Regn No: _____

Name: _____

(To be written by the candidate)

9th NATIONAL CERTIFICATION EXAMINATION – December, 2009
FOR
ENERGY MANAGERS AND ENERGY AUDITORS

PAPER – 2: Energy Efficiency in Thermal Utilities

Date: 19.12.2009 Timings: 1400-1700 HRS Duration: 3 HRS Max. Marks: 150

General instructions:

- *Please check that this question paper contains **14** 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	The material used to control SO_x in the FBC boiler is a) lime b) alumina c) silica **d) limestone**
2	Carpet loss occurs in a) coal combustion b) atomization of oil c) furnaces **d) coal storage**
3	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
4	Mark the best choice of insulation material for electric heat treatment furnace among the following a) glass wool b) calcium silicate c) fire bricks **d) ceramic fibre**

5	The low combustion temperature in FBC boilers results in minimal formation of a) CO b) SO_x **c) NO_x** d) CO_2
6	For same inlet conditions of the steam which of the following will generate the maximum power a) **condensing turbine** b) back pressure turbine c) extraction-cum-condensing turbine d) extraction-cum-back pressure turbine
7	Demineralisation of water is the process to remove a) dissolved oxygen **b) dissolved salts** c) carbon-dioxide d) chlorine
8	In a glass industry waste heat is used for power generation. This type of cogeneration is called a) topping cycle **b) bottoming cycle** c) gas turbine cycle d) reheat cycle
9	If the furnace temperature is T (^oK) and the area of opening is A, quantity of radiation loss in a reheating furnace is directly proportional to a) T^4 b) T c) A^4 d) A^2
10	Water hammer is common in a) water pipes b) condensate pipes **c) steam pipes with steam and condensate** d) main steam lines with good traps
11	Which of the following requires the least amount of oxygen/ kg of substance for combustion a) methane b) carbon **c) sulphur** d) hydrogen
12	Good opportunity for energy savings from continuous blow down of boiler is by **a) recovery of flash steam for use in deaerator** b) using the blow down steam to run steam turbine c) reusing the hot water so formed as make-up water d) none of the above
13	Which of the following benefits is not achieved by maximizing condensate recovery? a) minimization of boiler exit flue gas temperature b) maximization of boiler output c) reduction in water treatment costs d) reduction in energy input costs
14	Furnace wall heat loss does not depend on a) temperatures of external wall surfaces b) velocity of air around the furnace **c) material of stock to be heated** d) brick thermal conductivity of wall
15	Which fuel requires the lowest amount of excess air for combustion? a) pulverised coal b) bagasse c) fuel oil d) **natural gas.**
16	One kg of wood contains 20% moisture and 5% hydrogen by weight. How much water is evaporated during complete combustion of one kg of wood? **a) 0.65 kg** b) 250 gram c) 0.2 kg d) none of the above

17	Which data is not required to calculate the efficiency of boiler by indirect method? a) flue gas temperature b) ambient temperature c) calorific value of fuel **d) blow down rate**
18	The pour point of furnace oil is a) 100^{o}C b) 25^{o}C c) 50^{o}C **d) 20^{o}C**
19	Which property is the most important for an insulating brick? a) mechanical strength b) chemical resistance c) compact strength **d) porosity**
20	In which of the following equipment is stored heat used for preheating combustion air a) convective recuperator b) radiation recuperator **c) regenerator** d) heat pump
21	"Turndown ratio" for oil fired burners is the ratio of a) air to fuel input b) maximum fuel input to actual fuel input c) maximum air input to minimum air input **d) maximum fuel input to minimum fuel input with same excess air**
22	Flame flickering occurs in an oil fired burner because of a) oil not preheated **b) moisture in oil** c) oil pressure not sufficient d) high excess air
23	The unit of specific heat is a) kCal/kg b) kCal/m^3 **c) kCal/kg ^{o}C** d) kCal
24	LPG is predominantly a mixture of propane and ___ a) isopropane b) methane c) ethane **d) butane**
25	The amount of oxygen required to burn one kg of hydrogen is a) 3 b) 9 c) 8 d) 0.5
26	An axial compressor is used in conjunction with which of the following a) back pressure steam turbine b) condensing turbine c) **gas turbine** d) none of the above
27	If the pressure of saturated steam is reduced through a pressure reducing valve a) enthalpy of evaporation will reduce b) it will get superheated c) enthalpy will reduce d) it will produce wet steam
28	What is the average yield in re-rolling mill furnace? a) 40-50% b) 70-80% c) 80-85% **d) 90-95%**
29	Radiation losses from a boiler practically a) increase with increase in its % loading b) decrease with increase in its % loading **c) are independent of its % loading** d) none of the above.

