SUMMER-18 EXAMINATION

Model Answer

Subject title: Plant Utilities Subject code 17425

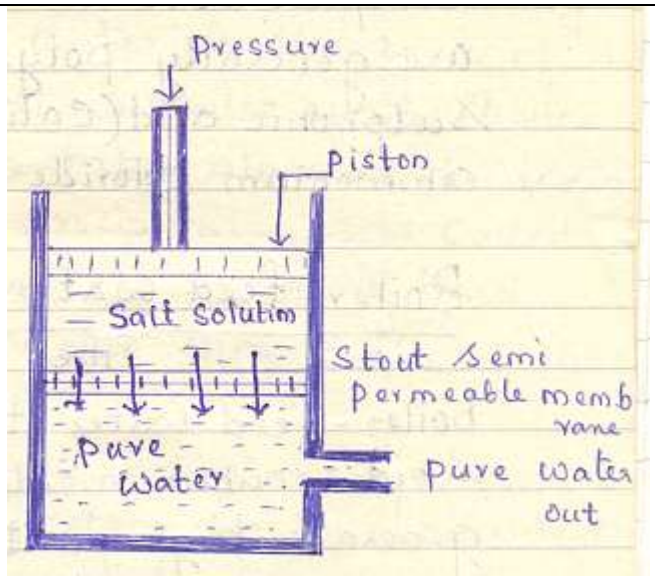
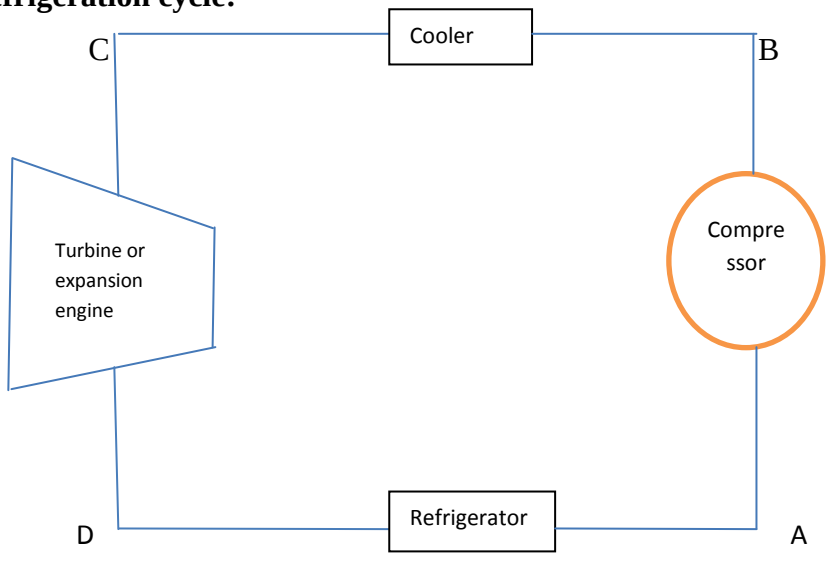
Important Instructions to examiners:

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.

