Regn No: ___________________

Name : ___________________
(To be written by the candidate)

17^{th} NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – September, 2016

PAPER – 2: Energy Efficiency in Thermal Utilities		
Date: 24.09.2016	**Timings: 1400-1700 HRS**	**Duration: 3 HRS**

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

1.	Which trap is preferred in discharge of condensate recovery from process equipment? **a) Float trap** b) Thermodynamic trap c) Thermostatic trap d) All of the above
2.	Which of these is not true of ‘critical point’ of steam/water mixture? a) the temperature at critical point is 374.15°C b) the pressure at critical point is 221.2 bar c) saturated liquid and saturated vapour lines meet at critical point **d) enthalpy of evaporation is maximum at critical point**
3.	Which of the following is used for controlling pressure in a natural draft furnace? a) Forced draft fan b)Induced draft fan **c) Dampers** d)Both (a) & (b)
4.	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**
5.	Which of the following is not a property of ceramic fibre ? a) low thermal conductivity b) light weight **c) high heat capacity** d) thermal shock resistant
6.	Which of the following is considered in the calculation of 'Evaporation ratio'? a) calorific value of fuel b) latent heat of steam **c) fuel quantity** d) all of the above
7.	Which of the following has the lowest stoichiometric oxygen demand (kg/kg of fuel)? a) Hydrogen b) Carbon c) **Sulphur** d) Nitrogen
8.	Which of the following fuels has the least viscosity? a) Furnace Oil b) Diesel **c) Kerosene** d) Crude Oil
9.	Which of the following depends on physical properties of fluids as well as geometry of the heat exchanger? a) Overall heat transfer coefficient **b)** Fouling coefficient c) LMTD (Log Mean Temperature Difference d) Effectiveness
10	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) humidity of air
11	Which causes alkaline hardness **a) bicarbonates of Ca and Mg** c) Chlorides of Mg and Ca c) Silicates d) nitrates of Ca and Mg
12	When pure hydrogen is burned, with theoretical air, the volume percentage of nitrogen in flue gas on dry basis will be a) **100%** b) 79% c) 21% d) 0%
13	What is the most effective way to avoid ambient air infiltration into a continuous reheating furnace? a)maintain negative pressure in furnace b) increase the chimney height c) operate at about 90%capacity **d) maintain slightly positive pressure in the furnace**
14	Water logging of 2 m lift of condensate at trap discharge will result in back pressure

	of ____ a) 0.02 kg/cm^2 b) **0.2 kg/cm^2** c) 2 kg/cm^2 d) 20 kg/cm^2
15	Water flows at a rate of 30 m^3/hr. at 15^{o}C in a 150 mm bore pipe horizontally. What is the velocity of water flow in the pipe? **a) 0.47 m/s** b) 0.94 m/s c) 1.88 m/s d) none of the above
16	Velocity of steam in steam pipe is directly proportional to; a) number of bends in pipe **b) specific volume of steam** c) length of pipe d) diameter of the pipe
17	The working media in a thermo-compressor is a) electricity b) compressed air c) high temperature oil **d) steam**
18	The turbine heat rate is expressed as a) kWh/kCal b) kg/kCal **c) kCal/kWh** d) none of the above
19	The major limitation of metallic recuperator is ------- a) limitation of handling CO_x, NO_x etc. **b) limitation of reduced life for handling temperature more than 1000^{o}C** c) manufacturing difficulty of the required design d) none of the above
20	The large difference between GCV and NCV of gaseous fuels is due to their a) large moisture content b) negligible moisture content c) low hydrogen content d) **large hydrogen content**
21	The insulation used for temperatures more than 350^{o}C a) Polyurethane b) polystyrene **c) Calcium silicate** d)magnesia
22	The heat recovery device in which high conductivity bricks are used for storing heat is a) heat pipe b) heat pump c) thermo compressor **d) regenerator**
23	The head loss due to friction in a pipe is a) directly proportional to the diameter b) directly proportional to the gravitational constant c) inversely proportional to the velocity **d) directly proportional to the square of velocity**

