Paper 2 Pink

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.	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
2.	'Specific Heat' is measured with which unit. a) Kcal/Kg b) kcal/^{o}C c) Kg/cubic meter **d) None of the above**
3.	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
4.	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
5.	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**
6.	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**
7.	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
8.	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

9.	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.**
10.	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.**
11.	Recuperators are used for . **a) Preheating of combustion air** b) Preheating of Fuel c) Preheating of water. d) Preheating the stock.
12.	The wall losses of furnace depends on : a) Emissivity of wall b) Thermal conductivity of refractories c) wall thickness **d) All of the above**
13.	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**
14.	The unit of surface heat loss is a) kcal/hr m **b) kcal/hr m^2** c) kcal/hr Deg C d) None of the above
15.	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
16.	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
17.	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
18.	Simultaneous generation of steam, power and refrigeration refers to: a) Triple point **b) Trigeneration** c) Combined cycle generation d) Bottoming cycle cogeneration

19.	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%
20.	Which of the following is direct contact heat exchanger___________ a) Reboiler/Kettle b) Heat Pipe **c) Deaerator** d) Heat Pump
21.	A pinch analysis can result in a) Reduction in cooling water b) Increase in cooling water c) reduction in steam d) **both a & c**
22.	Regenerators utilizing waste heat are widely used in __________ a. Cement industries **b. Steel** **c. Glass melting furnace** d. Aluminium
23.	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
24.	Low combustion temperature in FBC boiler results in reduction of _______ a. Sox **b. NOx** c. CO_2 d. O_2
25.	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**
26.	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
27.	The devise 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
28.	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
29.	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
30.	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

31.	Which among the following is most viscous fluid? a. LDO b. Kerosene c. HSD **d. Furnace oil**
32.	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 % b. 12.48 % **c. 8.48 %** d. 14.48 %
33.	Correction factor for LMTD is applicable for a. Counter current b. Parallel flow **c. Cross flow** d. Both a & b
34.	Which one is the preferred waste heat recovery system in large gas turbine? a. Economiser b. Air pre heater **c. HRSG** d. Heat wheel
35.	An axial compressor is used in conjunction with which of the following a. Back pressure steam turbine **b. Gas turbine** c. Condensing turbine d. Extraction cum condensing turbine
36.	Pick up the wrong statement: The thermal efficiency of the furnace increases by a. Increasing the furnace loading **b. Increasing the excess air flow rate** c. Reducing the surface heat loss d. Minimizing the CO loss and unburnt losses
37.	Major heat loss in an oil-fired boiler is accounted by a. Blowdown loss b. Un-burnt carbon loss c. Surface radiation loss **d. Stack loss**
38.	For complete combustion of every kg of FO firing, the approximate theoretical quantity of air required is: a. 12 kg **b. 14 kg** c. 16 kg d. 18 kg
39.	Select the odd one among the following a. Condenser b. distillation column c. evaporator **d. cooling tower**
40.	The equipment having the highest efficiency in case of cogeneration plant is **a. Electric generator** b. Boiler ID fan c. Steam or gas turbine d. Boiler
41.	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**
42.	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

43.	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
44.	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
45.	The best quality of steam for industrial process heating is a. High pressure steam b. Wet steam c. Superheated Steam **d. Dry saturated steam**
46.	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
47.	Condensate recovery in steam system ______ a) Improves boiler feed water quality b) Maximizes boiler output c) Reduces water consumption **d) All the above**
48.	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**
49.	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
50.	Unit of heat to power ratio is ____________ a) kwh/kcal **b) kcal/kWh** c) kwh/btu d) All the above

