

**22nd NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS - JULY, 2022
PAPER - 2 : ENERGY EFFICIENCY IN THERMAL UTILITIES**

Date : 30.07.2022 Timings : 14:00-17:00 HRS Duration : 3 HRS Max. Marks : 150

Section – I: OBJECTIVE TYPE

Marks: 50 x 1 = 50

1.	Oxygen percentage (by volume) can be measured in flue gas by using_____. a. Ultrasonic tester b. Potassium oxide probe c. Copper tubes d. Zirconium oxide probe
2.	1000 kg of water is to be heated from 30 to 70 °C. the heat gained by water will be a. 40000 kcal/hr b. 40000 kcal c. 40000 kJ d. 40000 kJ/hr
3.	Heat wheels are mostly used in situation of _____ a. high temperature exhaust gases b. heat exchange between large masses of air having small temperature differences c. heat transfer between a liquid and gas d. corrosive gases
4.	In a CFBC boiler the capture and recycling of bed materials is accomplished by a. Bag filter b. Settling chamber c. Cyclone d. Scrubber system
5.	The best quality of steam for industrial process heating is a. High pressure steam b. Wet steam c. Super-heated d. Dry saturated
6.	Which of the following is related with heat pipe _____ a) Can transfer upto 100 times more thermal energy than copper b) Uses a pump for moving the working fluid c) Consists of several plates in series d) All the above
7.	Condensate recovery in steam system _____ a) Improves boiler feed water quality b) Maximizes boiler output c) Reduces water consumption d) All the above
8.	Across the pressure reducing valve of a steam system _____. a) Output enthalpy decreases b) Steam becomes wet c) Steam temperature increases d) Enthalpy remains the same
9.	The flash point of a fuel is the _____ temperature at which fuel can be heated so that the vapour gives off flashes momentarily when an open flame is passed over it. a) highest b) lowest c) medium d) None of the above

10.	Unit of heat to power ratio is _____ a) kwh/kcal b) kcal/kwh c) kwh/btu d) All the above
11.	Which of the following is correct for 'Viscosity'. a) Increases with temperature b) Increase with pressure and temperature c) Decreases with temperature d) None of the above
12.	'Specific Heat' is measured with which unit. a) Kcal/Kg b) kcal/°C c) Kg/cubic meter d) None of the above
13.	How much Energy is released from burning of 1 kg Hydrogen. a) 28922 Kcal/Kg b) 36200 Kcal/kg c) 8084 Kcal/Kg d) 2225 Kcal/Kg
14.	How much air is required for burning of 3 kg of Carbon in fuel. a) 8.0 Kg b) 34.7 Kg c) 3.6 Kg d) 47.8 Kg
15.	Which of the following refers to External Water Treatment Methods. a) Ion Exchange Process b) De-aeration c) Reverse Osmosis d) All of the above
16.	Which of the following is correct related to critical point of water? a) 221.2 bar absolute pressure and 374.18 Deg C b) Latent heat is zero. c) Super critical boilers operate above critical conditions d) All of the above
17.	With increase in steam pressure, which of the following is correct for 'Latent Heat' of water. a) Latent heat decreases b) Sensible heat decreases c) Boiling point decreases d) Total enthalpy decreases
18.	If h_f is 159 kcal/Kg, h_{fg} is 498 kcal/Kg , what will be total heat of steam with 5% Moisture. a) 649 Kcal/Kg b) 632 Kcal/Kg c) 657 Kcal/kg d) 624 Kcal/Kg
19.	Which of the following is function of steam trap : a) To discharge condensate as soon as it is formed. b) Not to allow steam to escape c) To discharge air and other non-condensable gases d) All of the above.