30	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
31	Ceramic fibre gives the maximum energy savings when used in a) continuous furnace b) **annealing furnace** c) arc furnace d) re-heating furnace
32	Air compressor alone consumes about _____ of the energy generated in a gas turbine a) 5-10% b) 10-20% c) 20-30% **d) 50-60%**
33	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
34	Which of the following heat recovery equipment works on a vapour compression cycle? a) thermocompressor b) heat wheel **c) heat pump** d) heat pipe
35	Maximum heat transfer to the stock in a reheating furnace is by a) **radiation** b) conduction c) convection d) none of these
36	What should be the appropriate coal size for fixed grate coal firing? a) 25-50 mm b) 50-75 mm **c) 75-100 mm** d) 100-125 mm
37	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
38	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**
39	The efficiency of a typical FBC boiler is of the order of **a) 80%** b) 30% c) 40% d) 70%
40	Flash steam can be recovered from a) leaking steam b) condensate at vacuum c) **condensate at high pressure** d) condensate at atmospheric pressure
41	In a chain grate coal firing system primary air pressure is 75 mmWC. What should be the secondary air pressure with respect to primary air pressure? a) lower b) same c) double **d) more than double**
42	The pressure in the heating zone of a furnace should be **a) slightly positive** b) slightly negative c) highly negative d) highly positive

43	Which of the following will be an ideal heating medium for heat transfer in a heat exchanger? a) hot water b) super heated steam c) dry saturated steam d) wet steam
44	Which of these fuels has the highest heating value? a) LPG b) methane **c) hydrogen** d) diesel oil
45	The viscosity of furnace oil will be maximum at which of the following temperatures **a) 40^{o}C** b) 60^{o}C c) 90^{o}C d) 110^{o}C
46	For coal fired boilers the flame length is influenced by a) moisture b) ash content **c) volatile matter** d) fixed Carbon
47	The difference in temperature between steam and condensate is the principle of operation in a a) temperature trap b) thermodynamic trap c) thermostatic trap d) orifice type trap
48	Fluidized bed combustion takes place in the temperature range of a) above 1000^{0}C b) below 500^{0}C c) 600-700^{0}C **d) 800-900^{0}C**
49	In an equipment with steam consumption of 1 ton/hr, the steam trap capacity will be a) < 1 ton/hr b) equal to 1 ton/ hr **c) 1.5 ton/hr** d) 2 ton/hr
50	Latent heat of any vapour at its critical point will be a) highest b) above zero **c) zero** d) less then zero

……. 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 An oil fired boiler with a rated capacity of 12 ton/hr steam generation is switched over to rice husk firing. The boiler is de-rated to 7 ton/hr. List down five major reasons for de-rating.

Ans: (a) The external combustion zone reduces radiation heat transfer
(b) Rice husk ash deposition in heat transfer area
(c) High excess air as compared to oil firing
(d) Moisture content and fuel quality variation
(e) Boiler furnace temperature drops down during ash cleaning.

(1 Mark each)

S-2 What are the disadvantages of "direct method" of boiler efficiency evaluation over the "indirect method"?

Ans: **Disadvantage of Direct Method**

- **Does not indicate individual losses**
- **If there is wetness in steam it may indicate higher efficiencies than actual**
- **Does not indicate the improvement to be made in various loss areas**
- **Fuel and steam flow measurements are difficult and may not be accurate**
- **Any small error in measurement would lead to large variation in efficiency levels**

(1 Mark each)

S-3 The efficiency of a billet heating furnace with an output of 15 tonne/ hr was 32%. Find out the specific fuel consumption in litres/ tonne of billet heating and total fuel consumption per hour as per data given below:

Billet heating furnace:

Initial temp.	=	50^oC
Final temp.	=	1150^oC
Specific heat of billet	=	0.12 kCal/ kg^oC
Density of fuel oil	=	0.95 kg/ litre
GCV of fuel oil	=	10,000 kCal/kg

Determine the specific fuel consumption in litres/ tonne and total fuel consumption in litres/hr.