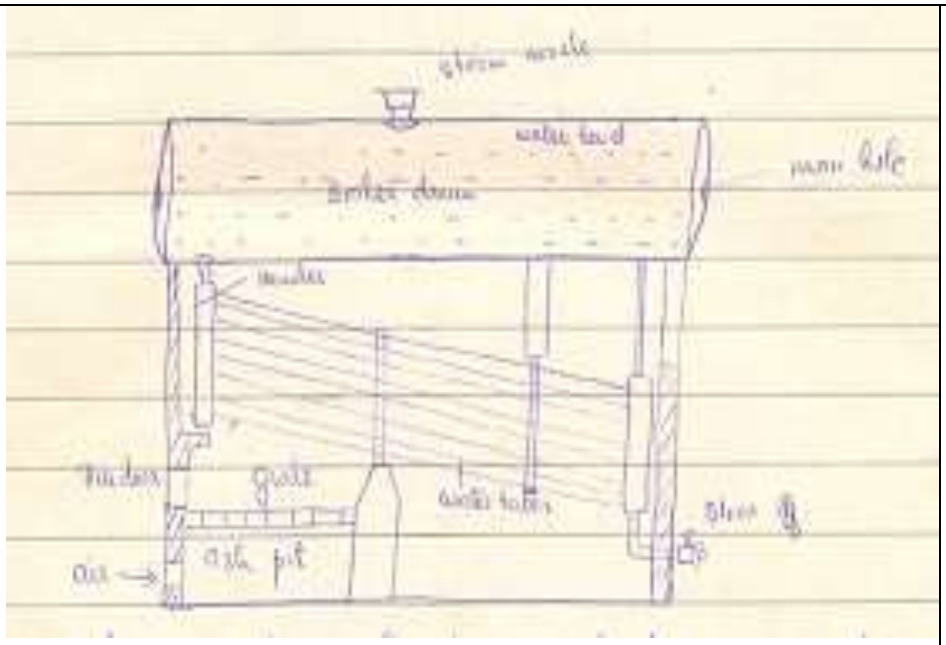
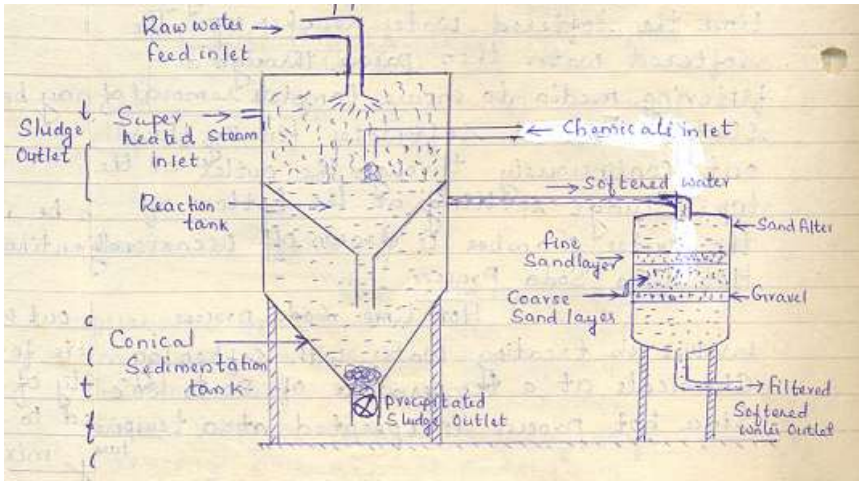
Q No.	Answer	Marking scheme
1 A	**Attempt any six**	**12**
1A-a	**Demineralization:** It is a method for treatment of water by which all the impurity ions present in the water are removed.	2
1A-b	**Scale and sludge formation:** When hard water is evaporated in boiler, the concentration of soluble salts of calcium and magnesium reaches saturation point and they are thrown out along with other soluble impurities in the form of precipitate. If the precipitate forms a hard adhering coating on the inner walls of the boiler, it is called scale. If the precipitation takes place in the form of loose and slimy precipitate, it is called sludge. They are formed at comparatively colder portions of the boiler where the flow rate is low.	2
1A-c	**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 **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. (ß). COP= refrigeration effect/ work input to produced R.E. ß =RE/W	1 1

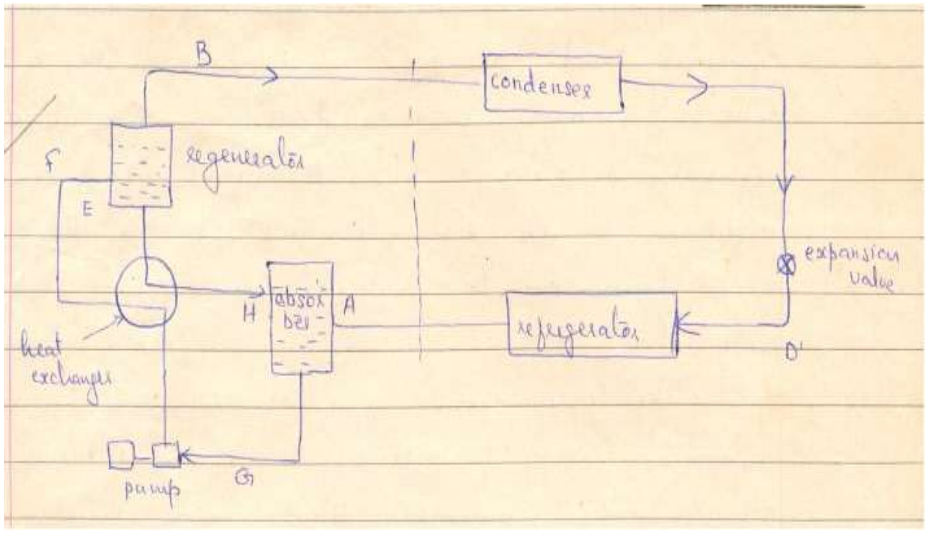
1A-d	**Boiler accessories: (any 2)** i)air preheater ii)economizer ii) super heater iv)feed pump v) steam injector. vi) pressure reducing valve vii) steam trap	1 mark each
1A-e	**Methods for removal of scales: (any 2)** Scales can be removed 1. With the help of scraper or piece of wood or wire brush, if they are loosely adhering. 2. By giving thermal shocks ,if they are brittle. 3. By dissolving them by adding some chemicals, if they are adherent and hard. 4. By frequent blow down operation, if they are loosely adhering	1 mark each
1A-f	**Uses of process air: (any 2)** 1. In the oxidation of acetaldehyde to acetic acid 2. Oxidation of NO to NO_2 in manufacture of HNO_3 3. In H_2SO_4 manufacture 4. In spray painting 5. In furnace 6. In refrigeration system 7. In boiler 8. In petroleum refining and petrochemical process	1 mark each

