

Regn No: _____

Name: _____

(To be written by the candidate)

**12th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – October, 2011**

PAPER – 2: Energy Efficiency in Thermal Utilities

Date: 15.10.2011 Timings: 14:00 - 17:00 HRS Duration: 3 HRS Max. Marks: 150

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 density of a substance relative to water is called a) viscosity <u>b) specific gravity</u> c) dew point d) pour point
2.	Which of the following is not a unit of viscosity a) Engler b) <u>Rankine</u> c) Saybolt d) Redwood
3.	The amount of heat required to raise the temperature of 1 kg of a substance by 1°C is called a) sensible heat b) latent heat c) <u>specific heat</u> d) net calorific value
4.	Which among the following fuels is likely to contain maximum percentage of sulphur? a) kerosene b) diesel oil c) LSHS d) <u>furnace oil</u>
5.	Which of the following grades of Indian coal will have the highest calorific value? a) B b) F c) <u>A</u> d) E
6.	Which of the following is not measured in proximate analysis? a) volatile matter b) fixed carbon c) <u>sulphur</u> d) ash
7.	Which of the following is not measured in the ultimate analysis of a fuel ?

	a) oxygen b) <u>fixed carbon</u> c) sulphur d) nitrogen
8.	Carpet loss is associated with a) combustion of coal b) <u>storage of coal</u> c) combustion of oil d) storage of natural gas
9.	Which of the following is not true with respect to improper sizing of coal a) results in poor combustion b) <u>lower excess air resulting in lesser stack loss</u> c) increase of unburnts in ash d) lower thermal efficiency
10.	Which of the following fuel constituents releases maximum amount of heat per kg during combustion ? <u>a) hydrogen</u> b) carbon c) sulphur d) nitrogen
11.	Which is the statement that is true of a fire tube boiler a) has a single steam drum b) <u>fire is in the tubes</u> c) water in the tubes d) has multiple steam drums
12.	Coal is not burnt in suspension in a) fluidised bed boiler b) <u>chain-grate boiler</u> c) spreader stoker boiler d) pulverised fuel fired boiler
13.	Which of the following is considered in the calculation of 'Evaporation ratio'? a) calorific value of fuel b) latent heat of steam c) <u>fuel quantity</u> d) all of the above
14.	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) <u>osmosis</u>
15.	Flash steam can be recovered from a) superheated steam b) saturated steam c) <u>high pressure condensate</u> d) condensate at atmospheric pressure
16.	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) <u>enthalpy of evaporation is maximum at critical point</u>

17.	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) <u>directly proportional to the square of velocity</u>
18.	Select the wrong statement with respect to steam traps a) discharges condensate as soon as it is formed b) does not allow steam to escape c) capable of discharging air and other incondensable gases d) <u>does not allow condensate to escape</u>
19.	Heat transfer in a furnace is effected by a) radiation from flame b) radiation from furnace walls c) convection due to movement of hot gases over the stock d) <u>all of the above</u>
20.	In a coke fired cupola, carbon monoxide is produced in the a) preheating zone b) <u>reducing zone</u> c) combustion zone d) melting zone
21.	In an oil fired heat treatment furnace which of the following is not required to determine its efficiency by direct method a) weight of input material b) <u>oxygen percentage in flue gas</u> c) fuel consumption d) calorific value of fuel
22.	Which of the following may not help in energy efficient furnace operation? a) maintaining a positive draft inside the furnace b) minimizing refractory losses c) <u>complete combustion with maximum excess air</u> d) use of ceramic fibre in batch type furnace
23.	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) <u>ceramic fibre linings are used in the exterior of the furnace</u> d) heat loss through openings is proportional to T^4
24.	The effectiveness of a heat exchanger does not depend on a) specific heat of hot fluid b) Inlet temperature of hot fluid c) <u>LMTD</u> d) Inlet temperature of cold fluid

