15th NATIONAL CERTIFICATION EXAMINATION FOR ENERGY MANAGERS & ENERGY AUDITORS– August, 2014

PAPER – 2:	**Energy Efficiency in Thermal Utilities**		
Date:23-8-2014	Timings:14:00-17:00	Duration: 3 HRS	Max. Marks: 150

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

(i) Answer all **50** questions
(ii) Each question carries **one** mark
(iii) Please hatch the appropriate oval in the OMR answer sheet with black pen or HB pencil.

1.	If the terminal temperature differences at the hot and cold end of a heat exchanger is same, then the LMTD is a) 100 ^oC b) 0 ^oC c) 50 ^oC d) none of the above
2.	Which of the following fuel fired steam boiler will have the least evaporation ratio? a) coconut shell b) natural gas c) oil d) rice husk
3.	Which of these is not true of 'critical point' of steam/water mixture? a) the temperature at critical point is 374.15^{o}C b) the pressure at critical point is 221.2 bar c) saturated liquid and saturated vapour lines meet at critical point d) enthalpy of evaporation is maximum at critical point
4.	Which of these fuels has the highest heating value? a) LPG b) methane c) hydrogen d) diesel
5.	The difference in temperature between steam and condensate is the principle of operation in a a) thermodynamic trap b) thermostatic trap c) orifice type trap d) none of the above
6.	Which of the following will be ideal for heat transfer in a heat exchanger? a) hot water b) super heated steam c) saturated dry steam d) wet steam
7.	What is the predominant mode of heat transfer in reheating furnaces? a) convection b) radiation c) conduction d) pulsation
8.	In a gas turbine, air compressor alone consumes about _____of the energy generated

	a) 5-10% b) 20-30% c) 30-40% d) <u>40-45%</u>
9.	In an oil fired steam boiler the Air to fuel ratio by mass is 15:1 & evaporation ratio is 14:1. The flue gas to fuel ratio will be a) 29:1 <u>b) 16:1</u> c) 1:1 d) 15:1
10.	The cogeneration system which has high overall system efficiency is one which uses <u>a) back pressure steam turbine</u> b) combined cycle c) extraction condensing steam turbine d) reciprocating engine
11.	Regenerator is used mainly along with a a) boiler <u>b) high temperature furnace</u> c) compressor d) gas turbine
12.	The device used to upgrade a lower pressure steam to a higher pressure steam is called a) heat pump <u>b) thermo compressor</u> c) heat pipe d) heat wheel
13.	Which of the following works on a refrigeration cycle? a) thermo compressor b) heat pipe c) heat wheel <u>d) heat pump</u>
14.	Which agro-residue has the lowest gross calorific value? <u>a) deoiled bran</u> b)paddy husk c)sawdust d) coconut shell
15.	The highest % of sulphur is present in a) LDO <u>b) Furnace oil</u> c) LSHS d) Kerosene
16.	Which of the following is not a property of ceramic fibre insulation? a) low thermal conductivity <u>b) high heat capacity</u> c) light weight d) thermal shock resistance
17.	For stoichiometric combustion of 1 kg of carbon, the required amount of air will be about a) 31 kg b) 21 kg <u>c) 11.6 kg</u> d) 2.67 kg
18.	For coal fired system, the flame length is influenced by a) moisture <u>b) volatile matter</u> c) ash content d) fixed carbon .
19.	Which of the following in fuel contributes to erosive effect on burner tips? <u>a) ash</u> b) water c) sulphur d) volatile matter

