WINTER-17 EXAMINATION

Model Answer

Subject title: Plant Utilities Subject code 17425

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.	Answer	Marking scheme
1 A	Attempt any six	12
1A-a	**Hard water**: Contains dissolved salts of calcium and magnesium. It does not produce lather with soap solution. **Soft water:** Does not contain dissolved salts of calcium and magnesium. It produces lather or foam with soap	1 1
1A-b	**Hardness of water can be measured by: (any 2)** 1. ppm(parts per million) 2. Milligrams/ litre 3. Clarke's degree **4.** Degree French	1 mark each
1A-c	**Coefficient of Performance** .: Working performance of any machine is usually expressed by output/input ratio known as efficiency. In refrigeration it is denoted by C.O.P. (β). COP= refrigeration effect/ work input to produced R.E. β =RE/W	2
1A-d	**Boiler mountings(any 2)** They are devices mounted on the boiler which are essential for the safe working of the boiler. 1. Water level indicator: To indicate water level inside the boiler. 2. Pressure gauge: To measure the pressure of steam inside the boiler	1 mark each

	3. Fusible plug: To put off the fire in the furnace of the boiler when the water level in the boiler falls below an unsafe level . 4. Safety valve: To prevent the steam pressure in the boiler from exceeding a predetermined maximum pressure for which the boiler is designed.	
1A-e	**Enthalpy of dry saturated steam.** It is the quantity of heat required to raise the temperature of 1 kg of water from the freezing point to the boiling point and then convert it into dry saturated steam at that temperature and pressure.	2
1A-f	**Advantage Of thermic fluid over steam:(any 2)** (1)High temperature can be obtained at moderate pressure (2) Have wide range of operation stability. (3) More economical at high temperature. (4) No pretreatment equipment is required when used in boiler (5) no heat loss (6) No risk of corrosion (7) Low maintenance cost (8) Quiet and easy to operate	1 mark each
1A-g	**i)Dry bulb temperature:** Temperature recorded by ordinary thermometer is called dry bulb temperature. **(ii)Wet bulb temperature:** It is the temperature indicated by thermometer whose bulb is covered with cotton or muslin wire wetted with moisture	1 1
1 B	**Attempt ant two**	8
1B-a	**Comparison between Zeolite process and lime soda process(any 4)**	1 mark each

	Zeolite process / **Lime soda process** Residual hardness is 10-15 ppm / Residual hardness is 15-50 ppm The quantities of sodium salts are increased / The quantities of sodium salts dissolved are lower. Cost of equipment and material is higher / Cost of equipment and material is lower Operating expenses are lower / Operating expenses are higher Not suitable for acidic water because zeolite undergoes disintegration / Can be used for any type of water Plant occupies less space / Plant occupies large space Water must be free from suspended impurities / Water containing suspended impurities can be used It does not involve problem of settling, coagulation, filtration and removal of sludge and precipitate / It involves process of settling, coagulation, filtration and removal of sludge and precipitate Soft water obtained contains more dissolved salts / Soft water obtained contains less dissolved salts Zeolite can be reused / Lime-soda is used in the process	
1B-b	**Selection criteria for refrigerant** : 1. Working pressure range and pressure ratio. The pressure required to be maintained in the evaporator and condenser should be low enough to reduce the material cost and must be positive to avoid leakage of air into the system. 2. Corrosiveness and flammability: Non corrosive to mechanical components. It should be safe to operate(including non-toxic,	1 mark each for any 4

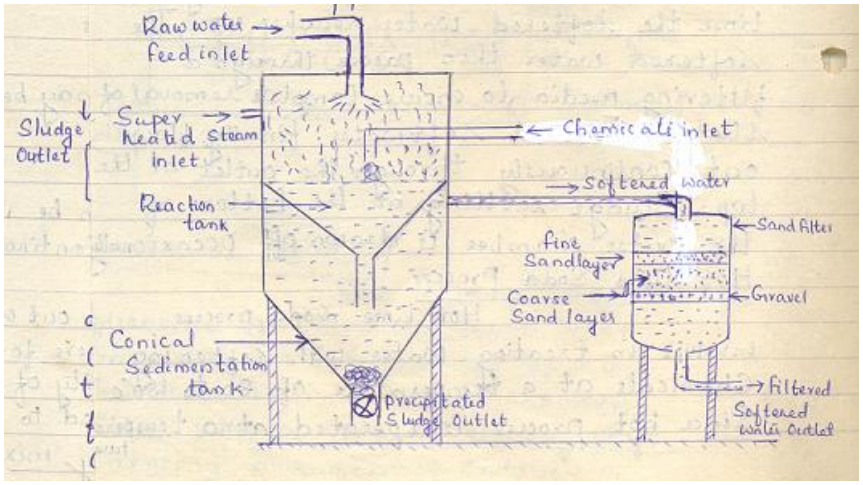
nonflammable)

3. Space limitations: It should have low specific volume to reduce the size of the compressor.
4. Temperature required in the evaporator: It should have low boiling point and low freezing point.
5. Oil miscibility. It should have high miscibility with lubricating oil and it should not have reacting property with lubricants.
6. It should not have any bad effect on the stored material or food when any leak develops in the system.
7. It should have low thermal conductivity to reduce the area of heat transfer in the evaporator and condensers.
8. It should have high critical pressure and temperature to avoid large power requirement.
9. It must have low specific heat and high latent heat.
10. It should have moderate density in liquid form, a relatively high density in gaseous form.