25.	Pinch analysis uses the _____ law of thermodynamics a) First b) Second c) Third d) <u>Both (a) & (b)</u>
26.	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) <u>100°C</u> b) 280°C c) 0°C d) 20
27.	What is the best-suited pump for pumping heavy fuel oil? a) centrifugal pump b) <u>gear pump</u> c) diaphragm pump d) plunger pump
28.	Which of the following components in fuel limits exit flue gas temperature in a boiler waste heat recovery system? a) hydrogen content b) volatile matter c) <u>sulphur content</u> d) ash content
29.	Which of the following requires the largest amount of oxygen/kg of substance for combustion? a) carbon b) <u>hydrogen</u> c) sulphur d) nitrogen
30.	A paper plant needs steam at 3.5 bar and 10.5 bar in addition to electric power. The most suitable choice among the following will be a) condensing turbine b) bottoming cycle c) back pressure turbine d) <u>extraction cum back pressure turbine</u>
31.	An increase in the steam pressure from 3 bar to 10 bar, will result in a decrease of a) sensible heat b) enthalpy of steam c) saturation temperature d) <u>specific volume</u>
32.	Chemical used for dozing boiler drum to reduce dissolved gases is a) <u>hydrazine</u> b) chlorine c) alum d) all of the above
33.	Saturated steam when throttled to a lower pressure results in a) wet steam b) <u>super heated steam</u> c) super critical steam d) same state of steam
34.	Radiation losses from the surface of a boiler practically a) increase with increase in its % loading b) decrease with increase in its % loading c) <u>are independent of its loading</u> d) none of the above
35.	In oil fired boiler, the measured CO ₂ in flue gas is 11 % by volume against the theoretical CO ₂ of 15.5% . The percentage excess air will be a) <u>40.9%</u> b) <u>38.7%</u> c) 240.9% d) none of the above
36.	Which of the following fuel fired steam boiler will have the least evaporation ratio? a) coal b) <u>bagasse</u> c) oil d) gas

37.	_____ indicates the softening temperature of the refractory	a) refractoriness under load (RUL)	b) cold crushing strength
		c) <u>pyrometric cone equivalent (PCE)</u>	d) porosity
38.	An increase in bulk density of a refractory increases its		
	a) volume stability b) heat capacity c) resistance to slag penetration <u>d) all of the above</u>		
39.	The insulation material used for medium temperature application is		
	a) <u>calcium silicate</u>	b) polyurethane	c) wood d) mica
40.	A coal fired FBC boiler can operate at _____ excess air		
	a) 3 – 4 %	<u>b) 20 -25 %</u>	c) 30 – 40 % d) 10 – 15 %
41.	The balance draft furnace is one using		
	a) induced draft fan and chimney	<u>b) induced draft fan and forced draft fan</u>	
	c) forced draft fan and chimney	d) without induced and forced draft fans	
42.	Higher excess air in an oil fired furnace would result in		
	a) increased furnace temperature	b) increase in CO ₂ presence in flue gas	
	<u>c) reduced flame temperature</u>	d) all of the above	
43.	_____ is the commonly employed flux in a cupola furnace		
	a) calcium carbide	b) fluorspar	c) limestone <u>d) any of the above</u>
44.	By installing a recuperator ,1% fuel reduction is possible for every _____ reduction in flue gas temperature		
	a) 5°C	b) 33°C	<u>c) 22°C</u> d) 10°C
45.	The heat loss rate from a surface is expressed in		
	a) Joules	b) W/m ² °C	c) Watt/sec <u>d) kCal/m²/hr</u>
46.	Which among the following uses a working fluid for heat recovery ?		
	<u>a) heat pipe</u>	b) recuperator	c) heat wheel d) regenerator
47.	Which of the following is most suitable for high temperature waste heat recovery ?		
	a) heat wheel	b) heat pump	c) heat pipe <u>d) recuperator</u>
48.	Among the following, cogeneration concept is not applicable to which type of industry?		
	a) sugar	b) paper & pulp	c) refinery <u>d) refractory</u>
49.	A device used to convert low pressure steam to high pressure steam is called		
	a) heat pump	b) heat pipe	<u>c) thermocompressor</u> d) economizer
50.	The unit of thermal conductivity is		
	a) W / m ² °C	b) W °C / m ²	<u>c) W / m °C</u> d) W °C / m

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99.	A device used to convert low pressure steam to high pressure steam is called			
	a) heat pump	b) heat pipe	c) <u>thermocompressor</u>	d) economizer
100.	The unit of thermal conductivity is			
	b) W / m ² °C	b) W °C / m ²	c) <u>W / m °C</u>	d) W °C / m