20.	The largest heat loss in the heat balance of a coal fired boiler is due to a) dry flue gas loss b) loss due to hydrogen in the fuel c) radiation losses d) moisture in the air
21.	Water treatment for steam boilers is generally required to a) remove hydrogen b) prevent scale formation c) help improve combustion efficiency d) reduce stack temperature
22.	The stoichiometric air to natural gas ratio by volume for complete combustion is a) 14-15 b) 7-8 c) 9.5-10.5 d) none of the above
23.	A rise in conductivity of boiler feed water indicates a) drop in the contamination of feed water b) greater purity of feed water c) rise in the TDS of feed water d) rise in oxygen level
24.	For transporting the steam to the long distance, the best quality of steam is a) dry saturated steam b) slightly superheated steam c) mildly wet steam d) very high pressure steam
25.	In a steam system, the purpose of air venting is because air a) is a good conductor b) acts as insulator c) is inert d) is diluent
26.	The inverted bucket trap operates on the principle of _______ difference between water and steam a) pressure b) density c) temperature d) velocity
27.	Furnace wall heat loss does not depend on ______ a) temperatures of external wall surfaces b) velocity of air around the furnace c) thermal conductivity of wall brick d) material of stock to be heated.
28.	The insulation material suitable for low temperature application to prevent heat gain is a) mineral fiber b) fiber glass c) silica d) polyurethane
29.	In FBC boiler, the combustion is carried out at a temperature a) closer to steam temperature. b) adiabatic combustion temperature c) below ash fusion temperature d) above ash fusion temperature
30.	The material used to control SOx in the FBC boiler is a) limestone b) alumina c) silica d) lime
31.	In an industry, exhaust gas from the furnace is used for power generation by installing waste heat recovery steam boiler and a steam turbine. This type of co-generation is termed as a) combined cycle b) Braton cycle c) topping cycle d) bottoming cycle
32.	F&A(from and at) rating of the boiler is the amount of steam generated from

	a) water at 0 ^oC to saturated steam at 100 ^oC b)water at feed water temperature to saturated steam at 100 ^oC <u>c)water at 100 ^oC to saturated steam at 100 ^oC</u> d)water at ambient temperature to saturated steam at 100 ^oC
33.	Pinch analysis of heat exchangers depicts plot of a) temperature vs entropy b) temperature vs area c) temperature vs specific heat <u>d) temperature vs enthalpy</u>
34.	The effectiveness of a heat exchanger does not depend on a) specific heat of hot fluid b) inlet temperature of hot fluid c) inlet temperature of cold fluid <u>d) LMTD</u>
35.	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) all the above
36.	How much kg of SO_2 is produced in complete combustion of 32 kg of sulphur? a) 16 b) 32 <u>c) 64</u> d) 128
37.	Micro turbine can be used to replace _______ for energy savings a)gas turbines b) diesel generator c) HRSG <u>d) PRV</u>
38.	When steam pressure reduces, which of the following increases ? a) sensible heat b) enthalpy of steam c) saturation temperature <u>d) specific volume</u>
39.	If excess air is 20% in a boiler, the excess oxygen in flue gas would be <u>a) 3.5%</u> b) 4% c) 2% d) 1.5%
40.	Which of the following requires the lowest stoichiometric oxygen demand (kg/kg of fuel)? a) hydrogen b) carbon <u>c) sulphur</u> d) methane
41.	Temperature control in fuel oil storage tank is intended to control <u>a) viscosity</u> b) density c) specific heat d) caloric value
42.	An increase in bulk density of a refractory increases its a) thermal conductivity b) heat capacity c) resistance to slag penetration <u>d) all of the above</u>
43.	In a CFBC boiler,the capture and recycling of bed material is accomplished by a) bag filter b) settling chamber <u>c) cyclone</u> d) scrubber system

44.	Bomb calorimeter is used to measure a) atmospheric pressure b) pour point of liquid Fuels c) <u>calorific value of fuels</u> d) viscosity of fuel
45.	Pick the wrong statement. The thermal efficiency of a furnace increases by a) preheating combustion air b) <u>increasing the excess air flow rate</u> c) reducing the surface heat loss d) minimizing the CO loss and un-burnt losses
46.	In a steam turbine power plant, vacuum is generated at a) turbine inlet <u>b) condenser</u> c) deaerator d) all of the above
47.	Heat wheels are mostly used in a situation of…. a) high temperature exhaust gases b) <u>heat exchange between large masses of air having small temperature differences</u> c) heat transfer between a liquid and gas d) corrosive gases
48.	In a condenser, which part of the heat of the steam is rejected? a) super heat b<u>) latent heat</u> c) sensible heat d) latent heat and super heat
49.	The highest energy loss occurs in which of the following thermal power plant equipment ? a) boiler b) steam turbine c) generator d<u>) condenser</u>
50.	Which of the following gives a rough estimate of calorific value of coal ? a) moisture content b) volatile matter c) <u>fixed carbon</u> d) ash content

-------- *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

S1	An economizer was installed in the furnace-oil fired boiler. The following are the data monitored after commissioning the economiser. Air to fuel ratio = 20 Evaporation ratio of the boiler = 12 Specific heat of flue gas = 0.25 kcal/kg^{O}C. Condensate recovery in the plant = Nil. Calculate the rise in temperature of feedwater in an economizer, which brings down the flue gas temperature from 280 ^{O}C to 180 ^{O}C.