Ans.

$$\eta = \frac{M_g Cp \ \triangle t}{M_f \times GCV}$$

(1 Mark)

Fuel consumption per tonne S.F.C. = 1000 X 0.12 X (1150 – 50) / 0.32 X 10000
= 41.25 kg/ hr
= 41.25 / 0.95
= 43.42 litres/ tonne

(2 Marks)

Fuel consumption for 15 TPH production = 15 X 43.42 = 651.3 litres/hr

(2 Marks)

S-4 A gas turbine was running with naphtha as a fuel. The following are the data collected during the gas turbine operation:

a) Fuel (Naphtha) consumption = 360 kg/hr
b) GCV of naphtha fuel = 11500 kCal/kg

c) Overall efficiency of gas turbine which includes air compressor and alternator = 30 %

d) Cost of naphtha fuel = Rs 22000/ton

Find out the cost of generating one unit of electricity?

ANSWER:

Heat input to the turbine = 11500*360
= 4140000

Efficiency of gas turbine = 30 %

Gas Turbine Output = [(4140000*0.3)/860]
= 1444 kWh **[3 marks]**

Cost of generating 1444 units of electricity = 360 kgs * Rs 22
= Rs 7920

Cost of one unit of electricity generated = (7920)/1444
= Rs 5.49 **[2 marks]**

S-5 The fuel oil consumption in a 4 TPH oil fired boiler generating steam at 10 kgf/cm^{2}g is 300 litres/ hours. Its efficiency by indirect method was found to be 80%. Find out the evaporation ratio and the steam generation rate with the following data:

Enthalpy of Steam	=	665 kCal/ Kg
Feed water temperature	=	65^{o}C
G.C.V. of fuel oil	=	10,000 kCal/ Kg
Density of oil	=	0.95 kg/ litre

Ans. Efficiency = ER (hs – hw) / G.C.V

(1 Mark)

Boilere efficiency = 0.80
hg = Enthalpy of steam = 665 kCal / Kg.
hw = Feed water enthalpy = 65 kCal / Kg.
G.C.V. of oil = 10,000 kCal / Kg.

$$\textbf{ER} = \frac{\textbf{0.80 X 10,000}}{\textbf{(665 – 65)}} = \textbf{13.33}$$

(2 Marks)

Steam generation = 13.33 X 300 X 0.95 = 3799 Kg / hr

(2 Marks)

S-6 State the stoichiometric combustion equation for methane (CH_4).
How many kg of carbon dioxide will be generated by 8 kg of methane?

Ans $\textbf{CH}_4 + \textbf{2O}_2 \longrightarrow \textbf{CO}_2 + \textbf{2H}_2\textbf{O}$

(2 Marks)