1A-g	Different thermic fluids are: (any 4) 1. Dowtherm A 2. Dowtherm E 3. Therminol FR 4. Oil mobiltherm 600 5. Oil Mobiltherm light 6. Hydrotherm 750-200	½ mark each
1 B	**Attempt ant two**	8
1B-a	**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 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	2

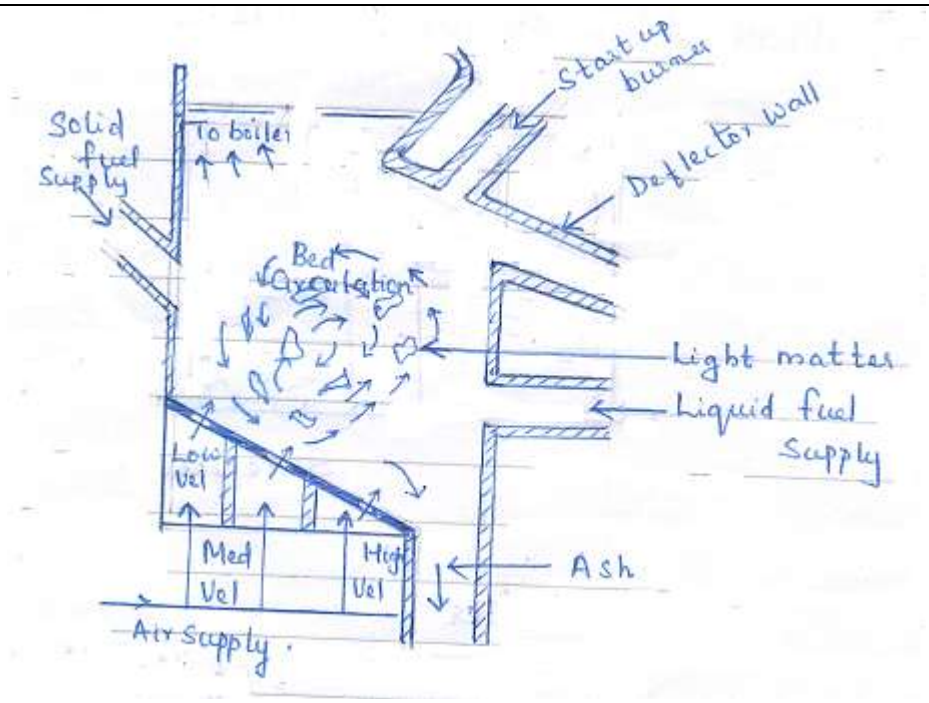
	 In this process, pressure of the order of 400 * 10^4N/ m^2 is applied to the impure water / seawater to be treated to force its pure water out through the semi permeable membrane, leaving behind the dissolved salts.	2
1B-b	**Air refrigeration cycle:** 	4

	This cycle ABCD can be used to produce refrigeration. In this, air absorbs heat essentially at constant pressure P1 in the cold space, and rejects heat to the surroundings in the cooler at the higher constant pressure P2. The gas is compressed at constant entropy from A to B, using part of the necessary energy of work obtained from expansion process CD. In both the refrigerator and cooler the heat must be transferred through a gas film having low heat transfer coefficients and hence temperature difference between air and refrigerator must be relatively large. The net result is that the difference in temperature between the air and the cooler and that in the refrigerator for a given refrigeration requirement is increased and the efficiency is decreased. The air refrigeration machine includes an expansion device in addition to the compressor normally used in common vapour compression, evaporating liquid cycles. Relatively large quantities of air must be handled in these expansion and compression process in order to achieve significant amount of refrigeration.	
1B-c	**Babcock and Wilcox boiler**	

		4
2	**Attempt ant four**	16
2-a	**Hot lime soda process**  It consists of a 1. Reaction tank in which raw water, chemicals (slaked lime and soda ash) and	1