Ans	For 1 kg of fuel, steam generated = 12 kg For 1 kg of fuel, required combustion air = 20 kg For 1 kg of fuel, flue gas generated = 20 +1= 21 kg In economizer heat given by flue gas = heat received by water 21 x 0.25 x (280-180) = 12 x 1 x ΔT **Rise in temperature of water** ΔT = 43.75 **ºC**
S2	Hot condensate from a heat exchanger is coming out at 9 bar with a sensible heat of 176.4 kcal/kg. The condensate is flashed to 3 bar with a sensible heat of 133.4 kcal/kg and latent heat of 517 kcal/kg. The flash steam generated is 50 kg/hr. Find out the flow rate of hot condensate in kg/hr from the heat exchanger..
Ans	=S1- S2 / L2 % Flash steam available = (176.4-133.4) / 517 =8.3 % **Flow rate of hot condensate** = 50/.083 = **602 kg/hr**.
S3	The measured CO_2 in flue gas of oil fired boiler is 10 % against the theoretical CO_2 content of 14.5 %, Air to fuel ratio for combustion in the boiler is found to be 20. Calculate the theoretical air required for combustion.
Ans	% Excess air = (Theoretical CO_2 / Actual CO_2) – 1 = (14.5 / 10) – 1 **= 45 %** Theoretical air required for combustion = 20 / 1.45 **= 13.8 kg of air / kg of fuel**
S4	A gas turbine generator is operating with naphtha as a fuel. The following are the data collected during the gas turbine generator operation: Fuel (Naphtha) consumption = 350 kg/hr GCV of naphtha fuel = 10550 kcal/kg Overall efficiency of gas turbine generator = 35 % Cost of naphtha fuel = Rs 45000 / ton Find out the cost of generating one unit of electricity.
Ans	Heat input to the turbine = 10550 * 350 = 3692500 kcal/hr Efficiency of gas turbine = 35 % Gas Turbine Output = [(3692500x0.35) / 860] = 1503 kWh Cost of generating 1503 units of electricity = 350 kg/hr x Rs 45.0

	Cost of one unit of electricity generated	= Rs. 15750 = 15750 / 1503 **= Rs 10.5 per kWh**

S5	A paint drier requires 75.4 m^3/min of air at 93°C, which is heated in a steam-coil unit with 4 bar saturated steam. The density of air is 1.2 kg/m^3 and specific heat of air is 0.24 kcal/kg°C. Inlet air temperature to drier is 32°C.

Steam pressure bar	Steam temperature °C	Enthalpy kcal/kg		
		Water	Evaporation	Steam
4.0	143	143	510	653

How many kg of steam at 4 bar does this steam coil unit require per hour?

Ans

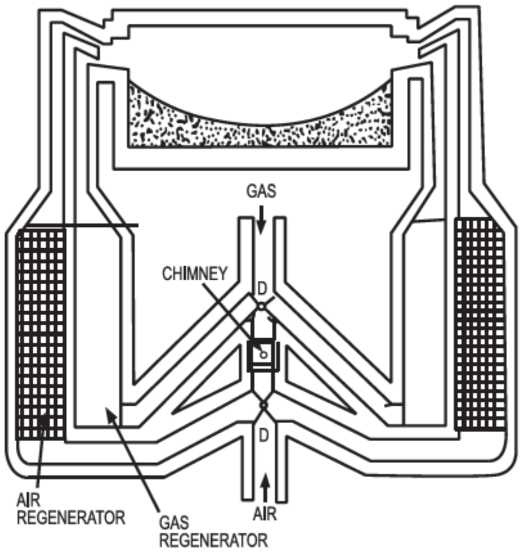
Air flow rate (vol) = 75.4 m^3/min x 60
= 4524 m^3/hr

