Regn No: ____________________

Name : ____________________
(To be written by the candidate)

16th 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.	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) reduces the volume of combustion by-products c) dilutes the flue gases d) carries useful heat in flue gases
2.	Which one of the following fuel has the highest hydrogen content and lowest sulphur content a) coal b) fuel oil c) natural gas d) LSHS
3.	Which of the following yields a low CO_2 reading a) soot deposits on boiler tubes b) flue gas bypass in air pre-heater c) proper air-fuel mixture d) air ingress in flue gas duct
4.	Which of the following salt causes temporary hardness in water a) calcium sulphate b) calcium bicarbonate c) calcium chloride d) calcium nitrate

5.	Which of the following requires the largest amount of oxygen/kg of substance for combustion a) carbon b) hydrogen c) sulphur d) nitrogen
6.	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
7.	Which of the following has the lowest stoichiometric oxygen demand (kg/kg of fuel) a) hydrogen b) carbon c) sulphur d) methane
8.	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
9.	Which of the following contribute to spontaneous combustion of coal a) low Volatile matter b) low fixed carbon c) less ash d) none of the above
10.	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
11.	Which of the following boiler water treatment ensures complete removal of salts a) demineralization b) softening c) de-aeration d) all of the above
12.	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
13.	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
14.	Which fuel among the following needs temperature control during storage a) coal b) furnace oil c) diesel oil d) kerosene
15.	What happens when the float in a float trap develops a puncture a) loss of condensate b) loss of live steam c) fails to open d) fails to close
16.	Transfer of heat without a conveying medium is possible with a) conduction b) radiation c) convection d) none of the above
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.	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) $W/m^3 K$

19.	The thermal resistance of an insulation <u>a) decreases with increased thermal conductivity</u> b) increases with increased thermal conductivity c) decreases with decreased thermal conductivity d) has no relation with thermal conductivity
20.	The stoichiometric amount of air required to burn 1 kg of methane is a) 69.57 b) 4 <u>c) 17.39</u> d) 16
21.	The parameter assumed to remain constant during LMTD calculation of a Heat exchanger is a) temperature drop b) heat transfer area <u>c) specific heat of fluids</u> d) none of the above
22.	The material used to control SO_x in the FBC boiler is <u>a) limestone</u> b) alumina c) silica d) fly ash
23.	The heat loss in a furnace depends on a) emissivity of walls b) conductivity of refractory c) wall thickness <u>d) all of the above</u>
24.	The chemical used to prevent oxidation in boiler feedwater is <u>a) sodium sulphite</u> b) sodium phosphate c) calcium phosphate d) magnesium phosphate
25.	The best time for intermittent blow down in a boiler a) High load under full pressure <u>b) low load under full pressure</u> c) high load under partial pressure d) low load under partial pressure
26.	The amount of CO_2 produced in complete combustion of 18 Kg of carbon a) 50 b) 44 <u>c) 66</u> d) 792
27.	Scale losses in reheating furnaces will <u>a) increase with excess air</u> b) decrease with excess air c) have no relation with excess air d) increase with CO in combustion gases
28.	Removal of condensate from main steam line is done to prevent a) steam locking b) air locking <u>c) water hammer</u> d) all of the above
29.	Presence of _____ in flue gas confirms incomplete combustion in furnace <u>a) CO</u> b) NOx c) SOx d) all of the above
30.	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 <u>d) both (a) & (b)</u>
31.	On an inverted bucket trap, what happens to the bucket as the trap fills with water a) it rises b) it inclines <u>c) it sinks</u> d) it remains stationary

