Regn No: ____________________

Name : ____________________
(To be written by the candidate)

18th NATIONAL CERTIFICATION EXAMINATION FOR ENERGY MANAGERS & ENERGY AUDITORS – September, 2017

PAPER – 2: Energy Efficiency in Thermal Utilities			
Date: 23.09.2017	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**

a) Answer all **50** questions
b) Each question carries **one** mark
c) Please hatch the appropriate oval in the OMR answer sheet with Black Pen or HB pencil

1.	In a Heat exchanger with a high LMTD results in a) higher heat transfer area **b) lower heat transfer area** c) higher u-factor d) none of the above
2.	" Heat Loss = Heat gain " is the principle of ____ a) Boiler **b) Heat Exchanger** c) Steam traps d) All of the above
3.	Flash steam quantity per kg of condensate depends upon a) condensate pressure only b) condensate pressure and flow **c) condensate pressure and flash steam pressure** d) none of the above
4.	Which of the following waste heat recovery systems is of thermal storage type?

	a) ceramic recuperator b) metallic recuperator **c) regenerative burner** d) waste heat boiler
5.	A boiler trial indicated 2% O_2 at boiler exit and 7% O_2 at stack. The in-leak air quantity between these two measurement is a) 25% **b) 40%** c) 50% **d) none of the above**
6.	The concentration of solids in a boiler is controlled by a) steam venting **b) blow down** c) air venting d) deaeration
7.	Insulating material made by blending and melting of alumina and silica is known as **a) ceramic fibre** b) high alumina brick c) fire brick d) insulating brick
8.	Tangential firing is used in which type of boiler: a) CFBC b) Chain Grate c) Spreader Stoker **d) Pulverised Fuel**
9.	_____ is required for the simple estimation of flame temperature of the fuel. **a) Ultimate analysis** b) Proximate analysis c) Size of the coal d) All of the above
10.	Overall heat transfer co-efficient in Heat exchangers depends on ____. a) Conductivity of the wall separating the two fluids b) Convective coefficients of hot and cold fluids c) Fouling coefficients **d) All of the above**
11.	The key property of bio mass fuel which influences storage, handling and transportation a) Calorific Value b) Percentage of Ash **c) Bulk Density** d) None of the above
12.	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
13.	When 100 kg of fuel with 60% carbon is burnt with theoretical air, the mass of CO_2 released will be a) 319 kg b) 4400 kg c) 4500 kg **d) 220 kg**
14.	Which of the following heat recovery equipment works on a vapour compression cycle? a) thermo-compressor b) heat wheel

	c) heat pump d) heat pipe
15.	Which of the following releases large amount of heat per kg during combustion? **a) Hydrogen** b) Carbon c) Sulphur d) Nitrogen
16.	Auxiliary power consumption for coal preparation will be highest in a; a) stoker fired boiler b) AFBC boiler c) CFBC boiler **d) pulverized coal fired boiler**
17.	In a heat exchanger, for the same heat duty, higher the heat transfer coefficient; a) higher will be the heat transfer area needed b) higher will be the LMTD **c) lower will be the heat transfer area needed** d) lower will be the LMTD
18.	Which of the following increases, when steam is passed through PRV? **a) specific volume** b) enthalpy of steam c) sensible heat d) saturation temperature
19.	Which of the following is not true with respect to improper sizing of coal a) results in poor combustion **b) lowers excess air resulting in lesser stack loss** c) increases un-burnt in ash d) lowers thermal efficiency
20.	When solutions of differing concentrations are separated by a semi-permeable membrane, water from less concentrated solution passes through the membrane to dilute the liquid of high concentration. This is called a) reverse osmosis b) ion exchange c) softening **d) osmosis**
21.	_______ is used as heat carrier in thermic fluid heaters a) steam **b) mineral oil** c) water d) all of the above
22.	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
23.	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°C
24.	Which of the following is not measured in the ultimate analysis of a fuel ? a) oxygen **b) fixed carbon** c) sulphur d) nitrogen
25.	Ceramic fibre gives the maximum energy savings when used in a) continuous furnace **b) batch furnace** c) arc furnace d) induction furnace
26.	In industrial applications the commonly used trap for main steam lines is a) thermostatic trap b) inverted bucket trap **c) thermodynamic trap** d) open bucket trap
27.	Fluidized bed combustion takes place in the temperature range of a) above 1000^0C b) below 500^0C c) 600-700^0C **d) 800-900^0C**
28.	In a glass industry waste heat is used for power generation. This type of cogeneration is called a) topping cycle **b) bottoming cycle** c) combined cycle d) none of the above
29.	Select the odd one among the following a) condenser b) distillation column c) evaporator **d) cooling tower**
30.	In a boiler, air preheater is installed a) before the economizer **c) after economizer** b) before superheater d) after ESP
31.	A pinch analysis can result in a) reduction in cooling water b) reduction in steam c) increase in cooling water **d) both a & b**
32.	The main contributor for temporary hardness in Boiler water is ____. a) calcium chloride b) magnesium sulphate **c) calcium bicarbonate** d) calcium nitrate