20.	Which of the following trap is suited for steam tracing applications. a) Inverted Bucket trap b) Ball Float trap c) Thermostatic trap. d) Thermodynamic trap.
21.	Recuperators are used for . a) Preheating of combustion air b) Preheating of Fuel c) Preheating of water. d) Preheating the stock.
22.	The wall losses of furnace depends on : a) Emissivity of wall b) Thermal conductivity of refractories c) wall thickness d) All of the above
23.	Determination of economic thickness of insulation depends on a) Cost and heat content of fuel b) Estimated cost of insulation and hours of operation c) Boiler efficiency d) All of the above
24.	The unit of surface heat loss is a) kcal/hr m b) kcal/hr m² c) kcal/hr Deg C d) None of the above
25.	Electrostatic Precipitators can remove ash upto: a) 60-85 % of fly ash b) 70-95 % of fly ash c) 95-99% of fly ash d) 50-80% of fly ash
26.	Which of the following boiler will have lowest size for 500 MW generation. a) CFBC Boiler b) AFBC Boiler c) PFBC Boiler d) None of the above
27.	A co-generation system configuration in which heat is utilized and power is produced in next stage a) Combined cycle b) Bottoming Cycle c) Topping Cycle d) None of the above
28.	Simultaneous generation of steam, power and refrigeration refers to: a) Triple point b) Trigeration c) Combined cycle generation d) Bottoming cycle cogeneration
29.	For every 15° C rise in feed water temperature of boiler will result into overall thermal efficiency improvement by _____ a) 6% b) 1% c) 3% d) 5%

30.	Which of the following is direct contact heat exchanger _____ a) Reboiler/Kettle b) Heat Pipe c) Deaerator d) Heat Pump
31.	A pinch analysis can result in a) Reduction in cooling water b) Increase in cooling water c) reduction in steam d) both a & c
32.	Regenerators utilizing waste heat are widely used in _____ a. Cement industries b. Steel c. Glass melting furnace d. Aluminium
33.	A pulp and paper needs steam at 3 bar and 10 bar in addition to the electric power. The most suitable cogeneration choice among the following will be a. Condensing turbine b. Back pressure turbine c. Extraction cum back pressure turbine d. Bottoming cycle
34.	Low combustion temperature in FBC boiler results in reduction of _____ a. Sox b. NOx c. CO ₂ d. O ₂
35.	An increase in bulk density of refractory increases its a. Volume stability b. Heat capacity c. Resistance to slag penetration d. All of the above
36.	The efficiency of a reheating furnace, operating at 10 tonnes per hour consuming furnace oil of 230 kg/hour for reheating the material from 40 °C-1100 °C (consider specific heat of material is 0.13 kcal/kg °C and calorific value of furnace oil is 10000 kcal/kg) is _____ . a. 55 b. 60 c. 65 d. 70
37.	The device that upgrades a low temperature heat source to a high temperature sink is called a. Heat pipe b. Heat pump c. Plate heat exchanger d. economiser
38.	The difference between mean solid and mean gas velocity in FBC boilers is called a. Fluidization factor b. Slip velocity c. Settling velocity d. None of the above
39.	Which of the following is not a property of ceramic fibre insulation? a. Low thermal conductivity b. Light weight c. High heat capacity d. Thermal shock resistant
40.	Furnace wall heat loss does not depend on a. Temperature of external wall surfaces b. Velocity of air around the furnace c. Temperature of combustion air d. None of the above

41.	Which among the following is most viscous fluid? a. LDO c. HSD	b. Kerosene d. Furnace oil
42.	Hot condensate at 4 bar g pressure has heat content of about 600 kJ/kg, when it released to atmospheric pressure (0 bar g), each kilogram of water can only retain about 419 kJ of heat, The latent heat of flash steam is 2134 kJ/kg, then percentage (%) flash steam available will be a. 11.48 % c. 8.48 %	b. 12.48 % d. 14.48 %
43.	Correction factor for LMTD is applicable for a. Counter current c. Cross flow	b. Parallel flow d. Both a & b
44.	Which one is the preferred waste heat recovery system in large gas turbine? a. Economiser c. HRSG	b. Air pre heater d. Heat wheel
45.	An axial compressor is used in conjunction with which of the following a. Back pressure steam turbine c. Condensing turbine	b. Gas turbine d. Extraction cum condensing turbine
46.	Pick up the wrong statement: The thermal efficiency of the furnace increases by a. Increasing the furnace loading c. Reducing the surface heat loss	b. Increasing the excess air flow rate d. Minimizing the CO loss and unburnt losses
47.	Major heat loss in an oil-fired boiler is accounted by a. Blowdown loss c. Surface radiation loss	b. Un-burnt carbon loss d. Stack loss
48.	For complete combustion of every kg of FO firing, the approximate theoretical quantity of air required is: a. 12 kg c. 16 kg	b. 14 kg d. 18 kg
49.	Select the odd one among the following a. condenser c. evaporator	b. distillation column d. cooling tower
50.	The equipment having the highest efficiency in case of cogeneration plant is a. Electric generator c. Steam or gas turbine	b. Boiler ID fan d. Boiler