24	The exhaust from which of the following is not suitable for waste heat boiler application? a) gas turbine **b) hot air dryer** c) diesel engine d) furnace
25	The effectiveness of insulation with ingress of moisture would a) increase **b) decrease** c) may increase or decrease depending on temperature and thickness of insulation d) remain unaffected
26	Sulphur percentage in furnace oi **a)sets lower flue gas temperature limit** b) improves viscosity c) does not add to heat value d) forms soot
27	Select the wrong statement with respect to furnace operations a) the burner flame should not touch the stock b) air infiltration leads to oxidation of billets **c) ceramic fibre linings are used in the exterior of the furnace** d) heat loss through openings is proportional to T^4
28	Select the odd one among the following a) Condenser b) Distillation tower c) Evaporator **d) Economiser**
29	Pinch analysis uses the _____ law of thermodynamics a) First b) Second c)Third **d) Both (a) & (b)**
30	In an FBC boiler with low ash fusion coal, if the bed temperature exceeds 950°C, the result is: a) Low steam temperature **b) clinker formation** c) Melting of lime stones d) Ash carry over
31	In a turbine, the thermodynamic process taking place is a) contraction **b) expansion** c) condensation d) all the above
32	In a reheating furnace, soaking time of a cycle depends typically on; a) excess air level b) preheat temperature of charge c) **thickness of the charged material** d) furnace atmosphere
33	In a pressure reduction valve, which of these does not change? a) Temperature b) Pressure c) **Enthalpy** d) None of above
34	In a counter-flow heat exchanger, cold fluid enters at 30°C and leaves at 50°C, whereas the hot fluid enters at 150°C and leaves at 130°C. The LMTD is

	a) 100°C b) 280°C c) 0°C d) 20
35	In a boiler Air preheater is installed a) Before the economizer **b) after economizer** c) after ESP d) Before superheater
36	Ideal furnace for melting & alloying of special steels is **a) induction furnace** b) Cupola furnace c) rotary hearth d) recirculating bogie furnace
37	Higher excess air in an oil fired furnace would result in a) increased furnace temperature b) increase in CO_2 presence in flue gas **c) reduced flame temperature** d) increased flame length
38	For coal fired system the flame length is dictated by a) moisture **b) volatile matter**. c) ash content. d) fixed carbon
39	Enthalpy of Evaporation of any vapour at its Critical Point will be a)Maximum **b)Zero** c)Less than zero d) Unpredictable
40	Electrical energy consumption for coal sizing will be maximum for a) stoker fired boiler b) AFBC boiler c) CFBC boiler **d) pulverised coal boiler**
41	Dissolved CO_2 in boiler feed water when left untreated would result in occurrence of in boiler tubes a) creep **b) water side corrosion** c) scale d) water hammer
42	Desirable boiler water pH should be? a)5-7 **b) 7-9** c) 9-11 d) None of the above
43	Deaerator is a ____________________ Heat exchanger. a) Shell and tube type b) Plate type **c) Direct contact type** d) Run Around Coil type
44	Corrosion in stack, Air Pre-Heater, Economizer is mainly influenced by _____ **a)Sulphur content in fuel** **b)**Ash content in fuel **c)**Moisture content in fuel d) All of the above

45	Controlled wetting of coal (during the coal preparation) would result in a) reduction in flue gas exit temperature **b) decrease in the percentage of unburnt carbon** c) improper combustion d) increase in the fines of coal
46	Chemical used for dozing in boiler drum to reduce dissolved gases is **a) hydrazine** b) chlorine c) alum d) all of the above
47	At saturation temp, there can be a) Hot water b) Wet steam c) Saturated steam **d) all of them are possible**
48	Arrange the following fuels by their GCV in decreasing order- (p)Rice husk, (q) Diesel, (r) Grade-C Coal, (s)Hydrogen **a) s-q-r-p** b) p-q-r-s c) r-s-q-p d) q-r-s-p
49	A rise in conductivity of boiler feed water indicates a) drop in the total dissolved solids in boiler water b) more steam generation **c) rise in the total dissolved solids in boiler water** d) greater purity of feed water
50	1% of the fuel is saved in boiler fuel consumption, if the feed water temperature is increased by 4^0C b) 9^oC **c) 6^oC** d) 10^oC