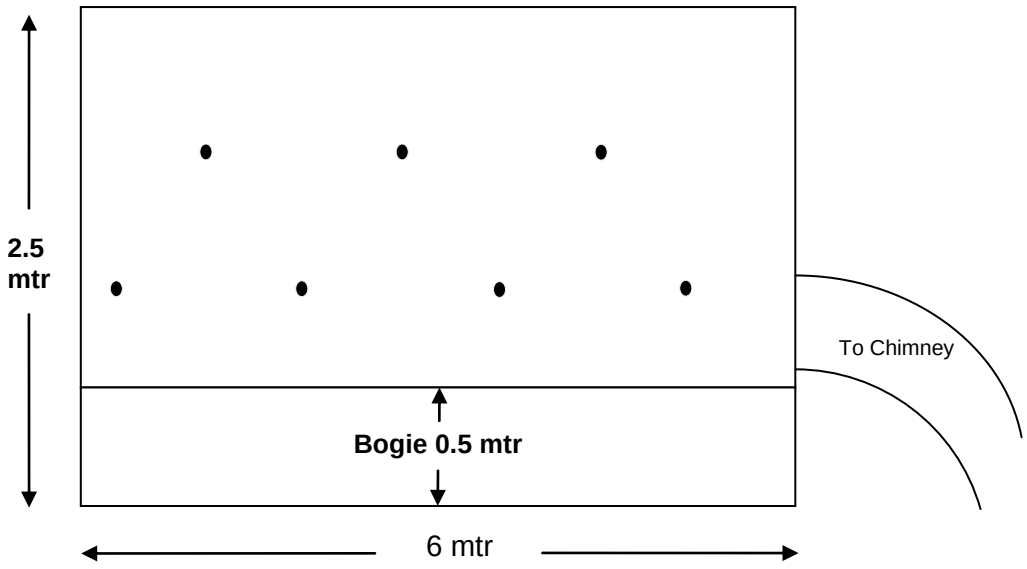
16 Kg 64 44 36

16 Kg methane produces 44 Kg. CO_2
8 Kg methane produces 22 Kg. CO_2

(3 Marks)

S-7 An oil fired bogie type re-heating furnace has 2.5 meter width, 2.5 meter height and 6 meter length. The furnace has 14 oil fired burners with 7 burners on each of the side walls. The bogie height is 0.5 meter. Draw a sketch of one side wall indicating the location of burners and chimney.

Ans:



(5 Marks)
(Burner 3 marks, chimney 2 marks)

S-8 Mention five important areas which reduces yield in a re-rolling mill.

Ans. (i) High excess air
(ii) Non-uniform temperature
(iii) High scale losses
(iv) High negative furnace draft
(v) Insufficient soaking of charge.

(1 Mark each)

------- 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 a chemical process industry a coal fired boiler of 77% efficiency is proposed to be replaced with paddy husk fired boiler of 67% efficiency. Calculate the fuel cost savings for changing over to paddy husk?

GCV of coal	= 4800 kCal/kg
Cost of coal	= Rs 4000/MT
GCV of paddy husk	= 3500 kCal/kg
Cost of paddy husk	= Rs 2200/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	= 7000 hours

Ans

(A) For Paddy Husk Fired Boiler:

Heat content in the output steam	**= 20000*(760-120)**	
	= 12800000 kCal/hr	
Paddy husk requirement	**= (12800000)/(3500*0.67)**	
	=5458 kg/hr.	
Annual operating hours	**= 7000**	
Annual paddy husk consumption	**= 5458*7000**	
	= 38206 MT	
Annual cost of paddy husk	**= 38206* Rs 2200**	
	=Rs 840.53 lakh	**[5 marks]**

(B) For Coal Fired Boiler :

Coal requirement	**= (12800000)/(4800*0.77)**
	= 3463 kg/hr
Annual operating hours	**= 7000**
Annual coal consumption	**= 3463 * 7000 = 24241 MT**
Annual cost of coal	**= 24241 * Rs 4000**

	= 969.64 lakh	**[4 marks]**
Cost saving	**= { 969.64 – 840.53 }**	
	= Rs 129.11 lakh.	**[2 marks]**

L-2 List 10 energy saving measures in a steam distribution and utilization system.

Ans

1. **Monitoring Steam Traps**
2. **Avoiding Steam Leakage**
3. **Providing Dry Steam for Process**
4. **Proper Utilisation of Directly Injected Steam**
5. **Miminising Heat Transfer Barrier**
6. **Proper Air Venting**
7. **Condensate Recovery**
8. **Insulation of steam pipe lines and hot process equipments**
9. **Flash Steam Recovery**
10. **Reducing the work to be done by steam**
11. ***Any other relevant options***

(1 Mark each)

L-3 A process industry needs saturated steam at 5 kg/cm^2(g) and 10 kg/cm^2(g) pressure level for process heating. A fluidized bed boiler generates steam at 22 kg/cm^2(g) pressure at the rate of 24 TPH. 4 TPH of steam is reduced through PRDS for meeting the 10 kg/cm^2(g) steam requirement. The balance steam is passed through a Back pressure steam turbine. The turbine back pressure steam at 5 kg/cm^2(g) is sent to a process in the plant.

a) Mechanical Efficiency of steam turbine = 92 %
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

Calculate the total power output from the system.

Ans.