33.	The amount of oxygen required to burn 0.5 kg of Sulphur is a) 1 b) 16 c) 32 **d) 0.5**
34.	_____ is required to accommodate expansion of steam lines. a) prv **b) expansion loop** c) steam trap d) air vent
35.	Steam mains should be run with a falling slope of … in the direction of steam flow for effective line condensate drainage a) 50 mm in 30 meters **b) 125 mm in 30 meters** c) 250 mm in 30 meters d) 350 mm in 30 meters
36.	Degasser in water treatment is used to remove a) Dissolved oxygen and other gas **b) carbonic acid** b) Sulphuric acid d) dissolved CO_2
37.	In a boiler Theoretical Air to fuel ratio is 15:1. If 10% excess air is supplied, Flue gas to Fuel ratio will be ____ a) 16:1 **b) 17.5:1** c) 16.5:1 d) 17:1
38.	Increased 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
39.	Which among the following is most viscous fuel? **a) furnace oil** b) HSD c) kerosene d) Light Diesel oil
40.	The turbine heat rate is expressed as

	a) kWh/kcal b) kg/kcal **c)kcal/kWh** d) none of the above
41.	Heat loss through openings in furnaces is directly proportional to a) fourth power of furnace temperature b) square of absolute furnace temperature c) absolute furnace temperature **d) fourth power of absolute furnace temperature**
42.	Which of the following is an example of a basic refractory a) Alumino-silicate b) chrome b) **Magnesite** d)pure alumina
43.	Which property of the refractory determines the deformation under stress? **a) creep** b) refractoriness under load (rul) c) porosity d) pyrometric cone equivalent (PCE)
44.	Electro static precipitator in FBC boiler is used for ________ a) Bottom ash removal **b) Fly ash removal** c) SO_2 removal d) CO_2 removal
45.	Heat rate is likely to be the least for _________ a) back pressure turbine **b) condensing turbine** c)extraction condensing turbine d) double extraction turbine
46.	Which of the following is true of plate heat exchangers a) close approach b) expandable area c) Counter current **d) All of the above**
47.	In FBC boilers fluidization depends largely on --------- i) Particle size ii) Air velocity iii) Bed Material iv) Size of Boiler a) i & iii b) ii & iii **c) i & ii** d) i,ii,iii,iv
48.	When the boiler bed temperature exceeds beyond 950°C, the result is: a) Low steam temperature **b) clinker formation** c) Melting of lime stones d) Ash carry over
49.	Automatic blowdown controls for boilers work by sensing

	a) TDS b) conductivity c) pH **d) conductivity and pH**
50.	Latent heat of steam at the critical point is a) infinite b) 540 kcal **c) zero** d) none of the above