..... **End of Section – I**

Section - II: SHORT DESCRIPTIVE QUESTIONS

Marks: 8 x 5 = 40

S-1	Calculate the heat loss from an uninsulated pipeline of 50 mm diameter of 500 mtr length carrying process liquid. The surface temperature of the pipe is 150 °C. After process modification the liquid temperature was brought down resulting in a surface temperature of 50° C. Calculate the reduction in heat loss if the ambient temperature is 32°C in both the cases.
Soln	<p>Existing Heat loss (S) = $\{10+(150-32)/20\} \times (150-32)$ = 1876.2 kcal/hr-m² 2 marks</p> <p>Modified Heat Loss (S1) = $\{10+(50-32)/20\} \times (50-32)$ = 196.2 kcal/hr-m²..... 2 marks</p> <p>Reduction in heat loss = $\pi \times D \times L \times (2035-196.2)$ = $3.14 \times 0.05 \times 500 \times (1876.2-196.2)$ = 131946.89 kcal/hr..... 1 mark</p>
S2	Write short notes on : Each 2.5 Marks a) Heat wheel b) Heat pump
Soln	a) Heat wheel – Refer Guidebook -2, Page 222 b) Heat pump – Refer Guidebook -2, Page 228
S3	A counter flow heat exchanger using hot process liquid is used to heat water. The flow rate of water is 10 m ³ /hr. The process liquid enters the heat exchanger at 95 Deg C and leaves at 55 Deg C. The inlet and exit temperatures of water are 30 Deg C and 42 Deg C respectively. The specific heat of water is 4.18 KJ/Kg Deg C. Calculate the heat transfer area, if the overall heat transfer coefficient is 762 W/m ² °C.
S3 Sol	<p>Water flow rate = 10 x 1000 = 10,000 kg/hr Heat content in water = 10000 x 4.18 x (42-30) = 10000 x 4.18 x 12 = 5,01,600 kJ/hr = 501600/3600 = 139.33 kW</p> <p>Now LMTD_{CF} = $\frac{\Delta T_1 - \Delta T_2}{\ln \left(\frac{\Delta T_1}{\Delta T_2} \right)}$</p> <p>$\Delta T_1 = 95-42 = 53$ $\Delta T_2 = 55-30 = 25$</p> <p>= $\frac{53-25}{\ln \left(\frac{53}{25} \right)}$</p> <p>= $\frac{28}{\ln [2.12]}$</p> <p>= 37.33 °C</p> <p>Area of Heat Exchanger = 139.33x1000/ (762x37.33)</p>

	$= 139330 / 28445.46$ $= 4.89 \text{ m}^2$
S4	<p>A coal fired boiler is generating 40TPH steam and operates for 8000 hrs/year. The TDS in boiler feed water is 500 ppm. The maximum permissible limit is 3000 ppm and make up water is 8%. The temperature of blow down water is 170 °C and feed water temperature is 75 °C. The GCV of fuel is 5000 kCal/kg and efficiency of boiler is 72%.</p> <p>Calculate the fuel saving achieved by reduction in blow-down, if the TDS of feed water is reduced to 300 ppm.</p>
S4 Sol	$\text{Blow Down (\%)} = \frac{[\text{Feed Water TDS in ppm} \times \frac{\text{Makeup Water (\%)}}{100}] \times 100}{(\text{Maximum Permissible TDS} - \text{Feed Water TDS})}$ <p>Initial blow down = $(500 \times 8/100 \times 100)/(3000-500) = 1.6 \%$ Improved blow down with TDS of 300 ppm = $(300 \times 8/100 \times 100)/(3000 - 300) = 0.88\%$</p> <p>Reduction in Blow down = $1.6 - 0.88 = 0.72\%$ Reduction in blow down quantity = $0.72 \times 40 \times 1000/ 100 = 288 \text{ kg/hr}$ Heat Energy Saving = $M \times C_p \times dT = 288 \times 1 \times (170 - 75) = 27360 \text{ kcal/hr}$ Fuel Oil Saving = $27360 / (5000 \times 0.72) = 7.6 \text{ kg/hr}$ Annual Fuel Saving = 7.6 x 8000 = 60800 kg/annum = 60.8 MT/annum</p>
S5	Explain the difference between bottoming and topping cycle with an example.
S5 Sol	Refer Guidebook -2, Page no: 194 & 195
S-6	<p>The ultimate analysis of Indonesian coal is as given below:</p> <p>Carbon : 59%, Hydrogen: 4%, Sulphur : 0.56%, Mineral Matter: 14% Oxygen : 12%, Moisture: 9.43%, Nitrogen: 1.01%</p> <p>a. Find out actual mass of air supplied for combustion of 2000 kg/hr of coal with 60% excess air 3 Marks</p> <p>b. Find out NCV of the fuel if GCV of the coal is 5500 kcal/kg 2 Marks</p>
Soln	<p>a) Theoretical air required for complete combustion</p> $= [(11.6 \times C) + \{34.8 \times (H_2 - O_2 / 8)\} + (4.35 \times S)]/100 \text{ kg/kg of fuel}$ $= [(11.6 \times 59) + \{34.8 \times (4 - 12/8)\} + (4.35 \times 0.56)]/100 \text{ kg/kg of fuel}$ $= 7.73 \text{ kg of air/kg of fuel}$ <p>Excess air supplied = 60%</p> <p>Actual mass of air supplied = $\{1 + EA/100\} \times \text{theoretical air}$ $= \{1+60/100\} \times 7.73$ $= 12.37 \text{ kg of air/kg of fuel}$</p> <p>Air supplied for combustion of 2000 kg/hr of coal = $(12.37 \times 2000)/1000$ $= 24.74 \text{ TPH} \dots\dots\dots 3 \text{ marks}$</p> <p>b) NCV of the fuel</p> <p>GCV = $NCV + 584 \times (9H+M)$ 5500 = $NCV + 584 \times (9 \times 0.04 + 0.094)$ NCV = 5234 kcal/kg2 marks</p>
S-7	Name any five parameters required for determination of furnace oil fired reheating furnace efficiency by direct method.

