16^{th} NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – September, 2015

PAPER – 2: Energy Efficiency in Thermal Utilities			
Date: 19.09.2015	**Timings: 1400-1700 HRS**	**Duration: 3 HRS**	**Max. Marks: 150**

General instructions:

- *Please check that this question paper contains **8** printed pages*
- *Please check that this question paper contains **64** questions*
- *The question paper is divided into three sections*
- *All questions in all three sections are compulsory*
- ***All parts of a question should be answered at one place***

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

a) Answer all **50** questions
b) Each question carries **one** mark
c) Please hatch the appropriate oval in the OMR answer sheet with Black Pen or HB pencil

1.	Coal size of 75% below 75 micron is required for use in a) spreader stoker boiler b) chain grate stoker boiler c) fluidized bed boiler d) <u>pulverized fuel boiler</u>
2.	Which one of the following fuel has the highest hydrogen content and lowest sulphur content a) coal b) fuel oil <u>c) natural gas</u> d) LSHS
3.	A small quantity of leakage of stored Liquid LPG evaporates to produce about ------ times of volume of gas. a) 100 b) 150 <u>c) 250</u> d) 350
4.	Secondary air requirement for a coal fired boiler is influenced by a) fixed carbon b) mineral matter c) <u>volatile matter</u> d) sulphur
5.	Which one of the following is not true with respect to the role of nitrogen in the combustion of any fuel a) produces oxides of nitrogen b) <u>reduces the volume of combustion by-products</u> c) dilutes the flue gases d) carries useful heat in flue gases
6.	In which of following, heat loss due to moisture formation on complete combustion will be maximum a) LSHS b) furnace oil <u>c) natural gas</u> d) coal

7.	Which of the following requires the largest amount of oxygen/kg of substance for combustion a) carbon b) hydrogen c) sulphur d) nitrogen
8.	Which of the following boiler utilizes the combination of suspension firing and great firing a) traveling grate stoker boiler b) packaged boiler c) spreader stoker boiler d) pulverized fuel boiler
9.	Which of the component is common to supercritical boiler and sub critical boiler for power generation a) economizer b) water walls c) re-heaters d) all of the above
10.	The TDS level in boiler water for boiler blow down, is measured through a) alkalinity of water b) thermal conductivity of water c) electrical conductivity of water d) turbidity of water
11.	NO_x formation in FBC boilers is minimised because of a) higher velocity of flue gas in combustion chamber b) higher pressure of the air supplied c) lower temperatures in the bed and combustion chamber d) higher contact of solid particles in the flue gas
12.	The material used to control SO_x in the FBC boiler is a) limestone b) alumina c) silica d) fly ash
13.	Condensate at pressure of 4 kg/cm2 and 160°C temperature when exposed to atmosphere will a) become super heated b) partly convert to flash steam c) remain as condensate d) fully convert to flash steam
14.	As the pressure of water increases from 1kg/cm^2 to 8 kg/cm^2, the values of enthalpy of steam and enthalpy of evaporation respectively a) increases & remains the same b) increases & decreases c) decreases & increases d) decreases & remains the same
15.	The difference in temperature between steam and condensate is the principle of operation in a a) thermodynamic trap b) thermostatic trap c) float trap d) inverted bucket trap
16.	Scale losses in reheating furnaces will a) increase with excess air b) decrease with excess air c) have no relation with excess air d) increase with CO in combustion gases
17.	The velocity of steam in steam pipe is directly proportional to a) number of bends in pipe b) 5th power of the diameter of pipe c) length of pipe d) specific volume of steam
18.	Ceramic coating is used in furnaces because it enhances a) conductivity b) convective heat transfer coefficient