..... **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	The specification of furnace oil from lab analysis is given below, Carbon : 82.7 % Hydrogen : 14.5 % Oxygen : 0.9 % Sulphur : 0.8 % Water : 0.45 % Ash content : 0.65 % If actual mass of air supplied to the furnace is 16.5 kg/kg of furnace oil, calculate the % of excess air supplied to the furnace.
Ans	Theoretical air required for complete combustion $= ((11.6 * C) + (34.8 * (H_2 - O_2 / 8)) + (4.35 * S)) / 100$ $= ((11.6 * 82.7) + (34.8 * (14.5 - 0.9/8)) + (4.35 * 0.8)) / 100$ $= 14.63 \text{ kg / kg of FO}$ Actual mass of air supplied = 16.5 Kg/Kg of FO Actual mass of air supplied = (1 + Excess air) * (Theoretical air) $(1 + \text{Excess air}) = 16.5 / 14.63$ $(1 + \text{Excess air}) = 1.1278$ $\text{Excess air} = 0.1278$ Excess air supplied , % = 12.78
S-2	In a dryer, 100 m³/hr of hot thermic fluid is circulated at 270°C. The thermic fluid heater fired by coal, operates at a range of 20°C. Estimate the coal requirement if the thermal efficiency of the heater is 65% and GCV of the coal is 4200 kCal/hr. Consider specific heat & density of the thermic fluid to be 0.55 kCal/kg°C & 820 kg/m³ respectively.

Ans	Absorbed heat in thermic fluid = $m \times C_p \times \Delta T$ Absorbed heat in thermic fluid = $(100 \times 820) \times 0.55 \times 20$ Absorbed heat in thermic fluid = 902000 Kcal/hr Thermal efficiency of the heater = absorbed duty / heat duty Mass of coal required = absorbed duty / (efficiency * calorific value of coal) Mass of coal required = $902000 / (0.65 \times 4200)$ Mass of coal required = 330.4 kg/hr
S-3	A heat exchanger is to be designed to condense a vapour at the rate of 8.5 kg/sec which is available at its saturation temperature of 80°C. The latent heat of condensation of vapour is 550 kJ/kg. The cooling water at 20°C and a flow rate of 62 kg/sec is used to remove the heat. Determine the LMTD of the heat exchanger.
	Heat of condensation = heat gained by the liquid $M_v \times h_{fgv} = M_c \times C_{pc} \times (T_{out} - T_{in})$ $8.5 \times 550 = 62 \times 4.2 \times (T_{out} - 20)$ $T_{out} = 37.95^\circ\text{C}$ $LMTD = \frac{(80 - 20) - (80 - 37.95)}{\ln(60/42.5)}$ $= 50.49^\circ\text{C}$
S-4	List five energy saving measures in an oil fired reheating furnace

Ans	1) Complete combustion with minimum excess air 2) Correct heat distribution 3) Operating at the desired temperature 4) Reducing heat losses from furnace openings 5) Maintaining correct amount of furnace draught 6) Optimum capacity utilization 7) Waste heat recovery from the flue gases 8) Minimum refractory losses 9) Use of Ceramic Coatings
S-5	a) Why de-superheating is done in Pressure Reducing Desuperheating Stations? b) Why individual trapping is preferred over group trapping in a steam distribution system ?
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. b) The steam consumption of a number of units is never the same at a moment of time and therefore the pressure in the various steam spaces will also be different. It follows that the pressure at the drain outlet of a heavily loaded unit will be less than in the case of one that is lightly loaded. Now, if all these units are connected to a common steam trap, the condensate from the heavily loaded and therefore lower pressure steam space finds it difficult to reach the trap as against the higher pressure condensate produced by lightly or partly loaded unit. The only satisfactory arrangement, thus would be to drain each steam space with own trap and then connect the outlets of the various traps to the common condensate return main.
S-6	List down five advantages of FBC boiler.
ANS	Solution (any 5 five of the following): 1.High efficiency – FBC boilers can operate with overall efficiency of 84% 2.Reduction in boiler size – high heat transfer rate over a small heat transfer area 3.Fuel flexibility – can be operated with variety of fuels 4.Ability to burn low grade fuel 5.Ability to burn fines 6.Pollution control– addition of limestone/dolomite can greatly minimise SO₂ formation 7.Low corrosion and erosion