32.	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 <u>c) lower temperatures in the bed and combustion chamber</u> d) higher contact of solid particles in the flue gas
33.	In which zone of cupola furnace does the conversion of CO_2 to CO take place? a) combustion zone b) melting zone <u>c) reduction zone</u> d) preheating zone
34.	In a fire-tube boiler, soot forms on a) outside tube surface <u>b) inside tube surface</u> c) waterside surface d) water wall surface
35.	If the volatile matter in coal is low, which of the following equipment is the best waste heat recovery option in a boiler a) economiser <u>b) air preheater</u> c) deaerator d) heat pipe
36.	Hydrometer is used for the measurement of a) viscosity <u>b) density</u> c) water content d) humidity
37.	Heat transfer rate for indirect heating application will be less if we heat with a) saturated steam b) dry steam <u>c) superheated steam</u> d) high pressure steam
38.	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 <u>d) all of the above</u>
39.	For flash steam calculation, flash steam quantity available depends upon <u>a) condensate pressure and flash steam pressure</u> b) steam pressure c) steam enthalpy at atmospheric pressure d) total heat of flash steam
40.	Enthalpy of evaporation of any vapour at its critical point will be a) more than zero <u>b) zero</u> c) less than zero d) unpredictable
41.	Corrosion in chimney, air pre-heater and economizer is mainly influenced by <u>a) sulphur content in fuel</u> b) ash content in fuel c) moisture content in fuel d) all of the above
42.	Condensate at pressure of 4 kg/cm2 and 160°C temperature when exposed to atmosphere will a) become super heated <u>b) partly convert to flash steam</u> c) remain as condensate d) fully convert to flash steam
43.	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 <u>d) pulverized fuel boiler</u>
44.	Ceramic coating is used in furnaces because it enhances

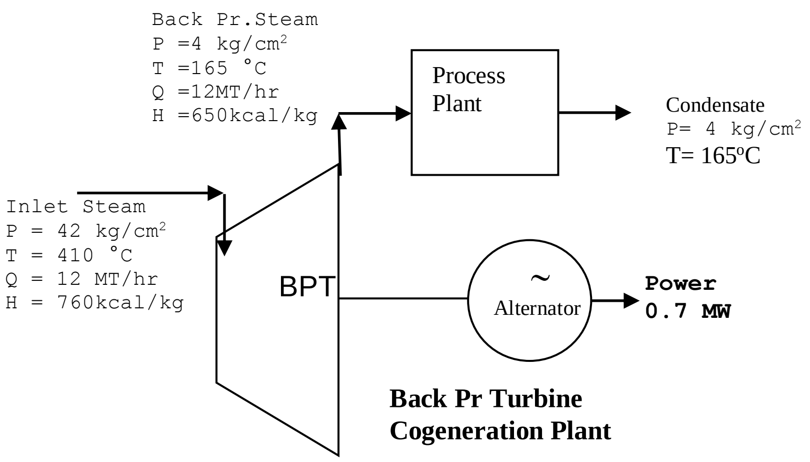
	a) conductivity b) convective heat transfer coefficient c) emissivity d) radiation factor
45.	As the pressure of water increases from 1kg/cm^2 to 8 kg/cm^2, the values of enthalpy of steam and enthalpy of evaporation respectively a) increases & remains the same b) increases & decreases c) decreases & increases d) decreases & remains the same
46.	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
47.	A small quantity of leakage of stored Liquid LPG evaporates to produce about ____ times of volume of gas. a) 100 b) 150 c) 250 d) 350
48.	A high carbon monoxide reading indicates a) moisture in the fuel b) high furnace temperature c) high excess air d) none of the above
49.	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
50.	_____ gives an estimate of heating value of coal a) ash content b) moisture content c) fixed carbon d) volatile matter

-------- *End of Section*

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

(i) Answer all eight questions
(ii) Each question carries five marks

S-1	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 = 12,000 x 760 = 91,20,000 Kcal/hr ….(1 mark) Useful heat to process Plant = 12,000 x 650-165 = 5820,000 Kcal/hr ….(1 mark) Useful Electrical output in alternator = 700x860= 602000 Kcal/hr ….(1 mark) Energy Utilization Factor (EUF) = [(602000+5820,000) /91,20,000] x 100 = 70.42% ….(2 marks)
S-2	For combustion of 500 kg/hr of natural gas containing 100% methane, calculate the percentage of CO_2 in the flue gas while 15% 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 produce 1375 Kg/hr of CO_2. …. (1 mark) Theoretical air required for combustion = 2000 / 0.23 = 8696 Kg/hr …. (1 mark) Considering 15% excess air, Actual air supplied for combustion is = 8696 * 1.15 = 10,000.4 Kg/hr of air …. (1 mark) Flue gas generation with 15% excess air = 500 + 10,000.4 = 10,500.4 Kg/hr …. (1 mark) % CO_2 in the flue gas = (1375 / 10,500.4)x 100 = 13.1 % …. (1 mark)