-------- End of Section - I ---------

Section - II: SHORT DESCRIPTIVE QUESTIONS

S-1	Two identical oil fired boilers of capacity 100 TPH are operated in a refinery. They have a full load efficiency of 90%. The part load efficiencies at 70% and 40% load are 70% and 60% respectively. For meeting 140 TPH requirement of steam, which one of the case would you prefer to run and estimate the % savings in the preferred case. The enthalpy of steam generated is 550 Kcal/kg and feed water enters the boiler at 50°C in all the cases. Calorific value of the fuel oil is 10,000 Kcal/hr. Case 1: both the boilers operated at 70 TPH capacity each. Case 2: one at full load capacity and other at 40% capacity.

Ans	Case-1: Amount of Fuel energy required when both the boilers are run at 70% load i.e, at 70 TPH load Enthalpy change = (550 – 50) = 500 Kcal/kg = (2 * 70 * 1000 * 500)/ (0.70 * 10000) = 10000 Kg/hr (or) 10 Tons/hr Case-2: Amount of Fuel required when one boilers is running at full load at 100 TPH and other at part load of 40 TPH Enthalpy change= (550 – 50) = 500 Kcal/kg = (100 * 1000 * 500) / (0.9*10000) + (40 * 1000 * 500) / (0.60*10000) = 5555 + 3333 = 8888 Kg/hr (or) 8.88 Tons/hr Fuel required for Case 2 is less & hence Case 2 is preferred % Fuel Savings= (10 – 8.88) / 10 x 100 = 11.2 %
S-2	**List down any five good practices in Furnaces for energy efficiency**
Ans	a) Improve capacity Utilisation b) Minimise Excess air c) Minimise heat loss due to radiation, walls and openings d) Adopt Waste heat recovery e) Ensure Complete combustion f) Maintain Furnace in slightly positive pressure g) Adopt Variable frequency drives for fans h) Optimise cycle time. i) Emissivity Coatings ***Any five of the above can be awarded marks, 1 mark each***
S-3	In a process plant, 40 TPH of steam after pressure reduction with pressure reducing valve to 20 kg/cm^2 gets superheated. The temperature of steam is 280^{o}C. The management wants to install a de-superheater to convert superheated steam into saturated steam at 20 kg/cm^2 for process use, and its saturation temperature is 210^{o}C. Calculate quantity of water at 30^{o}C to be injected in de-superheater to get the desired saturated steam using the following data. Specific heat of superheated steam = 0.45 kcal/Kg^{o}C, Latent heat of steam at 20kg/cm^2 =