	8.No clinker formation 9.Less excess air 10.Simple operation, quick startup 11.Fast response to load fluctuations 12.No soot blowing 13.Provision of automatic coal and ash handling systems 14.Provision of automatic ignition system 15.High reliability 16.Reduced maintenance 17.Quick response to changing demand 18.High efficiency of power generation
S-7	a) Why steam is most preferred heating media in process industries? b) Why saturated steam is preferred over superheated or wet steam for indirect heating in a process?
ANS	Steam is most preferred for following reasons – Very high heat content – Gives up heat at constant temperature – Produced from water (cheap, plentiful) – Clean, odorless, tasteless – It's heat can be used over and over – Can generate power, then used for heating – Can be readily distributed, easily controlled Saturated steam has a high heat transfer coefficient. It immediately releases the latent heat on contacting the cold surface. So heat transfer is faster and at uniform temperature. Superheated steam has a low heat transfer coefficient and first it has to give up its superheat which happens slowly and then once it reaches the saturation state it gives up the latent heat. So it takes more time to heat with superheated steam. Hence saturated steam is preferred.
S-8	For a 5 tonne/hour capacity furnace oil fired boiler, estimate the rise in temperature of water in an economizer, which brings down the flue gas temperature from 310 °C to 180 °C. Air to fuel ratio and evaporation ratio of the boiler are 20 and 10 respectively. Assume condensate recovery is nil. Specific heat of flue gas is 0.23 kCal/kg°C

	For 1 kg of fuel steam generated is	= 10 kg
	For 1 kg of fuel makeup water is	= 10 kg
	For 1 kg of fuel required combustion air is	= 20 kg
	For 1 kg of fuel flue gas generated is	= 20 +1= 21 kg
	In economizer heat given by flue gas	= heat received by makeup water
	$21 \times 0.23 \times (310-180) = 10 \times 1 \times \Delta T$	
	$\Delta T = 62.8^{\circ}\text{C}$	

----- End of Section - II -----

Section – III: LONG DESCRIPTIVE QUESTIONS

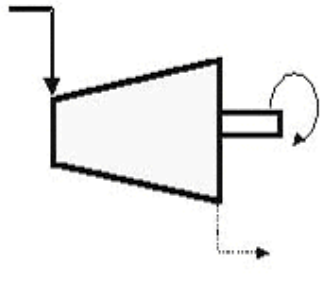
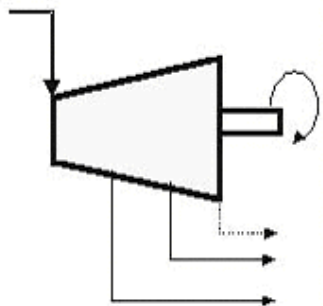
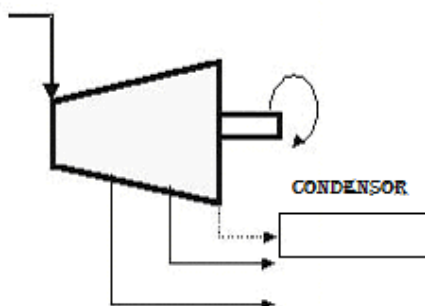
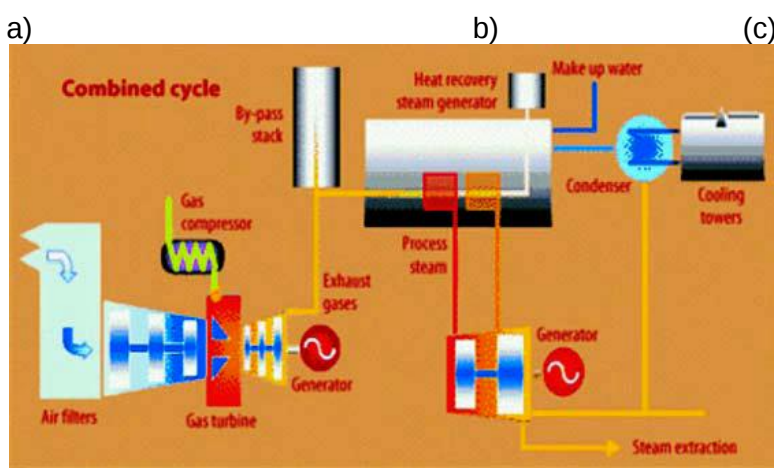
Marks: 6 x 10 = 60