	c) emissivity d) radiation factor
19.	The thermal resistance of an insulation a) decreases with increased thermal conductivity b) increases with increased thermal conductivity c) decreases with decreased thermal conductivity d) has no relation with thermal conductivity
20.	The presence of calcium and magnesium bicarbonates in water to steam boiler would form a) acidic solution b) basic solution c) neutral solution d) none of the above
21.	Heat transfer rate for indirect heating application will be less if we heat with a) saturated steam b) dry steam c) superheated steam d) high pressure steam
22.	For flash steam calculation, flash steam quantity available depends upon a) condensate pressure and flash steam pressure b) steam pressure c) steam enthalpy at atmospheric pressure d) total heat of flash steam
23.	The inverted bucket operates on the principle of _______ difference between water and steam a) pressure b) density c) temperature d) velocity
24.	Furnace wall heat loss depends on a) temperatures of external wall surfaces b) velocity of air around the furnace c) thermal conductivity of wall brick d) all of the above
25.	The unit of overall heat transfer coefficient is a) W/m^2 K b) W^2/m^2 K c) W^2/m^3 K d) W/m^3 K
26.	Which of the following can be used as desiccant in boiler preservation a) silica gel b) activated carbon c) un-slaked lime d) all of the above
27.	Transfer of heat without a conveying medium is possible with a) conduction b) radiation c) convection d) none of the above
28.	Which of the following depends on physical properties of fluids as well as geometry of the heat exchanger a) overall heat transfer coefficient b) fouling coefficient c) LMTD (Log Mean Temperature Difference) d) effectiveness
29.	The parameter assumed to remain constant during LMTD calculation of a Heat exchanger is a) temperature drop b) heat transfer area c) specific heat of fluids d) none of the above
30.	Hydrometer is used for the measurement of a) viscosity b) density c) water content d) humidity

31.	Corrosion in chimney, air pre-heater and economizer is mainly influenced by a) sulphur content in fuel b) ash content in fuel c) moisture content in fuel d) all of the above
32.	_____ gives an estimate of heating value of coal a) ash content b) moisture content c) fixed carbon d) volatile matter
33.	The amount of CO_2 produced in complete combustion of 18 Kg of carbon a) 50 b) 44 c) 66 d) 792
34.	Enthalpy of evaporation of any vapour at its critical point will be a) more than zero b) zero c) less than zero d) unpredictable
35.	Removal of condensate from main steam line is done to prevent a) steam locking b) air locking c) water hammer d) all of the above
36.	2 m lift of condensate in steam pipe will result in back pressure of a) 0.02 bar b) 0.2 bar c) 2 bar d) 20 bar
37.	Portable fyrite is used for the measurement of a) CO_2 content in flue gas b) O_2 content in flue gas c) stack temperature d) both (a) & (b)
38.	Which fuel among the following needs temperature control during storage a) coal b) furnace oil c) diesel oil d) kerosene
39.	The stoichiometric amount of air required to burn 1 kg of methane is a) 69.57 b) 4 c) 17.39 d) 16
40.	Which of the following has the lowest stoichiometric oxygen demand (kg/kg of fuel) a) hydrogen b) carbon c) sulphur d) methane
41.	Presence of _____ in flue gas confirms incomplete combustion in furnace a) CO b) NOx c) SOx d) all of the above
42.	Which of the following salt causes temporary hardness in water a) calcium sulphate b) calcium bicarbonate c) calcium chloride d) calcium nitrate
43.	In which zone of cupola furnace does the conversion of CO_2 to CO take place? a) combustion zone b) melting zone c) reduction zone d) preheating zone
44.	Which among the following operates at vacuum a) heat wheels b) heat pump c) heat pipe d) all of the above
45.	Which of the following boiler water treatment ensures complete removal of salts

	a) demineralization b) softening c) de-aeration d) all of the above
46.	The heat loss in a furnace depends on a) emissivity of walls b) conductivity of refractory c) wall thickness d) all of the above
47.	An increase in bulk density of a refractory increases its a) volume stability b) heat capacity c) Resistance to slag penetration d) all of the above
48.	Economiser in a boiler exchanges heat between a) flue gas & combustion air b) steam & feed water c) steam & combustion air d) feed water & flue gas
49.	Which of the following is not required for determining economic thickness of steam line a) cost of fuel b) boiler efficiency c) enthalpy of steam d) calorific value of fuel
50.	On an inverted bucket trap, what happens to the bucket as the trap fills with water a) it rises b) it inclines c) it sinks d) it remains stationary