<u>Step 1:</u>

Enthalpy drop across the turbine per kg of inlet steam (h1-h2)

= (708-658)

= 50 kcal/kg

(2 Marks)

Step 2:

Total steam flow rate through turbine = 20000 kg/hr
Total enthalpy drop across the turbine =20000*50=1000000 kcal/hr

(2 Marks)

Step 3:

Mechanical Efficiency of steam turbine	**= 92%**
Efficiency of alternator	**= 96 %**
% losses in gear transmission	**= 4%**

Over all efficiency of the turbo alternator = 0.92 x 0.96 x 0.96 = 0.848
= 84.8%
Energy output of turbine = 1000000 x 0.848 = 848000
Power output of the alternator = 848000/ 860 = 986 kW

(6 Marks)

L-4 In an engineering industry, a heat treatment electrical furnace is consuming 500 kWh per batch. The Energy Manager of the company wanted to convert it to furnace oil firing for cost savings. Estimate the furnace oil requirement in litres and cost savings, per batch, considering the following data.

Calorific value of furnace oil	: 10,000 kCal/kg
Specific gravity of furnace oil	: 0.9
Efficiency of electrical furnace	: 70%
Efficiency of furnace oil fired furnace	: 58 %
Cost of electricity	: Rs 4.5/kWh
Cost of furnace oil	: Rs 20/litre

Ans. **Operating electrical load : 500 kWh**
Efficiency of electrical furnace : 70%
Useful heat (heat duty) : 500 x 860 x 0.70 = 301000 kCal/ batch

(2 Marks)

FO required for meeting useful heat : 301000/10000 = 30.1 kg
Efficiency of FO fired furnace : 58%
Net FO required to meet useful heat : 30.1 / 0.58 = 51.9 kg
= 51.9 / 0.9 = 57.6 liters/ batch
Estimated furnace oil quantity : 57.6 litres/ batch

(6 Marks)

Cost savings = (500 x 4.5) – (57.6 x 20) = Rs. 1098/batch

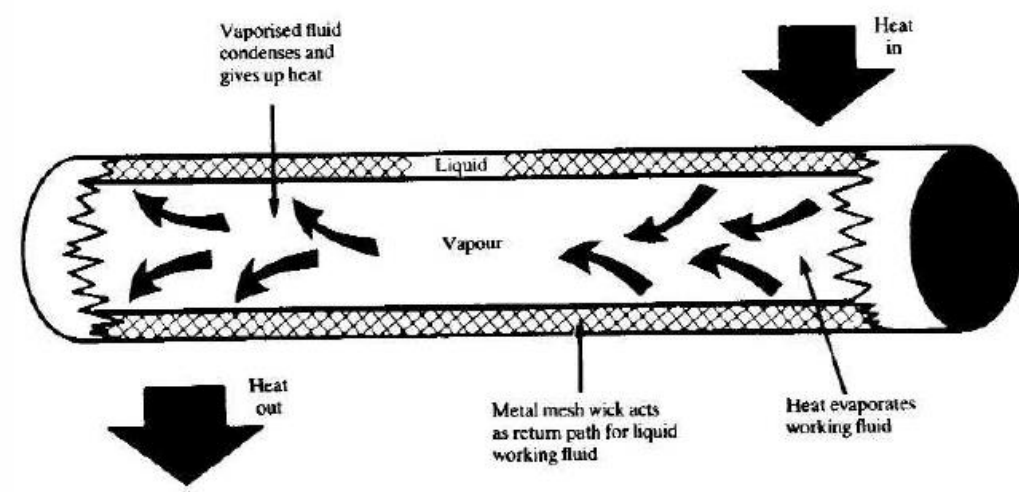
(2 Marks)

L-5 Explain briefly with the schematic the following heat recovery devices.

a) Heat Pipe
b) Metallic recuperator
c) Plate heat exchanger

Ans.

