14^{th} NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY AUDITORS – August, 2013

PAPER – 4: Energy Performance Assessment for Equipment and Utility Systems

Date: 25.8.2013 Timings: 14:00-16:00 Hrs Duration: 2 Hrs Max. Marks: 100

Section - I: BRIEF QUESTIONS Marks: 10 x 1 = 10

(i) Answer all **Ten** questions
(ii) Each question carries **One** mark

S-1	**If EER of a 1.5 TR window airconditioner is 3 what will be the power input?**
Ans	1.5 x 3.5163 = 1.758 kW
S-2	**What is the significance of monitoring dew point of compressed air for pneumatic instruments application?**
Ans	To check the moisture level/dryness in instrument air
S-3	**For a thermal power plant, the percentage auxiliary consumption of a 110 MW unit is ____than that of a 500 MW unit.**
Ans	More
S-4	**Between one kg of 'liquid hydrogen' and one litre of 'liquid gasoline' which will have a higher heat content?**
Ans	Liquid hydrogen
S-5	**Why is the COP of a vapour absorption refrigeration system always less than one?**
Ans	COP is given by (heat taken by evaporator/ heat given to generator). The heat given to generator of VAR is always more than heat taken away in the evaporator (refrigeration effect)
S-6	**Regenerators utilising waste heat are widely used in _________furnaces**
Ans	Glass melting or Open hearth furnaces
S-7	**Why small bypass lines are provided in a centrifugal pump?**

Ans	To avoid pump running at zero flow
S-8	**If the speed of a reciprocating pump is reduced by 50 %, what will be its effect on the head?**
Ans	The head will remain the same
S-9	**As the 'approach' decreases, the other parameters remaining constant, the effectiveness of cooling tower will _____________**
Ans	Increase
S-10	**In a DG set, waste heat is used for steam generation. This type of cogeneration is called _________cycle.**
Ans	Topping

…………. End of Section - I ………….

Section - II: SHORT NUMERICAL QUESTIONS Marks: 2 x 5 = 10

(i) Answer all **Two** questions
(ii) Each question carries **Five** marks

L-1	**An automobile plant has a maximum demand of 5000 kVA at a PF of 0.95. The plant has shifted its electric annealing furnace with a steady resistive load of 500 kW to its foundry unit in a nearby location after suitable modifications. What will be the new PF of the automobile plant without the electric annealing furnace?**
Ans	Existing maximum demand in kW, 5000 x 0.95 = 4750 KW Existing reactive power load in the plant $(KVAR)^2 = KVA^2 – KW^2 = (5000)^2 – (4750)^2$ KVAR = 1561 Electrical load after shifting 500 KW annealing furnace = 4750 – 500 = 4250 KW However, KVAR load will remain same as 500 kW annealing furnace did not impose any kVAr loading. KVA = SQRT $[(4250)^2 + (1561)^2]$ = 4528 PF = 4250 / 4528 = 0.938

L-2	**In a medium sized engineering industry a 340 m^3/hr reciprocating compressor is operated to meet compressed air requirement at 7 bar. The compressor is in loaded condition for 80% of the time. The compressor draws 32 kW during load and 7 kW during unload cycle.** **After arresting the system leakages the loading time of the compressor came down to 60%.** **Calculate the annual energy savings at 6000 hours of operation per year.**
Ans	Average power consumption with 80% loading = = [0.8 x 32 + 0.2 x 7] = 27 KW Average power consumption with 60% loading after leakage reduction = = [0.6 x 32 + 0.4 x 7] = 22 kW Saving in electrical power = 5 KW Yearly savings = 5 x 6000 = 30,000 kWH

…………. End of Section - II ………….

Section - III: LONG NUMERICAL QUESTIONS Marks: 4 x 20 = 80

(i) Answer all <u>**Four**</u> questions

N1	**A multi-product chemical plant has an oil fired boiler for meeting its steam requirements for process heating. The average fuel oil consumption for the boiler was found to be 950 litres per hour. Calculate the cost of steam per tonne considering only the fuel cost.** **The performance and other associated data are given below:** **O_2 in the flue gas (dry) at boiler exit = 6%** **Temperature of the flue gas at boiler exit = 200°C** **Enthalpy of steam = 665 kcal/kg** **Enthalpy of feed water = 80 kcal/kg** **Steam is dry saturated.** **Fuel analysis data:** **Carbon (C) = 85% Hydrogen (H_2) = 12% Nitrogen (N_2) = 0.5%** **Oxygen (O_2) = 1% Sulfur (S) = 1.5%** **Gross calorific value of fuel oil = 10,000 kcal/kg** **Specific gravity of fuel oil = 0.9** **Cost of fuel oil per KL = Rs.40,850/-** **Specific heat of flue gas = 0.262 kcal/kg°C**