1B-c **Comparison between fire tube and water tube boiler:** — 1 mark each for any 4

Particulars	Fire tube	Water tube
Position of water and hot gases	Hot gases inside the tube and water outside the tubes	water inside the tube and hot gases outside the tubes
Mode of firing	Generally internally fired	Externally fired
Operating pressure	Limited to 16 bar	Can work under as high as100 bar

	Rate of steam production	Lower	Higher	
	Suitability	Not suitable for large power plants	suitable for large power plants	
	Risk on bursting	Involves lesser risks due to lower pressure	Involves more risks due to higher pressure	
2	**Attempt ant four**			16
2-a	**Hot lime soda process**			1



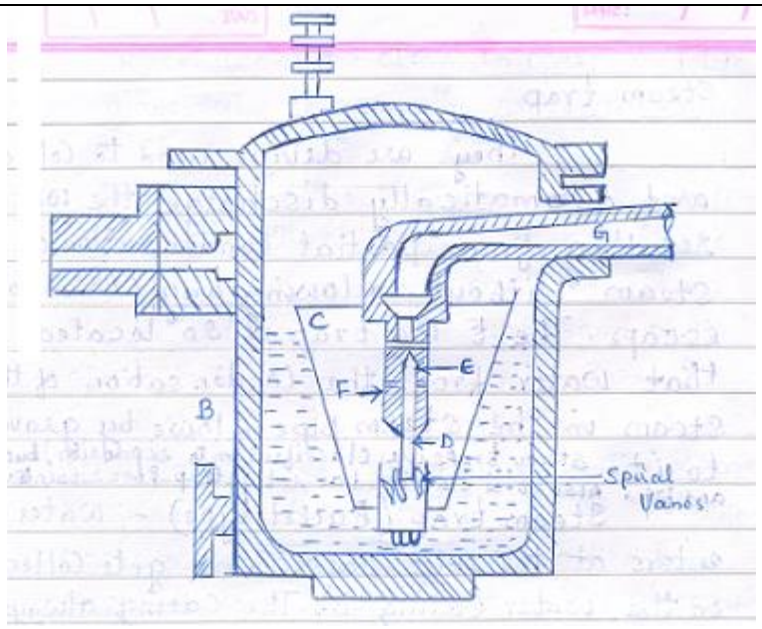
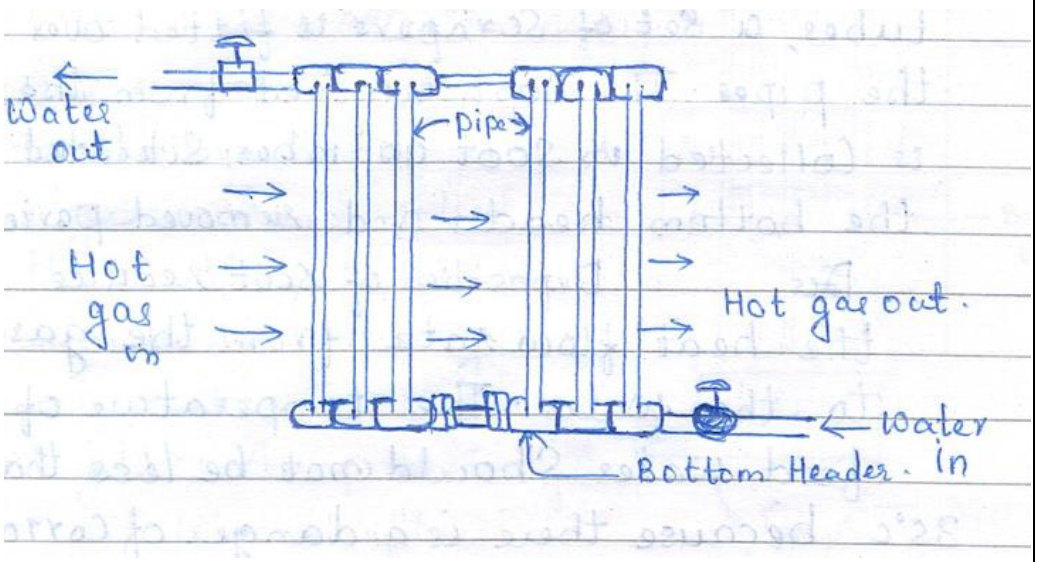
It consists of a

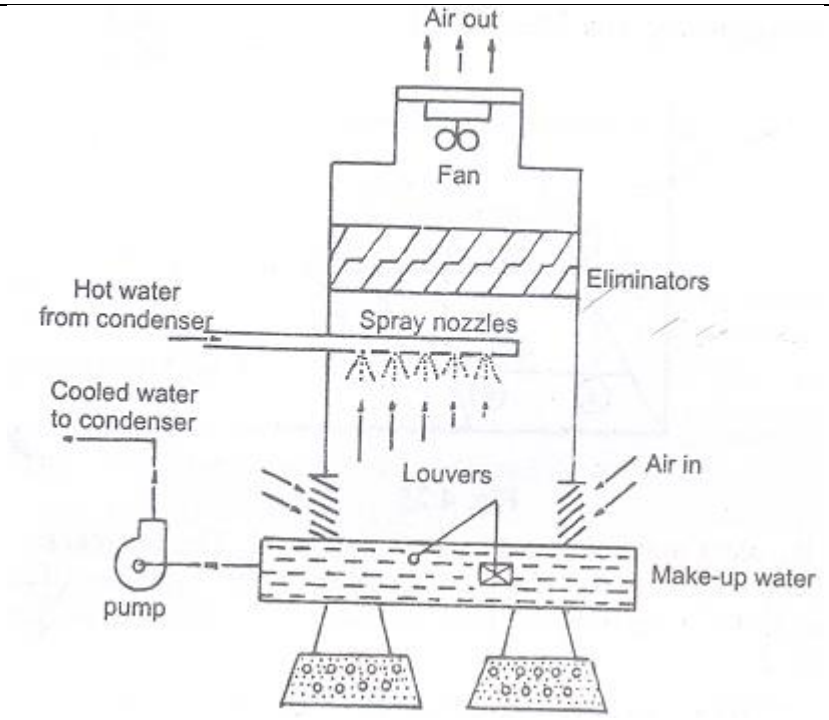
1. Reaction tank in which raw water, chemicals (slaked lime and soda ash) and steam are thoroughly mixed at 80-100^{0}c.
2. Conical sedimentation vessel in which the sludge settles down
3. Sand filter which ensures complete removal of sludge from the softened water. 1