………….. End of Section – I ……………

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

S-1	The ultimate analysis of Indonesian coal is as given below: Carbon : 59%, Hydrogen: 4%, Sulphur : 0.56%, Mineral Matter: 14% Oxygen : 12%, Moisture: 9.43%, Nitrogen: 1.01% a. Find out actual mass of air supplied for combustion of 2000 kg/hr of coal with 60% excess air **3 Marks** b. Find out NCV of the fuel if GCV of the coal is 5500 kcal/kg **2 Marks**
Soln	a) Theoretical air required for complete combustion = [(11.6 x C) + {34.8 x (H_2 -O_2 /8)} + (4.35 x S)]/100 kg/kg of fuel = [(11.6 x59) + {34.8 x (4 -12/8)} + (4.35 x0.56)]/100 kg/kg of fuel = 7.73 kg of air/kg of fuel Excess air supplied = 60% Actual mass of air supplied = {1 + EA/100} x theoretical air = {1+60/100} X 7.73 = 12.37 kg of air/kg of fuel Air supplied for combustion of 2000 kg/hr of coal = (12.37 x 2000)/1000 = 24.74 TPH……………………………………3 marks b) NCV of the fuel GCV = NCV + 584 x (9H+M) 5500 = NCV + 584 x (9x0.04+0.094) NCV = 5234 kcal/kg ……………………………………………………………………………………..2 marks
S2	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
S3	Milk is evaporated in a steam jacketed kettle of 700 kg capacity as a batch process. Milk is heated from 35 ^{O}C to 100 ^{O}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 ^{O}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.
S3 Sol	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.
S4	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 ^{O}C. After process modification the liquid temperature was brought down resulting in a surface temperature of 50^{O} C. Calculate the reduction in heat loss if the ambient temperature is 32^{o}C in both the cases.
S4 Sol	Existing Heat loss (S) = {10+(150-32)/20}x(150-32) = 1876.2 kcal/hr-m^{2} .... 2 marks Modified Heat Loss (S1) = {10+(50-32)/20}x(50-32) = 196.2 kcal/hr-m^{2}... 2 marks Reduction in heat loss = πxDxL x(2035-196.2) = 3.14x0.05x 500x(1876.2-196.2) = 131946.89 kcal/hr... 1 mark
S5	Write short notes on : Each 2.5 Marks a) Heat wheel b) Heat pump
S5 Sol	Heat wheel – Refer Guidebook -2, Page 222 Heat pump – Refer Guidebook -2, Page 228
S6	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} ^{O}C.
S6 Sol	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 x12 = 5,01,600 kJ/hr = 501600/3600 = 139.33 kW Now $LMTD_{CF} = \dfrac{\Delta T_1 - \Delta T_2}{\ln\left(\dfrac{\Delta T_1}{\Delta T_2}\right)}$ ΔT_1 = 95-42 = 53 ΔT_2 = 55-30 = 25 $= \dfrac{53-25}{\ln\left(\dfrac{53}{25}\right)}$

	$= \frac{28}{\ln(2.12)}$ = 37.33 ^{0}C Area of Heat Exchanger = 139.33x1000/ (762x37.33) = 139330 /28445.46 = 4.89 m^2
S7	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 ^{0}C and feed water temperature is 75 ^{0}C. The GCV of fuel is 5000 kCal/kg and efficiency of boiler is 72%. Calculate the fuel saving achieved by reduction in blow-down, if the TDS of feed water is reduced to 300 ppm.
S7 Sol	$Blow\ Down\ (\%) = \frac{[Feed\ Water\ TDS\ in\ ppm\ x\ \frac{Makeup\ Water(\%)}{100} x\ 100}{(Maximum\ Permissible\ TDS - Feed\ Water\ TDS}$ Initial blow down = (500 x 8/100 x 100)/(3000-500) = 1.6 % Improved blow down with TDS of 300 ppm = (300 x 8/100 x 100)/(3000 – 300) = 0.88% Reduction in Blow down = 1.6 – 0.88 = 0.72% Reduction in blow down quantity = 0.72 x 40 x 1000/ 100 = 288 kg/hr Heat Energy Saving = M x Cp x dT = 288x 1 x (170 – 75) = 27360 kcal/hr Fuel Oil Saving = 27360 / (5000 x 0.72) = 7.6 kg/hr **Annual Fuel Saving = 7.6 x 8000 = 60800 kg/annum = 60.8 MT/annum**
S8	Explain the difference between bottoming and topping cycle with an example.
S8 Sol	Refer Guidebook -2, Page no: 194 & 195

………….. End of Section – II ……………

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

L-1	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
S	i) Refer Guidebook -2, Pg 173, 178 & 179 ii) Refer Guidebook -2, Pg 156 & 157	
L-2	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?	Each 2 Marks

S

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

L-3

An oil refinery has a captive power plant with petcoke fired boiler. The following are the data collected to assess the boiler performance.

Ultimate analysis of Petcoke (%)	
Carbon	88.8
Hydrogen	3.6
Nitrogen	1.2
Oxygen	1.4
Sulphur	3.6
Moisture	1.4

GCV of Petcoke : 8430 kcal/kg
O_2 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
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**

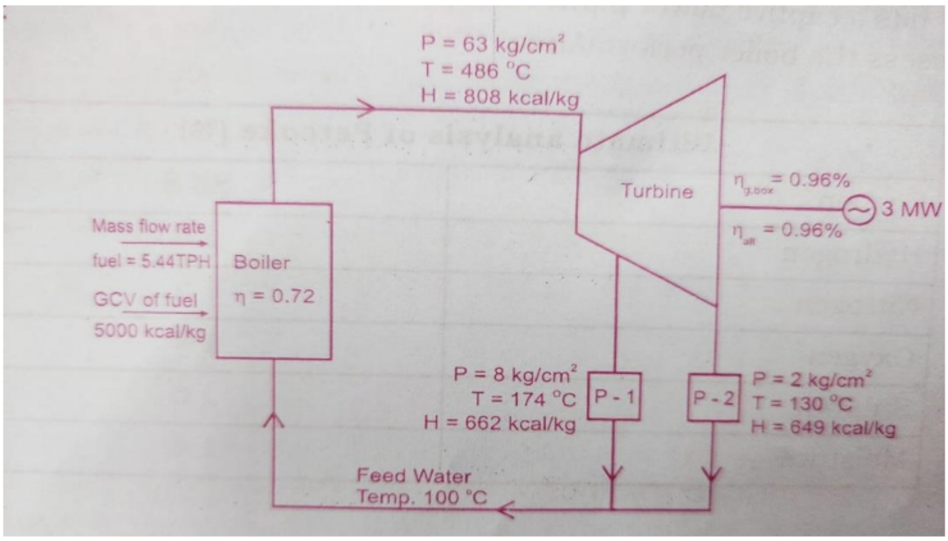
b) Specific boiler steam generation MT/MT of petcoke (Evaporation Ratio) **2 Marks**