Soln	Weight of input material t/Hr Furnace oil consumption litre/hr Specific gravity of oil Final material temperature Deg C Initial material temperature Deg C Outlet flue gas temperature Deg C Specific heat of the material Kcal/Kg Deg C GCV of Oil Kcal/Kg																				
S-8	Milk is evaporated in a steam jacketed kettle of 700 kg capacity as a batch process. Milk is heated from 35 °C to 100 °C, where 35 % of its mass is driven off as vapour. The other data's are given below: Specific heat of milk is 0.9 kcal/kg °C Latent heat of steam at 1 kg/cm ² g is 525 kcal/kg. Ignoring the heat required for heating the kettle, calculate the quantity of steam required per batch.																				
Soln	<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 60%;">Quantity of Water evaporated from milk</td> <td style="text-align: right;">= 700 x 0.35</td> </tr> <tr> <td></td> <td style="text-align: right;">= 245 kg/batch</td> </tr> <tr> <td>Heat required to raise temperature of milk</td> <td style="text-align: right;">= 700x0.9x(100-35)</td> </tr> <tr> <td></td> <td style="text-align: right;">= 40950 kcal/batch</td> </tr> <tr> <td>Amount of heat required to evaporate 245 kg of water</td> <td style="text-align: right;">= 245x540</td> </tr> <tr> <td></td> <td style="text-align: right;">=132300 Kcal/Batch</td> </tr> <tr> <td>Total Heat required</td> <td style="text-align: right;">= 40950+132300</td> </tr> <tr> <td></td> <td style="text-align: right;">= 173250 Kcal/batch</td> </tr> <tr> <td>Total steam required</td> <td style="text-align: right;">=173250/525</td> </tr> <tr> <td></td> <td style="text-align: right;">=330 kg/batch.</td> </tr> </table>	Quantity of Water evaporated from milk	= 700 x 0.35		= 245 kg/batch	Heat required to raise temperature of milk	= 700x0.9x(100-35)		= 40950 kcal/batch	Amount of heat required to evaporate 245 kg of water	= 245x540		=132300 Kcal/Batch	Total Heat required	= 40950+132300		= 173250 Kcal/batch	Total steam required	=173250/525		=330 kg/batch.
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..... End of Section - II