S-3	In a sugar mill, a process requires 5000 kg/hr of dry saturated steam at 7 kg/cm^2 (g). For the flow velocity not to exceed 28 m/s, determine the pipe diameter size for distribution of steam. Specific volume at 7 kg/cm^2 = 0.24 m^3/kg.
	Ans: The velocity of steam maximum = 28 m/s Specific volume at 7 kg/cm^2 = 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) Therefore, using: Volumetric flow rate(m^3/s) = Velocity (m/s) x Cross sectional area (m^2) …. (1 mark) $D = \sqrt{\frac{4 \times Volumetric\ flowrate}{\prod \times Flow\ velocity}}$ $D = \sqrt{\frac{4 \times 0.333}{\prod \times 28}}$ $D = 0.123\,m\ or\ 123\,mm$ …. (3 marks) Since the steam velocity must not exceed 28 m/s, the pipe size must be at least 123 mm; the nearest commercially available size, 150 mm, would be selected.
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 Typical Agro Residues	%
Moisture	10.8
Mineral Matter	16.7
Carbon	34.0
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	34	$C + O_2 = CO_2$ 12 + 32 = 44	2.67 (32/12)	90.78 (34 x 2.67)
Hydrogen	5	$H_2 + 0.5\ O_2 = H_2O$ 2 + 16 = 18	8.0 (16/2)	40.0 (5 x 8)
Sulphur	0.1	$S + O_2 = SO_2$ 32 + 32 = 64	1.0 (32/32)	0.1 (0.1 x 1)
Oxygen	32.5			(-)32.5
Nitrogen	0.9			-
Moisture	10.8			-
Mineral matter	16.7			-
Total	100			98.38

….. (4 marks)

Total Oxygen required = 98.38 kg oxygen / 100 kg fuel

Therefore theoretical quantity of dry air reqd. = 98.38 / 0.23 =427.7 kg air / 100 kg fuel

(air contains 23% oxygen by wt.)

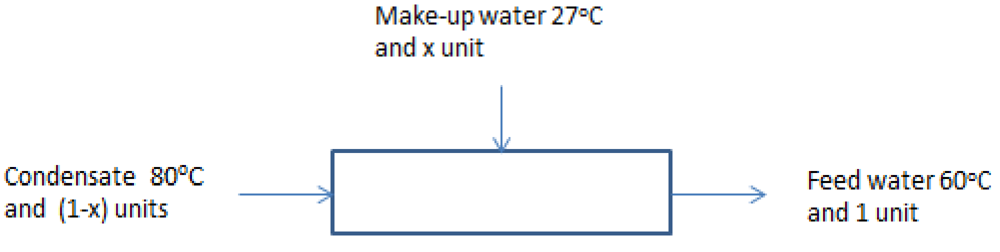
….. (1 mark)

S-5 (a) Why should LPG cylinders not be stored in basements or cellars?

(b) Why should the stack temperature of furnace oil fired boilers not be maintained below 160-170°C?

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 on cool parts of the chimney or stack, air preheater and economiser. ….(2.5 marks)
S-6	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 : 1450 ^{0}C Inlet MS charge temperature : 35 ^{0}C Efficiency of furnace : 70%
	Ans: Theoretical energy required for melting = 1250 (0.68 x (1450 – 35) + 270)/3600 = 427.8 kWh …. (3 marks) Actual energy input to the furnace = 427.8 / 0.7 Electricity consumption = 611.2 kWh …. (2 marks)
S-7	Feed water is provided to a boiler from the feed water tank at 60°C, temperature of condensate water returning to the tank is 80°C, and temperature of makeup water is 27°C. What is the amount of condensate recovered?
	Solution: 