a) Heat pipe

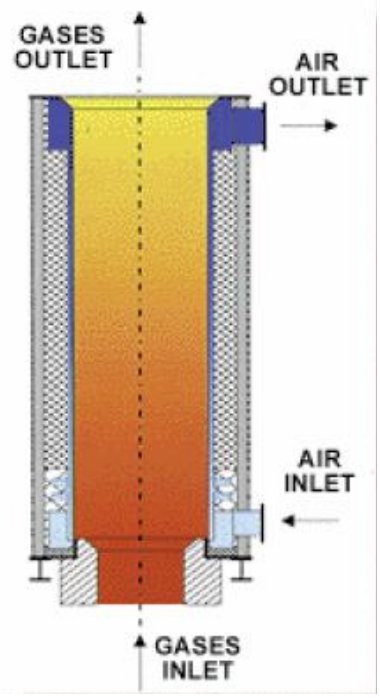


The Heat Pipe comprises of three elements – a sealed container, a capillary wick structure and a working fluid. The capillary wick structure is integrally fabricated into the interior surface of the container tube and sealed under vacuum. Thermal energy applied to the external surface of the heat pipe is in equilibrium with its own vapour as the container tube is sealed under vacuum. Thermal energy applied to the external surface of the heat pipe causes the working fluid near the surface to evaporate instantaneously. Vapour thus formed absorbs the latent heat of vapourisation and this part of the heat pipe becomes an evaporator region. The vapour then travels to the other end the pipe where the thermal energy is removed causing the vapour to condense into liquid again, thereby giving up the latent heat of the condensation. This part of the heat pipe works as the condenser region. The condensed liquid then flows back to the evaporated region.

(4 Marks)

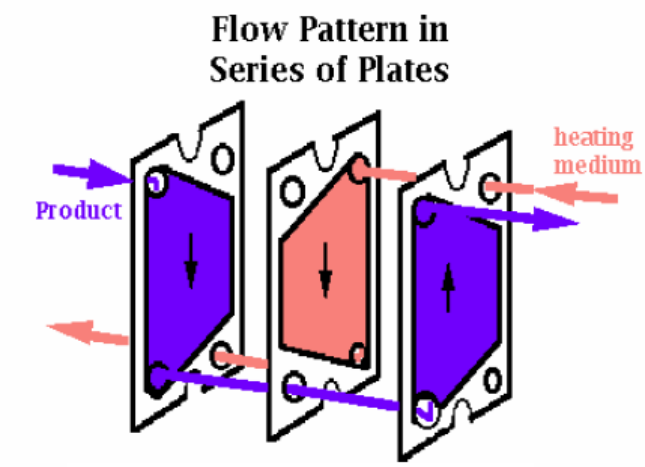
b) Radiation Repuperator

A metallic radiation recuperator consists of two concentric lengths of metal tubing. The inner tube carries the hot exhaust gases while the external annulus carries the combustion air from the atmosphere to the air inlets of the furnace burners. The hot gases are cooled by the incoming combustion air which now carries additional energy into the combustion chamber. Radiation recuperator gets its name from the fact that a substantial portion of the heat transfer from the hot gases to the surface of the inner tube takes place by radiative heat transfer.



(3 Marks)

c) Plate heat exchanger



A plate type heat exchanger consists of a series of separate parallel plates forming thin flow pass. Each plate is separated from the next by gaskets and the hot stream passes in parallel through alternative plates whilst the liquid to be heated passes in parallel between the hot plates. To improve heat transfer the plates are corrugated.

Hot liquid passing through a bottom port in the head is permitted to pass upwards between every second plate while cold liquid at the top of the head is permitted to pass downwards between the odd plates. When the directions of hot & cold fluids are opposite, the arrangement is described as counter current. The plate heat exchanger is a potential heat recovery device to recover heat from hot liquids and hot effluents.

(3 Marks)

L-6 a) Explain why dry saturated steam is preferred over wet or superheated steam for industrial process heating

b) Explain with the help of enthalpy equation the impact of dryness fraction on the enthalpy of wet steam

c) Why should one use dry saturated steam at the lowest possible pressure for indirect steam heating?

Ans a) Dry saturated steam is the preferred choice because:

- **Superheated steam gives up heat at a slower rate than saturated steam.**
- **Dry steam alone condenses quickly, thereby providing a higher heat transfer rate.**

(3 Marks)

b) $h_g = h_f + X \times h_{fg}$

Where h_f = Enthalpy of saturated water at a given pressure.

h_{fg} =Enthalpy of evaporation

h_g =Enthalpy of saturated steam.

X=Dryness fraction of steam.

If the dryness fraction is low, then the enthalpy of wet steam will be lower as the mass of water in the wet steam will be higher.

(4 Marks)

c) The latent heat of steam increases with reduction of steam pressure. At lower pressure the latent heat is more which is mainly responsible for heat transfer.

(3 Marks)

-------- End of Section - III ---------