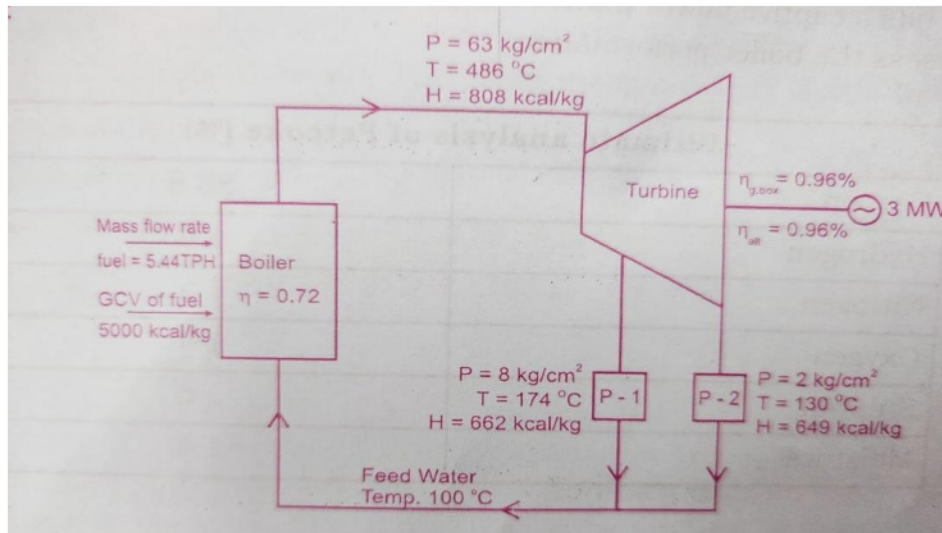
Section - III: LONG DESCRIPTIVE QUESTIONS

Marks: 6 x 10 = 60

L-1	<p>In a paper industry a coal fired boiler of 72% efficiency is proposed to be replaced with paddy husk fired boiler of 65% efficiency. The boiler and steam requirement details are given below.</p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;">GCV of coal</td> <td style="text-align: right;">= 3900 kcal/kg</td> </tr> <tr> <td>Cost of coal</td> <td style="text-align: right;">= Rs.12,000/MT</td> </tr> <tr> <td>GCV of paddy husk</td> <td style="text-align: right;">= 3500 kcal/kg</td> </tr> <tr> <td>Cost of paddy husk</td> <td style="text-align: right;">= Rs 9,000/MT</td> </tr> <tr> <td>Quantity of steam requirement</td> <td style="text-align: right;">= 20 TPH</td> </tr> <tr> <td>Enthalpy of steam</td> <td style="text-align: right;">= 760 kcal/kg</td> </tr> <tr> <td>Enthalpy of feed water</td> <td style="text-align: right;">=120 kcal/kg</td> </tr> <tr> <td>Annual operating hours of boiler</td> <td style="text-align: right;">= 8000 hours</td> </tr> </table> <p>Calculate the annual fuel cost savings by changing over to paddy husk boiler?</p>	GCV of coal	= 3900 kcal/kg	Cost of coal	= Rs.12,000/MT	GCV of paddy husk	= 3500 kcal/kg	Cost of paddy husk	= Rs 9,000/MT	Quantity of steam requirement	= 20 TPH	Enthalpy of steam	= 760 kcal/kg	Enthalpy of feed water	=120 kcal/kg	Annual operating hours of boiler	= 8000 hours
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Sol	<p><u>For Coal Fired Boiler :</u></p> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;">Heat content in the output steam</td> <td style="text-align: right;">= 20000x (760-120)</td> </tr> </table>	Heat content in the output steam	= 20000x (760-120)														
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	<p>Coal requirement = 12800000 kcal/hr</p> <p>= (12800000)/(3900x0.72)</p> <p>= 4558.4 kg/hr</p> <p>Annual operating hours = 8000</p> <p>Annual coal consumption = 4558.4 x 8000 = 36467.2 MT</p> <p>Annual cost of coal = 36467.2 x Rs 12000</p> <p>= 4376 lakhs</p> <p><u>For Paddy Husk Fired Boiler:</u></p> <p>Paddy husk requirement = (12800000)/(3500*0.65)</p> <p>= 5626.4 kg/hr.</p> <p>Annual operating hours = 8000</p> <p>Annual paddy husk consumption = 5626.4 x 8000</p> <p>= 45011.2 MT</p> <p>Annual cost of paddy husk = 45011.2 x Rs 9000</p> <p>=Rs 4050.98 lakh.</p> <p>Annual fuel Cost saving = 4376– 4050.98</p> <p>= Rs 325.02 lakhs</p>
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L-2 The co-generation configuration of a process plant along with relevant data are given in the figure below.