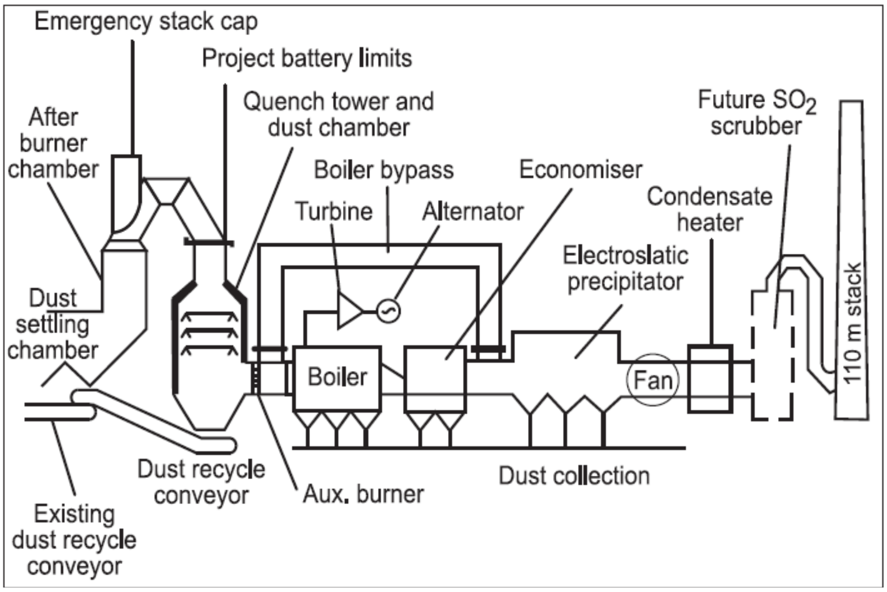
Air flow rate (mass) = 4524 x 1.2
= **5428.8 kg/hr**

Sensible heat of air = m x Cp x ΔT
= 5428.8 x 0.24 x (93-32)
= **79477 kcal/hr**

Latent heat of Steam = 510 kcal/kg
Steam required = 79477 / 510
Steam required **= 156 kg/hr**

S6	List three functions of steam traps. What type of trap is generally used for main steam lines?
Ans	i) Page no 80 & 81 To discharge condensate as soon as it is formed Not to allow steam to escape To be capable of discharging air and other incondensable gases ii) Thermodynamic steam trap is used in the main line
S7	Explain with sketch the working principle of a regenerator used for high temperature furnace
Ans	Ref page no 222

	Regenerator The Regeneration which is preferable for large capacities has been very widely used in glass and steel melting furnaces. Important relations exist between the size of the regenerator, time between reversals, thickness of brick, conductivity of brick and heat storage ratio of the brick. In a regenerator, the time between the reversals is an important aspect. Long periods would mean higher thermal storage and hence higher cost. Also long periods of reversal result in lower average temperature of preheat and consequently reduce fuel economy. (Refer Figure 8.5).  **Figure 8.5 Regenerator** Accumulation of dust and slagging on the surfaces reduce efficiency of the heat transfer as the furnace becomes old. Heat losses from the walls of the regenerator and air in leaks during the gas period and out-leaks during air period also reduces the heat transfer.
S8	Explain briefly the bottoming cycle cogeneration system and mention any two of its application in industry
Ans	i) Ref page no 191 **Bottoming Cycle** In a bottoming cycle, the primary fuel produces high temperature thermal energy and the heat rejected from the process is used to generate power through a recovery boiler and a turbine generator. Bottoming cycles are suitable for manufacturing processes that require heat at high temperature in furnaces and kilns, and reject heat at significantly high temperatures. Typical areas of application include cement, steel, ceramic, gas and petrochemical industries. Bottoming cycle plants are much less common than topping cycle plants. The Figure 7.6 illustrates the bottoming cycle where fuel is burnt in a furnace to produce synthetic rutile. The waste gases coming out of the furnace is utilized in a boiler to generate steam, which drives the turbine to produce electricity.

	 ii) steel, cement, ceramic, glass industry

-------- 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 counter-flow double pipe heat exchanger using hot process liquid is used to heat water, which flows at 10.5m^3/hr. The process liquid enters the heat exchanger at 180°C and leaves at 130°C. The inlet and exit temperature of water are 30°C and 90°C respectively. Specific heat of water is 4.18 kJ/kg°C. a) Calculate the heat transfer area, if overall heat transfer coefficient is 814 W/m^2°C.. b) What would be the percentage increase in area, if the fluid flows were parallel?
Ans	Water flow rate = 10.5 x 1000 = 10500 kg/hr Heat content in water = m x Cp x ΔT = 10500 x 4.18 x (90 – 30) = 2633400 KJ/hr = 2633400 / 3600 **= 731.5 kW** **For Counter current flow**: ΔT1 = 180 – 90 = 90°C ΔT2 = 130 – 30 = 100°C LMTD of counter flow = (100-90)/ ln(100/90) **= 95°C**