- (i) Answer all **Six** questions
- (ii) Each question carries **Ten** marks

L-1	An oil fired boiler is generating 30 T/hr Steam and operates for 8000 hrs/year. The TDS in boiler feed water was reduced from 500 ppm to 200 ppm. The maximum permissible limit of TDS in the boiler is 3000 ppm and make up water is 10%. Temperature of the blow down water is 170°C and boiler feed water temperature is 40°C. GCV of fuel is 10000 kCal/kg and efficiency of the boiler is 80%. Calculate the savings in fuel oil per annum due to reduction in the blow down
ANS	Blow down % = $\text{Feed water TDS} \times \% \text{ make up water} \times 100 / (\text{maximum permissible TDS in boiler water} - \text{Feed water TDS})$ Initial blow down = $500 \times 10 / (3000 - 500)$ Initial blow down = 2.0 % Improved blow down = $200 \times 10 / (3000 - 200)$ Improved blow down = 0.71 % Reduction in blow down = $2.0 - 0.71$ Reduction in blow down = 1.29 % Reduction in blow down = $1.29 \times 30 \times 1000 / 100$ Reduction in blow down = 387 kg/hr Heat savings = $387 \times 1 \times (170 - 40)$ Heat savings = 50310 kcal/hr Fuel Oil saving = $50310 / (10000 \times 0.8) = 6.28 \text{ kg/hr}$ = $6.28 \times 8000 \text{ hr} = \mathbf{50.24 \text{ MT / annum}}$
L-2	a) Draw the schematics of a heat pump system and state two examples of heat pump applications. b) An oil fired boiler has the following operating parameters Steam generation : 5 T/hr Steam pressure : 8 kg/cm²

	Feed water temperature : 50 °C Steam enthalpy : 660 kCal/kg Steam Saturation temperature : 170 °C GCV of fuel oil : 9550 kCal/kg Consumption of fuel oil : 300 kg/hr Calculate the boiler efficiency if the dryness fraction is 0.8.
ANS	a) Refer Book 3, Page No. 229-230 b) Steam generated = 5 T/hr Dry steam = 4 T/hr Wet steam = 1 T/hr Total heat of the steam = $4000 * (660-50) + 1000*1*(170 - 50)$ Total heat of the steam = $2.56 * 10^6$ Kcal/hr Boiler Efficiency = Heat of steam / (mass of fuel * calorific value) Boiler Efficiency = $2.56 * 10^6 / (300 * 9550) * 100$ Answer: Boiler Efficiency = 89.3 %

L-3	In a crude distillation unit of a refinery, 50 MetricTonne/hr of crude is heated using saturated steam in a heat exchanger from 35°C to 85°C. Plant is operating for 8000 hrs/annum. Consider specific heat of the crude as 0.631 kCal/kg°C. The plant has two steam headers operating at 3 bar and 8 bar respectively, passing nearby the heat exchanger. Cost of steam is same for both 3 bar and 8 bar @ Rs.4.50/kg As an Energy Manager, which of the following options will you recommend to the unit based on the annual cost of steam? a) Utilising 3 bar steam b) Utilising 8 bar steam Given: Data from steam table: <table><tr><th rowspan="2">Steam Pressure, bar</th><th colspan="3">Enthalpy kCal/kg</th></tr><tr><th>Water</th><th>Evaporation</th><th>Steam</th></tr><tr><td>3.0</td><td>133</td><td>517</td><td>650</td></tr><tr><td>8.0</td><td>171</td><td>489</td><td>660</td></tr></table>	Steam Pressure, bar	Enthalpy kCal/kg			Water	Evaporation	Steam	3.0	133	517	650	8.0	171	489	660
Steam Pressure, bar	Enthalpy kCal/kg															
	Water	Evaporation	Steam													
3.0	133	517	650													
8.0	171	489	660													
ANS	Heat gain in crude = $m \cdot C_p \cdot \Delta T$ Heat gain in crude = $50 \cdot 1000 \cdot 0.631 \cdot (85 - 35)$ Heat gain in crude = 1577500 kCal/hr Heat gain in crude = heat loss in steam Heat loss in steam = mass of the steam * latent heat of steam Option A: 3 bar pressure steam having 517 Kcal/kg of latent heat Mass of the steam = $1577500 / 517$ Mass of the steam = 3051 kg / hr Cost of steam expenditure = $3051 \cdot 8000 \cdot 4.5$ Cost of steam expenditure = 10.98 Cr Option B: 8 bar pressure steam having 489 Kcal/kg of latent heat Mass of the steam = $1577500 / 489$ Mass of the steam = 3225 kg / hr Cost of steam expenditure = $3226 \cdot 8000 \cdot 4.5$ Cost of steam expenditure = 11.61 Cr Answer: Option A is recommended as it is found to be economical (Steam @ 3 bar pressure) since the expenditure per annum is less when compared to Option B.															