-------- End of Section - I ---------

Section – II: SHORT DESCRIPTIVE QUESTIONS **Marks: 8 x 5 = 40**

(i) Answer all **Eight** questions
(ii) Each question carries **Five** marks

S-1	(a) Why should LPG cylinders not be stored in basements or cellars? **(2.5 marks)** (b) Why should the stack temperature of furnace oil fired boilers not be maintained below 160-170°C ? **(2.5 marks)**
	Ans: (a) LPG is a predominant mixture of propane and butane. Both propane and butane are denser than air. Consequently, the vapour flows along the ground into drains and sinks to the lowest level of the surroundings and gets ignited at a considerable distance from the source of leakage. Escape of even small quantities of LPG can give rise to large volume of vapour mixture and can cause considerable hazard. Hence there should be adequate ground level ventilation where LPG cylinders are stored. For this reason LPG cylinders should not be stored in cellars or basements, which have no ventilation at ground levels. **(2.5 marks)**

	(b) For fuels containing sulphur, low temperatures (below 160-170°C) of stack can lead to sulphur dew point corrosion. The main disadvantage of sulphur is the risk of corrosion by sulphuric acid formed during and after combustion, and condensing in cool parts of the chimney or stack, air preheater and economiser. **(2.5 marks)**
S-2	A steam pipe of 100mm diameter is insulated with mineral wool. As a part of energy saving measures, the insulation is upgraded with efficient Calcium silicate insulation. Calculate the percentage reduction in heat loss as a result of implementation of the above measure given the following data, Boiler efficiency : 80% Surface temperature with mineral wool : 95°C Surface temperature with calcium silicate : 55°C Ambient temperature : 25°C
	Ans: Heat loss thru non-insulated pipe = $[10 + (T_s – T_a) / 20] * (T_s – T_a)$] T_s = Surface temperature T_a = Ambient temperature Heat loss thru non-insulated pipe = [10 + (95 – 25) / 20] * (95 – 25)] = 945 kcal/hr-m2 **(2 marks)** Heat los thru insulated pipe = [10 + (55 – 25) / 20] * (55 – 25)] = 345 kcal/hr-m2 **(2 marks)** % Reduction in heat loss = (945 – 345) / 945 = 63.5 % **(1 mark)**
S-3	Calculate the electricity consumption in an induction melting furnace from the following melt cycle data, Mild steel (MS) scrap charged : 1250 kg Specific heat of MS : 0.68 kJ/kg ^{0}C Latent heat of MS : 270 kJ/kg MS melting temperature : 1650 ^{0}C Inlet MS charge temperature : 35 ^{0}C Efficiency of furnace : 65%
	Ans: Theoretical energy required for melting = 1250 (0.68 x (1650 – 35) + 270)/3600

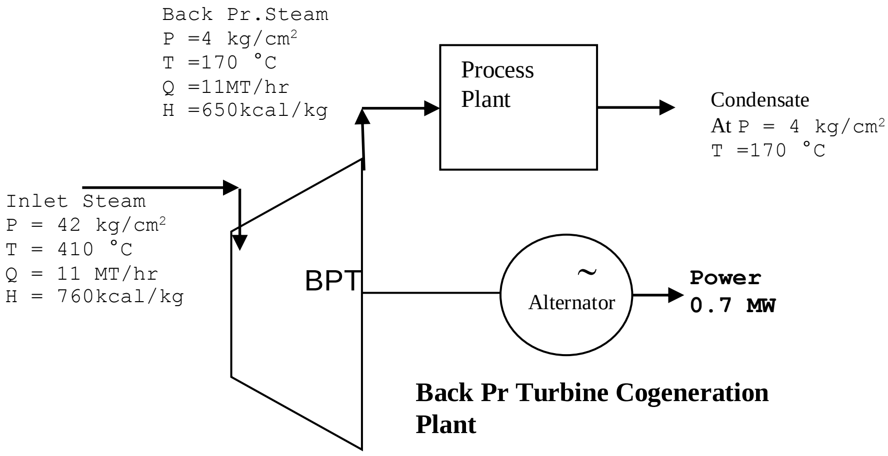
	= 475.1 kWh/hr or 475.1 kw **(3 marks)** Actual energy input to the furnace = 475.1 / 0.65 Electricity consumption = 730.9 Kwh/hr or 730.9 kw **(2 marks)**
S-4	Paddy husk is being used as a combustion fuel in a water tube boiler. The ultimate analysis of fuel is given below. Calculate theoretical amount of air required per 100 kg of husk for the combustion from the following data