	450 kcal/kg
Ans	Quantity of heat available above saturation = 40,000 x 0.45 x (280-210) = 12,60,000 kCal/hr Quantity of water required in de-superheater = Q x{1x (210-30) + 450}= 1260000 **= 2000 Kg/hr**
S-4	In a plant, a boiler is generating saturated steam of 10 TPH at a pressure of 7 kg/cm^2(g) with furnace oil as a fuel. Feed water temperature 60°C Evaporation ratio 14. Calorific value of FO 10000 kCal/kg Specific gravity of FO 0.95. Enthalpy of steam at 7 kg/cm^2(g) 660 kCal/kg Find out the efficiency of the boiler by direct method and volume of furnace oil tank (in m^3) required for 100 hrs of operation
Ans	$\text{Effy } \eta = \frac{E.R \times (h_g - h_f)}{GCV} = \frac{14 \times (660-60)}{10000} = 84\%$ (Note: Deduct 1 mark if 60 is not subtracted from 660) Furnace oil requirement = 10 / 14 = 0.714 TPH = 714 kg/hr For 100 hrs of operation, oil requirement = 751.57 x 100 = 75157ltr Oil tank volume = 75157 / 1000 = 751.157 m^3 **OR** $\text{Effy } \eta = \frac{E.R \times (h_g - h_f)}{GCV} = \frac{14 \times (660-60)}{10000} = 84\%$ (Note: Deduct 1 mark if 60 is not subtracted from 660) Furnace oil requirement = 10 / 14 = 0.714 TPH = 714 kg/hr = 714 / 0.95 = 751.57 ltr/hr For 100 hrs of operation, oil requirement = 751.57 x 100 = 75157ltr Oil tank volume = 75157 / 1000 = 751.157 m^3
S-5	1) **a) List any six losses in a Boiler** 2) **Name two sources of wet flue gas loss in a coal fired boiler**
Ans	a)

	1. Dry flue gas, L_1 2. Loss due to hydrogen in fuel, L_2 3. Loss due to moisture in fuel, L_3 4. Loss due to moisture in air, L_4 5. Partial combustion of C to CO, L_5 6. Surface heat losses, L_6 7. Loss due to Unburnt in fly ash, L_7 8. Loss due to Unburnt in bottom ash, L_8 **(b)** Moisture in air, Moisture in fuel and H_2 in fuel.
S-6	**1) A steam pipe of 100mm diameter is insulated with mineral wool. As a part of energy saving measure, the insulation is upgradated with efficient Calcium silicate insulation. Calculate the percentage reduction in heat loss due to above measure with the following data,** **Boiler efficiency : 80%** **Surface temperature with mineral wool : 98°C** **Surface temperature with calcium silicate : 55°C** **Ambient temperature : 30°C**
Ans	Heat loss thru non-insulated pipe = [10 + (98 – 30) / 20] * (98 – 30)] = 911.2 kcal/hr-m^2 Heat loss thru insulated pipe = [10 + (55 – 30) / 20] * (55 – 30)] = 281.25 kcal/hr-m^2 % Reduction in heat loss = (911.2-281.25) / 911.2

	= 69.13 %
S-7	A cogeneration plant has an electrical output of 4MW with a back pressure turbine which has a input steam conditions to the turbine as 27 TPH with Enthalpy of 3418 KJ/kg @ 64 ata and 500^{o}C and the exit conditions of steam at the end of the back pressure turbine is 186^{o}C, with enthalpy of 2835.8 KJ/kg. After the process heating, all the condensate @ 73^{0}C returns to the boiler. Calculate the Heat to power Ratio and Energy Utilization factor of the process. Fuel consumption of the boiler is 6.5 TPH Coal at 4800 GCV.
Ans	Heat to power Ratio = 27*((2835.8/4.18)-73)/(4*860) = 4.75 Energy Utilization Factor = (27* ((2835.8/4.18)-73) + 4*860))/(6.5*4800) =63.4%
S-8	(a) Calculate the blow down rate for a boiler with an evaporation rate of 8 tons/hr, if the maximum permissible TDS in boiler water is 3000 ppm and with 18 % make up water addition. The feed water TDS is around 500 ppm. (b) Briefly explain temporary hardness and permanent hardness in boiler water
Ans	**a) Blow down (%)** = $\frac{Feed\ water\ TDS\ x\ \%\ Makeup}{Permissible\ TDS\ in\ Boiler - feedwaterTDS}$ Percentage blow down = 500 x 18/(3000-500) = 3.6 % If boiler evaporation rate is 8000 kg/hr then required blow down rate is: = 8000 x 3.6/100 = **288 kg /hr** b) **Ref Book-2 :; Page Nos. 45 & 46** Temporary hardness ; It is the hardness that can be removed by boiling. Calcium and magnesium bi carbonate dissolve in water to form an alkaline solution and these salts are called alkaline hardness. They decompose upon heating releasing carbon dioxide and forming a soft sludge which settles out. Permanent hardness: calcium and magnesium sulphates and chlorides, nitrates etc when dissolved in water are chemically neutral and are known as non alkaline hardness. These are called permanent hardness and form hard scale on the boiler surface which are difficult to remove.