L-4	Make an illustrative sketch of the followings a) simple back pressure turbine b) double extraction back pressure turbine c) double extraction condensing turbine d) gas turbine combined cycle
ANS	 High pressure steam  Extracted steam  Exhaust steam  (i) Simple backpressure  ii) Double extraction backpressure  (iii) DOUBLE EXTRACTION CUM CONDENSING  d)

L-5	In a counter flow heat exchanger, water is being chilled by sodium chloride brine. The rate of flow of the brine is 2.7 kg/s and that of the water is 1.58 kg/s. Estimate the temperature to which the water is cooled if the brine enters at – 8 °C and leaves at 10 °C, and if the water enters the exchanger at 38 °C. Calculate the area of the heat exchanger surface if the overall heat transfer co-efficient is 100 J/m²s°C. Consider the specific heat of brine and water is 3.38 & 4.18 kJ/kg°C respectively.
ANS	Heat gain by brine = heat lost by water $2.7 * 3.38 * (10 - (-8)) = 1.58 * 4.18 * (38 - T)$ $T = 13.2\text{ }^{\circ}\text{C}$ i) Water leaves the exchanger at 13.2°C ii) LMTD of counter flow pattern $\Delta T_{LMTD} = \frac{(38 - 10) - (13.2 - (-8))}{\ln \left(\frac{38 - 10}{13.2 - (-8)} \right)}$ $\Delta T_{LMTD} = \frac{6.8}{\ln 1.32} = 24.4\text{ }^{\circ}\text{C}$ $Q = m * C_p * \Delta T = U * A * LMTD$ $2.7 * 3.38 * (10 - (-8)) * 1000 = 100 * A * 24.4$ $A = 67.3\text{ m}^2$ Area of the heat exchanger surface is 67.3 m²
L-6	Write short notes on <u>any two</u> of the following a) general requirements of refractory material for furnace application b) causes of boiler tube leakages c) thermocompressor d) heat pipe
ANS	a) Requirements of refractory material a) Ability to withstand high temperatures. b) Ability to withstand sudden changes of temperatures. c) Ability to withstand action of molten metal slag, glass, hot gases, etc. d) Ability to withstand load at service conditions. e) Ability to withstand load and abrasive forces. f) Low coefficient of thermal expansion. g) Should be able to conserve heat. h) Should not contaminate the material with which it comes into contact.

b) Tube failures can be attributed to design, manufacturing, operational, maintenance and ageing related aspects. The tube failures mechanisms can be classified as Mechanical, chemical, metallurgical & in adequate quality compliance.

Mechanical causes

Mechanical damage of tubes takes place due to fly ash erosion, steam impingement from soot blowers, falling clinker and fuel particles. The Mechanical damage increases the stress level leading to tube failure.

Chemical causes

Water side and fire side corrosion failure of tubes occurs due to phenomenon like caustic gouging, hydrogen embrittlement, pitting, and stress corrosion cracking while fire side corrosion is often due to high as well as low temperature effects

Metallurgical causes

In high temp components like superheaters, reheaters creep damage occurs due to overheating wherein the tube material loses its strength and failure occurs by stress rupture. Weld joint failures by cracking and fatigue failures by vibration, thermal and corrosion phenomenon are other reasons for metallurgical related tube failures.