Ultimate Analysis of Paddy Husk	%
Moisture	11.8
Mineral Matter	17.7
Carbon	32.0
Hydrogen	5.0
Nitrogen	0.9
Sulphur	0.1
Oxygen	32.5

Ans

Considering a sample of 100 kg of paddy husk.

Component in fuel	% (wt) in fuel	Equation	Specific stoichiometric oxygen required	Actual stoichiometric oxygen required
Carbon	32	$C + O_2 = CO_2$ 12 + 32 = 44	2.67 (32/12)	85.44 (32x2.67)
Hydrogen	5	H2 + 0.5 02 = H2O 2 + 16 = 18	8.0 (16/2)	40.0 (5x8)
Sulphur	0.1	S + O2 = SO2 32 + 32 = 64	1.0 (32/32)	0.1 (0.1x1)
Oxygen	32.5			(-)32.5
Nitrogen	0.9			-
Moisture	11.8			-
Mineral matter	17.7			-
Total	100			93.04

	(4 marks) Total Oxygen required = 93.04 kg oxygen / 100 kg fuel Therefore theoretical quantity of dry air reqd. = 93.04 / 0.23 = 404.5 kg air / 100 kg fuel (air contains 23% oxygen by wt.) **(1 mark)**
S-5	Determine the Energy Utilization Factor (EUF) from the following back pressure cogeneration plant diagram and data given.  **Back Pr Turbine Cogeneration Plant**
	Solution Input heat to turbine = 11,000 x 760 = 8360000 Kcal/hr **(1 mark)** Useful heat to process Plant = 11,000 x 650-170 = 5280000 Kcal/hr **(1 mark)** Useful Electrical output in alternator = 700x860= 602000 Kcal/hr **(1 mark)** Energy Utilization Factor (EUF) = (602000+5280000) /8360000 = 70.36% **(2 marks)**
S-6	For combustion of 500 kg/hr of Natural Gas containing 100% Methane, Calculate the percentage of CO_2 in the flue gas while 20% excess air is supplied.

	Ans: $CH_4 + 2\ O_2 \rightarrow CO_2 + 2H_2O$ 1 mole of Methane requires 2 moles of Oxygen. 16 Kg of Methane requires 64 Kg of Oxygen. 16 Kg of Methane produces 44 Kg of CO_2. 500 Kg/hr of Methane requires 2000 Kg/hr of Oxygen. 500 Kg/hr of Methane requires 1375 Kg/hr of CO_2 Theoretical air required for combustion = 2000 / 0.23 = 8695 Kg/hr **(2 marks)** Considering 20% excess air, Actual air supplied for combustion is = 8695 * 1.2 = 10434 Kg/hr of air **(1 mark)** Flue gas generation with 20% excess air = 500 + 10434 = 10934 Kg/hr **(1 mark)** % CO_2 in the flue gas = 1375 / 10934 = 12.5 % **(1 mark)**
S-7	In a heat exchanger, steam is used to heat 3.0 KL/hr of furnace oil from 30°C to 100°C. The specific heat of furnace oil is 0.22 kCal/ kg/°C and the density of furnace oil is 0.95 gm/cc. How much steam per hour is needed if steam at 4 kg/cm^2 with latent heat of 510 kCal/ kg is used. If steam cost is Rs. 4.0/kg and electrical energy cost is Rs.8.0/kWh, which type of heating would be more economical in this particular case? (assume no losses in electrical and steam heating process)
	Ans: Total heat required = m Cp ΔT = (3 x 1000 x 0.95) x 0.22 x (100-30) = 43890 kcal/hr **(1.5 mark)** a) Amount of steam required = 43890/510 = 86 kg/hr Steam cost = 86 x Rs.4 = Rs. 344/hr **(1.5 marks)** b) Amount of electricity required = 43890/860 = 51 kWh = 51 x Rs. 8 = Rs.486/ hr Steam heating will be more economical **(2 marks)**

