PAPER-2 CODE: GREEN

21st NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS

PAPER - 2 : ENERGY EFFICIENCY IN THERMAL UTILITIES

Date : 25.09.2021 Timings : 14:00-17:00 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**

1.	Radiation and convection heat losses in a boiler can be improved by a) economizer b) air preheating **c) proper insulation** d) increasing steam pressure	**C**
2.	Mechanical de-aeration is accomplished with the help of a) turbine b) sodium sulphite **c) steam** d) reverse osmosis	**C**
3.	Which property of the ceramic coating influences the efficiency increase in the furnace? a) conductivity b) convection c) coating thickness **d) emissivity**	**D**
4.	Heat loss from the wall in a furnace depends on a) Emissivity of the wall b) wall thickness c) insulation thickness **d) all of the above**	**D**
5.	Which one of the following is an organic insulation material? a) mineral wool **b) thermocol** c) calcium silicate d) mica	**B**
6.	Refractories with higher thermal conductivity is preferred in a) boilers b) furnaces c) kiln **d) regenerator**	**D**
7.	In FBC boiler the combustion is carried out at a temperature a) above the ash fusion temperature of the fuel used b) close to the steam temperature **c) below the ash fusion temperature of the fuel** d) close to the critical temperature	**C**
8.	The extraction condensing turbines when compared to the back pressure turbines has **a) higher power to heat ratios** b) lower power to heat ratios c) same power to heat ratios d) higher thermal efficiency	**A**
9.	When a pressure reducing valve is replaced by a steam turbine? a) inlet and outlet enthalpies are same	**C**

	b) outlet temperature is more than inlet temperature **c) Inlet enthalpy is more than outlet enthalpy** d) Outlet enthalpy is more than inlet enthalpy	
10.	Power is generated from the waste gases of a gas turbine. This type of co-generation is called **a) topping cycle** b) bottoming cycle c) Rankine cycle d) Brayton cycle	A
11.	Pinch analysis generally depicts the plot of a) temperature Vs entropy **b) Temperature Vs enthalpy** c) Temperature Vs specific heat d) Temperature Vs heat transfer coefficient	B
12.	Tuyeres is part of the equipment associated with a) re-heating furnace b) induction furnace c) electric arc furnace **d) none of the above**	D
13.	If 10% air is entrained in a steam system at 5 kg/cm²g then the saturation temperature of steam will be **a) less than the saturation temperature at 5 kg/cm²g** b) more than the saturation temperature at 5 kg/cm²g c) equal to the saturation temperature at 5 kg/cm²g d) equal to the saturation temperature at 5.5 kg/cm²g	A
14.	Steam at 6 bar has a sensible heat of 159.33 kcal/kg and latent heat of 498.59 kcal/kg. If the steam is 95% dry then the total enthalpy is a) 625 kcal/kg b) 649.95 kcal/kg **c) 633 kcal/kg** d) none of the above	C
15.	Insulation used for temperatures more than 350°C is a) polyurethane b) polystyrene **c) calcium silicate** d) wood	C
16.	A power plant which uses a gas turbine first followed by steam turbine for power generation is called a) Rankine cycle **b) Combined cycle** c) Brayton cycle d) Bottoming cycle	B
17.	Sulphur percentage in furnace oil **a) sets lower flue gas temperature limit** b) improves viscosity c) does not add to heat value d) forms soot	A
18.	A paper plant needs steam at 3 bar and 10 bar in addition to 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	C
19.	The maximum possible evaporation ratio of a boiler (From & At 100°C basis with an enthalpy of 540 kcal/kg steam) fired with coal having a calorific value of 4050 kcal/kg and operating at 80% efficiency will be a) 5 **b) 6** c) 7.5 d) 9.4	B
20.	In a turbine, the thermodynamic process taking place is a) contraction **b) expansion**	B

	c) condensation d) both (a) & (b)	
21.	Specific Heat of oil is a function of a) viscosity b) flash Point c) pour point **d) specific gravity**	**D**
22.	NCV of a fuel is 8200 kcal/kg, moisture content is 9% and hydrogen is 12%. The GCV of fuel is **a) 8883** b) 7380 c) 9400 d) 8322	**A**
23.	Sulphur percentage is the highest in a) kerosene b) diesel **c) furnace oil** d) LSHS	**C**
24.	For optimum combustion of fuel oil, the O_2 in the flue gases should be around **a) 4%** b) 14% c) 800ppm d) 21%	**A**
25.	Which of the following metal requires the highest latent heat for melting? a) gold b) copper c) steel **d) aluminium**	**D**
26.	Stored Heat loss in furnace is high due to a) numbers of cold starts b) mass of refractory c) high thermal conductivity of refractory **d) all the above**	**D**
27.	If the actual O_2 measured in flue gas is 3.5%, what is the % excess air supplied? a) 21% **b) 20%** c) 30% d) 3.5%	**B**
28.	The amount of O_2 required for complete combustion of 18 kg of sulphur is ________. **a) 18** b) 36 c) 27 d) 9	**A**
29.	Fuel utilization factor will be high with a) gas turbine cogeneration b) diesel engine cogeneration c) gas engine cogeneration **d) gas engine trigeneration**	**D**
30.	Deaerator is a _____type heat exchanger a) shell and tube heat exchanger b) double pipe heat exchanger **c) direct contact heat exchanger** d) single stage evaporator	**C**
31.	Expansion loops in steam distribution lines are useful a) to reduce steam velocity b) to reduce friction in pipe **c) to manage cold start requirements** d) to reduce steam loss in large lines	**C**
32.	The optimum steam pressure required for direct injection of steam for making hot water is ______________. a) 5 Kg/cm^2 b) 7 kg/cm^2 c) 3 Kg/cm^2 **d) 1 kg/cm^2**	**D**
33.	The ratio of the weight of a given volume of oil to the weight of the same volume of water at a given temperature is a) Density **b) Specific gravity** c) Viscosity d) Specific volume	**B**

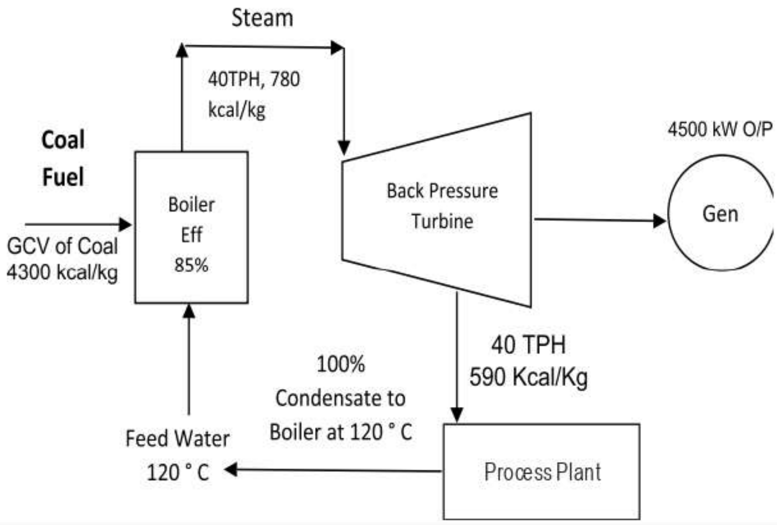
34.	Which of the following Agro residues has the highest GCV? a) Deoiled bran b) Paddy husk **c) Saw dust** d) Coconut shell	**C**
35.	For each kg of CO formed in combustion reaction, the heat released in kcal is a) 8084 kcal b) 2430 kcal **c) 5654 kcal** d) 2224 kcal	**C**
36.	The typical evaporation ratio of Coal Fired Boilers with a calorific value of 4500 kcal/kg will be in the range of a) 2.0-3.0 **b) 4.0-5.5** c) 13.5-14.5 d) 11.0-13.0	**B**
37.	Which of the following fuels require the lowest excess air %? a) Pulverized Coal b) Fuel Oil **c) Natural Gas** d) Wood	**C**
38.	Which of the following boiler water treatment ensures complete removal of salts? **a) Demineralization** b) Softening c) De-Aeration d) none of the above	**A**
39.	The velocity of steam in steam pipe is directly proportional to a) Number of bends in pipe b) 5^{th} power of the diameter of pipe **c) Specific volume of steam** d) Length of pipe	**C**
40.	Which of the following traps work under the principle of buoyancy? **a) Inverted bucket type** b) Thermodynamic c) Thermostatic d) all of the above	**A**
41.	The working medium in a Thermo-Compressor is a) Electricity b) Compressed air c) Atmospheric air **d) Steam**	**D**
42.	Which of the following is not true of "Critical Point" of steam/water mixture? a) The temperature at critical point is 374.15 Deg 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**	**D**
43.	The temperature at which a refractory will deform under its own weight is indicated by **a) Pyrometric cone equivalent** b) Cold crushing strength c) Refractoriness under load d) none of the above	**A**
44.	Which of the following is a property of ceramic fibre? a) Low thermal conductivity b) Light weight c) Thermal shock resistant **d) all of the above**	**D**
45.	In a FBC Boiler, the bottom ash constitutes roughly _____ % of the total ash. a) 20-30% **b) 30-40%** c) 40-50% d) 50-60%	**B**
46.	A temperature cross cannot be achieved in a) Cross flow heat exchanger **b) Parallel flow heat exchanger** c) Counter flow heat exchanger d) all of the above	**B**
47.	In a counter flow heat exchanger, cold fluid enters at 40°C and leaves at 60°C, whereas the hot fluid enters at 160°C and leaves at 140°C. The LMTD is **a) 100°C** b) 300°C c) 0°C d) none of the above	**A**

48.	The effectiveness of a heat exchanger does not depends on **a) Specific heat of hot fluid** **b) Specific heat of cold fluid** **c) Inlet temperature of hot fluid** **d) all of the above**	**A,B, C,D**
49.	In determining the economic cost of insulation thickness for a steam pipe, which of the following factors need to be considered? a) Calorific value of the fuel b) Annual hours of operation c) Cost of fuel **d) all of the above**	**D**
50.	Temporary hardness is caused by **a) bicarbonates** b) chlorides c) sulphates d) silica	**A**

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

(i) Answer all **Eight** questions

(ii) Each question carries **Five** marks

S-1	**The schematic of a backpressure steam turbine cogeneration system of a process plant operating round the clock is depicted below. Find the Heat to Power ratio and the Energy Utilization Factor.** **5 Marks** 
	Heat output to process Q_{th} = 40000 * (590-120) = 1,88,00,000 kcal/hr Power O/P, Q_e = 4500 KW = 4500*860 kcal/hr = 38,70,000 kcal/hr Heat to Power Ratio = 18800000 /3870000 = 4.85 **Fuel input Calculation:** Boiler Efficiency = Steam Flow * (Steam Enthalpy-FW Enthalpy)/(GCV * Fuel Flow) Fuel input to boiler = 40000*(780-120)/(4300*.85) = 7222.982 Kg Fuel input heat (Q_f)= Fuel input to boiler * GCV = 7222.982*4300 = 31058823 kcal/hr EUF = $(Q_{th}+Q_e)/Q_f$ = (18800000+3870000)/ 31058823 EUF = 0.729 (72.9%)
S-2 a)	**List five factors for reducing energy use in hot air dryers using steam.** **3 Marks**

	Page no 81, Book 2 , Chapter 3
S-2 b)	**In a process plant, 12,000 kg/hr of hot condensate is discharged at 8 bar(g) having a sensible heat of 186 kcal/kg. The plant also requires steam at 2 bar(g) for some other heating application. Find out the quantity of flash steam generation possible in kg/hr if the condensate at 2 bar(g) has a sensible heat of 135 kcal/kg and a latent heat of 550 kcal/kg. 2 Marks**

Flash steam generation % = S1 – S2 x 100 / L2

S1 – sensible heat of high pressure condensate
S2 – sensible heat of low pressure steam
L2 – latent heat of low pressure steam

Flash steam % = $\frac{186-135}{550}$ x 100
= 9.273 %

Flash steam generated = flash steam % x Volume of hot condensate
= 0.0927 x 12000 = 1112.73 kgs/hr

S-3	**In a double pipe heat exchanger, flow rates of hot and cold-water streams are 50 and 60 kg/min. Hot and cold streams inlet temperatures are 100°C and 35°C. The exit temperature of the cold stream is 55°C. The specific heat of water is 4.18 kJ/kg K. The overall heat transfer coefficient is 800 W/m²K. Calculate the heat transfer area required for parallel flow. 5 Marks**

Rate of heat transfer of cold stream Q (Watts) = mx Cpx(t2-t1)
= (60/60) x (4.18 x 1000) x (55-35) J/s
= 83,600 W

Hot stream temperature difference = Q/ (mxCpx 1000)
= 83600/ ((50/60)x 4.18 x 1000)
t1- t2 = 24 °C
t2 = 100 – 24
= 76 °C
For parallel flow Δ T1 = 100 °C – 35°C = 65 °C
ΔT2 = 76 °C – 55°C= 21 °C

LMTD = (65 – 21) /ln(65/21)
= 38.97
Overall heat transfer co efficient U = 800 W/m² k

Heat transfer area required = A = Q/(U x LMTD) = 83600/(800 x 38.97)
= 2.68 m²

S-4 a)	**Explain the function of a steam trap? 2 Marks**

- To discharge condensate as soon as it is formed.
- Not to allow live steam to escape

Refer Guidebook-2, Page 82 & 83

S-4 b)	**Name the suitable trap for each of the following applications: 3 Marks**

Sl.No	Application	Type of Trap to be installed
1	Heat Exchangers	Bucket, Inverted bucket, Float trap
2	Tracer Lines	Thermostatic trap/ Bimetallic traps

	3	Steam mains	Thermodynamic trap

S-5	**A small foundry is producing cast iron products through Cupola. Monthly liquid metal production is 150 Tons. The existing Coke to Iron ratio is 1: 7. After modifying the hot air system, the coke to iron ratio has improved to 1:9. Calculate the annual coke savings and annual monetary savings, if the cost of coke is Rs. 8400/ton. 5 Marks**
	Present coke consumption = (1/7) x 1000 = 142.86 kg/ton Coke consumption with Hot air system = (1/9) x 1000 =111.11 kg/ton Savings in Coke = 142.86-111.11 = 31.75 kg/ton Annual Coke Savings = 31.75 x 150 x12 = 57.163tonne. Annual monetary savings = Rs 8400 x 57.163 = Rs.4,80,160/- **(or)** Present coke consumption = (1/7) x 150x 1000 = 21428.57 kgs coke Coke consumption with Hot air system =(1/9)x150x1000 =16665 kgs coke Savings in Coke = 21428.57 -16665= 4763.6 kg/month Annual Coke Savings = 4763.6 x12 = 57162.84 kgs/yr = 57.163 TPY Annual monetary savings = Rs 8400 x 57.163 = Rs.4,80,160/-
S-6	**A steam pipe with OD of 100 mm is carrying steam from a boiler to an offsite location at a distance of 1 km from the boiler plant. The steam line already had 20 mm of outer insulation. The management has decided to increase the insulation thickness by 20 mm, to further reduce heat loss. Calculate the reduction in annual heat loss in Million kcals, with this additional 20 mm insulation.** **Given Data:** i) Outside surface temperature with 20 mm insulation: 90°C ii) Outside surface temperature after adding 20 mm additional insulation thickness: 40°C iii) Ambient Temperature: 25°C iv) Annual operating hours: 8000 hrs **5 Marks**
	Heat loss with 20mm insulation: Heat Loss in Case S1 = [10 +(90-25)/20] x (90-25) = 861.25 Kcal/hr-m^2 Surface Area A1 = 3.14x(100+20+20/1000)x1000 = 439.6 m^2 Total Heat Loss with 20mm insulation thickness L1 = S1 x A1 =(861.25x439.6) = 378605.5 kcal/hr **Heat lost with (20+20= 40 mm) insulation** Heat Loss in Case 2 S2 = [10+ (40-25)/20] x (40-25) = 161.25 Kcal/hr-m^2 Surface Area A2 = 3.14x(100+40+40/1000)x1000 = 565.2 m^2 Total Heat Loss L2 = 161.25 x 565.2 = 91184.727 kcal/hr Additional hourly heat savings = (378605.5-91184.727) =287612.8 kcal/hr Annual heat savings = (288738.7 x 8000 /10^6) =2300.90 Million kcals/yr
S-7	**List five advantages of Thermo-compressors. 5 Marks**
	Refer Guidebook-2, Page 80 • No condensation loss takes place

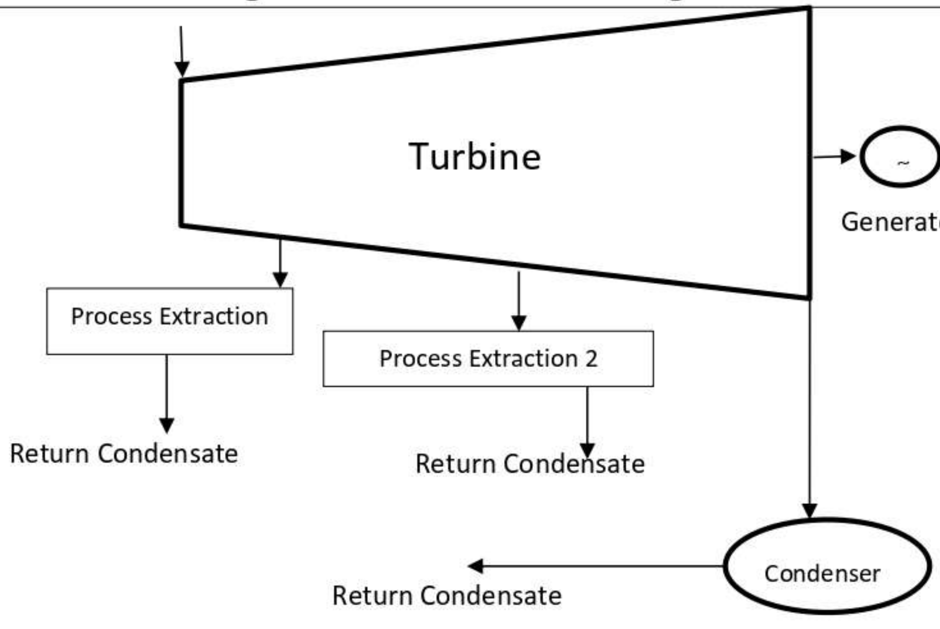
	• Thermal efficiency of system is extremely high • Entrainment of low-pressure steam results in substantial savings • No moving parts and hence maintenance need is minimum • No major operational changes • Low space requirements • Insensitive to fouling • High operating reliability
S-8 i)	**Explain any three advantage of FBC Boilers.** **3 Marks**
	Refer Guidebook-2, Page 182-183
S-8 ii)	**Explain how SOx and NOx are controlled in FBC Boilers** **2 Marks**
	Refer Guidebook-2, Page No 183

…………. 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	**Explain the following:**
i)	**Turbine Cylinder Efficiency** **3 Marks**
	Refer Guidebook-2, Page 205
ii)	**Double extraction condensing turbine with a schematic diagram** **3 Marks**
	
iii)	**Operation and application of heat pump with a schematic diagram** **4 Marks**
	Refer Guidebook-2, Page 228-230
L-2	**A process liquid of 7 lakh litres per day is heated in a Plate heat exchanger as per process requirements using 4 kg/cm²(g) steam.** **The operating details are given below :**

Evaporation ratio of the boiler is	13.5
Process Liquid Inlet temperature	30°C
Process Liquid Outlet temperature	120°C
Specific heat of the process liquid	0.94 kcals/kg.°C

		Density of process liquid	1.035 kg/Lit
		Fuel cost	Rs. 35/ kg
		Configuration	Counter flow
		Annual operation	350 days
		Daily Operating hours	16 hours/day

Steam Parameters:

Pressure Kg/cm²(g)	Temperature °C	Enthalpy in kcal/kg		
		Water	Evaporation	Steam
3	133	133.42	517.15	639.15
4	143	143.70	509.96	653.66

If the existing 4 kg/cm²(g) steam is replaced by 3 kg/cm²(g) steam, estimate the annual monetary savings. **10 Marks**

Process flow = 700 000/16 = 43750 LPH = 43750 x 1.035 =45,281.25 kg/hr
Heat load = 45281.25 x 0.94 x(120-30)= 38,30,793.75 Kcal/hour
Steam required at 4 Kg/cm² =3830794/509.96 = 7511.95 kg
Steam required at 3 kg/cm² =3830794/517.15 = 7407.51 Kg/hr
Fuel required for 4 Kg/cm² Steam = 7511.95/13.5 = 556.44 kg/hr
Fuel required for 3 Kg/cm² Steam = 7407.51/13.5 = 548.70 kg/hr
Annual fuel savings =(556.44-548.70)*16*350= 43344 Kg
Annual Monitory savings =43344*35 = Rs 15,17,040/-

L-3 **In a process plant, fuel oil is being pre-heated. This fuel oil is pumped from pump house located 500 m away from the boiler. Steam is supplied for pre-heating the fuel oil to raise its temperature from 25°C to 130°C in a counter flow Shell & Tube Heat Exchanger.**
Calculate the Inner Diameter (ID) in "mm" of the pipe carrying the steam for pre-heating the fuel oil. The maximum permissible velocity in the pipeline is 25 m/sec.

Fuel Oil Parameters:

Flow : 60 m³/hr
Specific Heat : 0.7 kcal/kg°C
Density : 830 kg/m³

Steam Parameters:

Pressure : 8 kg/cm²
Temperature : 170°C
Specific Volume : **0.22 m³/kg**
Enthalpy of water : 170 kcal/kg
Enthalpy of evaporation : 490 kcal/kg
Enthalpy of Steam : 660 kcal/kg **10 Marks**

Heat gained by Fuel Oil = m x Cp x (ΔT)
= 60x830x.7x(130-25)
= 3660300 Kcal/hr

Heat gained by Fuel Oil = Heat lost by Steam

Heat lost by Steam = m * H

3660300 = m x 490

Mass flow of Steam = 7470 kg/hr

Volumetric Flow of Steam = Mass Flow * Specific Volume

	= 7470 x 0.22 = 1643.4 m^3/hr = 1643.4/3600 m^3/s = 0.4565 m^3/s Velocity = 25m/s Area = Volume/Velocity = 0.4565/25 = 0.01826 m^2 Area = $\pi D^2/4$ D = $\sqrt{(Area * 4)/3.14}$ = $\sqrt{(.1826 * 4)/3.14}$ = 0.1525 m =15.25 cm = 152.5 mm 2 Marks **Note:** There was a typo error in the question paper instead of "Specific Volume 0.22 m^3/kg" it was printed "Specific Volume 22 m^3/kg" though the announcement was made in the classroom any candidate who had solved using the "Specific Volume 22 m^3/kg", it was considered for awarding marks though it is technically wrong.
L-4	**A medium size textile processing unit has installed a Thermic fluid heater, which is giving an output of 2,50,000 kcal/hr. The operating details of thermopack are given below:** **Details:** Fuel used : Coconut shell Fuel consumption : 80 kg/hr GCV of fuel : 4,500 kcal/kg Forward oil temperature : 255°C Return oil temperature : 245°C Flue gas Temperature (T_g) : 295°C Ambient temperature (T_a) : 30°C Specific heat of flue gas : 0.25 kcal/kg.°C O_2% in flue Gas : 10 % Stoichiometric Air Requirement : 6 kg/kg of fuel Moisture in fuel : 13 % Hydrogen in Fuel : 5 % **Calculate:**
L-4 1.	**Efficiency of thermopack** **2 Marks**
	Capacity of thermopack : 2,50,000 Kcal/hr Fuel consumption : 80 kg/hr Heat input : 80 X 4500 = 360000 kcal/hr Heat output : 250000 kcal/hr Efficiency : 250000/360000= 69.444%
L-4 2.	**Flue gas Loss (*Ignore ash content in the coconut shell for calculations*).** **3 Marks**
	Excess air = (O_2/ 21- O_2) x 100 = 10/21-10 x 100 = 90.9 % Actual Air Supplied = 6 X 1.909 = 11.454 Kg/kg of fuel Flue gas quantity = 11.454 + 1 = 12.454 kg/kg Flue gas loss = ((12.454*0.25*(295-30))/4500)*100 = 18.34 % (**or** 66024 Kcal/hr)

L-4 3.	**Loss due to Moisture and Hydrogen.**	**3 Marks**
	Loss due to moisture in fuel =((M x ((584 + Cp (Tg- Ta)))/GCV)) X 100 =((0.13*((584+0.45*(295-30)))/4500))*100 = 2.03 % (**or** 7308 Kcal/hr) Loss due to Hydrogen in fuel = (9 H_2 x 584 + Cp (Tg- Ta)/GCV) X 100 = ((9*0.05)*((584+0.45*(295-30)))/4500)*100 = 7.03 % (**or** 25308 Kcal/hr)	
L-4 4.	**Find out radiation and other unaccounted losses.**	**2 Marks**
	Radiation Loss and Unaccounted loss (by difference) = 100- 69.444 – (18.34+2.03+7.03) = 100-69.44-27.4= 3.156 % (**or** 11361.6 Kcal/hr)	
L-5 1.	**List seven fuel economy measures in Furnaces.**	**7 Marks**
	Refer Guidebook-2, Page No 129	
L-5 2.	**Discuss briefly the effect of positive and negative pressure on furnace performance.**	**3 Marks**
	Refer Guidebook-2, Page No 132	
L-6	**Explain**	
L-6 i)	**LMTD with an example of counter flow heat exchanger**	**4 Marks**
	Refer Guidebook-2, Page 237-238	
L-6 ii)	**Temperature Correction Factor**	**3 Marks**
	Refer Guidebook-2, Page 239	
L-6 iii)	**Heat Exchanger Effectiveness**	**3 Marks**
	Refer Guidebook-2, Page 243-244	

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