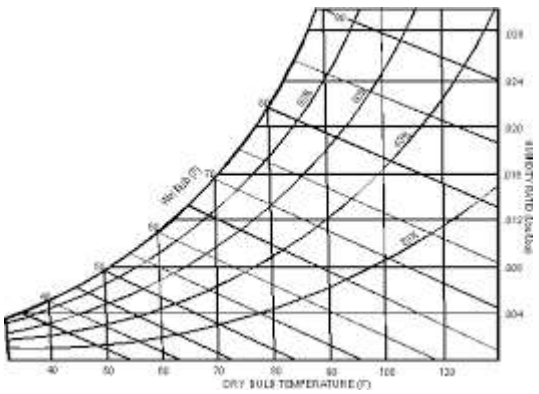
	steam are thoroughly mixed at 80-100^{0}c. 2. Conical sedimentation vessel in which the sludge settles down 3. Sand filter which ensures complete removal of sludge from the softened water. In this process, raw water is treated with softening chemicals at a temperature of 80^{o}C to 100^{o}C. At this temperature, the chemical reactions are much faster than in cold process. It requires less storage capacity tanks. In this process, the dissolved gases are driven out due to high temperature. The reactions are $2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$ $Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$ $MgCl_2 + Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCl_2$ $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$	1 2
2-b	**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.	2

	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	2
2-c	**Fluidized bed boiler:**	

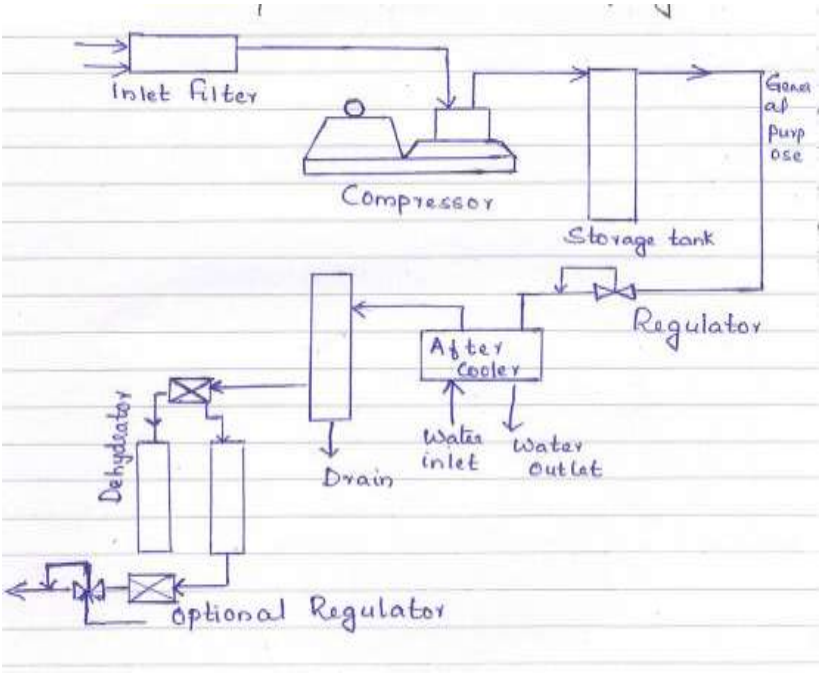
		4
2-d	**Construction of cooling tower:** A cooling tower is a heat rejection device which rejects waste heat to the atmosphere through the cooling of water stream to a lower temperature. Cooling towers may either use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature or, in the case of closed circuit dry cooling towers, rely solely on air to cool the working fluid to near the dry-bulb air temperature. In natural draft deck type tower, water distributing through are used which help to break the water into small droplets. In Forced draught — A mechanical draft tower with a blower type fan at the intake, the water from the condenser is sprayed at the top of the tower and air is forced by the blower from the bottom of the tower. The fan forces air into the tower, creating high entering and low exiting air velocities.	4

	The low exiting velocity is much more susceptible to recirculation. With the fan on the air intake, the fan is more susceptible to complications due to freezing conditions. The benefit of the forced draft design is its ability to work with high static pressure. Such setups can be installed in more-confined spaces and even in some indoor situations. This fan/fill geometry is also known a blow through	
2-e	**Advantages of multistage compression** 1.Interstage cooling can be provided thereby reducing the discharge gas temperature. 2. Work done in compressing the air is reduced, thereby saving the power. 3.The suction and delivery valve remains in cleaner condition as the temperature and vaporization of lubricating oil is less. 4. Prevents mechanical damage as air temperature is controlled. 5.Better mechanical balance and uniform torque 6.Reduced leakage loss swing to reduce pressure difference in either side of piston and valve. 7. Less difficulty in lubrication. 8. Lighter cylinders.	1 mark each for any 4
2-f	**Boiler corrosion by dissolved oxygen:** Dissolved oxygen can destroy the protective hydrogen film that can form of many metals and oxidize dissolved ions into insoluble forms. Deposits of rust in a plumbing system is such an example of differential aeration cells and accelerate corrosion.	2