S-8	In a sugar mill, a process requires 5 000 kg/hr of dry saturated steam at 7 kg/cm^2 (g). For the flow velocity not to exceed 25 m/s, determine the pipe diameter size for distribution of steam. Specific volume at 7 kg/cm^2 = 0.24 m3/kg
	Ans. The velocity of steam maximum = 25 m/s Specific volume at 7 kg/cm2 = 0.24 m^3/kg Mass flow rate = 5000 kg/hr = 5000/3600 = 1.389 kg/sec Volumetric flow = 1.389 x 0.24 = 0.333 m^3/sec **(1 mark)** Volumetric flow rate(m3/s) = Velocity (m/s) x cross sectional area (m^2) **(1 mark)** Therefore, $D = \sqrt{\frac{4 \times Volumetric\ \ flowrate}{\prod \times Flow\ velocity}}$ $D = \sqrt{\frac{4 \times 0.333}{\prod \times 25}}$ $D = 0.130\, m\, or\, 130\, mm$ Since the steam velocity must not exceed 25 m/s, the pipe size must be at least 130 mm; the nearest commercially available size, 150 mm, would be selected. **(3 marks)**

-------- End of Section - II ---------

Section - III: LONG DESCRIPTIVE QUESTIONS Marks: 6 x 10 = 60

(i) Answer all SIX questions
(ii) Each question carries **<u>Ten</u>** marks

L-1	A liquid waste stream has a flow rate of 3.5 kg/s and a temperature of 75^{o} C with a specific heat capacity of 4190 J/kgK. Heat recovered from the hot waste stream is used to pre-heat boiler make-up water. The flow rate of the make-up water is 2.8 kg/s, its temperature is 12^{o}C and its specific heat capacity is 4190 J/kg/K. The overall heat transfer coefficient of the heat exchanger is 800 W/m^{2}K. If a make-up water exit temperature of 50^{o}C is required, and assuming that there are no heat loss from the heat losses from the exchanger, determine 1) The heat transfer rate 2) The exit temperature of the effluent and 3) The area of the heat exchanger required

Solution

i) Heat gained by makeup water = $Q_c = m_c\, c_c\, \Delta T$ = 2.8 x 4190 x (50-12)
= 445816 W = 445.82 kW

(2 marks)

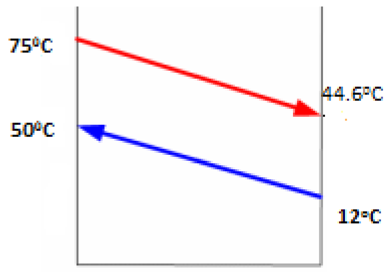
ii) $m_h\, c_h\, (t_{h1} - t_{h2}) = m_c\, c_c\, (t_{c1} - t_{c2})$

$3.5 \times 4190 \times (75 - t_{h2}) = 2.8 \times 4190 \times (50 - 12)$

$t_{h2} = 44.6\ ^{o}C$

(3 marks)

iii) Now because the water outlet temperature is above the outlet temperature of the effluent a counter-flow heat exchanger is required



Counter Flow Arrangement

$$LMTD = \frac{\Delta t_1 - \Delta t_2}{\ln\left(\Delta t_1 / \Delta t_2\right)}$$

$$= \frac{((75-50)-(44.6-12)}{\ln (75-50)/(44.6-12)}$$

$$= \frac{25-32.4}{\ln(25/32.4)}$$

LMTD = 28.54^{o}C

(2.5 marks)