	Overall heat transfer coeff. = 814 W/m2°C Area of heat exchanger for counter flow = 731.5 x 1000 / (814x 95) **= 9.5 m^2** **For Parallel flow:** ΔT1 = 180 – 30 = 150°C ΔT2 = 130 – 90 = 40°C LMTD of parallel flow = (150-40)/ ln(150/40) = 83°C Overall heat transfer coeff. = 814 W/m2°C Area of heat exchanger for parallel flow = 731.5 x 1000 / (814 x 83) **= 10.8 m^2** Increase in the area for parallel flow = [(10.8 – 9.5) / 9.5] x 100 **= 14 %**
L 2	In a chlor-alkali plant, 100 TPD caustic solution at 30% concentration is dried to 55% concentration in a single effect evaporator, where the ratio of steam input to moisture removal is 1.0 kg/kg. It is proposed to be replaced by a triple effect evaporator at an investment cost of Rs. 5 crore, for which the ratio of steam input to moisture removal is 0.45 kg/kg. Steam for the evaporator is generated from an oil fired boiler at an evaporation ratio of 14 which operates for 300 days in a year. Calculate payback period if the cost of Fuel Oil is Rs.50,000 per ton.
Ans	% salt concentration at inlet = 30% % salt concentration at outlet = 55% Input quantity of caustic solution to drier = 100 TPD Amount of salt at drier inlet = 100x 0.3 = 30 TPD Flow rate of salt solution at drier outlet = 30 / 0.55 = 54.5 TPD Amount of water removed = 100 – 54.5 **= 45.5 TPD** Ratio of steam / moisture for single effect = 1.0 Amount of steam required for single effect = 45.5 TPD Ratio of steam / moisture for triple effect = 0.45 Amount of steam required for triple effect = 45.5 x 0.45 = 20.475 TPD Amount of steam saved by triple effect = 45.5 – 20.45 **= 25 TPD** Evaporation ratio = 14 Amount of fuel savings = 25 / 14 = **1.79 TPD**

	FO savings per year = 1.79 x 300 = 537 Tons/year Cost of FO saved = 537 x 50,000 = **Rs. 2.69 Crores per year** Investment on triple effect evaporator = Rs. 5 Crores Payback period = 5 / 2.69 = **1.86 years (or) 22 months**
L 3	a) List the advantages of CFBC boilers over AFBC boilers. b) What are the advantages of plate heat exchanger over shell and tube heat exchanger?
Ans	a) List the advantages of CFBC boilers over AFBC boilers. i. Higher processing temperature because of high gas velocity through the system. ii. Lower combustion temperature of about 870 oC can be achieved constantly, which results in minimal NOx formation. iii. The combustion air is supplied at 1.5 to 2 psig rather than 3 to 5 psig as required by bubbling bed combustors. iv. Higher combustion efficiency. v. Better turndown ratio. vi. Erosion of heat transfer surface in the combustion chamber is reduced, since the surface is parallel to the flow. In AFBC system, the surface is generally perpendicular to the flow. b) i. The heat recovery efficiency is higher for plate heat exchanger when compared with shell and tube heat exchanger ii. Plate heat exchanger is compact in size. iii. If the temperature difference is small between cold and hot stream, then plate heat exchanger is used more effectively when compared with shell and tube heat exchanger iv. Heat exchange surface is easily increased or decreased by addition or removal of plates.
L 4	List five energy saving measures **in each** of the following a) Oil fired industrial reheating furnace. b) Steam systems

	Typical energy efficiency measures for an industry with furnace are: 1) Complete combustion with minimum excess air 2) Correct heat distribution 3) Operating at the desired temperature 4) Reducing heat losses from furnace openings 5) Maintaining correct amount of furnace draught 6) Optimum capacity utilization 7) Waste heat recovery from the flue gases 8) Minimum refractory losses 9) Use of Ceramic Coatings b) Steam Systems 1) Avoiding Steam Leakages 2) Providing Dry Steam for Process 3) Utilising Steam at the Lowest Acceptable Pressure for the Process 4) Proper Utilization of Directly Injected Steam 5) Minimising Heat Transfer Barriers 6) Proper Air Venting 7) Condensate Recovery 8) Insulation of Steam Pipelines and Hot Process Equipments 9) Flash Steam Recovery 10) Pipe Redundancy 11) Reducing the Work to be done by Steam 12) Monitoring Steam Traps
L 5	A boiler utilizes Coconut shell as fuel and the ultimate analysis (by weight %) of the fuel is given below:

COMPONENT	Ultimate ANALYSIS %
Carbon	45
Hydrogen	5
Nitrogen	0.6
Oxygen	32
Sulfur	0.08
Mineral matter	4
Moisture	13.32

The CO_2 content of the exit flue gas measured is 10%.

