14th NATIONAL CERTIFICATION EXAMINATION FOR ENERGY MANAGERS & ENERGY AUDITORS – August, 2013

PAPER – 2:	**Energy Efficiency in Thermal Utilities**
Date: 24.8.2013 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

1.		In coal fired combustion, the flame length is influenced by a) moisture b) ash content c) <u>volatile matter</u> d) fixed carbon
2.		With increase in the percentage of excess air for combustion of coal, percentage of CO_2 in flue gas a) increases <u>b) decreases</u> c) remains same d) none of the above
3.		100 kg of a fuel contains 3% sulphur. For complete combustion of sulphur in the fuel it will require _________kg of oxygen <u>a) 3</u> b) 6 c) 30 d) 103
4.		Which property indicates the lowest temperature at which fuel oil is readily pumpable? a) flash point b) <u>pour point</u> c) specific heat d) specific volume
5.		Which of the following contributes to spluttering of flame at burner tip during combustion of fuel oil ? a) ash content b) <u>water content</u> c) sulphur content d) humidity of air
6.		In an oil fired steam boiler the air to fuel ratio is 15:1 & evaporation ratio is 14:1. The flue gas to fuel ratio will be

		a) 29:1 b) <u>16:1</u> c) 14:1 d) 15:1
7.		Which among the following fuels, on combustion ,has higher tendency towards acid corrosion in the flue gas path? a) a) LSHS b) <u>furnace oil</u> c) Diesel d) kerosene
8.		The balanced draft furnace is one that is operated with a) a) positive pressure b<u>) induced and forced draft fan</u> b) c) negative pressure d) Natural draft
9.		The factor that influences atomisation of fuel oil is a) <u>viscosity</u> b) density c) flash point d) pour point
10.		Which of the following is not measured in ultimate analysis ? a) carbon b) sulphur c) hydrogen d) <u>moisture</u>
11.		In flue gas, the oxygen measured is 4% by volume. The percentage excess air will be a) <u>a) 23.5%</u> b) 40% c) 21% d) 36%
12.		A boiler generates 5 TPH of steam at an efficiency of 78 %. The enthalpy added to steam in the boiler is 580 kcal/kg. The fuel consumption with a GCV of 4200 kcal/kg is a<u>) 885 kg/hr</u> b) 985 kg/hr c) 1038 kg/hr d) 1200 kg/hr
13.		Automatic blowdown controls for boilers work by sensing a) dissolved gases b) dissolved solids c) pH d) <u>conductivity and pH</u>
14.		Dissolved CO_2 in boiler feed water when left untreated would result in occurrence of _____in boiler tubes a) creep b) <u>water side corrosion</u> c) scale d) water hammer
15.		Recommended boiler feed water pH value at 25°C is --------- a<u>) 8.0 - 9.0</u> b) 5.2 - 6.2 c) 9.8-10.2 d) 10-10.5
16.		Which of the following is not applicable in the preservation of boiler by dry method ? a) un-slacked lime b) activated alumina c) anhydrous calcium cloride <u>d) hydrazine</u>

17.		Which one of the following is true of a water softening process? a) It reduces hardness but not TDS b) It reduces both hardness and TDS c) It reduces TDS but not hardness d) None of the above
18.		Soot deposit in boiler tubes is predominantly due to a) poor water treatment b) low steam pressure c) incomplete combustion d) high excess air
19.		Which of the following will be the most suitable heating medium for heat transfer in indirect heating? a) dry saturated steam b) superheated steam c) wet steam d) hot water
20.		Ten meter lift of condensate in a distribution pipe will result in a back pressure of a) 0.1 bar b) 1 bar c) 10 bar d) 1.1 bar
21.		The difference in temperature between steam and condensate is the principle of operation of a) thermodynamic trap b) thermostatic trap c) orifice type trap d) float trap
22.		Water flows at a rate of 30 m^3/hr. at 15ºC 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) 3.7 m/s
23.		To drain condensate from tracer steam lines , the most common trap used is__________ a) thermodynamic b) bimetallic c) inverted bucket d) float trap
24.		The 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) fifth power of pipe diameter
25.		Condensate, at 3 bar pressure & 160°C, when exposed to atmosphere will a) fully convert to flash steam b) partly convert to flash steam c) remain as condensate d) convert to superheated steam
26.		Steam at 4 bar has sensible heat of 144 kcal/kg and latent heat of 510 kcal/kg. If the steam is 90% dry than the total enthalpy of steam in kcal/kg is a) 588 b) 654 c) 603 d) 459
27.		For transporting steam to a long distance, the most suitable among the following will be a) slightly superheated steam b) dry saturated steam