	Q = UA (LMTD) $= \dfrac{445816}{800 \times 28.54}$ Area =19.5 m^2 **(2.5 marks)**
L-2	Oil fired Boiler is generating 100 TPH of steam at 85% efficiency, operating 330 days in a year. Management has installed a water treatment plant at Rs 2 Crore investment for reducing the TDS in boiler feed from 450 ppm to 150 ppm. The maximum permissible limit of TDS in the boiler is 3000 ppm and make up water is 10%. Temperature of blowdown water is 175°C and boiler feed water temperature is 45°C. Calorific value of Fuel oil is 10200 Kcal/kg. Calculate the payback period if the cost of fuel is Rs.34500 per ton.
	Ans: Blow down % = $\dfrac{\text{Feed water TDS * \% make up water}}{\text{(maximum permissible TDS in boiler water – Feed water TDS)}}$ x 100 Initial blow down = 450 * 10 / (3000 – 450) Initial blow down = 1.76 % Improved blow down = 150 * 10 / (3000 – 150) Improved blow down = 0.53 % Reduction in blow down = 1.76 – 0.53 Reduction in blow down = 1.24 % Reduction in blow down = 1.24 * 100 * 1000 / 100 Reduction in blow down = 1238 kg/hr **(4 marks)** Specific heat of water is 1 kcal/kg°C Heat savings = m * Cp * (T_1 – T_2) = 1238 * 1 * (175 – 45) Heat savings = 160991 kcal/hr Fuel Oil saving = 160991 / (10200 * 0.85) = 18.6 kg/hr = 18.6 * 24 * 330 / 1000 = 147.1 MT / annum Fuel Oil cost savings = 147.1 * 345000 = Rs. 50.75 lakh **(4 marks)** Investment on water treatment plant = Rs. 2 Crore Payback period = 2 / 0.5075 Payback period = 3.9 years (or) 47months **(2 marks)**

L-3	As a part of energy conservation measure, APH (Air Pre-heater) is installed in a fired heater. The APH is designed to pre-heat 240 m^3/min of combustion air to 250°C. Flue gas enters the APH at 375°C. Calculate the flue gas leaving the stack and also determine the improvement in furnace efficiency after the installation of APH with the following data Density of air : 1.15 kg/m^3 Specific heat of air : 0.23 Kcal/kg°C Specific heat of flue gas : 0.26 Kcal/kg°C Calorific value of fuel : 9850 Kcal/kg Air to fuel ratio : 17 Efficiency of furnace : 69 % Ambient temperature : 30°C
	Solution: Amount of Air flow = 240 * 60 * 1.15 = 16560 Kg/hr **(1 mark)** Amount of fuel = 16560 / 17 = 974.12 Kg/hr **(1 mark)** Amount of flue gas = 16560 + 974.12 = 17534.1 Kg/hr **(1 mark)** Heat absorbed by combustion air = 16560 * 0.23 * (250 – 30) = 837936 Kcal/hr **(1.5 mark)** Temperature difference in flue gas = 837936 / (17534.1 * 0.26) = 183.8 °C **(1.5 mark)** Flue gas leaves the stack at temp = 375 – 183.8 = 191.2 °C **(1 mark)** Efficiency of APH = heat absorbed by air / Heat input * 100 = 837936 * 100 / (974.12* 9850) = 8.73 % **(2 marks)** Overall efficiency after APH = 69 + 8.73 % = 77.73 % **(1 mark)**
L-4	Write short notes on any two of the following: **(5 marks each)** a) Plate heat exchanger (page 242 of book-2) b) Multiple effect evaporator (page 247-248 of book-2) c) Gas turbine cogeneration system (page 192 of book-2)