-------- *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

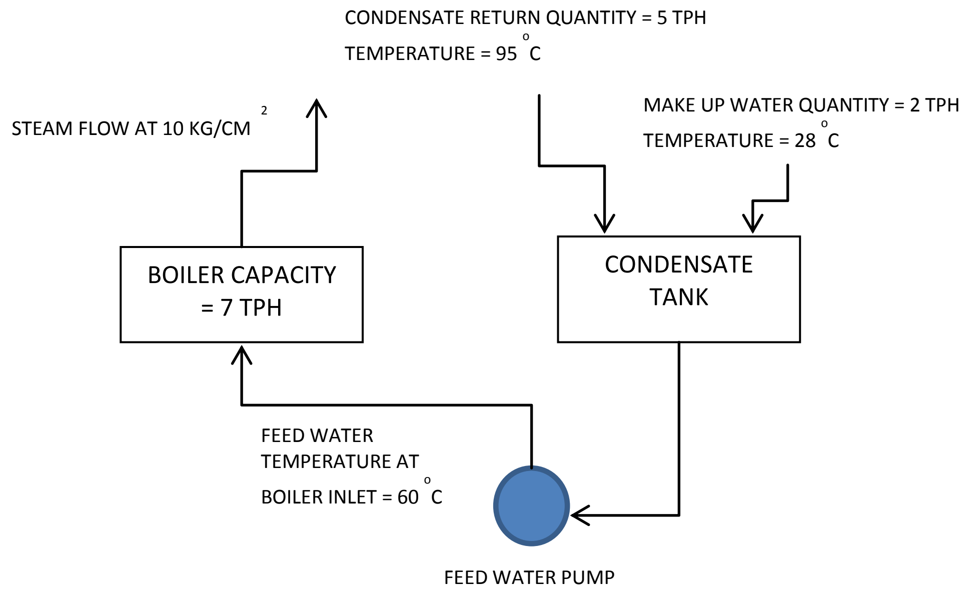
L-1	Answer the followings: (a) Explain why dry saturated steam is preferred over wet or superheated steam for industrial process heating. (b) Why should one use dry saturated steam at the lowest possible pressure for indirect steam heating? (c) What are the two major advantages of direct injection of steam for heating of liquid? (d) Why drain points are required in a steam system? (e) What is flash steam?
Ans	a) Dry saturated steam is the preferred choice because: • Wet steam has a lower heat content than dry steam. • Superheated steam gives up heat at a slower rate than saturated steam. • Dry steam alone condenses quickly, thereby providing a higher heat transfer rate. b) The latent heat of steam increases with reduction of steam pressure and it is only the latent heat that is transferred during indirect heating applications. c) • No condensate recovery system is necessary • The heating is quick, and the sensible heat in the steam is also used up along with the latent heat, making the system thermally more efficient. d) The drain points help in removing water in pipes due to condensation of steam. e) Flash steam is produced when condensate at a high pressure is released to a lower pressure.

