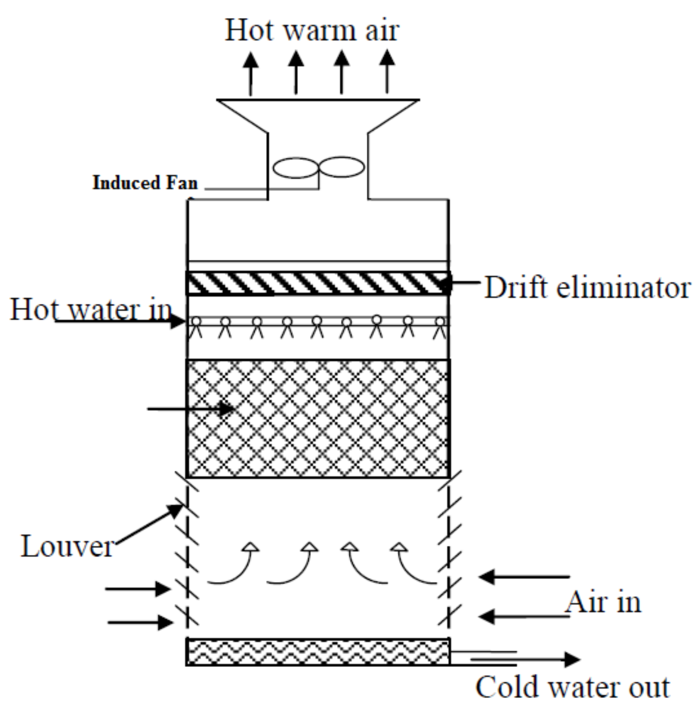
		It consists of closely spaced parallel plates fins held in between. The plate separate the two fluids which flow through passages alternately, formed between plates.it also has fin attached over primary heat transfer surface so as to increase heat transfer areas. This improves the effectiveness of heat exchanger. The counter flow or parallel flow arrangement can also be possible. The fin may be plain fin are attached to plate by brazing or soldering. They are more suitable for gas to gas application. **Applications:** a. Milk chilling plants b. Radiator in automobile c. Air conditioning d. Food industries	2 2
6	a	**Induced draught cooling towers:** 	3

Figure: Induced draught cooling tower

Construction:

In this, fan is located at the top of the tower and air enters the side of the tower. The hot water from the condenser is sprayed in the tower from top. Drift eliminator are attached below the fan to remove the water in the air. Louvers are attached both the side of the tower for air. 3

Working:

Depending on the air inlet and flow pattern, induced draft towers are of two types, cross-flow and counter flow towers.

Figure shows that schematic diagram of a induced draught cooling tower. In this system, a fan is installed at the top of the cooling tower.

The hot water from the condenser is supplied at the top of the cooling tower which is sprayed through the nozzles. Fan sucks the air from louvers and cools the water. The water in the air is eliminated by drift eliminator.

b

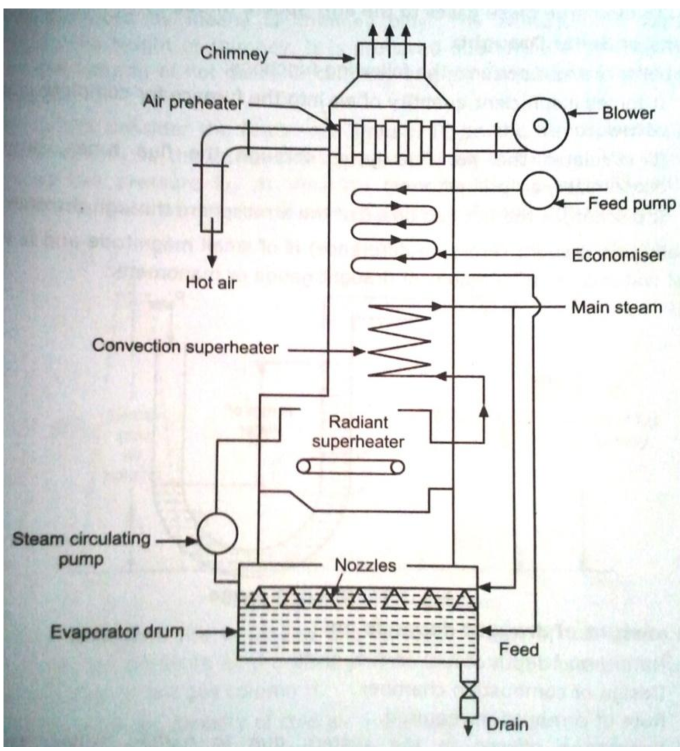


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Figure: Loeffler Boiler

		Construction : 1. Loeffler boiler consists of evaporator drum, which may be placed at any convenient point outside the furnace setting. 2. The evaporator drum which is used provided with set of nozzle through which steam enters in evaporator drum. 3. Nozzles are made of special design to avoid priming and noise. 4. The feed water pumps feed the water to economizer, which is placed in the path of flue gases. 5. This is water tube boiler using a forced circulation. 6. In this boiler water is heated mainly by means of superheated steam. 7. The steam will act as heat carrying and heat absorbing medium. 8. Thus, boiler uses the circulation of steam instead of water and difficulty of deposition of salt and sediment in boiler tubes is completely eliminated.	2
		Working: The economizer extracts sensible heat from flue gases and hot water 1. at temp. close to saturation temp. is passed to evaporator drum. 2. From super heater big portion of steam (about 3/4) is trapped off for external use and remainder portion (about 1/4) is passed to evaporator drum. 3. The steam from evaporator drum is passed to super heater through circulating pump. 4. The air preheater maybe placed in path of flue gases to supply the hot air in combustion chamber. Loeffler boiler has steam-generating capacity of 100 tons/hour at 140 bar pressure.	2
	C (i)	✓ **The main sources of air leakage found in condenser are given below:** 1) There is leakage of air from atmosphere at the joint of the parts which are internally under a pressure less than atmospheric pressure. 2) Air is also accompanied with steam from the boiler into which it enters dissolved in feed water. 3) In jet condensers, a little quantity of air accompanies the injection water.	3

	(ii)	Q. 6. C). Ans. → Given data :- Actual vacuum = 695 mm of Hg. Barometer reading = 760 mm of Hg. Inlet temp. of steam = 36 °c find. vacuum efficiency = ? from steam table saturation pressure at 35 °c is 0.0595 bar. Barometric pressure = 760 mm of Hg = 1.01325 bar Absolute pressure in condenser = 760 − 695 = 65 mm of Hg. $= \frac{65}{760} \times 1.01325 = 0.0866$ bar ∴ vacuum efficiency = $\frac{\text{Barometric Pr.} - \text{condenser Pr.}}{\text{Barometric Pr.} - \text{Pr. corresponding to condensation temp.}}$ $= \frac{1.01325 - 0.0866}{1.0325 - 0.0595}$ $= \frac{0.92665}{0.95375} = 0.97158$ = 97.158 %. So, The vacuum efficiency is 97.158 %.	3