L-5	a) Find out the efficiency of the furnace oil fired boiler by the direct method in an agro product manufacturing plant given the following data: Type of boiler : Furnace oil fired Quantity of steam (dry) generated : 5 TPH Steam pressure / temp : 10 kg/cm^2(g)/ 180 ^{0}C Quantity of oil consumed : 0.350 TPH Feed water temperature : 75 ^{0}C GCV of Furnace oil : 10300 kCal/kg Enthalpy of saturated steam at 10 kg/cm^2 pressure : 665 kCal/kg Enthalpy of feed water : 75 kCal/kg Cost of furnace oil : Rs 32/kg Annual operating hours : 7200 hrs /year b) The oil fired boiler was converted to coconut shell firing maintaining the same steam and feed water parameters. i) Determine the fuel consumption per hour ii) Return on investment for the conversion scheme. Fuel fired in the boiler : coconut shell fuel GCV of coconut shell : 4200 kCal/kg Efficiency with coconut shell firing : 76% Cost of coconut shell : Rs 12/kg Annual operating hours : 7200 hrs /year Investment towards boiler conversion : Rs 50 lakhs Annual interest on capital : Rs 6 lakhs /yr
	Solution: a) Efficiency of furnace oil fired boiler (Direct method) Boiler Efficiency (η) = 5000 x (665-75) / (350 x 10300) Boiler efficiency = 81.8% (on GCV basis) **(2.5 marks)** b) i) Coconut shell fuel consumption after conversion: Fuel consumption = 5000 x (665-75) / (0.76 x 4200) = 924.2 kg/hr **(2.5 marks)** ii) ROI for the conversion scheme Annual fuel cost of furnace oil fired boiler = 350 x 7200 x 32 = Rs 8,06,40,000 /year **(1 mark)** Annual fuel cost of coconut shell fired boiler = 924.2 x 7200 x 12 = Rs 7,98,50,880/year **(1 mark)** Annual net monetary savings after conversion $= \frac{[(8,06,40,000 - 7,98,50,880) – 6,00,000]}{50,00,000} \times 100$ =3.8 % **(3 marks)**

L-6	a. State two examples of heat pump applications b. In which situation are heat pumps most promising c. Draw the schematics of a heat pump system d. Briefly discuss each sub process stage of the heat pump system

a) heat pump applications

i) space heating system

ii) use in plastic factory where chilled water is used to cool injection moulding machines, and

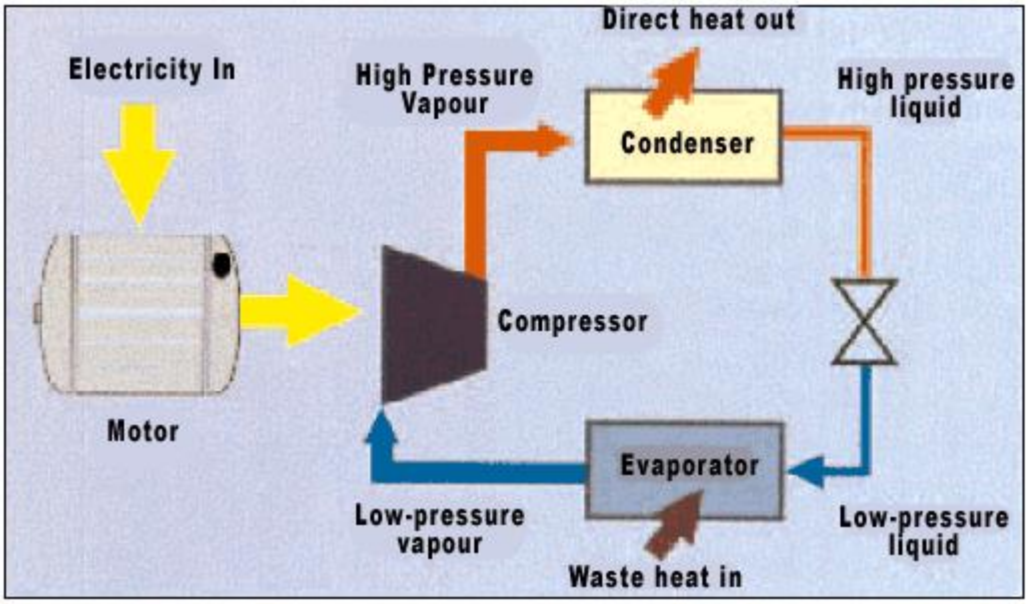
iii) drying applications such as maintaining dry atmosphere in storage and drying compressed air

(2 marks)

b) In a situation when both the cooling and heating capabilities of the cycle can be used in combination

(2 marks)

c) Schematic of a heat pump system:



Heat Pump Arrangement

(2 marks)

Step 1: In the evaporator the heat is extracted to boil the circulating working fluid

Step 2: The evaporated working fluid is compressed in a compressor rising working fluid temperature and pressure

Step 3: The heat is delivered to the condenser

Step 4: The pressure of the working fluid is reduced in a throttling valve and condensate returned to the compressor

(4 marks)

…………. End of Section – III …………..