		c) mildly wet steam d) high pressure steam
28.		Heat transfer in a reheating furnace is achieved by a) conduction b) convection c) radiation d) <u>all of the above</u>
29.		Which of the following is not a property of ceramic fibre ? a) low thermal conductivity b) light weight c<u>) high heat capacity</u> d) thermal shock resistant
30.		The unit of overall heat transfer coefficient is a) kcal/m-hr-°C b) <u>kcal/ m²-hr-°C</u> c) kcal/m²-°C d) kcal/ m-°C
31.		Which property of ceramic coating influences energy savings in furnaces? a) <u>emissivity</u> b) coating thickness c) conductivity d) convective heat transfer coefficient
32.		In a CFBC boiler the capture and recycling of bed materials is accomplished by a) elecrostatic precipitator b) bag filter <u>c) cyclone</u> d) scrubber
33.		What is the most effective way to avoid ambient air infiltration into a continuous furnace? a) close all openings b) increase the chimney height c) operate at about 90% capacity d) <u>maintain slightly positive pressure inside the furnace</u>
34.		The storage heat losses in a batch type furnace can be best reduced by use of a) hot face insulating bricks b) <u>hot face ceramic fibre</u> c) cold face insulating bricks d) cold face ceramic fibre
35.		Tuyeres is a terminology associated with a) forging furnace b) <u>cupola</u> c) open hearth furnace d) heat treatment furnace
36.		Which of the following is a synthetic refractory? a) MgO b) Al_2O_3 <u>c) SiC</u> d) SiO_2
37.		Alumina is a ___________________ type of refractory a) basic b) acidic **c)** <u>neutral</u> d) none of the above
38.		An increase in bulk density of a refractory increases its a) volume stability b) heat capacity c) resistance to slag penetration d) <u>all of the above</u>

39.		Which of these is used in a fluidised bed boiler to control sulphur dioxide emissions? a) charcoal b) limestone c) sand d) silica
40.		In FBC boiler the combustion is carried out at a temperature a) closer to steam temperature b) at adiabatic combustion temperature c) at and above ash fusion temperature d) below ash fusion temperature of fuel used
41.		Low combustion temperature minimises___ in FBC boilers **a) NOx** b) SOx c) CO d) Suspended particulate matter
42.		A chemical plant needs steam at 3 bar and 10 bar in addition to electric power. The most suitable co-generation choice among the following will be a) extraction cum condensing b) condensing turbine c) back pressure turbine d) extraction cum back pressure turbine
43.		Power is to be generated from a cement kiln exhaust gas. The applicable type of cogeneration is called a) topping cycle b) Carnot cycle c) bottoming cycle d) Brayton cycle
44.		Which of the following works on a refrigeration cycle? a) heat pipe b) heat wheel c) heat pump d) thermo compressor
45.		Which of these devices can be used for recovering waste heat from the textile drier exhaust? a) heat wheel b) recuperator c) economizer d) regenerator
46.		Wick in heat pipe is provided to facilitate a) forward movement of hot vapors b) forward movement of hot liquid c) return of condensed liquid d) return of hot vapors
47.		Which of the following requires electrical energy for equipment operation? a) thermo compressor b) heat pump c) heat pipe d) economizer
48.		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
49.		Pinch analysis of process streams depicts the plot of a) temperature vs entropy b) temperature vs area c) temperature vs specific heat d) temperature vs enthalpy

50.		Correction factor for LMTD calculation is applicable for a) parallel flow b) counter current flow c) <u>cross flow</u> d) both (a) & (b)