If the extraction steam from the turbine is 8 TPH, calculate the following

- Energy Utilization Factor
- Heat to power ratio, kW thermal to kW electrical

6 Marks
4 Marks

Sol a) Energy Utilization Factor

Total steam flow into co-generation system:

$$0.72 = X \times (808-100) / (5000 \times 5.44 \times 1000)$$

$$19584000 = X \times (808-100)$$

$$X = 27661.0 \text{ kgs or } 27.66 \text{ TPH}$$

Extraction steam flow = 8TPH

$$\text{Back pressure steam flow} = 27.66 - 8 = 19.66\text{TPH}$$

$$\text{EUF} = (\text{Electrical o/p } (Q_e) + \text{Thermal o/p } (Q_t)) / \text{Fuel Input} \times \text{GCV } (Q_f)$$

$$Q_f = (5.44 \times 1000 \times 5000) = 27.2 \text{ Mkcals}$$

$$Q_e = 3 \times 1000 \times 860 = 2.58 \text{ Mkcals}$$

$$\begin{aligned} Q_t &= [8 \times 1000 \times (662-100)] + [19.66 \times 1000 \times (649-100)] \\ &= 4.49 + 10.79 \\ &= 15.28 \text{ Mkcals} \end{aligned}$$

$$\begin{aligned} \text{EUF} &= ((2.58 + 15.28) \times 100) / 27.2 \\ &= 0.656 \times 100 = 65.66 \end{aligned}$$

b) Heat to power ratio, kW thermal to kW electrical

$$Q_{th} = 15.28 / 860 = 17.77 \text{ MW}$$

$$Q_e = 2.58 / 860 = 3 \text{ MW}$$

$$\text{Heat to power ratio} = 17.77 / 3 = 5.92$$

a) Two boilers A & B are delivering steam in equal amount to a common header, both at pressure of 15 bar. Boiler A has super heater and Boiler B is without super heater. The temperature of steam supplied by boiler A is 300 °C. The temperature of resulting mixture of steam in the common header is 235 °C. Find out the dryness fraction of steam supplied by the boiler B. Take specific heat of superheated steam, $C_p = 2.09 \text{ kJ/kg}$

Properties of Steam at 15 bar:

- Saturation temperature, $t_{sat} = 198.3 \text{ }^\circ\text{C}$
- Sensible heat of Steam, $h_f = 844.6 \text{ kJ/ kg}$
- Latent heat of steam, $h_{fg} = 1945.3 \text{ kJ/ kg}$
- Total heat of steam, $h_g = 2789.9 \text{ kJ/kg}$

5 Marks

b) An oil-fired boiler is rated for 10 TPH of saturated steam and pressure of 10 kg/cm² at F&A condition. The Boiler is operating at rated pressure with a feed water temperature of 60°C. Estimate the maximum possible steam generation at the operating pressure. The following data is provided