The reactions are

$2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$

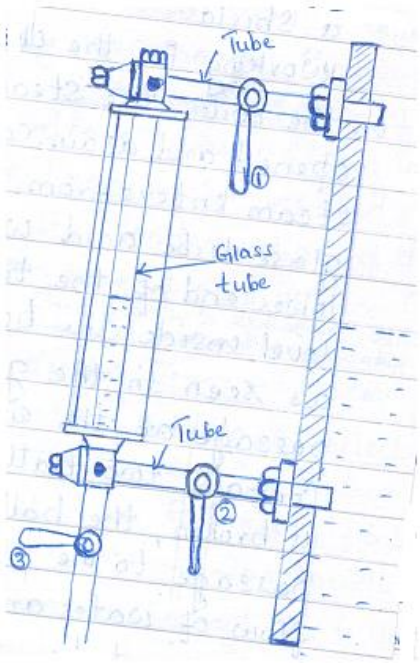
	$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$ $MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCl_2$ $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$	2
2-b	**Dry ice:** Solid carbon dioxide is called dry ice. **Unit of refrigeration** is **Ton of refrigeration**: It is defined as the quantity of heat required to be removed from 1Ton water at 0^oC to get ice at 0^oC in one day	1 1 2
2-c	**Boiler accessories: (any 2)** i)air preheater ii)economizer ii) super heater iv)feed pump v)steam injector. vi) pressure reducing valve vii) steam trap	1 mark each 2 mark for any one

	 Steam trap  Economiser ***Any other diagram of boiler accessories should be given mark***	diagram
2-d	**Induced draft cooling tower**:	4

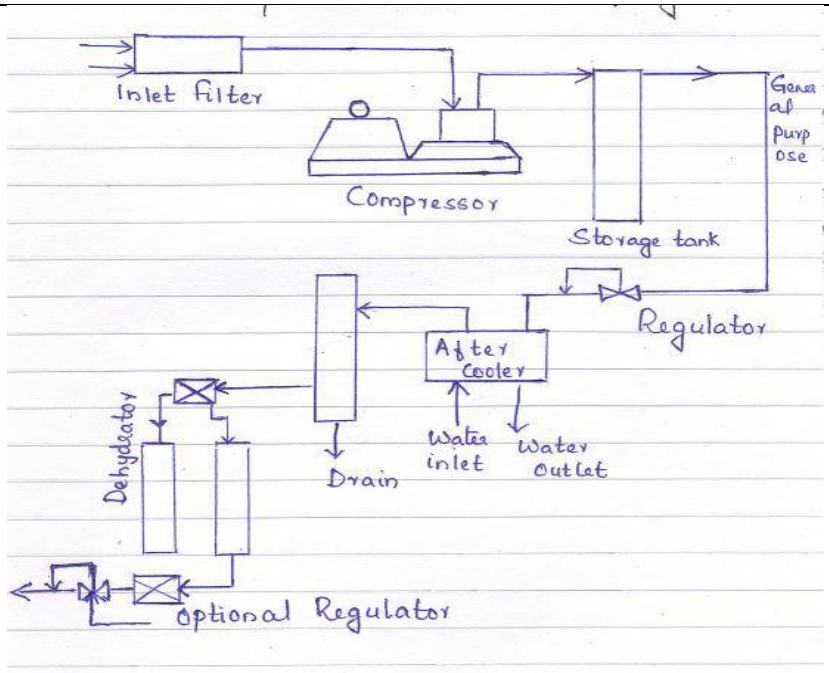
		
2-e	**Humidification:** i)if unsaturated air is passed through a spray of continuously recirculated water the specific humidity will increase while the dry bulb temp. decrease .this is the process of adiabatic saturation or evaporative cooling . ii)If water is added to air without any heat supply the state of air changes adiabatic along a constant enthalpy line - h - in the Mollier or psychrometric chart. The dry temperature of the air decreases. **Dehumidification:** i)The process in which the moisture or water vapor or the humidity is removed from the air keeping its dry bulb (DB) temperature constant is called as the dehumidification process. ii)This process is represented by a straight vertical line on the psychrometric	2 2

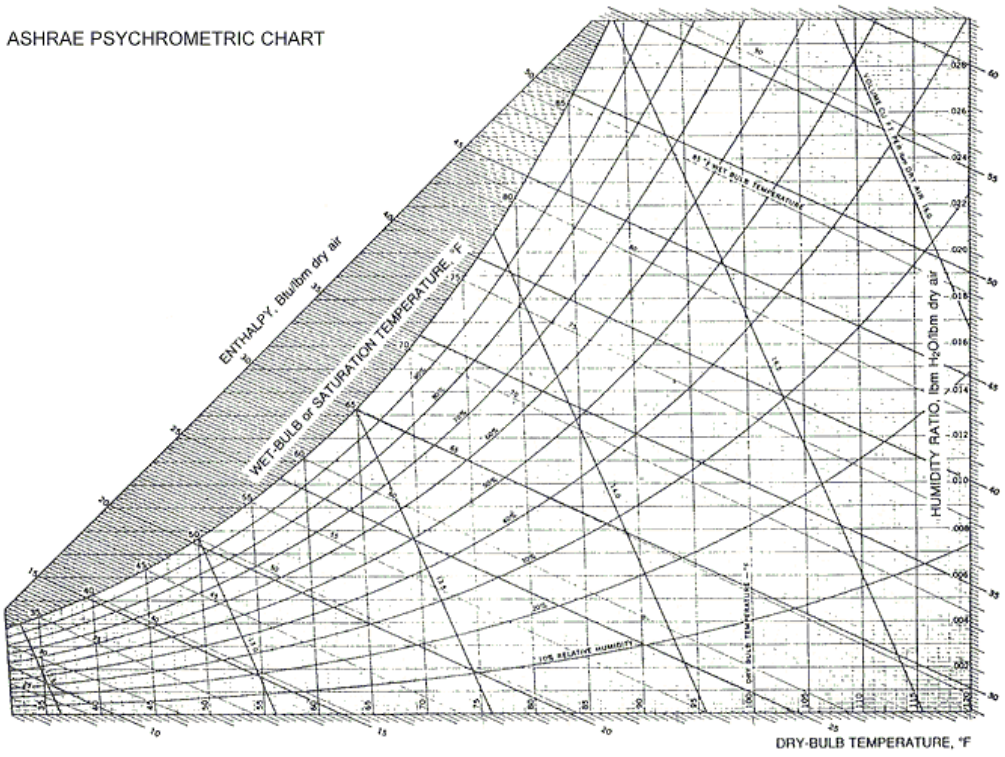
	charts starting from the initial value of relative humidity, extending downwards and ending at the final value of the relative humidity. Like the pure humidification process, in actual practice the pure dehumidification	
2-f	**Removal of Temporary hardness:** **Pre boiling of water**: Temporary hardness is developed in water due to the presence of dissolved bicarbonates of of calcium and magnesium. It is destroyed by boiling of water. Heat $Ca(HCO_3)_2$ -----.$CaCO_3 + H_2O + CO_2$ heat $Mg(HCO_3)_2$ -----. $Mg(OH)_2 + 2\ CO_2$ **Removal of Permanent hardness:** These are due to the presence of chlorides and sulphates of Ca and Mg. Removal methods are: **i)** Lime soda process: $2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$ $H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2H_2O$ $Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$ $Mg(HCO_3)_2 + 2\ Ca(OH)_2 \rightarrow 2CaCO_3 + Mg(OH)_2 + 2H_2O$ $MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCl_2$ $MgSO_4 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaSO_4$ $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$ $CaSO_4 + Na_2CO_3 \rightarrow CaCO_3 + Na_2SO_4$ **ii) Zeolite process** $CaCl_2$ (or Ca SO_4) + $Na_2Ze \rightarrow CaZe + 2NaCl$ (or Na_2SO_4) $MgSO_4$ (or $MgCl_2$) + $Na_2Ze \rightarrow MgZe + Na_2SO_4$ (or 2NaCl)	2 2 marks for any one method