	1. Corrosion due to dissolved oxygen (DO) $2\,Fe + 2\,H_2O + O_2 \longrightarrow 2\,Fe(OH)_2\downarrow$ $4\,Fe(OH)_2\downarrow + O_2 \longrightarrow 2\,[Fe_2O_3.2H_2O]\downarrow$ Ferrous hydroxide — Rust **Prevention of corrosion:** 1. Mechanical de aeration 2. Chemical degasification	2
3	**Attempt any four**	16
3-a	**R-22** is monochlorodifluoromethane(CHClF2) or Freon-22 **Properties of R-22:** 1. Stable 2. Non toxic 3. Non corrosive 4. Non irritating 5. Non inflammable 6. Boiling point 0f -40.80C at atmospheric pressure Good solubility in oil up to -100C 0C **Properties of lithium bromide:** 1. The freezing temp. of the brines is lower than the freezing temp. of the water 2.Freezing temp. decreases with increase in the salt concentration up to eutectic temp.. 3.It is eco-friendly refrigerants.	½ mark for any 4 ½ mark for any 4

	4. More corrosive. 5. Less toxicity.	
3-b	**Preparation of boiler for inspection** : Boiler is inspected before the certificate for its operation is given to its employer. Before inspecting the boiler 1. It is cleaned 2. All fittings such as burners etc. are removed 3. Valves and cocks are opened. 4. An inspector examine the all parts of boiler , carries the hydraulic test , where the boiler pressure is raised to hydraulic pressure 1.5 psi or working pressure + 50 psi. (or 3.5 kg/ sq. cm) When the hydraulic test pressure reaches the boiler is inspected for water leakage if any.	4
3-c	**Humidity chart**  The dry bulb temp. is indicated by vertical lines drawn parallel to the ordinate. The mass of water vapour in kg per kg of dry air is drawn parallel to the	4

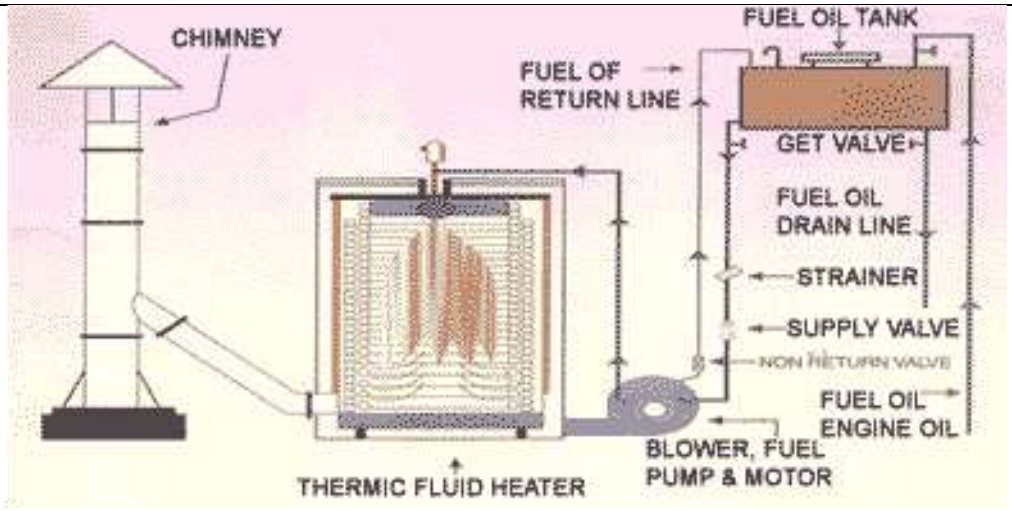
	abscissa for different valued of dry bulb temp. Pressure of water vapour in mm of Hg is shown in the scale at left and is the absolute pressure of steam. Dew point temp. Re shown in the scale on the upper curved line. Constant RH Lines in per cent are indicated by marking off vertical distances between the saturation line or the upper curved lines and the base of the chart **Uses:** The psychrometric chart are prepared to represent graphically all the necessary moist air properties, used for air conditioning calculations. The values are based on actual measurements verified for thermodynamic consistency	
3-d	**Humid heat :** It is the heat capacity **(**specific heat**)** of humid air**,** expressed per unit mass of dry air in the mixture. **Humid volume:** Humid volume is defined as,volume occupied by unit mass of dry gas and its associated vapor . This is also sometimes called as specific volume and is simply reciprocal of density. Humid volume increases as the temperature or water vapor content increases.	2 2
3-e	**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	2