-------- 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

S-1	Explain the working of Thermic fluid heating system and why it is preferred to steam heating in some cases?
Ans	**Thermic Fluid Heaters:** • At high temperatures, steam requires a corresponding high operating pressure and establishing high temperatures with steam can be very cumbersome and expensive in some cases. • In thermic fluid heaters, a special type of oil-synthetic / mineral is used as heat carrier. This fluid can be heated up to 300^{o}C at atmospheric pressure. In comparison steam would require a pressure of 85 bar to obtain this temperature. ……………………..2.5 marks **Advantages:** – High temperature operation at atmospheric pressure – Optional temperature level set points – No supply or treatment of hot water and hence no heat loss due to condensate flash steam – No risk of corrosion – Easy to operate **Functioning of Thermic Fluid Heaters** • Heat is transferred to the fluid through radiation. The hot thermic-fluid is circulated to various process equipments such as dryers, heaters, de-odouriser etc. where it gives up the heat. The return oil at a temperature 10 to 20 ^{0}C less, comes back to the thermic-fluid heater to get heated up again. The circulation is carried out by a thermic fluid circulation pump. • The thermic-fluid heater operates between two temperature ranges. Once the upper limit is reached the burner is switched OFF or goes into the low fire mode. In the case of solid fuel fired system the ID fan switches OFF on

	reaching the upper limit. When the temperature reaches the lower limit due to heat transfer in the process, the burners come ON again and in case of solid fuels, the ID fan comes ON again. • Since the thermic fluid heaters operate at a high temperature (250 – 300 ^{0}C), the leaving exhaust gas temperatures are more than the fluid temperature. Hence, the heat loss through the flue gas is a major component of fuel losses. This offers potential for heat recovery if there is a suitable application. • The capacity is specified in terms of Lakh kilo calories per hour or Million kilo calories per hour. **(Pg no 56 of Book 2 for explanation)** ……………………..2.5 marks
S-2	In a car manufacture company, Propane is used as fuel in heaters for preheating paints. Calculate the Air to Fuel ratio for complete combustion of C_3H_8 (Propane), if 15% excess air is supplied to the heater.
Ans	**C_3H_8 + 5 O_2 --> 3 CO_2 + 4 H_2O** ……………………..1 mark **1 mole of propane requires 5 moles of Oxygen.** **Molecular weight of Propane is 44 Kg per mole.** ……………………..1 mark **44 Kg of Propane requires 160 Kg of Oxygen.** **Theoretical air required for combustion = 160 / 0.23 = 695.6 Kg/hr** ……………………..1.5 marks **Excess air supplied is 15 %.** **Actual air supplied for combustion is = 695.6 * 1.15** **= 800 Kg/hr of air** **Air to Fuel ratio = 800 / 44** **= 18.18 or 18.2** ……………………..1.5 marks
S-3	To meet a process plant's heat and power requirements, high pressure steam at 70 MT/hr passes through a back pressure steam turbine, for power generation and the exhaust

	steam is sent for thermal process requirements in the plant. With the following operating data, calculate the heat to power ratio in kW/kW if the turbine and generator efficiencies are 90% and 92% respectively. **Steam Inlet conditions**: Pressure = 50 bar; Temperature = 530°C; Enthalpy of steam = 3515 kJ/kg **Steam outlet conditions**: Pressure = 10 bar; Temperature = 280°C; Enthalpy = 3020 kJ/kg; Enthalpy of water = 782 kJ/kg
Ans	– Power generated = 70 * 1000 * (3515 - 3020) * 0.90 * 0.92 / 3600 = 7969.5 kW ……………………..2 marks – Heat input to process = 70 * 1000 * (3020-782) / 3600 = 43517 kW – ……………………..2 marks – Heat to power ratio = 43517 / 7969.5 = 5.46 kW/kW ……………………..1 mark
S-4	a) Explain why de-superheating is done after pressure reduction in PRVs? b) Why is correction factor required for estimation of LMTD?
Ans	**a) A reduction in steam pressure through a pressure reducing valve (PRV) is an isenthalpic process. Saturated steam when reduced to a lower pressure results in super heated steam. Since process requires only saturated steam, de-superheating is often required, to compensate for superheat gained in PRV application due to isenthalpic expansion.** ……………………..2.5 marks **b) In multi pass shell and tube heat exchangers, the flow pattern is a mixture of co-current and counter current flow, as the two streams flow through the exchanger in the same direction on same passes and in the opposite on others. For these reasons, the mean temperature differences is not equal to the logarithmic mean. However it is convenient to retain the LMTD by introducing a correction factor, F which is appropriately termed as the LMTD correction factor.** ……………………..2.5 marks
S-5	What happens to steam properties such as saturation temperature, enthalpy of saturated water, latent heat of steam, enthalpy of steam and specific volume of steam, if the steam pressure is increased?
Ans	a) Saturation Temperature increases b) Enthalpy of saturated water Increases. c) Latent heat of steam decreases