……. 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 following are the parameters obtained from a steam audit of a cylindrical dryer used for drying cloth.** **Cloth Throughput = 20 m/minute** **Cloth Density = 9.8 m/kg** **Measured Condensate Rate = 135 kg/hour** **Calculate the specific steam consumption per kg of cloth.**
	Cloth throughput per hour = 20 x 60 = 1200 m/hr Weight of cloth = 1200 / 9.8 = 122.45 kg/hr Steam consumption = condensate collected Specific steam consumption = 135/122.45 =1.1 kg of steam per kg of cloth
S-2	**In a crude distillation unit of a refinery, furnace is operated to heat 300 kilo Litres/hr of crude oil at an inlet temperature of 255°C by firing 2.5 kilolitres/hr of furnace oil having GCV of 9880 kcal/kg. If the efficiency of the furnace is 82% ,calculate the outlet temperature of the crude oil from the furnace. Consider the following data:** **Specific heat of Crude Oil = 0.65 kcal/kg°C** **Specific gravity of Crude Oil = 0.86** **Specific gravity of furnace Oil = 0.98**
	Solution: Furnace oil consumption = 2.5 X 0.98 = 2.45 TPH Heat input to the furnace = 2.45 x 1000 x 9880 = 24.2 x 10^6 Kcal/hr Heat absorbed by the crude = 24.2 x 10^6 x 0.82 = 19.85x 10^6 Kcal/hr Q = m * Cp * Del T 19.85 * 10^6 = 300 * 0.86 * 1000 * 0.65 * ΔT ΔT = 118 °C T out = 255 + 118 = 373 °C

	Temperature of crude at furnace outlet is 373 °C
S-3	**In a process plant, 20 TPH of steam after pressure reduction with pressure reducing valve to 20 kg/cm^2 gets superheated. The temperature of steam is 280°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°C.** **Calculate quantity of water at 30°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°C** **Latent heat of steam at 20kg/cm^2 = 450 kcal/kg**
	Answer Quantity of heat available above saturation = 20,000 x 0.45 x (280-210) = 6,30,000 kCal Quantity of water required in de-superheater = Q x{1x (210-30) + 450}= 630000 = 1000 Kg/hr
S-4	**A 5 TPH capacity boiler is generating saturated steam at 8 kg/ cm^{2}g .The following operating parameters was measured during the survey.** **Furnace oil consumption - 200 kg/hr.** **GCV of furnace oil - 10,500 kcal/kg** **Qty of steam generation - 3000 kg/hr** **Feed water temperature - 60 °C** **Enthalpy of dry saturated steam - 660 kcal/kg** **Dryness fraction - 0.9** **Saturation temperature of steam - 170 °C** **Calculate the boiler efficiency by direct method.**
	Boiler Efficiency = $\frac{2700 \text{ kg x } (660-60) \text{ kcal/kg } + 300 \text{ x } (170-60) \text{ x } 100}{200 \text{ kg x } 10500 \text{ kcal/kg}}$ = 78.7%
S-5	**In a pharma industry, a chemical process requires 5000 kg/hr of dry saturated steam at 7 kg/cm^2 (g). Specific volume of steam at 7 kg/cm^{2}g is 0.24 m^3/kg . Determine the pipe diameter size for a steam flow velocity of 25 m/s.**
	The velocity of steam = 25 m/s Specific volume at 7 kg/cm^2 g = 0.24 m^3/kg Mass flow rate of steam = 5000 kg/hr