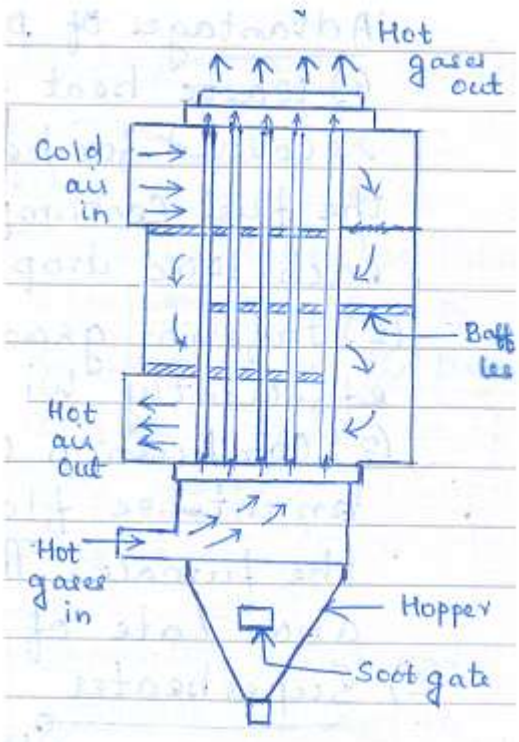
	moisture. A second pressure regulator is sometimes added to provide a constant reduced pressure in the supply line.  	2
3-f	**Use of steam trap:** They are used to collect and automatically discharge the water resulting from partial condensation of steam without allowing any steam to escape. **Use of pressure reducing valve:** Discard extra pressure to atmosphere for safe working of boiler. for manual control of steam pressure by throttling a valve. It is common practice to set these valves assuming a constant boiler pressure	2 2
4	**Attempt any four**	**16**
4-a	**Priming and foaming can be prevented by** i)controlling the concentration of impurities inside the boiler ii) By keeping the level of water as low as possible.	1 mark each

	iii) By addition of anti foam agents like gallic acid, cotton oil etc iv) By use of blow down of boiler sludge.	
4-b	**Secondary refrigerants:** Secondary refrigerants are first cooled with the help of primary refrigerants and are further used for cooling purpose. They are: 1. eco-friendly. 2. Cheap in cost. 3. Low toxicity Examples a) Air b) water c) brines solution	4
4-c	**Working of waste gas fired boiler:** Waste heat is a valuable resource, a way to save valuable energy, energy typically lost in waste heat. The WHR series are used in petrochemical plants, refineries, steel mills, ore converters, brick or cement plants, glass works, and food processing plants. The WHR boiler extracts the heat from these exhaust gasses, putting them to use generating plant steam or hot water. WHR boiler with supplemental fuel burners generates heat continuously to meet plant steam or hot water requirements. During periods when the heat content of waste exhaust gas is insufficient, the support burner will fire to provide steam within the desired range of operation. WHR Boilers allow for: High efficiency heat transfer	4