L2

Analyse the diagram as given below and calculate:

(i) Boiler Efficiency by direct method
(ii) Water Temperature in the condensate tank
(iii) Estimate fuel loss due to non-recovery of 2 TPH condensate, assuming the boiler efficiency to be the same

Given data:
Enthalpy of steam at 10kg/cm2 = 665 kCal/kg
Furnace Oil consumption = 550 liters/hr
Specific Gravity of furnace oil = 0.89
G.C.V. of furnace oil = 10,000 kCal/k



ANS

Oil Consumption = 550 x 0.89 = 489.5 kg/hr

1) Boiler Efficiency = 7000 (665 - 60) X 100/ 489.5 X 10000
= 86.52 %
2) Feed water temperature in condensate tank

= [5000 x 95 + 2000 x 28]/ 7000 = 75.85°C = 76 °C
3) Fuel Loss = [7000 x (76 – 60)]/ 10000 x 0.8652 = 12.94 kg/hr

L3

a) Explain the process of Mechanical de-aeration and chemical de-aeration

b) How does an energy auditor assess the performance of steam trap during energy audit?

Ans

a)

	Mechanical de-aeration Mechanical de-aeration for the removal of these dissolved gases is typically utilized prior to the addition of chemical oxygen scavengers. Mechanical de-aeration is based on Charles' and Henry's laws of physics. Simplified, these laws state that removal of oxygen and carbon dioxide can be accomplished by heating the boiler feed water, which reduces the concentration of oxygen and carbon dioxide in the atmosphere surrounding the feed water. Mechanical de-aeration can be the most economical. They operate at the boiling point of water at the pressure in the de-aerator. They can be of vacuum or pressure type. The vacuum type of de-aerator operates below atmospheric pressure, at about 82°C, can reduce the oxygen content in water to less than 0.02 mg/litre. Vacuum pumps or steam ejectors are required to maintain the vacuum. The pressure-type de-aerators operates by allowing steam into the feed water through a pressure control valve to maintain the desired operating pressure, and hence temperature at a minimum of 105°C. The steam raises the water temperature causing the release of O_2 and CO_2 gases that are then vented from the system. This type can reduce the oxygen content to 0.005 mg/litre. Where excess low-pressure steam is available, the operating pressure can be selected to make use of this steam and hence improve fuel economy. In boiler systems, steam is preferred for de-aeration because: • Steam is essentially free from O_2 and CO_2 • Steam is readily available • Steam adds the heat required to complete the reaction. **Chemical de-aeration** While the most efficient mechanical deaerators reduce oxygen to very low levels (0.005 mg/litre), even trace amounts of oxygen may cause corrosion damage to a system. Consequently, good operating practice requires removal of that trace oxygen with a chemical oxygen scavenger such as sodium sulfite or hydrazine. Sodium sulphite reacts with oxygen to form sodium sulphate, which increases the TDS in the boiler water and hence increases the blow down requirements and make-up water quality. Hydrazine reacts with oxygen to form nitrogen and water. It is invariably used in high pressures boilers when low boiler water solids are necessary, as it does not increase the TDS of the boiler water. **Ref page no 47** **b)**

	Steam trap performance assessment is basically concerned with answering the following two questions: • Is the trap working correctly or not? • If not, has the trap failed in the open or closed position? Traps that fail 'open' result in a loss of steam and its energy. Where condensate is not returned, the water is lost as well. The result is significant economic loss, directly via increased boiler plant costs, and potentially indirectly, via decreased steam heating capacity. Traps that fail 'closed' do not result in energy or water losses, but can result in significantly reduced heating capacity and/or damage to steam heating equipment. **The three performance test methods of steam traps are** **1. Visual testing,** **2. Sound Testing** **3. Temperature testing** **Ref page no 95**
L-4	A Textile plant has an extensive steam distribution network and the steam condensate is not being recovered. The plant management is planning to recover the condensate and generate flash steam for use as low pressure process steam for fuel savings. The following are the parameters about the system. Condensate quantity 1000 kg/hr Condensate Pressure 10 bar Cost of steam Rs 1100/ Ton Annual operating hours 7000 Low pressure process steam (flash steam) pressure 2 bar Sensible heat of condensate at 10 bar 188 kCal/kg Sensible heat of condensate at 2 bar 135 kCal/kg Latent heat of steam at 2 bar 518 kCal/kg Boiler Efficiency 82 % GCV of fuel oil 10,200 kCal/kg Specific Gravity of fuel oil 0.92 Condensate temperature when recovered 95 ^oC Make up water temperature 35 ^oC Calculate the Quantity of flash steam which can be recovered, and the annual fuel oil savings on account of condensate recovery
Ans	a) Flash steam available % = S1- S2/(L2) Where: S1 is the sensible heat of higher pressure condensate. S2 is the sensible heat of the lower pressure condensate L2 is the latent heat of flash steam (at lower pressure). % of Flash steam recoverable = (188 – 135)/518 = 10.2 % Quantity of flash steam recovered from condensate = 1000 x 0.102 = 102 kg/hr Condensate available for recovery after flash steam = 1000 – 102 = 898 kg/hr Heat recovered = 898 x (95 – 35) = 53880 kCal/hr Annual fuel oil saving= 53880 x 7000 / (0.82 x 10200) = 45.09 tons/yr
L-5	A heat exchanger is to be designed to condense the hydrocarbon vapor mixture from a distillation column at the rate of 11.0 kg/sec which is available at its saturation temperature