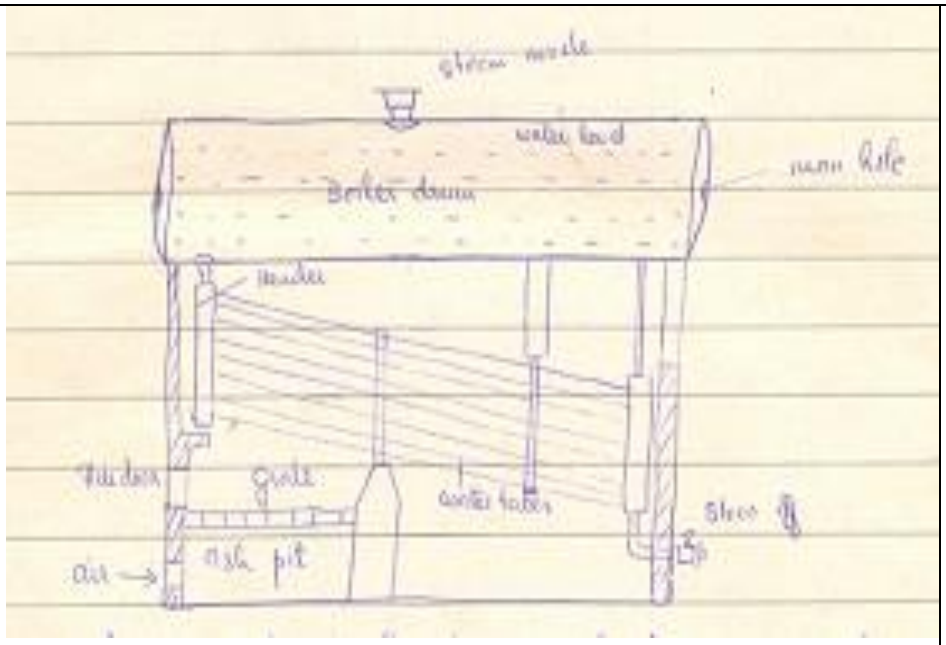
	$Ca(HCO_3)_2$ (or $Mg(HCO_3)_2$) + $Na_2Ze \rightarrow CaZe$ (or MgZe) +2 $NaHCO_3$ **iii) Ion exchange process:** $RCa + 2HCl \text{----}\rightarrow RH_2 + CaCl_2$ $RMg + 2HCl \text{---}\rightarrow RH_2 + MgCl_2$ $R'SO_4 + 2NaOH \text{--}\rightarrow R'(OH)_2 + Na_2SO_4$ $R'Cl_2 + 2NaOH \text{--}\rightarrow R'(OH)_2 + 2NaCl$	
3	**Attempt any four**	16
3-a	**Ecofriendly refrigerant**: Eco-friendly refrigerants: Secondary refrigerants used as eco friendly refrigerants. The heat carried by the secondary refrigerants from the generating sources is given to the refrigerant in the evaporator and recirculated again and again Example: air , water and brines solution (NaCl , LiBr) **Advantages:** It is eco-friendly Can be used again and again Low cost Easily available. It is pollution free	2 1 ½ mark each for any 2
3-b	Water level indicator:	