	= 5000/3600 = 1.389 kg/sec Volumetric flow of steam = 1.389 x 0.24 =0.333 m^3/sec Therefore, using formula:
S-6	**Distinguish between plate heat exchanger and shell and tube heat exchanger ?**
Ans	**Shell and Tube heat Exchangers** Shell-and-tube heat exchangers consist of a bundle of parallel tubes that provide the heat-transfer surface separating the two fluid streams. The tube-side fluid passes axially through the inside of the tubes; the shell-side fluid passes over the outside of the tubes. Baffles external and perpendicular to the tubes direct the flow across the tubes and provide tube support. Tube sheets seal the ends of the tubes, ensuring separation of the two streams. The process fluid is usually placed inside the tubes for ease of cleaning or to take advantage of the higher pressure capability inside the tubes. The thermal performance of such an exchanger usually surpasses a coil type but is less than a plate type. Pressure capability of shell-and-tube exchangers is generally higher than a plate type but lower than a coil type. **Plate Heat Exchangers** Plate heat exchangers consist of a stack of parallel thin plates that lie between heavy end plates. Each fluid stream passes alternately between adjoining plates in the stack, exchanging heat through the plates. The plates are corrugated for strength and to enhance heat transfer by directing the flow and increasing turbulence. These exchangers have high heat-transfer coefficients and area, the pressure drop is also typically low, and they often provide very high effectiveness. However, they have relatively low pressure capability. The biggest advantage of the plate and frame heat exchanger, and a situation where it is most often used, is when the heat transfer application calls for the cold side fluid to exit the exchanger at a temperature significantly higher than the hot side fluid exit temperature i.e. "temperature cross". This would require several shell and tube exchangers in series due to the lack of purely counter-current flow. The overall heat transfer coefficient of plate heat exchangers under favorable circumstances can be as high as 8,000 W/m^2 ºC. With traditional shell and tube heat exchangers, the U-value will be below 2,500 W/m^2 ºC.
S-7	**Give reasons for the following** a) **Explain why natural gas requires less amount of excess air compared to solid/liquid fuels** b) **Why steam is to be used at the lowest practicable pressure for indirect process heating ?**
Ans	**a) Natural gas requires less amount of excess air compared to solid/liquid fuels** Natural gas is in the gaseous form and lighter than air, it mixes with air readily (intimate mixing of air (oxygen) and fuel takes place) and aids to complete combustion with less amount of excess air. It does not produce smoke or soot. It has no sulphur content. It is lighter than air and disperses into air easily in case of leak. Natural gas is also free of ash. Solid or liquid fuels must be changed to a gaseous form before they will burn. Hence it requires more excess air compared to natural gas for complete combustion. Solid fuels need to be pulverized properly to get uniform sizes and liquid fuels need to be preheated and atomized

	properly for intimate mixing with air to ensure complete combustion. Hence more excess air is provided for solid and liquid fuels. **b) Steam is to be used at the lowest practicable pressure for indirect process heating** A study of the steam tables would indicate that the latent heat in steam reduces as the steam pressure increases. It is only the latent heat of steam, which takes part in the heating process when applied to an indirect heating system. Thus, it is important that its value be kept as high as possible. This can only be achieved if we go in for lower steam pressures. As a guide, the steam should always be generated and distributed at the highest possible pressure, but utilized at as low a pressure as possible since it then has higher latent heat. However, it may also be seen from the steam tables that the lower the steam pressure, the lower will be its temperature. Since temperature is the driving force for the transfer of heat at lower steam pressures, the rate of heat transfer will be slower and the processing time greater. In equipment where fixed losses are high (e.g. big drying cylinders), there may even be an increase in steam consumption at lower pressures due to increased processing time. There are, however, several equipment in certain industries where one can profitably go in for lower pressures and realize economy in steam consumption without materially affecting production time. Therefore, there is a limit to the reduction of steam pressure. Depending on the equipment design, the lowest possible steam pressure with which the equipment can work should be selected without sacrificing either on production time or on steam consumption.
S-8	**List down five major advantages of waste heat recovery in rolling mill furnace**
	1. Fuel economy 2. Improved combustion/less excess air/reduction in stack losses 3. Increased output 4. Reduction in scale losses 5. Uniform temperature across the material 6. Reduced pollution 7. Less auxiliary energy consumption 8. Reduction in equipment sizes

------- 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

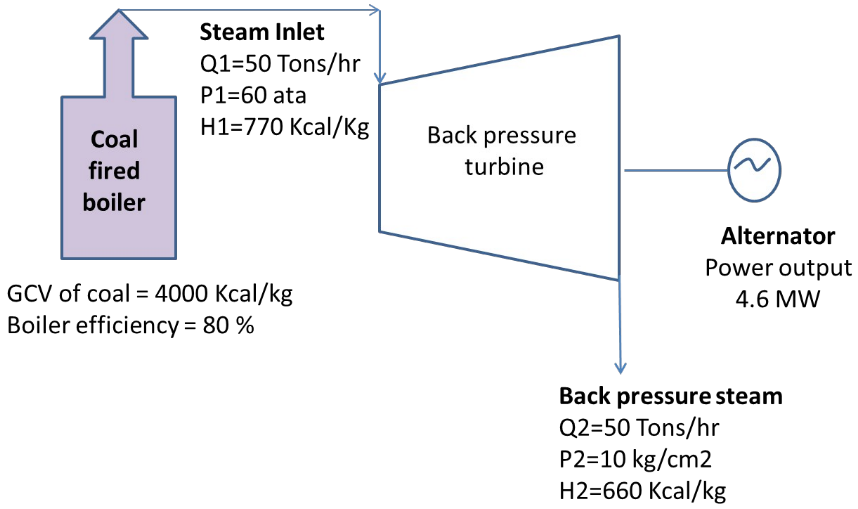
L-1	**An oil fired reheating furnace has an operating temperature of around 1000°C. Average furnace oil consumption is 440 litres/hour. The flue gas exit temperature after the air preheater is 300°C. Combustion air is preheated from ambient temperature of 35°C to 200°C through the air preheater. The other data are as given below.** **Specific gravity of oil = 0.92** **Calorific value of oil = 10,200 kcal/kg** **Average O_2 percentage in flue gas = 14%** **Theoretical air required = 14 kg of air per kg of oil**