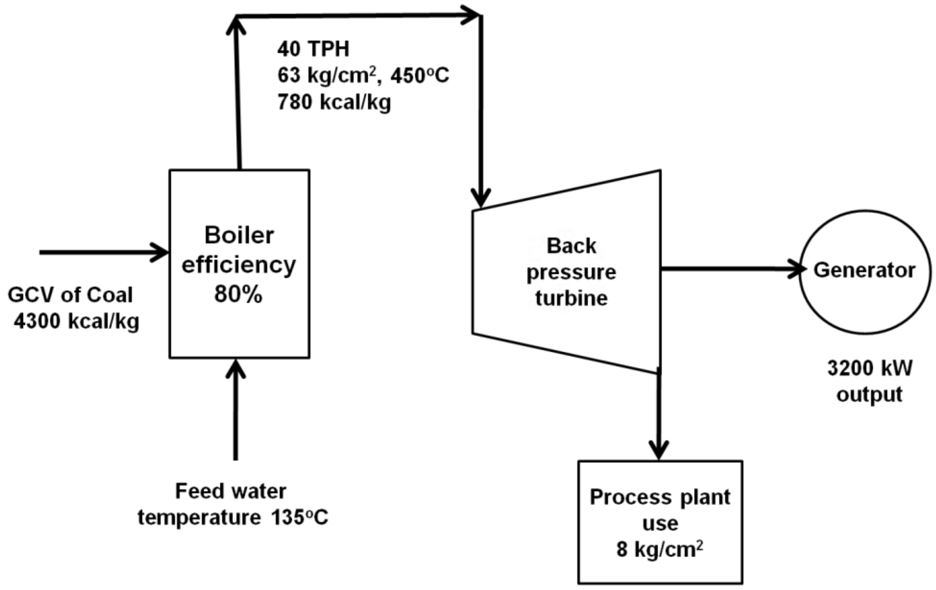
For 100 kg of coconut shell fuel fired calculate the following

(a) Theoretical amount of air required for combustion

(b) Theoretical CO_2 content in flue gas.

(c) % excess air supplied

Ans	a) Total oxygen required =45x2.67+ 5 x 8+.08 x 1 = 160.23kg Oxygen present in the fuel =32 kg

	Net oxygen required =160.23 - 32 = 128.23 kg Air required =128.23/0.23 = 557.52kg **Theoretical amount of air required for combustion =557.52 kg/100 kg of fuel.** b) Nitrogen in the air =557.52 - 128.23 = 429.29kg Nitrogen in the fuel =0.6kg Moles of Nitrogen = 429.89 / 28 = 15.35 Amount of carbon dioxide in flue gas = 45 x 44/12 = 165 kg Moles of Carbon dioxide =165 / 44 = 3.75 Moles of sulphur = 0.08 x 2/64 =0.0025 b)**Theoretical CO_2 content in flue gas = 3.75 / (3.75+15.35+.0025) =19.7%** **c) % Excess air supplied = 100x(19.7/10) -1 = 97%**
L-6	The schematic of a back pressure steam turbine cogeneration system of process plant operating round the clock with operating data is depicted below.  If the steam requirement of the process is to be increased to 44TPH which can be met by the existing boiler through the back pressure turbine, a) find out the reduction in cost of electrical energy drawn from the grid per day due to additional power generation ,assuming the same steam to power recovery as in the existing case and at a grid electricity cost of Rs.7/kWh, Aux power remains the same b) also find out the additional coal requirement per day?

Ans	Present steam to power recovery ratio =40,000 kg/hr / 3,200 kWh **= 12.5 kg/kWh** Additional steam generation = 4TPH Additional power generation potential = 4000 kg/hr /12.5 kg/kWh **=320 kW** **Daily saving** due to additional power generation =320 kW x24 hr x Rs.7 **= Rs 53,760** Additional coal requirement per hour = 4000 x(780-135) / (0.8 x 4300) **= 750 kg/hr** b)**Additional coal requirement** per day =750 kg/hr x 24 = 18,000 kg/day = **18 Ton/day**

-------- End of Section - III ---------