Latent heat of steam at 100°C is 540 kcal/kg

Enthalpy of steam at 10 kg/cm² is 662 kcal/kg

		5 Marks														
Sol	<p>Ans:</p> <p>a) Let us assume each boiler delivers 1 kg of steam. Then the mass of the mixture of steam in header = 1 + 1 = 2 kg. Using Heat and Mass Balance: Enthalpy from Boiler A + Enthalpy from Boiler B = Enthalpy in common header $\{2789.9 + 2.09 \times (300-198.3)\} + \{844.6 + X \times 1945.3\} = 2 \times \{2789.9 + 2.09 \times (235 -198.3)\}$ $X = 0.97$</p> <p>b) Ans: Maximum possible steam generation = $10 \times 1000 \times 540 / (662-60)$ $= 8970 \text{ kg/hr or } 8.97 \text{ TPH}$</p>															
L-4	i) Explain how a FBC boiler works. How is it different from CFBC boiler? ii) List any five properties of refractories.	5 Marks 5 Marks														
Sol	<p>i) Refer Guidebook -2, Pg 173, 178 & 179 ii) Refer Guidebook -2, Pg 156 & 157</p>															
L-5	<p>1) Explain the working of a direct contact heat exchanger. 2) Explain any two methods of testing of steam traps. 3) What are the benefits and applications of pinch technology in process industry? 4) List any two advantages of ceramic fibre. 5) Why slight positive pressure is to be maintained in a reheating furnace?</p>	Each 2 Marks Each 2 Marks														
Sol	<p>1) Refer Guidebook -2, Pg 230 2) Refer Guidebook -2, Pg 94 to 96 3) Refer Guidebook -2, Pg 252 4) Refer Guidebook -2, Pg 165 5) Refer Guidebook -2, Pg 132</p>															
L-6	<p>An oil refinery has a captive power plant with petcoke fired boiler. The following are the data collected to assess the boiler performance.</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th colspan="2">Ultimate analysis of Petcoke (%)</th> </tr> </thead> <tbody> <tr> <td>Carbon</td> <td style="text-align: center;">88.8</td> </tr> <tr> <td>Hydrogen</td> <td style="text-align: center;">3.6</td> </tr> <tr> <td>Nitrogen</td> <td style="text-align: center;">1.2</td> </tr> <tr> <td>Oxygen</td> <td style="text-align: center;">1.4</td> </tr> <tr> <td>Sulphur</td> <td style="text-align: center;">3.6</td> </tr> <tr> <td>Moisture</td> <td style="text-align: center;">1.4</td> </tr> </tbody> </table> <p>GCV of Petcoke : 8430 kcal/kg O₂ in flue gas : 6 % Flue gas temperature : 250 °C Heat loss due to radiation & convection : 1 % Loss due to unburnt in fly ash & bottom ash : 0.5% Specific heat of flue gas : 0.29 kcal/kg °C Specific heat of water vapour : 0.45 kcal/kg °C Ambient Temperature : 30 °C</p>		Ultimate analysis of Petcoke (%)		Carbon	88.8	Hydrogen	3.6	Nitrogen	1.2	Oxygen	1.4	Sulphur	3.6	Moisture	1.4
Ultimate analysis of Petcoke (%)																
Carbon	88.8															
Hydrogen	3.6															
Nitrogen	1.2															
Oxygen	1.4															
Sulphur	3.6															
Moisture	1.4															

Humidity in ambient air	: 0.0204 kg/kg dry air	
Steam generation at 110 barg & 520 °C		
Steam enthalpy at generation pressure and temp	: 816 kcal/kg	
Feed water temperature	: 200 °C	
Steam drum pressure	: 115 bar g	
Saturated liquid enthalpy at steam drum pressure	: 352 kcal/kg	
Calculate the following:		
a) Boiler efficiency using indirect method		8 Marks
b) Specific boiler steam generation MT/MT of petcoke (Evaporation Ratio)		2 Marks

Sol	a)	Theoretical Air required	$= \{(11.6 \times 0.888) + [34.8 \times (0.036 - 0.014/8)] + 4.35 \times 0.036\}$ = 11.64	kg air / kg of petcoke	
		% Excess Air supplied	$= (6/(21-6)) \times 100$ = 40.0	%	
		Actual Air supplied	$= (1+40/100) \times 11.65$ = 16.31	kg air / kg of petcoke	
		Mass of dry flue gas	$= \{(0.888 \times 44/12) + 0.012 + (16.31 \times 0.77) + (16.31 - 11.65) \times 0.23 + (0.036 \times 64/32)\}$ = 16.97	kg air / kg of petcoke	
		Stack losses, L1	$= 16.97 \times 0.29 \times (250-30)/8430 \times 100$ = 12.84	%	
		Loss due to formation of water vapor from H2 in fuel, L2	$= 9 \times 0.036 \times \{584 + 0.45 \times (250-30)\}/8430 \times 100$ = 2.63	%	
		Loss due to moisture in fuel, L3	$= 0.014 \times \{584 + 0.45 \times (250-30)\}/8430 \times 100$ = 0.11	%	
		Loss due to moisture in Air, L4	$= 16.31 \times 0.0204 \times 0.45 \times (250-30)/8430 \times 100$ = 0.39	%	
		Loss due to radiation and convection	= 1.0	%	
		Loss due to unburnt in ash	= 0.5	%	
		Efficiency of boiler using indirect method	$= (100 - 12.84 - 2.63 - 0.11 - 0.39 - 1.0 - 0.5)$ = 82.53	%	
		b)			
			Heat added per unit of steam generation	$= (816-200)$ = 616.0	kcal/kg of Steam
			Heat supplied by fuel for steam generation	$= (82.5/100) \times 8430$ = 6957	kcal/kg of petcoke
			Specific boiler steam generation (Evaporation Ratio)	$= 6957/616$ = 11.29	

..... **End of Section – III**