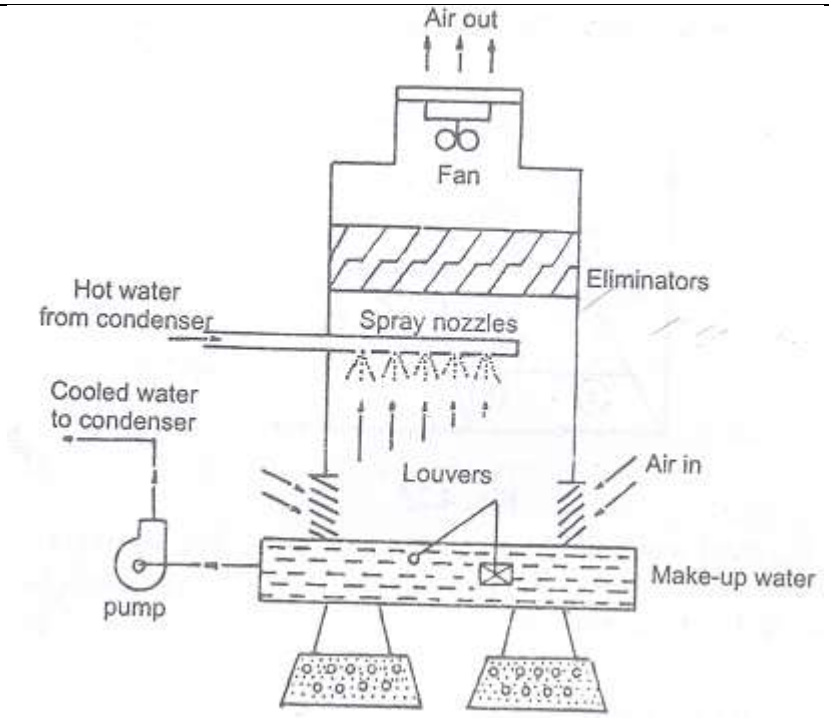
	Minimum gas side pressure drop Reduced installation time and cost Use of a wide range of gas types, gas weights and gas temperatures	
4-d	**Working of Spray ponds:** A spray pond is a reservoir in which warmed water (e.g. from a power plant) is cooled before reuse. This is done by spraying the warm water with nozzles into the cooler air, where cooling takes place by exchange of heat with the ambient air, involving both conductive heat transfer between the water droplets and the surrounding air and evaporative cooling (which provides by far the greatest portion, typically 85 to 90%, of the total cooling). The primary purpose of spray pond design is thus to ensure an adequate degree of contacting between the hot injection water and the ambient air, so as to facilitate the process of heat transfer. The spray pond is the predecessor to the natural draft cooling towers, which is much more efficient and takes up less space but has a much higher construction cost. A spray pond requires between 25 to 50 times the area of a cooling tower. The performance of a spray pond depends to a large degree on the effectiveness of the spray nozzles which are installed. Ideally, the chosen nozzles should provide a fine, evenly distributed spray in conical form, be capable of passing small particles of suspended matter without blocking and be readily dismantled for cleaning. Typical droplet sizes which are achieved by spray pond nozzles vary between 3 mm and 6 mm. While providing better cooling performance because of their increased surface-to-volume ratios, the generation of droplets of smaller size would require an excessive pressure drop	4

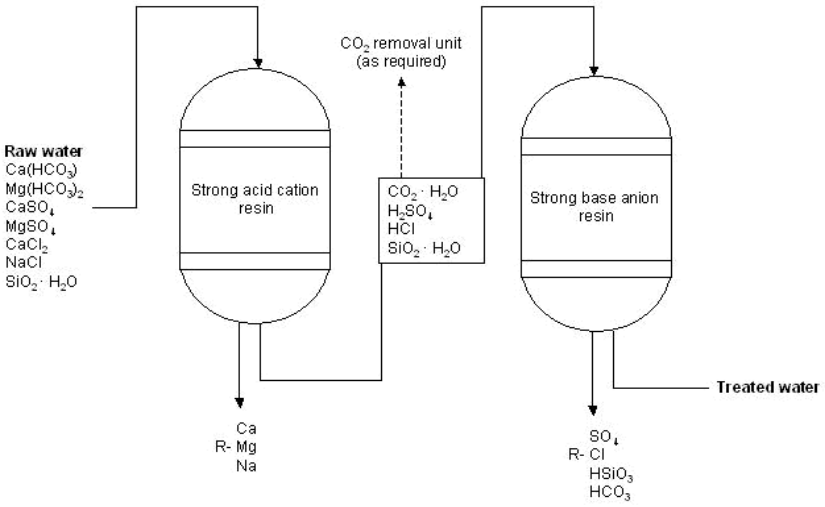
	across the nozzles and could lead to increased wind-drift losses from the pond.	
4-e	**Thermic fluid heater:** It is the heater where thermic fluid is used. **Construction**: It consists of two concentric coils in which inner coil acts as a radiation zone and outer coil act as convection zone. Flue gas velocity is generally higher between the 2 coils and between the coil and the outer shell, so higher the velocity higher will be the convective heat transfer between the flue gas and fluid. It can be made either 3 pass or 4 pass depending on the design of thermic fluid heater and the type of fuels to be burnt. The efficiency of the heater increases with increase in the number of passes. **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 = 30 + 273 = 303 K T2 = -10 + 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	**Classification of refrigerants:** A. National Refrigeration Safety Code, USA classifies all the refrigerants into 3 groups 1.Group 1 refrigerants (safest) 2. Group2 refrigerants (toxic and somewhat inflammable) 3. Group3 refrigerants (Inflammable refrigerants) B. National board of Fire Underwriters USA classifies refrigerants on the basis of their toxicity. There are six divisions on this scale. Class 1 is the most toxic and class 6 is least toxic C. Refrigerants are also classified as Primary refrigerants and secondary	4