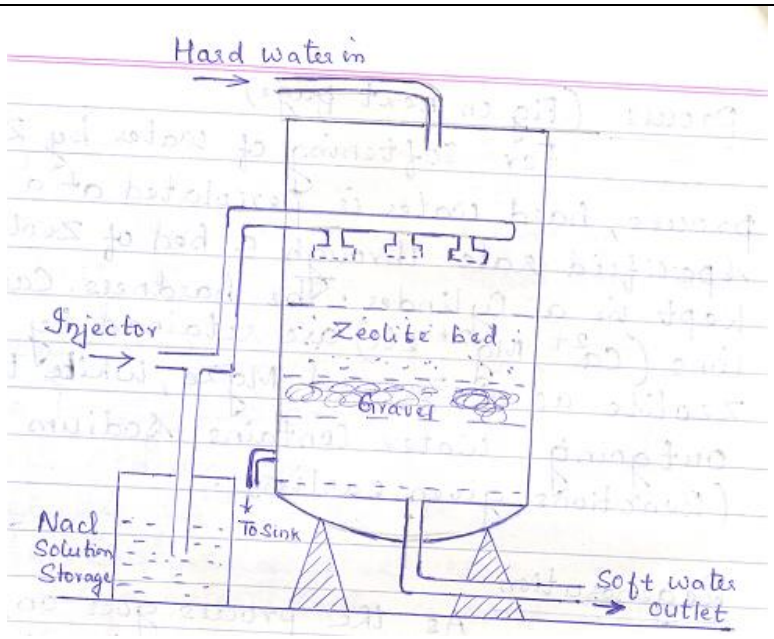
	 **Functions & importance:** Its function to indicate water level in boiler. Usually two water level indicator are fitted to in front of boiler. WLI shows the water level in in the boiler drum and warns to operator it by chance the water level goes below a fixed mark , so that corrosive action may be taken in time to avoid accident.	2 2
3-c	**Air requirement for instrumentation**: Instrument Air means an extremely clean supply of compressed air that is free from contaminates such as moisture & particulates. Importance: A system may utilize instrument air for various types of pneumatic equipment, valves & electrical controls. High efficiency filtration eliminates issues with pneumatic valves and electrical/pneumatic controls caused by suspended liquids, such as compressor	4

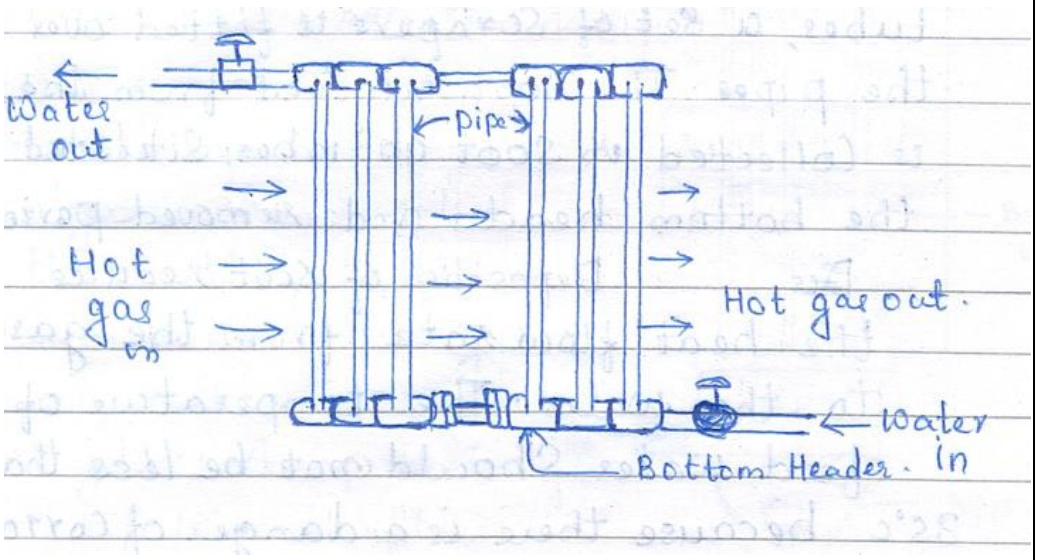
	oil and particulates that are often present in plant air, or also known as service air. By utilizing filtration, supplying instrument air when needed ensures the proper functioning of equipment, valves, and controls, and possibly preventing failure of these components.	
3-d	**Instrument air:** Air is passed through a filter to remove suspended impurities. The filtered air is supplied to the compressor. Discharge from the compressor will be at a pressure of 100 to 150 psi, which is stored in a storage tank. When required it is passed through a regulator and then through an after cooler to remove the heat. It is then passed through a stone filter to remove traces of oil if present. Filtered air is passed through dehydrator to remove the moisture. Silica gel, activated alumina, calcium chloride, glycol etc are used for removing the moisture. A second pressure regulator is sometimes added to provide a constant reduced pressure in the supply line.	2

		2
3-e	**Psychrometric chart:** 1. The DBT of unit mass of dry air for different humidity contents or humidity ratios are indicated by vertical lines drawn parallel to the ordinate. 2. The mass of water vapors in Kg. per Kg. of dry air is drawn parallel to the abscissa for different values of DBT. It is the major vertical scale of the chart. 3. Pressure of water vapor in mm of Hg. is shown in the scale at left and is the absolute pressure of steam. 4. Dew point temperatures are temp. corresponding to B.P of water at low Pressure of water vapor and are shown in the scale of the upper curved line. the dew pt. for different low pressure are read on diagonal co-ordinate. 5. Constant R.H. lines in percent are indicated by making off vertical distance	4

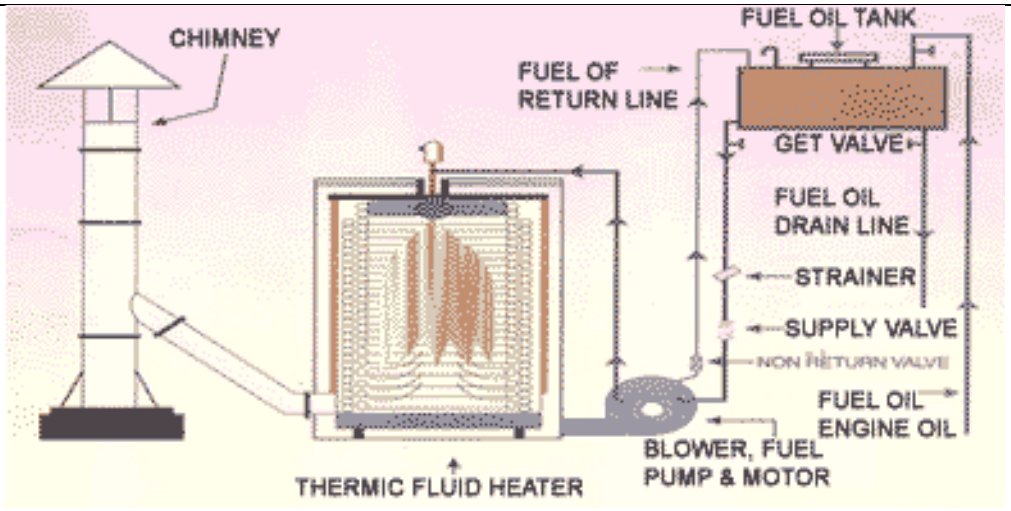
	between the saturation line or the upper curved line and the base of chart. Enthalpy in KJ/Kg of dry air is shown by a diagonal system of co-ordinates. 	
3-f	**Babcock and Wilcox boiler**	4