	27x + (1 – x) 80 =60 Therefore x = 0.37 (37 percent makeup water or only 63 per cent of condensate is recovered). ….(5 marks)
S-8	Milk is flowing in a pipe cooler at a rate of 0.95 kg/sec. Initial temperature of the milk is 55 °C and it is cooled to 18 °C using a stirred water bath with the constant temperature of 10°C around the pipe. Specific heat of milk is 3.86 KJ/kg°C. Calculate the heat transfer rate (kcal/hr) and also LMTD of the exchanger.
	Ans: Heat transfer in cooling milk = 0.95 * 3.86 * (55 – 18) = 135.7 KJ/sec =135.7 /4.18 = 32.46 kcal/sec =(32.46*3600)= 116856 kCal/hr …. (2.5 marks) LMTD: DT1 = 55 – 10 = 45 °C DT2 = 18 – 10 = 8 °C LMTD of the heat exchanger = (45 – 8) / ln (45 / 8) LMTD of the heat exchanger = 21.4 °C …. (2.5 marks)

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

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

(i) Answer all SIX questions
(ii) Each question carries **Ten** marks

L-1	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 : 10400 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 interest on capital : Rs 6 lakhs /yr Annual operating hours : 7200 hrs /year Investment towards boiler conversion : Rs 50 lakhs
	Solution: a) Efficiency of furnace oil fired boiler (Direct method) Boiler Efficiency (η) = 5000 x (665-75) / (350 x 10400) = 81% (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-2	A liquid waste stream has a flow rate of 3.5 kg/s and a temperature of 70° 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 kg/s, its temperature is 10°C and its specific heat capacity is 4190 J/kg/K. The overall heat transfer coefficient of the heat exchanger is 800 W/m²K. If a make-up water exit temperature of 50°C is required, and assuming that there is no 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 x 4190 x (50-10)

= 335200 W = 335.2 kW

…..(2 marks)

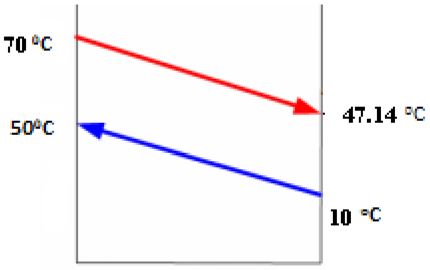
ii) $m_h\, c_h\, (t_{h1} - t_{h2}) = m_c\, c_c\, (t_{c1} - t_{c2})$

3.5 x 4190 x (70 - t_{h2}) = 2 x 4190 x (50 -10)

t_{h2} = 47.14 °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

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

-

$$= \frac{(70-50)-(47.14-10)}{\ln (70-50)/(47.14-10)}$$

LMTD = 27.69°C

…..(2.5 marks)

Q = UA (LMTD)

$$A = \frac{335200}{800 \times 27.69}$$

Area = 15.13 m²

…..(2.5 marks)

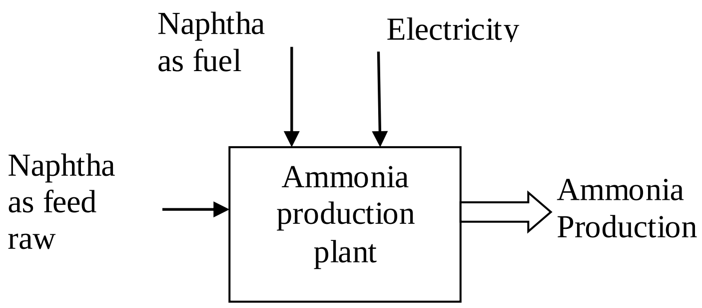
L-3 Write short notes on any two of the following: (5 marks each)

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-4 a) In a typical fertiliser manufacturing plant, the quantity of 133200 Ton of Ammonia is produced annually, using naphtha as fuel as well as raw material (feed) and electricity from captive power plant.



The quantity of annual raw material consumption and its heating values are given in table.

Raw material consumption	Quantity	Heating Value
1.Naphtha - feed	66800 Ton	10650 kCal / kg
2.Naphtha - fuel	31200 Ton	10650 kCal / kg
3.Electricity	1180 x Lakh kWh	2500 kCal/kWh