	d) Enthalpy of steam increases e) Specific Volume decreases ……………………..5 marks (each point carries one mark respectively)
S-6	Two identical biomass fired boilers of capacity 10 TPH are operated in a chemical industry. They each have a full load efficiency of 80%. The part load efficiencies at 70% and 40% load are 75% and 68% respectively. For meeting 14 TPH requirement of steam, would you prefer to run both the boilers at 7 TPH capacity or one at full load capacity and other at 40% capacity. Estimate the % savings in the preferred case.
Ans	**Fuel energy required when both the boilers are run at 7 TPH load** ***Governing equation to be used :*** ***(Fuel reqd) = [(Qty stm) * (Enth steam – Enth feedwater)] / [(GCV Fuel) * (Effy boiler)]*** ***(Fuel reqd) = [(Qty stm) * (Δh) / (Effy boiler)]*** ***Where : Δh = is same in both cases = [Enth steam – Enth feed-water) / (GCV Fuel)]*** ***Fuel required* = (2*7*Δh) / (0.75) = 18.67 Δh** ……………………..1 mark **Fuel energy required when one boiler is running at full load and the other at part load of 40%** ***Fuel required* = [(10*Δh) / (0.8)] + [(4*Δh) / (0.68)]= 18.38 Δh** ……………………..2 marks **The case where one boiler is running at full load and the other at part load of 40% is preferred** ……………………..1 marks • **% savings = [(18.67 Δh) – (18.38 Δh)] * 100 / (18.67 Δh)** **= 1.55%** ……………………..1 mark
S-7	A reheating furnace is operating with deteriorated wall insulation. The existing average outer surface temperature of the furnace (of area = 100 m^2) with surrounding ambient air temperature of 40ºC, is recorded to be 120ºC. After revamping the refractory, the furnace outer surface temperature reduces to 50ºC. If the fuel oil (GCV = 11,000 kcal/kg) cost is Rs. 25,000 per tonne, and efficiency of the furnace is 35%, estimate annual savings for 300 working days per year.
Ans	Rate of heat loss from furnace surface (existing) S = [10+(Ts – Ta) / 20] x (Ts- Ta) kcals/hr/m^2 Heat loss = S x A $= 100 m^2 \times [10 + \left(\frac{120-40}{20}\right)] (120-40)$ kcals/hr /m^2 = 112.0 x 10^3 kcal/hr ……………………..1 mark

	Rate of heat loss from furnace surface after revamping insulation refractory $= 100 \left[10 + \frac{50-40}{20} \right] (50-40)$ $= 10.5 \times 10^3$ kcal/hr ……………………1 mark Energy savings kcal/hr = $(112-10.5) \times 10^3$ = 101.5×10^3 kcal/hr Annual energy savings = $(112-10.5) \times 10^3 \times 300 \times 24$ = 7.308×10^8 kcal/yr ……………………1 mark Annual fuel oil savings = $\frac{7.308x10^8}{0.35x11000}$ = 1.9×10^5 kg of fuel …………………… 1 mark Annual Cost savings = $\frac{1.9x10^5 x25000}{1000}$ = Rs.4.75×10^6 ……………………1 mark
S 8	The efficiency of a boiler on GCV basis is 85%. The fuel contains 1.0 % moisture and 12 % hydrogen. The GCV of fuel is 10,500 Kcal/kg. What is the boiler efficiency on the basis of net calorific value?
	NCV = GCV – $\left[9 \times \frac{\text{\%age of Hydrogen in fuel}}{100} + \frac{\text{\%age of moisture in fuel}}{100}\right] \times 584$ NCV = $10500 - \left[9 \times \frac{12}{100} + \frac{1.0}{100}\right] \times 584$ = 10500 – [9 x 0.12 + 0.01] x 584 = 10500 - 636.56 = 9863.44 = 9863 kcal / kg ……………………3 marks Boiler efficiency on NCV = $\frac{85}{9863} \times 10500$ = 90.5% ……………………2 marks