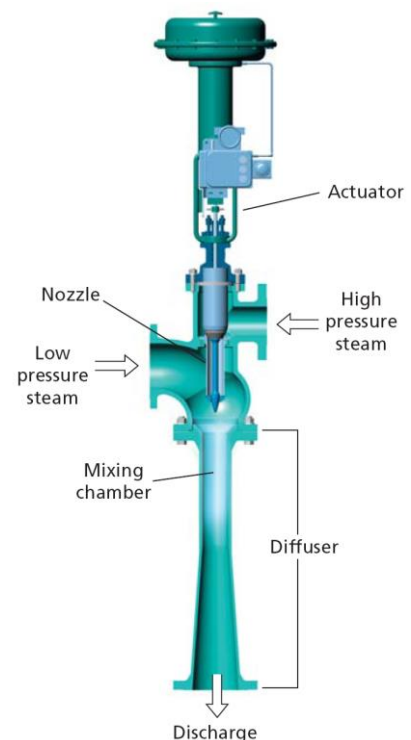
Quality assurance gaps

Tube failures are also known to occur due to inadequate quality assurance procedures during design/manufacturing of boiler tubes. Due care during material procurement, adoption of healthy fabrication practices, good operation and maintenance practices in tube manufacturing would help to minimize tube leakages and achieve high availability.

c) Thermocompressor

In many of the steam utilization equipment where condensate comes out at high pressure, a major portion of it flashes into low pressure steam which goes wasted. Using a thermocompressor it becomes feasible to compress this low pressure steam by high pressure steam and reuse it as a medium pressure steam in the process. The major energy in steam is in its latent heat value and thus thermocompressing would give a large improvement in waste heat recovery.

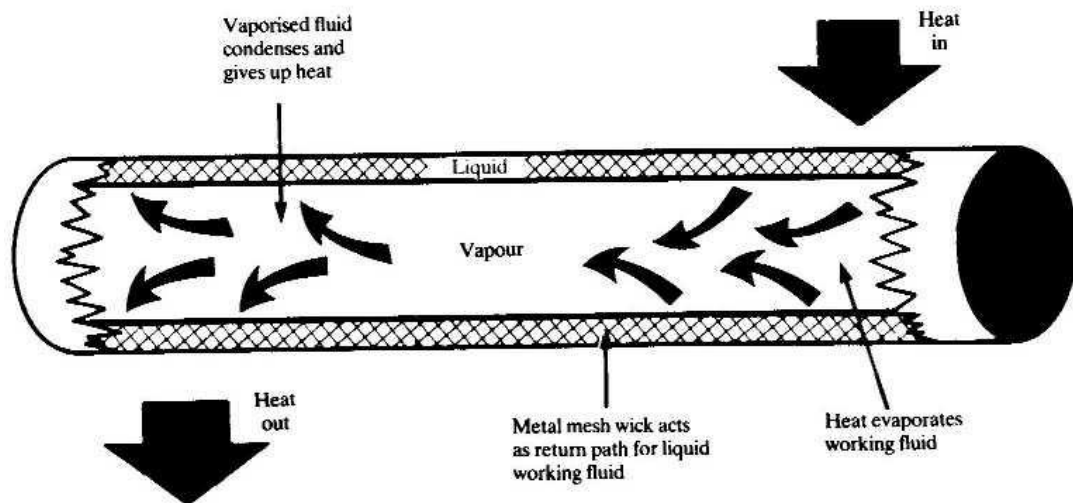
Thermocompressors are designed to accurately mix lower-pressure steam with higher-pressure steam. The higher-pressure motive steam entrains the



lower pressure steam and increases its pressure. The motive steam is introduced through the nozzle of the thermocompressor. As the nozzle opens, the high velocity motive steam draws the lower-pressure steam into the thermocompressor body. An exchange of momentum occurs as the steam flows are mixed and the mixed flow is accelerated to high velocity with a uniform profile in the mixing chamber of the thermocompressor. As the mixed flow enters the diffuser section, the diffuser flow area gradually increases to allow the velocity of the mixed flow to be reduced. As the velocity is reduced, the steam pressure increases. At the end of the diffuser, the discharge steam pressure is higher than the lower-pressure suction flow entering the thermocompressor. A figure of thermocompressor is shown in Figure 3.7. A typical application is in evaporators where the boiling steam is recompressed and used as heating steam.

d) Heat Pipe

A heat pipe can transfer up to 100 times more thermal energy than copper, the best known conductor. In other words, heat pipe is a thermal energy absorbing and transferring system and have no moving parts and hence require minimum maintenance.



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. A figure of Heat pipe is shown in Figure

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