	refrigerants.	
5-b	**Air preheater:** **Working:** Air preheater recovers some portion of the waste heat of flue gases. Air supplied to the combustion chamber of the boiler is preheated by using the heat in the waste flue gases. The hot gases are passed through the tubes and air circulates around them. Air is forced to deflect by using baffles and compelled to move in a zigzag path for a number of times. This increases the period of contact between air and hot surface and air is effectively heated. **Diagram:**  	2 2
5-c	**Comparison of fire tube and water tube boiler**	1 mark each

		Fire tube boiler	**Water tube boiler**	for any 4
	1) Furnace position	Inside boiler shell	Outside shell	
	2)Drum size	Large	Small	
	3)Heating area utilization	Not effective	effective	
	4)Use of fuel	Not used very efficiently	Effectively utilized by multipass flow	
	5) Overheating or tube failure	Furnace surrounded by water, so danger of overheating is less as long as water level is maintained.	Furnace not surrounded by water, so if circulation of water inside tube is not proper, tube failure can occur.	
	6)High pressure	Making large drum for high capacity and high pressure is very difficult	Drum size small, so drum can be made very strong for very high pressure.	
	7) Production of steam	Generates low pressure steam	Generates high pressure steam	
	8) Space	More space	Less space	
	9) Operating cost	Low	High	
	10) Scale formation	Low	Chances are high	
5-d	**Induced draft cooling tower**:			

		2 marks for diagram and 2 marks for marking the parts
5-e	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 **(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**	2 2
5-f	**Causes of 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	4

	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 causes embrittlement of boiler parts; particularly stressed parts like bends, joints, rivets etc causing even failure of the boiler.	
6	**Attempt any TWO of the following**	**16**
6-a	**Ion-exchanger process:**  **Description:** In this process, hard water is passed through cation exchanger which removes all the cations like Ca^{++} etc and equivalent amount of H^+ ions are released from this column to water. After cation exchangrer column, hard water is passed through anion exchanger which removes all the anions like Cl^-, SO_2^{--} present in water and an equivalent amount of OH^- ions are released from this column to water.	2 2

	Cation exchanger resin: These are capable of exchanging cations in water by hydrogen ions. The resins such as sulphonated coals, tannin formaldehade reprented as RH2 are the example. Their exchange reaction with cations can be reprented as $RH_2 + Ca^{++} \rightarrow RCa + 2H^+$ These cation exchanges when exhausted can be regenerated by acid solution $RCa + 2HCl \rightarrow RH_2 + CaCl_2$ Anion exchanger resins: These are capable of exchanging anion in water by hydraulic ion. The functional group in anion exchangers are $-N(CH_3)_2^+$, $OHNH_2$. The $N(CH_3)_2^+$ and –OH group are stable and react fast. These exchangers are reprented by $R(OH)_2$ $R'(OH)_2 + SO_4 \rightarrow R'SO_4 + 2OH$ Anion when exhausted regenerated by alkali solution. $R'SO_4 + 2NaOH \rightarrow R'(OH)_2 + Na_2SO_4$	2 2
6-b	**Selection criteria for refrigerant** (any 8) 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, nonflammable) 3. Space limitations: It should have low specific volume to reduce the size of the compressor.	1 mark each

	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.	
6-c	**Indian boiler act with respect to** **i)Duties of chief inspector:** The chief inspector shall 1. Maintain record of registered boilers. 2. Examine boiler inspection reports produced by inspector. 3. Decide whether to issue the certificate for the operation of boiler or not. 4. Supervise and control the work of inspectors **(ii)Certificate of renewal:** After generally 12 months. If boiler is transferred from one state to another. If some accidents is occurs. If some alteration is done in boiler parts , etc.	2 2

	(iii)Boiler accident: In case of boiler accident, the occupier shall inform the inspector with full details of the same. The inspector shall carry out investigation and decide whether to permit the usage of boiler in future and if so , then at what working pressure. The inspector shall inform the chief inspector about his investigations. **(iv)Boiler registration**: Boilers have to be registered before they can be used. The owner of the boiler shall give an application for the same. The inspector shall examine the boiler and find the maximum pressure at which the boiler may be operated. He will submit his report to the chief inspector and in turn the employer may get authorized for 1 year to use the boiler.	2 2