Specific heat of superheated vapour in flue gas = 0.43 kcal/kg°C
Humidity in combustion air = 0.025 kg/kg dry air
Ambient air temperature = 30°C
Radiation & convection loss from boiler = 1.8%

ANS

Calculate boiler efficiency by indirect method

↓

Calculate evaporation ratio Kg steam / Kg fuel oil

↓

And then compute fuel cost of steam

Boiler efficiency by indirect method:

Theoretical air required for complete combustion of fuel oil

= $\{11.6. C + [34.8 (H_2 – O_2/8)] + 4.35 S\} / 100$
= $\{11.6 \times 85 [34.8 (12 – 1/8)] + 4.35 \times 1.5\} / 100$
= 14.05 Kg/Kg fuel oil

% O_2 in fuel gas = 6
% Excess air = $[\%O_2 / (21 - \% O_2)] \times 100$
= $[6 / (21 – 6)] \times 100$
= 40%

Actual Air Supplied (ASS) = (1 + 0.4) x 14.05 = 19.67 Kg/Kg fuel oil

Mass of dry flue gas = m_{dfg}

Mass of dry flue gas = mass of combustion gases due to presence C, S, O_2, N_2
+ mass of N_2 in air supplied

M_{dfg} = 0.85 x (44 / 12) + 0.015 x (64 / 32) + .005 + [(19.67 – 14.05) x (23 / 100)] + 19.67 x (77/100)
M_{dfg} = 19.59 Kg/Kg fuel oil

Alternatively M_{dfg} = (AAS+1) – ($9xH_2$) = (19.67+1) – (9 x 0.12) = 19.59 kg/kg fuel oil

% heat loss in dry flue gas = m_{dfg} x C_{pf} x (Tg – Ta) / GCV of fuel
Tg = flue gas temperature = 200°C
Ta = ambient temperature = 30°C
Cp = SP ht of flue gas = 0.26 Kcal/Kg°C
GCV = Gross Calorific Value of fuel oil = 10,000 Kcal/kg

L1 = % heat loss in dry flue gases = [(19.59 x 0.262 x (200-30))/10,000] X 100 = 8.73 %

Heat loss due to evaporation of water due to H_2 in fuel
= $\{9 \times H_2 [584 + C_{PS} (Tg – Ta)]\} / GCV$
C_{PS} = Specific heat of superheated steam
= 0.43 Kcal/Kg°C

L2 = {9 x 0.12 [584 + 0.43 (200 – 30)] / 10000} x 100 = 7.09%
L3 = % heat loss due to moisture in fuel = 0
As % moisture in fuel is nil (not given)

% heat loss due to moisture in air

L4 = AAS x humidity factor x C_{PS} x (Tg – Ta) / GCV
Humidity factor = 0.025 Kg/Kg dry air

L4 = {[19.67 x 0.025 x 0.43 (200-30)] / 10000} x 100 = 0.36%

L5 = Radiation and convection loss from the boiler = 1.8% (given data)

Total losses in the boiler in %= L1 + L2 + L3 + L4 + L5
= 8.73 + 7.09 + 0 + 0.36 + 1.8
= 17.98 say 18 %
Efficiency of boiler by indirect method = 100 - % total loss = 100 – 18 = 82%

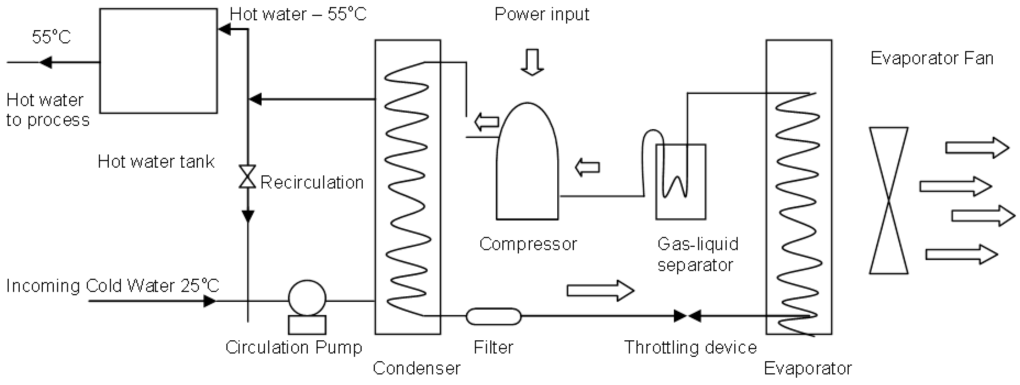
Boiler n = E.R. (hs – hw) / GCV x 100
ER = