Paper-2 Code: Green

20th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS& ENERGY AUDITORS- September, 2019

PAPER –2: Energy Efficiency in Thermal Utilities

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**

(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, as per instructions

1.	Dolomite is a ________ type of refractory: a) acidic **b) basic** c) neutral d) none of the above
2.	Which of the following is not true of condensate recovery? a) reduces water charges b) reduces fuel costs c) increases boiler output **d) increases boiler blow down**
3.	Calcium and magnesium bicarbonates present in feedwater fed to a boiler would form: a) acidic solution **b) alkaline solution** c) neutral solution d) none of the above
4.	In steam systems, the purpose of venting air is because, air is ________. a) a good conductor b) an inert substance c) an oxidizing agent **d) an insulator**
5.	A bottoming cycle is one in which fuel is used for producing: a) power primarily followed by byproduct heat output **b) heat primarily followed by byproduct power output** c) power, heat and refrigeration simultaneously d) none of the above
6.	A supercritical boiler has parameters beyond critical point, which refers to: **a) 221.2 bar (a) pressure and 374.15 ^{0}C temperature** b) 246.1 bar (a) pressure and 538.44 ^{0}C temperature c) 306.5 bar (a) pressure and 538.82 ^{0}C temperature d) 170.0 bar (a) pressure and 374.18 ^{0}C temperature
7.	Of the total volume of natural gas, the main constituent is : **a) methane** b) iso-octane c) propane d) hexane
8.	For optimum combustion of fuel oil, O_2 percentage in flue gases should be maintained at: **a) 2-3 %** b) 14-15 % c) 23 % d) 21%
9.	The draft caused solely by the difference in weight between the column of hot gas inside the chimney and

	column of outside air is known as : a) balanced draft b) induced draft c) forced draft **d) natural draft**
10.	The cogeneration system which has high overall system efficiency is : **a) back pressure steam turbine** b) combined cycle c) extraction condensing steam turbine d) reciprocating engine
11.	When 10 kg of fuel, with 60% carbon, is burnt with theoretical air, the mass of CO_2 released will be : a) 32 kg b) 440 kg c) 450 kg **d) 22 kg**
12.	F & A (from and at) rating of the boiler is the amount of steam generated from : a) water at 0 °C to saturated steam at 100 °C b) water at feed water temperature to saturated steam at 100 °C **c) water at 100 °C to saturated steam at 100 °C** d) water at ambient temperature to saturated steam at 100 °C
13.	Steam generated in a boiler is 36 tonnes in 3 hours. Fuel consumption in the same period is 1 tonne per hour. Continuous blow down is 8% of feed water input. The boiler evaporation ratio is ? **a) 12** b) 11.7 c) 36 d) 24
14.	Which of the following statement is false? **a) LPG vapour is twice as light as air** b) LPG is a mixture of propane and butane c) LPG is a gas at normal atmospheric pressure d) LPG is required to be odorized
15.	The inverted bucket operates on the principle of _______ difference between water and steam: a) pressure **b) density** c) temperature d) velocity
16.	Which of the following is not measured in proximate analysis? a) volatile matter b) fixed carbon **c) sulphur** d) ash
17.	Reduction of steam pressure, in a process heating application will: a) reduce the steam temperature b) reduce the sensible heat c) increase the enthalpy of evaporation **d) all of the above**
18.	The TDS level in boiler water, in the context of boiler blow down, can be determined by measuring : a) alkalinity of water b) thermal conductivity of water **c) electrical conductivity of water** d) turbidity of water
19.	De-aeration of boiler feed water helps in combating: **a) corrosion** b) TDS c) silica d) hardness
20.	In stoichiometric combustion of furnace oil, which of the following will be absent in flue gas ? a) nitrogen b) carbon dioxide **c) oxygen** d) Sulphur dioxide
21.	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**
22.	In determining the optimal economic insulation thickness for a steam pipeline, which of the following factors need not be considered ? a) annual hours of operation b) calorific value **c) pipe material** d) cost of fuel

23.	Which is not a property of Ceramic fiber insulation? a) low thermal conductivity b) light weight **c) high heat storage** d) thermal shock resistant
24.	Which property is the most important, for an insulating brick? a) Mechanical strength b) Chemical resistance c) Compact strength **d) Porosity**
25.	Quality of waste heat in flue gas refers to: a) dust concentration in flue gas **b) Temperature of flue gas** c) moisture in flue gas d) corrosive gases in flue gas
26.	In a low temperature waste heat recovery system, which of the following, is the most suitable? a) Economizer **b) Heat Pipe** c) regenerator d) ceramic recuperator
27.	Which of the following heat recovery equipment, requires a compressor for its operation? a) thermo-compressor b) heat wheel **c) Heat pump** d) heat pipe
28.	Pinch analysis of process streams, depicts the plot of : a) temperature vs entropy b) temperature vs. area c) temperature vs specific heat **d) temperature vs enthalpy**
29.	Which of the following is true for a process heating requiring direct injection of steam? a) Thermodynamic trap is required b) Thermostatic trap is required c) Inverted bucket trap is required **d) None of the above**
30.	If a vapor-liquid combination of 1 kg at 120 ºC is supplied with 50 kcal of heat without change in state and at constant pressure conditions; its temperature will be? a) 220 ºC b) 190 ºC c) 170 ºC **d) 120 ºC**
31.	Which of the following constituent in flue gas is used for determining excess air? a) % nitrogen b) % Sulphur Dioxide **c) % Carbon dioxide** d) % Moisture
32.	Arrange the following fuels in decreasing order of their GCV's - (p) Bagasse, (q) Furnace Oil, (r) Coal, (s) Hydrogen **a) s-q-r-p** b) p-q-r-s c) r-s-q-p d) q-r-s-p
33.	Which of the following contributes to spluttering of flame at burner tip during combustion of fuel oil? a) ash content **b) water content** c) Sulphur content d) ambient air humidity and temperature
34.	Which trap is preferred in condensate removal from steam main lines? a) Float trap **b) Thermodynamic trap** c) Thermostatic trap d) All of the above
35.	In an FBC boiler, with low ash fusion coal, if the bed temperature exceeds 950°C, the result is: a) Boiler explosion **b) clinker formation** c) Melting of lime stone d) Ash carry over
36.	Water logging of 3 m lift of condensate, at trap discharge, will result in back pressure of __________

	a) 0.03 kg/cm^2 b) **0.3 kg/cm^2** c) 3 kg/cm^2 d) 30 kg/cm^2
37.	When pure hydrogen is burnt with stoichiometric air, percentage CO_2 on volume basis, in dry flue gas, will be : a) 79% b) 21% **c) 0%** d) 100%
38.	Heat transfer rate for drying application will be low if we heat with : a) Saturated steam b) Dry steam **c) Superheated steam** d) None of the above
39.	The viscosity of furnace oil will be maximum at which of the following temperatures? **a) 40 °C** b) 60 °C c) 90 °C d) 105 °C
40.	Carpet loss in the context of coal consumers is related to : a) Short receipt b) Accounting mistakes c) Ash handling **d) coal storage**
41.	Thermo-compressor is commonly used for : a) compressing hot air **b) upgrading low pressure steam** c) converting saturated steam to super-heated steam d) reverse compression of CO_2
42.	Latent heat of any vapour at its critical point will be : a) highest b) above zero **c) zero** d) less than zero
43.	The temperature at which, refractory will deform under its own weight, is it's softening temperature, indicated by : a) melting point **b) Pyrometric Cone Equivalent** c) reform temperature d) critical point
44.	Which type of the following co-generation system has high heat-to-power ratio ? a) gas turbine **b) back pressure turbine** c) extraction condensing turbine d) reciprocating engine
45.	Drain pockets are provided in a steam line for : **a) effective removal of line condensate** b) effective removal of steam c) removal of dirt d) checking of steam line
46.	Capillary wick is a part of : a) heat pump b) heat wheel **c) heat pipe** d) regenerator
47.	Scale losses in reheating furnaces will : a) increase with CO in combustion gases **b) increase with excess air** c) decrease with excess air d) have no relation with excess air
48.	Tuyeres is a terminology associated with : a) induction furnace b) pusher type furnace c) arc furnace **d) cupola**
49.	The low combustion temperature in FBC boilers results in minimal formation of : a) CO b) SOx **c) NOx** d) CO_2
50.	Turn down ratio of a burner is the ratio of______________. **a) maximum to minimum fuel input without affecting optimum excess air levels** b) minimum to maximum fuel input without affecting optimum excess air levels c) maximum to average fuel input d) average to minimum fuel input

…………. 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	In an industry the process equipment need 5000 kg/hr of saturated steam at 10 kg/ cm^2(g). For a steam velocity of 25 m/sec, what will be the diameter of the steam pipe in 'mm', given that the specific volume of steam at 10 kg/ cm^2(g) is 0.1802 m^3/kg. **Ans :** Specific volume of steam at 10 kg/cm^2(g) = 0.1802 m^3/kg Flow rate = 25m/sec Mass flow rate = 5000 kg/hr = 1.389 kg/sec Volume flow rate = 1.389 x 0.1802 **= 0.25 m^3/sec** Volume flow rate is also = $(\pi/4 \times D^2)$x25 Therefore, $(\pi/4 \times D^2) \times 25 = 0.25$ Hence, **Diameter of steam pipe line** 'D' = $[(0.25/((\pi/4) \times 25)]^{0.5}$ = 0.1128m **or 112.8 mm**
S2	An economizer was installed in an oil-fired boiler. The following data was obtained after commissioning the economizer. ▪ Air to fuel ratio = 18 ▪ Evaporation ratio of the boiler = 12.5 ▪ Specific heat of flue gas = 0.25 kcal/kg°C. ▪ Condensate recovery in the plant = Nil. Calculate the rise in temperature of feed water across the economizer, corresponding to a drop in flue gas temperature from 280 °C to 190 °C. **Ans :** Steam generated per kg of fuel, (*from evaporation ratio*) = 12.5 kg Required combustion air per kg of fuel, (*from air to fuel ratio*) = 18 kg combustion air/kg fuel oil Flue gas generated per kg of fuel = (18 +1) **= 19 kg flue gas/kg fuel oil** Heat balance across the Economizer : Heat given by flue gas = Heat received by water ((19 x 0.25 x (280-190)) = (12.5 kg x 1kcal/kg°C x ΔT) **Rise in temperature of water ΔT = 34.2 °C**
S3	Compute the heat loss in percentage, due to unburnt in fly ash and bottom ash, for an AFBC Boiler, using Indian coal, with : ▪ GCV = 4200 kcal/kg. ▪ % Ash in coal = 38.8 ▪ Ratio of bottom ash to fly ash = 15 : 85 ▪ GCV of fly ash = 452.5 kcal/kg ▪ GCV of bottom ash = 800 kcal/kg

Ans:

<u>Unburnt in fly ash</u>

Amount of fly ash in 1 kg of coal = (0.85 x0.388)
= 0.3298 kg fly ash/kg coal
GCV of fly ash = 452.5 kcal/kg fly ash
Heat loss in fly ash = (0.3298 x 452.5 kcal per kg fly ash)
= 149.23 kcal/kg coal
% Heat loss in fly ash = (149.23 x 100 /4200)
= **3.55 %**

<u>Unburnt in bottom ash</u>

Amount of bottom ash in 1 kg of coal = 0.15 x 0.388
= 0.0582 kg bottom ash/kg coal
GCV of bottom ash = 800 Kcal/kg bottom ash
Heat loss in bottom ash = (0.0582 x 800 kcal per kg bottom ash)
= 46.56 kcal/kg coal
% Heat loss in bottom ash = (46.56 x 100 /4200)
= **1.11 %**

S4 List five main parameters considered for the selection of refractories?

Ans : **(Page No:166, Sec 5.11)**

S5 What is the significance of volatile matter, in case of solid fuels?

Ans : **(Page No: 9)**

S6

- List three functions of a steam trap. **(3 Marks)**
- Explain the working principle of thermodynamic trap. **(2 Marks)**

Ans :

- List three functions of a steam trap. **(Page 82)**
- Explain the working principle of thermodynamic trap. **(Page 86-87)**

S7 In an industry, an electrical oven consuming 1100 kWh/batch, is proposed for replacement, by a FO fuel fired oven. Calculate the simple payback period, given the following data:

Number of batches / years = 4000
Efficiency of electric oven = 82%
Efficiency of FO fired oven = 55%
Cost of FO = Rs.35,000/Tonne
GCV of FO = 10,200 kcal/kg
Electricity cost = Rs.6.0/kWh
Investment for FO fired oven = Rs. 125 Lakhs

Ans :

Useful heat, required per batch = (1100 x 860 x 0.82)
= 7,75,720 kcal/batch
FO input per batch = (7,75,720 /(0.55 x 10,200))

		= 138.27 kg FO/batch
	FO cost per batch	= (138.27 kg FO/batch x Rs.35/kg FO)
		= Rs.4,839.45
	Electricity cost per batch	= (1,100 kWh/batch x Rs.6.0/kWh)
		= Rs.6,600
	Cost savings per batch on account of replacement	= (Rs.6,600 – Rs.4,839.45)
		= Rs.1,760.55
	Annual cost savings at 4000 batches per year	= (1,760.55 x 4000)
		= Rs.70,42,200
		(Or) = Rs.70.422 lakhs
	Investment	**= Rs.125 lakhs**
	Simple payback period	= (125/70.422)
		= **1.78 years**
S8	In a process plant, 30 TPH of steam, after pressure reduction to 20 kg/cm^2(g), through a pressure reducing valve, gets superheated. The temperature of superheated steam is 350 °C. The management desires to install a de-super heater to convert the superheated steam into useful saturated steam at 20 kg/cm^2(g) for process use. The saturated steam temperature is 210°C. Calculate the quantity of water required to be injected at 30 °C, in the de-super heater, in order to obtain the desired saturated steam, using the following data: • Specific heat of superheated steam = 0.45 kcal/kg°C • Latent heat of steam at 20 kg/cm^2(g) = 450 kcal/kg **Ans :** ▪ Quantity of heat available above saturation = (30,000 x 0.45 x (350-210)) **= 18,90,000 kcal/hr** By Heat & Mass balance : Q x{1 x (210-30) + 450} **= 18,90,000** ▪ **Quantity of water (Q) required to be added in de-super heater** = 18,90,000/{1 x (210-30) + 450} = 18,90,000/630 = **3000 kg/hr**	

………….. 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) An open cycle gas turbine was running with naphtha as fuel. The following are the data collected during the gas turbine operation: Fuel (Naphtha) consumption = 300 kg/hr GCV of naphtha fuel = 11,500 kcal/kg Overall Efficiency of gas turbine (which includes air compressor and alternator) = 22% Cost of naphtha fuel = Rs.40,000/Tonne

	a) Find out the output power and cost of fuel for generating one unit of electricity. ....6 marks b) The management has decided to install a waste heat boiler, to generate 2 TPH of saturated steam, at 4 kg/cm^2(g), with an enthalpy of 656 kcal/kg. Assuming that, 50% of the input heat is available in the turbine exhaust gases, how much steam can be generated if the feed water temperature is 30 °C. ....4 marks **Ans:** a) Heat input to turbine = (300 kg Naptha/hr x 11,500 kcal/kg) = 34,50,000 kcal/hr Efficiency of gas turbine = 22% **Gas turbine output power** = ((34,50,000 kcal/hr x 0.22)/ 860) = **882.56 kW** Cost of generating 882.56 units of electricity = (300 kg Naptha/hr x Rs.40/kg Naptha) = Rs.12000/hr **Cost of One unit of Electricity generation** = (Rs.12000 per hour/882.56 kWh per hour) = **Rs.13.6/kWh** b) Waste heat potential in existing gas turbine = (0.5 x 34,50,000 kcal/hr) = 17,25,000 kcal/hr. Heat required for raising 1 kg of steam *(feed water temp 30 °C)* = (656-30) kcal/kg steam = 626 kcal/kg steam Steam generation potential = (17,25,000 kcal per hour/626 kcal per kg steam) = 2755.6 kg steam/hr **= 2.7556 TPH**
L-2	Explain any two of the following: (Each 5 Marks) 1. Regenerator (Page 222) 2. Heat Pipe (Page 223) 3. Gas turbine cogeneration system (Page 192)
L-3	A process industry consuming 10 TPH of saturated steam at 10 kg/sq.cm(g) pressure has been using coal as fuel in boiler. Typical ultimate analysis of the coal: **Carbon : 41.11%** **Hydrogen : 2.76 %** **Nitrogen : 1.22 %** **Oxygen : 9.89 %** **Sulphur : 0.41%** **Ash : 38.63** **Water : 5.89** Flue gas temperature = 200°C Ambient temperature = 30°C Enthalpy of steam = 668 kcal/kg Feed water temperature = 80°C Specific heat of flue gases = 0.23 kcal/kg°C

	Boiler efficiency with Indian coal =72 % GCV of coal = 4,000 kCal/kg Oxygen content in dry flue gases = 10% Annual Hours of operation = 8000 hrs. **Determine:** **(i) Quantity of annual coal requirement in tonnes/year** **(5 Marks)** **(ii) Calculate % dry flue gas losses** **(5 Marks)** Solution: a) Coal requirement Q = Steam (q) x (hg – hf)**/(** Efficiency x GCV) = 10 x (668-80) / (0.72 x 4000) = 2.042 T/Hr = 2.042 x 8000 hrs = 16336 Tonnes/year Theoretical air requirement for coal **=** $\frac{[(11.6 \times C\%) + \{34.8 \times (H_2\% - O_2\%/8)\} + (4.35 \times S\%)]}{100}$ kg / kg of coal **=** $\frac{[(11.6 \times 41.11) + \{34.8 \times (2.76 - 9.89/8)\} + (4.35 \times 0.41)]}{100}$ **= 5.31 kg / kg of coal** (Or) == =

C+ O_2 = CO_2	12+32= 44	(C%*32)/12
$2H_2$+ O_2 = $2H_2O$	4+32=36	(H%*32)/4
S+ O_2 = SO_2	32+32=64	(S%*32)/32

Total oxygen required = (41.11* 32/12) + (2.76*32/4)+ (0.41*32/32)
= (109.63) + (22.08) + (0.41)
= 132.1 kg/ 100 kg fuel

Oxygen already present in 100 kg fuel = 9.89 kg/ 100 kg fuel

Additional oxygen required = 132.1 – 9.89 kg/ 100 kg fuel
= 122.21 kg/ 100 kg fuel

Quantity of dry air required
(Air contains 23% O_2 by weight) = 122.1/ 0.23

= 531.35 kg/ 100 kg fuel

	Theoretical air required = 531.35/100 = 5.31 kg air/ kg fuel == Excess air = O_2x100/(21-O_2) Excess air = 10 x 100/ (21 – 10) = 90.9% Actual air= 5.31 * (100+90.9)/100 =10.137 kg air/kg coal Heat loss in dry flue gas = m x C_P (T_f – T_a) x 100 /GCV $= \frac{(10.137+1) \times 0.23 \times (200-30) \times 100}{4000}$ = 10.89 %
L-4	a) In a double pipe heat exchanger, flow rates of the hot and the cold water streams flowing through a heat exchanger are 10 and 25 kg/min, respectively. Hot and cold water stream inlet temperatures are 70 °C and 27 °C, respectively. The exit temperature of the hot stream is required to be 50°C. The specific heat of water is 4.179 kJ/ kg K. The overall heat transfer coefficient is 900 W/m^2 K. Neglecting the effect of fouling, calculate the heat transfer area for a) Parallel-flow b) Counter-flow. ………..7 marks b) Write a brief note on the operation and application of plate heat exchangers in process industries. ………..3 marks **Ans:** **a)**

B)

Rate of heat transfer, Q (watts)	Q= m x Cp x 1000 x (T2-T1) =(10/60)× 4.179 x 1000 ×(70 – 50) = 13930 W
Cold water exit temperature, T_2	T_2 = [Q/(mx Cp x 1000)]+ T1 = (13930/((25/60)* (4.179*1000)))+27 = 35°
Terminal temperature differences for parallel flow heat exchangers	= (70-27) & (50 – 35); i.e., 43°C and 15°C respectively.
LMTD	(43 – 15)/ln(43/15) = 26.59°C
Overall heat transfer coefficient U	900 W/m^2 °K
Heat transfer area required for parallel flow	A = Q/ (U*LMTD)
	= [13930/ (900 × 26.59)]
	= 0.582 m^2
Terminal temperature differences for counter flow heat exchangers	(70–35) and (50–27) ^{0}C i.e., 35 °C and 23 °C respectively.
LMTD	(35–23)/ln(35/23) = 28.58
Overall heat transfer coefficient U	900 W/m^2 °K
Heat transfer area required for counter flow	A = Q/ (U*LMTD)
	=[13930/ (900 × 28.58)]
	= 0.542 m^2

Plate heat exchangers consist of a stack of parallel thin plates that lie between heavy end plates. Each fluid stream

	passes alternately between adjoining plates in the stack, exchanging heat through the plates. The plates are corrugated for strength and to enhance heat transfer by directing the flow and increasing turbulence. These exchangers have high heat-transfer coefficients and area, the pressure drop is also typically low, and they often provide very high effectiveness. However, they have relatively low pressure capability. The biggest advantage of the plate and frame heat exchanger, and a situation where it is most often used, is when the heat transfer application calls for the cold side fluid to exit the exchanger at a temperature significantly higher than the hot side fluid exit temperature i.e. "temperature cross". This would require several shell and tube exchangers in series due to the lack of purely counter-current flow. The overall heat transfer coefficient of plate heat exchangers under favorable circumstances can be as high as 8,000 W/m^2°C. With traditional shell and tube heat exchangers, the U-value will be below 2,500 W/m^2°C.
L-5	a) In a fruit processing plant, 105 TPD of syrup at 33% concentration is dried to 50% concentration. The existing single effect evaporator, where steam input for water removal ratio is 1.0 kg/kg is proposed to be replaced by a triple effect evaporator where the ratio of steam input for water removal is 0.4 kg/kg. Calculate the annual fuel cost savings for 300 days of operation at an evaporation ratio of 13.5 in the oil fired boiler and at a furnace oil cost of Rs. 35,000/tonne. ………..7 marks b) Why steam is recommended to be used at the lowest practicable pressure for indirect process heating? ………..3 marks **Ans.:** a) Bone Dry material = (105 TPD x 0.33) = 34.65 TPD Product at 50 % concentrate = (34.65 / 0.5) = 69.3 Water removed/ day = (105 – 69.3) = 35.7 TPD Initial steam consumption with single effect evaporator at 1 kg/kg = (35.7 TPD x 1.0 kg/kg) = 35.7 TPD Steam consumption with triple effect evaporator at 0.4 kg/kg = (35.7 TPD x 0.4 kg/kg) = 14.28 TPD Steam savings per day = (35.7 TPD – 14.28 TPD) = 21.42 TPD FO savings per day at evaporation ratio of 13.5 = (21.42 TPD / 13.5 Tonne steam per Tonne FO) = 1.5867 TPD Rupee savings per day at Rs. 35,000/MT = (1.5867 TPD FO X Rs. 35,000/MT FO) = Rs. 55,535 Annual monetary savings at 300 working days per year = (Rs. 55,535 X 300 Days) = Rs.166.6 Lakhs b) The latent heat in steam reduces as the steam pressure increases. It is only the latent heat of steam, which takes part in the heating process when applied to an indirect heating system. Thus, it is important that its value be kept as high as possible. This can only be achieved if we go in for lower steam pressures.