-------- 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

In an engineering industry, an electrically heated furnace of efficiency 80%, is used for annealing of the components. The annealing cycle and corresponding energy consumption as follows.

S.No	Heat treatment cycle	Temperature ^0C	Time hrs	Power drawn in kW
1	Heat -Up	30 - 850	4	500
2	Holding at	850	4	100
3	Cooling	850 - 60	4	20

The electrical energy drawn in each sub-cycle is uniform and plant operates 50 batches per month. The cost of electricity is Rs.8/kWh.
The management has decided to replace the electric furnace with FO oil fired furnace with efficiency of 50%. The cost of F.O is Rs.30/kg. Calculate cost savings and payback period of converting from electric to oil fired furnace. Investment for FO fired furnace is Rs.25 lakhs. The GCV of F.O is 10,000 kcal/kg

Ans

Energy consumption per treatment batch :

– Heat up time = 500 x 4 = 2000kWh; …………………..1 mark
– Holding time = 100 x 4 = 400 kWh …………………..1 mark
– Cooling time = 20 x 4 = 80 kWh …………………..1 mark
– Total energy consumption per batch = 2480 kWh …………………..1 mark
– Monthly energy consumption by electric annealing furnace including losses = 2480 x 50
= 1,24,000 kWh / month
……………………..1 mark
– Actual consumption by the components at electrical furnace efficiency of 80% = (124000 x 0.8)
= 99,200 kWh / month
……………………..1 mark
– Eqvt FO required to be supplied to the oil fired furnace at an efficiency of 50% = 99200 x 860 / (10000 x 0.5)
= 17062.4 kg / mth
……………………..1.5 marks
– Annual Cost of = [(124000 x 8) – (17062.4 x 30)] x 12
= Rs.57,61,536 / yr
……………………..1.5 marks
– Payback period = 2500000 / 5761536 = 5.2 months
……………………..1 mark

L-2

Write short notes on any two of the following
a. Wet preservation method for boilers
b. Reverse osmosis
c. Reciprocating engine co-generation system