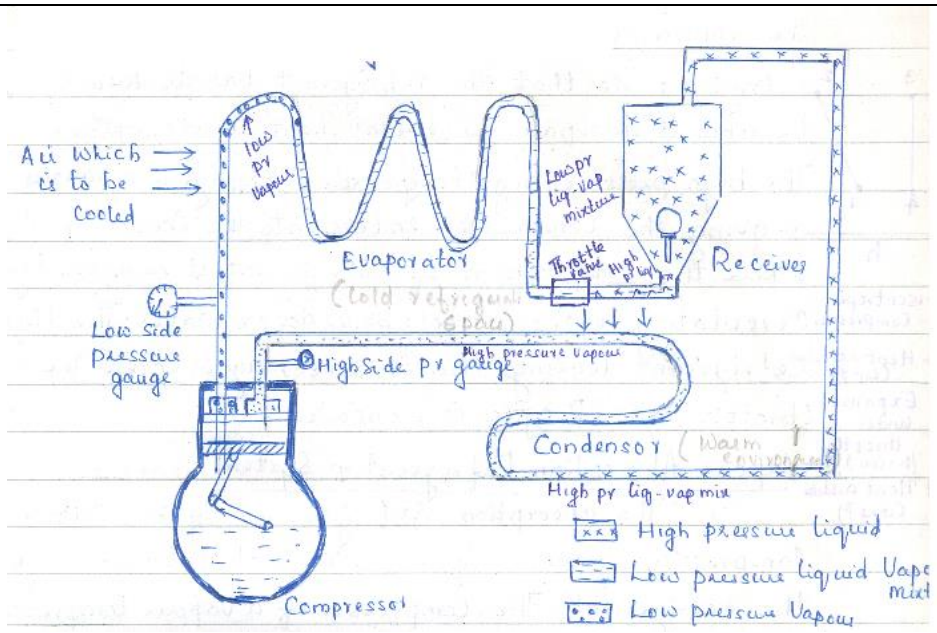
		
4	**Attempt any four**	16
4-a	**Methods of water softening** : 1. Pre-boiling of water 2. Lime-Soda process 3. Zeolite or permutit process 4. Ion-exchange process . **Zeolite process for water softening:**	2

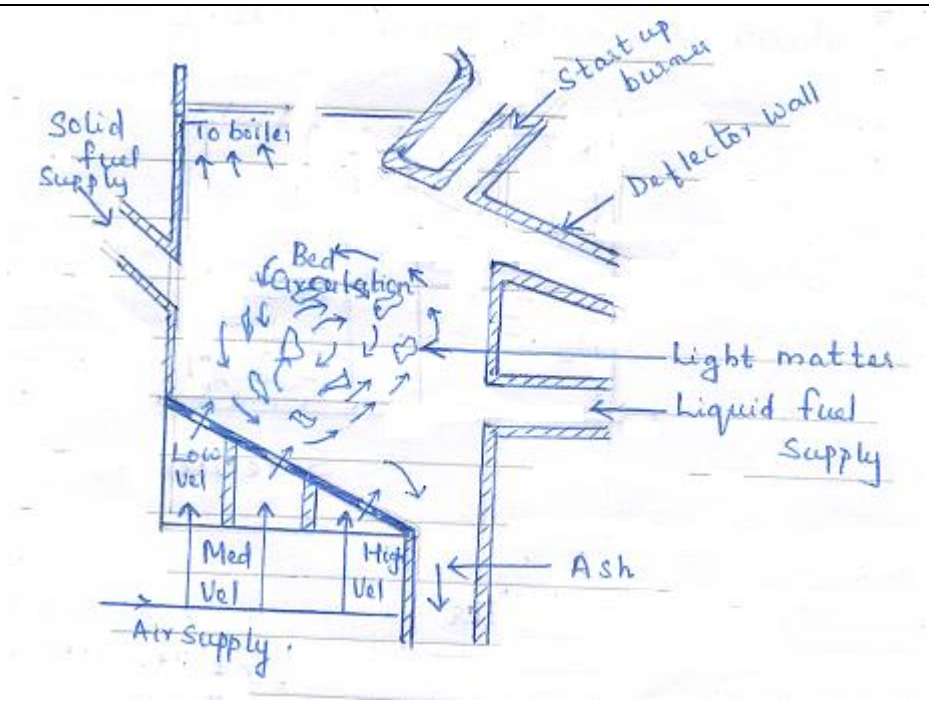
	 Hard water is percolated at a specified rate through a bed of zeolite, kept in a cylinder. The hardness causing ions(Ca^{2+} , Mg^{2+} etc) are retained by the zeolite as CaZe and MgZe, while the outgoing water contains sodium salts. Reactions are $CaCl_2$ (or Ca SO_4) + Na_2Ze → CaZe + 2NaCl (or Na_2SO_4) $MgSO_4$ (or $MgCl_2$) + Na_2Ze → MgZe + Na_2SO_4 (or 2NaCl) Ca $(HCO_3)_2$ (or Mg $(HCO_3)_2$) + Na_2Ze → CaZe (or MgZe) +2 $NaHCO_3$	2
4-b	**Primary refrigerant:** Primary refrigerants directly take part in the refrigeration system. Examples(any 2) a)halocarbon compound e.g. ethyl chloride , methyl chloride etc. b)azeotropes F- 152 c) hydrocarbon methane , ethane	1 ½ mark each