L 3 Sol	a)	Theoretical Air required	= {(11.6x0.888)+[34.8x(0.036-.014/8)]+4.35x0.036} = 11.64	kg air / kg of petcoke
		% Excess Air supplied	= (6/(21-6)x100 = 40.0	%
		Actual Air supplied	= (1+40/100)x11.65 = 16.31	kg air / kg of petcoke
		Mass of dry flue gas	={(0.888x44/12)+0.012+(16.31x0.77) +(16.31 -11.65)x0.23+(0.036x 64/32)} = 16.97	kg air / kg of petcoke
		Stack losses, L1	= 16.97x0.29x(250-30)/8430x100 = 12.84	%
		Loss due to formation of water vapor from H2 in fuel, L2	= 9x0.036x{584+0.45*(250-30)}/8430x100 = 2.63	%
		Loss due to moisture in fuel, L3	= 0.014x{584+0.45x(250-30)}/8430x100 = 0.11	%
		Loss due to moisture in Air, L4	=16.31x0.0204x0.45x(250-30)/8430x100 = 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)x 8430 = 6957	kcal/kg of petcoke
		Specific boiler steam generation (Evaporation Ratio)	= 6957/616 = 11.29	

L4

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.

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 Calculate the annual fuel cost savings by changing over to paddy husk boiler?
L4 Sol	<u>For Coal Fired Boiler :</u> Heat content in the output steam = 20000x (760-120) = 12800000 kcal/hr Coal requirement = (12800000)/(3900x0.72) = 4558.4 kg/hr Annual operating hours = 8000 Annual coal consumption = 4558.4 x 8000 = 36467.2 MT Annual cost of coal = 36467.2 x Rs 12000 = 4376 lakhs <u>For Paddy Husk Fired Boiler:</u> Paddy husk requirement = (12800000)/(3500*0.65) = 5626.4 kg/hr. Annual operating hours = 8000 Annual paddy husk consumption = 5626.4 x 8000 = 45011.2 MT Annual cost of paddy husk = 45011.2 x Rs 9000 =Rs 4050.98 lakh. Annual fuel Cost saving = 4376– 4050.98 = Rs 325.02 lakhs
L 5	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 a) Energy Utilization Factor **6 Marks**

	b) Heat to power ratio, kW thermal to kW electrical **4 Marks**
L5 Sol	a) Energy Utilization Factor Total steam flow into co-generation system: 0.72 = X x (808-100) / (5000 x 5.44 x 1000) 19584000 = X x (808-100) X = 27661.0 kgs or 27.66 TPH Extraction steam flow = 8TPH Back pressure steam flow = 27.66 - 8 = 19.66TPH EUF = (Electrical o/p (Qe) + Thermal o/p (Qt)) / Fuel Input x GCV (Qf) Qf = (5.44 x 1000 x 5000) = 27.2 Mkcals Qe = 3 x 1000 x 860 = 2.58 Mkcals Qt = [8 x 1000 x(662-100)] + [19.66x1000x(649-100)] = 4.49 + 10.79 = 15.28 Mkcals EUF = ((2.58 + 15.28) x 100)/ 27.2 = 0.656 x 100 = 65.66 b) Heat to power ratio, kW thermal to kW electrical Q_{th} = 15.28 / 860 = 17.77 MW Q_e = 2.58 /860 = 3 MW Heat to power ratio = 17.77 / 3 = 5.92
L6	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 ^{0}C. The temperature of resulting mixture of steam in the common header is 235 ^{0}C. Find out the dryness fraction of steam supplied by the boiler B. Take specific heat of superheated steam, C_p = 2.09 kJ/kg Properties of Steam at 15 bar: • Saturation temperature, t_{sat} = 198.3 ^oC • Sensible heat of Steam, h_f = 844.6 kJ/ kg • Latent heat of steam, h_{fg} = 1945.3 kJ/ kg • Total heat of steam, h_g = 2789.9 kJ/kg **5 Marks**

	b) An oil-fired boiler is rated for 10 TPH of saturated steam and pressure of 10 kg/cm^2 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/cm^2 is 662 kcal/kg **5 Marks**
L6 Sol	Ans: 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 x (300-198.3)} + {844.6 + X x 1945.3} = 2 x {2789.9 + 2.09 x (235 –198.3)} X = 0.97 b) Ans: Maximum possible steam generation = 10 x 1000 x 540 / (662-60) = 8970 kg/hr or 8.97 TPH

………….. **End of Section – III** ……………