	c) However, lower the steam pressure, the lower will be its temperature. Since temperature is the driving force for the transfer of heat at lower steam pressures, the rate of heat transfer will be slower and the processing time greater. In equipment where fixed losses are high (e.g. big drying cylinders), there may even be an increase in steam consumption at lower pressures due to increased processing time. There are however, several equipment's in certain industries where one can profitably go in for lower pressures and realize economy in steam consumption, without materially affecting production time. Therefore, there is a limit to the reduction of steam pressure. Depending on the equipment design, the lowest possible steam pressure with which the equipment can work should be selected without sacrificing either on production time or on steam consumption.
L-6	a) An oil fired reheating furnace has an operating temperature of around 1000 °C. Average furnace oil consumption is 330 litres/hour. Flue gas exit temperature after the air preheater is 820 °C. Combustion air is preheated from ambient temperature of 35 °C to 215°C through the air preheater. The other data are as given below. Specific gravity of oil = 0.92 Calorific value of oil = 10,200 kcal/kg Average O_2 percentage in flue gas = 13.5 % Theoretical air required = 14 kg of air per kg of oil Specific heat of air = 0.23 kcal/kg°C Specific heat of flue gas = 0.25 kcal/kg°C **Find out :** • The sensible heat carried away by the exhaust flue gases in kcals/hr and as a percentage of the energy input. ………..4 marks • The heat recovered by the combustion air in kcal/hr and as a percentage of the energy input. ………..3 marks b) Explain the concept and the advantage of a self-recuperative burner? ………..3 marks **Ans:** a) Fuel input = (330 litres/hr x 0.92 kg/litre) = 303.6 kg/hr Energy Input = (303.6 kg oil/hr x 10,200 kcals/kg oil) = 30,96,720 kcal/hr Excess air = [O_2 x 100/(21-O_2)] = (13.5 x 100)/(21 - 13.5) = 180 % Theoretical air required = 14 kg of air/kg of oil Actual mass of air required = 14 x (1 + 180 /100) = 39.2 kg air/kg of oil Mass of flue gas (m) = (39.2 + 1) = 40.2 kg flue gas/kg oil Specific heat of flue gas (Cp) = 0.25 kcal/kg.°C **Sensible heat loss in the flue gas** = $(m \times Cp \times \Delta T)_{flue\ gas}$ = (40.2 x 0.25 x (820-35)) = 7889.3 kcal/kg of oil (Or) = (7889.3 kcal/kg of oil x 303.6 kg oil/hr) = **2395176.3 kcal/hr** Sensible heat loss in the flue gas as % heat loss to input energy = (2395176.3 / 30,96,720) x 100 = **77.35 %**

	Heat recovered by combustion air = (39.2 x 0.23 x (215-35)) = 1622.88 kcal/kg of oil = (1622.88 kcal/kg oil x 303.6 kg oil/hr) = **492706.37 kcal/hr** Heat recovered by combustion air as % of input energy = (492706.37 kcal/hr/30,96,720 kcal/hr) x100 = **15.91 %** b) Self-recuperative burner (SRB)is based on traditional heat recovery techniques, in that, the products of combustion are drawn, through a concentric tube recuperator, around the burner body and used to pre-heat the combustion air. A major advantage of this type of system is that, it can be retro-fitted to an existing furnace structure, to increase production capability, without having to alter the existing exhaust gas ducting arrangements. SRBs are generally more suited to Heat-treatment furnaces, where exhaust gas temperatures are lower and there are no stock recuperation facilities.