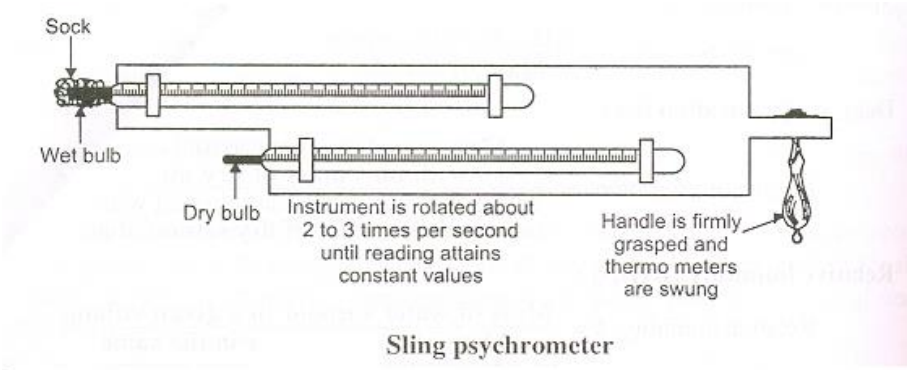
	d)inorganic compound ammonia , water e) unsaturated org. compound : ethylenr , propylene **Secondary refrigerants:** Secondary refrigerants are first cooled with the help of primary refrigerants and are further used for cooling purpose. Examples(any 2) a) Air b) water c) brines solution	1 ½ mark each
4-c	**Economizer:** **Importance:** Economizer is used to recover some of the heat from the heat carried away in the flue gases up the chimney and utilize for heating the feed water to the reboiler. By its use, fuel is economized and steaming rate is increased.  	2 2
4-d	**Industrial uses of air:**	½ mark

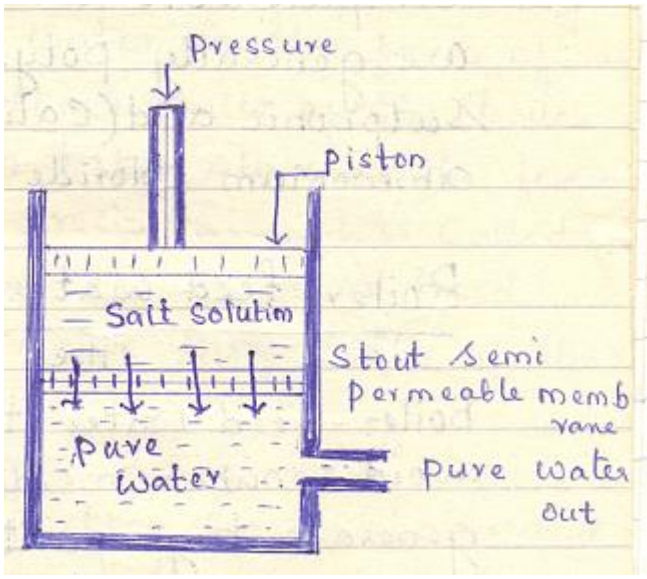
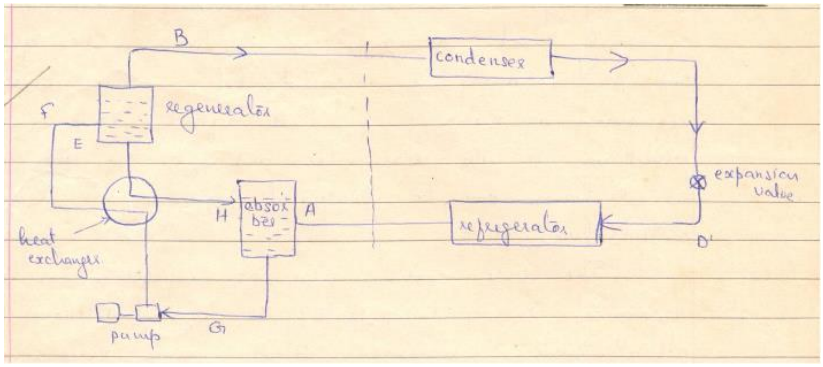
	i) Cleaning automobiles and workshops. ii) Starting I.C. engine. iii) Spraying fuel in high speed diesel engine. iv)Spraying paints in paint industry. v)Construction of bridges, roads, dams, structural work , sewage and tunnels vi) Cooling of large buildings. vii)Operation of pneumatic drills, wrenches, air motors, hammers, also for riveting and tightening nuts etc. viii) Supercharging I.C. engine and in working of gas turbine plants	each
4-e	**Thermic fluid heater:** It is the heater where thermic fluid is used. **Working** From fuel tank the oil goes to a fuel filter then into a fuel pump. Through the fuel pump it is passed into an electrically heated oil pre-heated tank and then forced to burner. The thermic fluid heater is supplied with pressure-jet burner of highly compact rugged and simple design. The burner is fully automatic in operation and switches ON and OFF as per the process heat requirements.	2

		2
4-f	T1 = 35 + 273 = 303 K T2 = -20 + 273 = 263 K C.O.P. = T2/(T1-T2) = 263/(303-263) = 4.6 C.O.P = **6.575**	1 1 1 1
5	**Attempt any four**	16
5-a	**Vapour compression cycle** :	2 marks for diagram and 2 marks for labeling