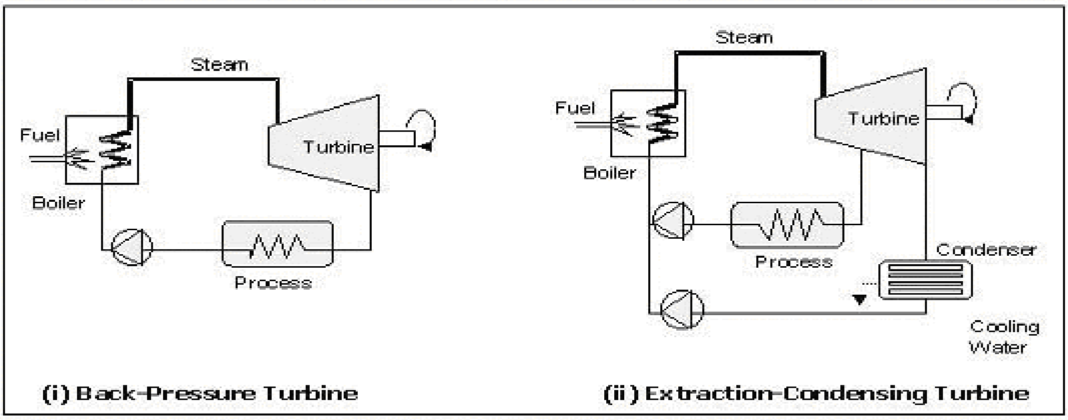
Calculate the specific energy consumption of ammonia production in Gcal / Ton.

b) Sketch the schematic diagram of "Back Pressure Turbine" and "Extraction Condensing Turbine" Cogeneration systems (Note: no explanation required).

Answer :

a) **Specific Energy Consumption(SEC) of Ammonia**

Raw material consumption	**Quantity**	**Heating Value**	**Gcal**	
1.Naphtha - feed	66800 Ton	10650 kCal / kg	711420	1 mark
2.Naphtha - fuel	31200 Ton	10650 kCal / kg	332280	1 mark
3.Electricity	1180 x Lakh kWh	2500 kCal/kWh	295000	1 mark
			1338700	
Ammonia production	133200 Ton			
Specific Energy Consumption(SEC) of Ammonia production =			**10.05 Gcal per Ton**	2marks

	b) Schematic diagram of (i) Back Pressure Turbine and (ii) Extraction Condensing Turbine Cogeneration systems  ……(2.5 marks for each schematic)
L-5	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 : 18 Efficiency of furnace : 73 % Ambient temperature : 30°C
	Solution: Amount of Air flow = 240 * 60 * 1.15 = 16560 Kg/hr …. (1mark) Amount of fuel = 16560 / 18 = 920 Kg/hr …. (1mark) Amount of flue gas = 16560 + 920 = 17480 Kg/hr …. (1mark) Heat absorbed by combustion air = 16560 * 0.23 * (250 – 30) = 837936 Kcal/hr …. (1.5 marks)

	Temperature difference in flue gas = 837936 / (17480 * 0.26) = 184 °C …. (1.5 mark) Flue gas leaves the stack at temp = 375 – 184 = 191 °C …. (1 mark) Efficiency of APH = Heat absorbed by air / Heat input * 100 = 837936 * 100 / (920* 9850) = 9.2 % …..(2 marks) Overall efficiency after APH = 73 + 9.2 % = 82.2 % ….. (1 mark)
L-5	A process industry is equipped with a steam power plant generating 1,00,000 units/day and a separate low-pressure boiler generating at an average steam production of 8.3 Tons of steam/hour at enthalpy of 630 kcal/kg for process heating. The feed water temperature to the boiler is 70°C. The efficiencies of the steam power plant and boiler are 29% and 75% respectively. Coal is used in both cases and calorific value of coal is 3800 kcal/kg. The management proposes to commission a cogeneration plant retaining the coal as fuel. The expected energy utilization factor of the cogeneration plant is 75%. Calculate coal savings with the new cogeneration plant.
	SOLUTION:

Heat input for separate production of power and useful heat	=	(100000 x 860) / (24 x 0.29) + (8.3 x (630-70) x 1000))/0.75
	=	12356321 + 6197333
	=	18553654 kcal/hr
		…..(4 marks)
Heat input with cogeneration plant	=	[(100000 x 860) /24 + (8.3 x (630-70) x 1000)] / 0.75
	=	(3583333 + 4648000) / 0.75
	=	10975111 kcal/hr
		…..(4 marks)
Coal savings	=	(18553654 – 10975111) / 3800
	=	1995 kg/h
		……(2 marks)

…………. End of Section – III …………..