	Specific heat of air = 0.24 kcal/kg°C **Specific heat of flue gas = 0.23 kcal/kg°C** **Find out the sensible heat carried away by the exhaust gases and heat recovered by the combustion air in kcal/hr as a percentage of the energy input.**
Ans	Energy input = 440 litres/hr = 440 x 0.92 kg/hr = 404.80 kg/hr = 404.80 x 10,200 = 41,28,960 kCal/hr : Excess air $= \frac{(\%O_2)}{(21-O_{2\%})} \times 100$ $= \frac{14 \times 100}{(21-14)}$ = 200% Theoretical air required = 14 kg of air to burn 1 kg of oil Actual mass of air required = 14 x (1 + 200/100) kg/kg of oil = 42 kg/kg of oil Sensible heat loss in the flue gas = m x C_p x ΔT m = mass of flue gas = 42 + 1 = 43 kg/kg of oil C_p = Specific heat of flue gas = 0.23 ΔT = Temperature of flue gas – Ambient Temperature = 300°C – 35°C = 265 °C Heat loss = 43 x 0.23 x (300-35) = 43 x 0.23 x 265 = 2620.85 kCal/kg of oil = 2620.85 x 404.80 Kcal/hr = 10,60,920 Kcal/hr Sensible heat loss in the flue gas as % heat loss to input energy $= \frac{10,60,920 \times 100}{41,28,960}$ = 25.7 % Heat gained by combustion air = 42 x 0.24 x (200-35) = 1663.2 kCal/kg of oil = 1663.2 x 404.80 Kcal/hr = 673263.36 Kcal/hr

	Heat gained by combustion air as % of input energy = $\frac{673263.36 \times 100}{41,28,960}$ = 16.3 %
L-2	**Describe briefly any two of the following** a) **Mechanical de-aeration and chemical de-aeration** b) **Functions of a steam trap** c) **Describe the operation of regenerator for high temperature furnace**
Ans	a) **Mechanical de-aeration and chemical de-aeration** In de-aeration, dissolved gases, such as oxygen and carbon dioxide, are expelled by preheating the feed water before it enters the boiler. **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. **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 is removed through blow down. 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. b) **Functions of a steam trap** The three important functions of steam traps are: 1 • To discharge condensate as soon as it is formed in the steam line / pipes. 2 3 • Not to allow steam to escape. • To be capable of discharging air and other incondensable gases from the steam pipe. c) **Operation of regenerator for high temperature furnace** There are two sets of regenerators consisting of refractory bricks. In one path, the flue gases flow heating up the chequered refractory bricks on one side, while through the

	other path, air for combustion flows which picks up the heat from heated chequered refractory bricks on the other side. The cycle reverses with the time interval.
L-3	**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 °C. Determine LMTD and area of the heat exchanger surface if the overall heat transfer co-efficient is 550 J/m²s°C.**
Ans	Heat loss in hydrocarbon vapour mixture = heat gain in cooling water 11 * 450 = 58 * 4.18 * (T – 32) T = 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* ΔT = U * A * LMTD 58 * 4.18 * (52.4 – 32) * 1000 = 550 * A * 77.4 A = 116.3 m^2 Area of the heat exchanger surface is 116.3 m^2
L-4	**A steam pipeline of 250 mm outer diameter & 100 meters long is insulated with 150 mm Mineral wool insulation. As an energy conservation measure, the management has upgraded the existing Mineral wool insulation with efficient calcium silicate insulation.** **Calculate the economics in terms of payback if the insulation is upgraded at a cost of 20 lakhs.** **Given:** **Operating hours : 8000** **Boiler efficiency : 87 %** **Fuel Oil Cost : Rs. 45,000 per ton** **GCV of the fuel : 10,200 kcal/kg** **Thickness of Mineral wool insulation : 150 mm** **Thickness of Calcium Silicate insulation : 100 mm** **Surface temperature with Mineral wool insulation : 70 °C** **Surface temperature with Calcium silicate insulation : 55 °C** **Ambient temperature : 30 °C**