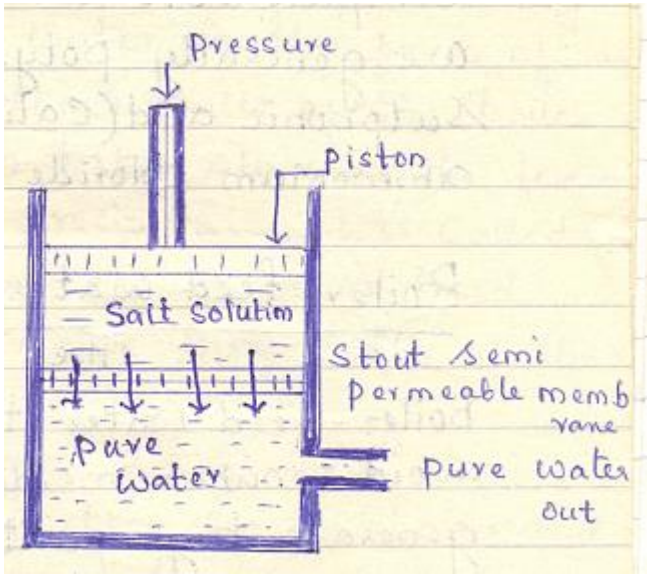
		
5-b	**Boiler act:** Indian boiler act 1923 insists on the registration and regular inspection of all the boilers in the country except those installed in ships or under the control of railway and military. This act is applicable to all the boilers, feed pipes, steam pipes and all economizers. **Duties of boiler inspector**: 1. Confirm all boilers are registered. 2. Make sure that all boilers are working according to the act. 3. Check and examine boilers, their parts and mountings etc. 4. Advise the employer of boiler regarding the matters of boiler maintenance, cleaning etc.	2 2
5-c	**Fluidized bed boiler:**	2

	 **Application:** 1. Used in coal burning power plants and heating plants 2. Biomass power plants and heating plants 3. Power plants and heating plants using combined combustion of different types of fuel.	1 mark each for any 2
5-d	**Caustic embrittlement:** It is a type of boiler corrosion caused by using highly alkaline water in the boiler. In high pressure boiler, sodium carbonate decomposes to give NaOH and CO_2 and this makes boiler water caustic. NaOH containing water flows in to the minute hair cracks always present in the inner side of the boiler by capillary action. Here water evaporates and the dissolved caustic soda concentration increases progressively. This caustic soda attacks the surrounding are, thereby dissolving iron of the boiler as sodium ferroate. This	2

	causes embrittlement of boiler parts; particularly stressed parts like bends, joints, rivets etc causing even failure of the boiler. **Foaming:** It is the phenomenon of formation of foam or bubbles on surface of water which do not break easily. **Priming:** It is a phenomenon caused by very rapid boiling of water inside the boiler with the result that the water particles get mixed up with steam. It is due to the presence of large quantities of dissolved organic oily matter, suspended material etc.	1 1
5-e	**Sling psychrometer**  Sling psychrometer Sling psychrometer consist of two thermometers mounted on base plate. The one with the sock is wet bulb thermometer and the other is dry bulb. The handle of the frame helps for rotating the psychrometer to produce necessary air motion. As the psychrometer is rotated , it provides necessary air velocity over the thermometer. The temperature spread between dry bulb and wet bulb readings depends upon the amount of moisture in the air.	4

5-f	**Desalination:** The process of removing extra common salt from water known as desalination. Reverse osmosis is employed for desalination process.  In this process, pressure of the order of 400 * 10^4N/ m^2 is applied to the impure water / seawater to be treated to force its pure water out through the semi permeable membrane, leaving behind the dissolved salts.	4
6	**Attempt any TWO of the following**	16
6-a	**Vapour Absorption Refrigeration system**  	

	In absorption system the compressor in the vapor compression cycle is replaced by an absorber- generator assembly involving less mechanical work. Ammonia is the refrigerant and water is the absorbent. Ammonia vapor is vigorously absorbed in water. So low pressure ammonia vapor from the evaporator comes in contact in the absorber with a weak solution coming from the generator, it is readily absorbed releasing the latent heat of condensation. The temperature of the solution tends to rise, while the absorber is cooled by the circulating water , absorbing the heat of solution, Q_A and maintaining a constant temperature. Strong solution, rich in ammonia, is pumped to the generator where Q_G is supplied from an external source like steam, electricity etc. Since the boiling point of ammonia is less than that of water, the ammonia vapor is given off from the aqua- ammonia solution at high pressure and the weak solution returns to the absorber through a pressure reducing valve. The heat exchanger preheats the strong solution and cools the weak solution, reducing both Q_A& Q_G. The ammonia vapor then condenses in the condenser, is throttled by the expansion valve, and then evaporates absorbing the heat of evaporation from the surroundings	4 4
6-b	**Membrane Technology:** It is a selective separation process using a membrane. The membrane allows only selective molecules to pass through it while rejecting the permeation of others. **Description of reverse osmosis process:** When two solutions of unequal concentrations are separated by a semi permeable membrane and if a hydrostatic pressure in excess of osmotic pressure is applied on the concentrate side, the solvent is forced to move from	2 4

	the concentrated side to dilute side across the membrane. This is known as reverse osmosis. The effectiveness of the process depends on the density of the membrane. It is also important that the membrane be cleaned regularly for proper functioning. Membranes are made of cellulose acetate, polymethacrylate, polysulphone, polyamide polymers etc. Reverse osmosis is employed for desalination process  In this process, pressure of the order of 400 * 10^4N/ m^2 is applied to the impure water / seawater to be treated to force its pure water out through the semi permeable membrane, leaving behind the dissolved salts. **Application:** 1. For desalination of brackish water. 2. For treating liquid effluents 3. Purifying water for food and pharmaceutical industries. 4. In dairy, starch and sugar industries	1 mark each for any 2 application
6-c	From steam table, corresponding to a pressure of 10 bar,	

	Specific enthalpy of saturated water hf = 762.6 KJ/ Kg Enthalpy of evaporation hfg = 2013.6 KJ/ Kg Specific entropy of water Sf= 2.138 KJ/ KgK Entropy of evaporation Sfg= 4.445 KJ/ KgK	2
	(i) When steam is dry and saturated Enthalpy of 1 kg of steam = hf + hfg = 762.6 + 2013.6 = **2776.2 KJ** Entropy of 1 kg of steam = Sf + Sfg = 2.138 + 4.445 = **6.583 KJ /K**	3
	(i) When steam is 75% dry Enthalpy of 1 kg of steam = $h_f + x\, h_{fg}$ = 762.6 + 0.75* 2013.6 = = **2272.8 KJ**	3
	Entropy of 1 kg of steam = $S_f + xS_{fg}$ = 2.138 + 0.75*4.445 = **5.47175 KJ /K**	