	of 120°C. The latent heat of condensation of the hydrocarbon vapor mixture is 450 kJ/kg. The cooling water at 32°C is used in counter-current direction at the rate of 58 kg/sec to condense the vapor mixture. The specific heat of cooling water is 4.18 kJ/kg ^oC. Determine LMTD and area of the heat exchanger surface if the overall heat transfer co-efficient is 550 J/m^2s°C.
Ans	Heat removal rate from hydrocarbon vapour mixture = heat gain rate in cooling water Q x h = M * cp* (T2-T1) 11.0 x 450 = 58 x 4.18 x (T2 – 32) T2 = 52.4 °C Water leaves the exchanger at 52.4°C LMTD = (120-32)-(120-52.4)/ln(120-32)/(120-52.4) LMTD of counter flow pattern = 77.4°C Q = m*Cp* deltaT = U * A * LMTD 58 * 4.18 * (52.4 – 32) * 1000 = 550 * A * 77.4 A = 116.179 m^2 Area of the heat exchanger surface is 116.179 m^2
L-6	A gaseous fuel has volumetric composition as CH_4 – 70 % & C_2H_6 – 30%. The Gross Calorific Value of CH_4 & C_2H_6 is 43000 kJ/Nm^3 & 68000 kJ/Nm^3 respectively. Find out the Net Calorific Value of gaseous fuel in kJ/Nm^3. (Latent heat of water vapor – 2445 kJ/kg)
Ans	$CH_4 + 2O_2 = CO_2 + 2H_2O$ 1 Nm^3 of CH_4 + 2 Nm^3 of O_2 = 1 Nm^3 of CO_2 + 2 Nm^3 of H_2O Hence, 0.70 Nm^3 of CH_4 will generate 0.70 x 2 = 1.4 Nm^3 of H_2O $C_2H_6 + 3.5\ O_2 = 2CO_2 + 3H_2O$ 1 Nm^3 of C_2H_6 + 3.5 Nm^3 of O_2 = 2 Nm^3 of CO_2 + 3 Nm^3 of H_2O Hence, 0.3 Nm^3 of C_2H_6 will generate 0.30 x 3 = 0.9 Nm^3 of H_2O Volume of water vapor = 1.4 + 0.9 = 2.3 Nm3/Nm^3 of fuel (We know that mass of 22.4 Nm^3 of H_2O = 18 kg i.e. mass of 1 kMol) Mass of Water vapor, Mm = 2.3 x 18 / 22.4 = 1.85 kg/Nm^3 of fuel GCV of gaseous Fuel = (70% x 43000) + (30% x 68000) = 50500 kJ/Nm^3 NCV = GCV – (Mm x 2245) = 50500 – (1.85 x 2245) = 46346.75 kJ/Nm^3

…………. End of Section – III ……….….