Ans	a) **Wet preservation method for boilers:** In the wet method the boiler is filled to the normal level with water at a pH of 10.5 to 11. Hydrazine to the extent of 200 ppm is to be dosed with the water. The unit is to be steamed in service to ensure uniform concentration of boiler water throughout the unit and to eliminate dissolved oxygen from water. Sodium sulphite (Na_2SO_3), which acts as a de-oxygenerator, can also be used as an alternative to hydrazine and the sulphite concentration has to be maintained at 300-400 ppm. Analysis of boiler water should be carried out frequently. If the hydrazine concentration in water happens to drop below 50 ppm, the water in the drum should be lowered to the normal operating level and an appropriate quantity of chemicals should be dosed to bring back 200 the concentration of hydrazine or sodium sulphite. The boiler should be steamed to circulate chemicals to uniform concentration. …………………..5 marks b) **Reverse osmosis:** When solutions of differing concentrations are separated by a semi-permeable membrane, water from less concentrated solution passes through the membrane to dilute the liquid of high concentration, which is called osmosis. If the solution of high concentration is pressurized, the process is reversed and the water from the solution of high concentration flows to the weaker solution. This is known as reverse osmosis. …………………..5 marks c) **Reciprocating engine co-generation system:** Also known as internal combustion (I. C.) engines, these cogeneration systems have high power generation efficiencies in comparison with other prime movers. There are two sources of heat for recovery: exhaust gas at high temperature and engine jacket cooling water system at low temperature. As heat recovery can be quite efficient for smaller systems, these systems are more popular with smaller energy consuming facilities, particularly those having a greater need for electricity than thermal energy and where the quality of heat required is not high, e.g. low pressure steam or hot water. …………………..5 marks (Consider any two of the above)
L3	A fluidized bed boiler generates 24TPH at 22 kg/cm^2(g), out of which, 18 TPH is going to the back pressure turbine and exhausts from it at 5kg/cm^2(g) to meet the process steam requirement in the plant. The balance steam from the boiler is passed through a PRDS to supply 10 kg/cm^2(g) steam at dry saturated condition to another process. DM water at 105^{0}C is used for de-superheating in PRDS. Given data: a) Mechanical Efficiency of steam turbine = 95 % b) Losses in gear transmission = 4% c) Efficiency of alternator = 96 % d) The total heat of steam at turbine inlet condition at 22 kg/cm^2(g) = 708 kcal/kg e) The total heat of steam at turbine outlet condition at 5 kg/cm^2 (g) = 658 kcal/kg f) The total heat of the steam at PRDS exit at 10kg/cm^2(g) = 670 kcal/kg Calculate 1. Power generation from back pressure turbine 2. Steam flow rate going to process at the exit of PRDS
ANS	<u>1: Power generation from back pressure turbine:</u> Enthalpy drop across the turbine per kg of inlet steam = (h1-h2) = (708-658)= 50 kcal/kg

	……………………1 mark Total steam flow rate through turbine = 18,000 kg/hr Total enthalpy drop across the turbine =18,000*50 = 900000 kcal/hr ……………………1 mark Mechanical Efficiency of steam turbine = 95% Efficiency of alternator = 96 % % losses in gear transmission = 4% Over all efficiency of the turbo alternator = 0.95 x 0.96 x 0.96 = 0.8755 = 87.55% ……………………2 marks Energy output of turbine = 900000 x 0.8755 = 787950 ……………………1 mark Power output of the alternator = 787950/ 860 = 916 kW ……………………1 mark <u>2: Steam Flow rate going to process at the exit of PRDS:</u> Flow rate of DM water = m Heat content of steam at exit of PRDS = Heat supplied by water and steam to PRDS (6000 + m) x 670 = (6000 x 708) + (m x 105) m = 403.54 kg/ hr = 403.54 kg/hr ……………………3 marks Steam flow at outlet of PRDS = 6000 + 403.54 = 6403.54 kg / hr ……………………1 mark
L4	In a chlor-alkali plant, 100 TPD caustic solution at 30% concentration is dried to 55% concentration in a single effect evaporator, where the ratio of steam input to moisture removal is 1.0 kg/kg. It is proposed to be replaced by a triple effect evaporator at an investment cost of Rs. 5 crore, for which the ratio of steam input to moisture removal is 0.45 kg/kg. Steam for the evaporator is generated from an oil fired boiler at an evaporation ratio of 14. Calculate ~~annual~~ fuel savings in TPD.
Ans	% salt concentration at inlet = 30% % salt concentration at outlet = 55% Input quantity of caustic solution to drier = 100 TPD Amount of bone dry salt at drier inlet = 100x 0.3 = 30 TPD ………………..1 mark Amount of water at drier inlet = 100 - 30 = 70 TPD ………………..1 mark Flow rate of salt solution at drier outlet = 30 / 0.55 = 54.5 TPD ………………..1 mark Amount of water at drier outlet = 54.5 - 30 = 24.5 TPD ………………..1 mark Amount of water removed = 70 - 24.5 = 45.5 TPD ………………..1 mark Ratio of steam / moisture for single effect = 1.0 ………………..1 mark Amount of steam required for single effect = 45.5 TPD Ratio of steam / moisture for triple effect = 0.45 Amount of steam required for triple effect = 45.5 x 0.45 = 20.475 TPD ………….1 mark Amount of steam saved by triple effect = 45.5 – 20.45 = **25.05 TPD**………….1 mark Evaporation ratio = 14 Amount of fuel savings = 25.05 / 14 = **1.789 TPD**……………2 marks

<table>
<tr><td>L-5</td><td>Write short notes on following refractory properties and their significance.
a) Porosity b) Bulk density c) Pyrometric cone equivalent d) Thermal conductivity</td></tr>
<tr><td>Ans</td><td>Porosity
Low porosity is desirable as it would prevent easy penetration of refractory and also larger number of small pores are preferred over small number of large pores
……………….2.5 marks
Bulk density
Increase in bulk density increases its volume stability, heat capacity and resistance to slag penetration
……………….2.5 marks
Pyrometric Cone Equivalent (PCE)
temperature at which refractory will deform under its own weight is its softening temperature indicated by PCE .
……………….2.5 marks
Thermal conductivity
It is the heat loss per unit area per unit insulation thickness per unit temperature difference W-m2/m°C or W-m/°C. Thermal conductivity of materials increases with temperature. So thermal conductivity is always specified at the mean temperature (mean of hot and cold face temperatures) of the insulation material
……………….2.5 marks
Refer Book 2, Page no 156 – 157</td></tr>
<tr><td>L-6</td><td>In a Crude Oil refining unit, a counter-flow shell & tube heat exchanger is used to preheat LDO (Light Diesel Oil) flowing at 60 m^3/hr at 50°C using steam at 8 kg/cm^2_g as a heating medium. Steam enters the heat exchanger through a pipe of 6” diameter. Density and Specific heat of LDO is 830 kg/m^3 & 0.7 kcal/kg°C respectively.

Properties of steam at 8 kg/cm^2 is given below,

<table>
<tr><th rowspan="2">Pressure, (kg/cm^2_g)</th><th rowspan="2">Temperature, (°C)</th><th rowspan="2">Specific volume (m^3/kg)</th><th colspan="3">Enthalpy (kcal/kg)</th></tr>
<tr><th>Water</th><th>Evaporation</th><th>Steam</th></tr>
<tr><td>8.0</td><td>170</td><td>0.22</td><td>170</td><td>490</td><td>660</td></tr>
</table>

a. Calculate the mass flow rate of Steam, if the maximum permissible velocity in the pipeline is 25 m/sec.
b. Temperature of the Fuel oil, after preheating in the heat exchanger</td></tr>
<tr><td>Ans</td><td><u>Steam Flow rate calculation:</u>

Diameter of the pipe = 6 inch
= 6 * 2.54
= 15.24 cm</td></tr>
</table>

	....................1 mark Area of the pipe = 3.14 * D^2 / 4 = 3.14* $(15.24)^2$ / 4 = 182.3 cm^2 = 0.0182 m^2 Volume flow rate of steam = Area * Velocity Velocity permissible = 25 m/sec Volumetric flow rate of steam = 0.0182 * 25 = 0.455 m^3/s * 3600 = 1638 m^3/hr ....2 marks Specific volume of steam = 0.22 m^3/kg Mass flow rate of steam = 1638 / 0.22 = 7445 kg/hr a. ***Mass flow rate of steam*** = 7.445 TPH ....1 mark **Temperature of the Fuel oil (LDO)** Heat transfer rate of Steam = m * H = 7445 * 490 = 3648050 kcal/hr ....2 marks Heat transfer rate of Steam = heat transfer rate of LDO Heat transfer rate of LDO = 3648050 kcal/hr Heat transfer rate of LDO = m * Cp * $(T_1 – T_2)$ = 60 * 830 * 0.7 * (T – 50) = 3648050 / (60 * 830 * 0.7) Delta Temperature = 104.65 °C ....2 marks Outlet Temperature of LDO = (104.65 + 50)°C

	= 154.65 °C ***b) Outlet temperature of LDO*** ***= 154.65 °C*** ....2 marks

…………. End of Section – III …………..