Ans	Heat loss with Mineral wool insulation = {10 + (Ts –Ta)/20} x (Ts – Ta) = (10 + (70 – 30)/20 } x (70 – 30) = 480 kCal/hr per Square meter Heat loss with Calcium silicate insulation = (10 + (55 – 30)/20 } x (55 – 30) = 281.25 kCal/hr – Sq. m Surface Area with Mineral wool = 3.14 D L = 3.14 x 0.550 x 100 = 172.7 Square meter Surface Area with Calcium Silicate= 3.14 x 0.450 x 100 = 141.3 Square meter Heat loss with Mineral wool = 480 x 172.7 = 82896 kCal/hr Heat loss with Calcium silicate = 281.25 x 141.3 = 39741 kCal/hr (82,896 - 39,741) x 8,000 x 45,000 10,200 x 1000 x 0.87 Annual savings = = Rs. 17.5 Lakhs / year Payback period = 20 / 17.5 = 1.14 years = 13.7 months
L-5	**The energy flow diagram in a cogeneration plant in paper industry is given below.**



Calculate the following

i) **Input coal consumption per hour if feed water temperature is 50°C**

ii) **Heat to power ratio of cogeneration plant**

iii) **% turbine and generator losses**

Ans

Input coal consumption = Q=50,000 x(770-50) / (0.8 x 4000) =11.25 Tons/ hr

Heat to power ratio = (50,000 x 660) / (4600 x 860) = 8.34

Turbine and generator loss = 50000 x 770 –(4600 x 860 +50,000 x 660)/10^6 = 1.544 Million kCal

% loss = 1.544 x 10^6 x 100 / (50,000 x 770) =4%

L-6 **List down any ten points that need attention while selecting biomass fluidised bed combustion boiler**

The following areas need attention with biomass fed boilers:

- Uneven spreading of biomass fuel on boiler grate can lead to secondary combustion in the super-heater zone, resulting in overheating of super heater tubes and fluctuations in steam pressure.
- Frequent erosion of super-heater and economizer coils can occur, due to high silica content in the biomass, especially in rice husk.
- High extraneous matter in biomass (sand and mud) causes tube fouling and fluidized bed to be drained more frequently, with resultant heat loss.
- Carbon and dust coating of boiler tubes results in lowering of steam temperatures, especially during soot blowing.
- Presence of Pesticides (used during farming) adds to tube failure frequencies; mainly due to potassium constituents.
- Corrosive constituents in biomass adversely affect boiler internals, especially the super-heater tubes. Chloride content in certain types of biomass (like cotton stalk, 8–9%) can combine

		with sodium and potassium in high temperature regime to aggravate the corrosion process. • Some boilers which use Red Gram husk/twigs as fuel pose corrosion problems at the cold end (i.e., secondary super-heater and economizer tubes), due to the sulfur content. • The biomass fuel mix fed to the boiler, in quite a few cases, contains a combination of 6 to 7 biomass types. Each biomass has a separate air-to fuel ratio, and it is difficult to set a workable air–fuel ratio. • High moisture content in the biomass causes frequent jamming of the fuel in feeders, leading to fluctuations in steam pressure and temperature. • High moisture content in the biomass also leads to plugging and choking of closely spaced heating surfaces. This situation is further aggravated by the super-heater tube coil with very close spacing, often the result of a desire to achieve a compact design. • Due to biomass fuel size variation, occurance of unburnts in flue gases and bottom ash is high, resulting in lower efficiency and also variation in steam pressure and temperature. • Absence of biomass feed rate measurement mechanism leaves little room for accurate assessment of heat rate/efficiency. Providing a weighing mechanism is difficult on account of different biomass fuel combinations being used, with different (and low) bulk densities. • Degradation of biomass during storage in exposed ambient wet atmosphere leads to loss of heat value. Loss of material due to windage and carpet loss, coupled with loss of heat value on account of decay (inherent biomass characteristics), can cause an error in assessment of input fuel energy (as the input heat is customarily evaluated based on received biomass quantities and GCV).

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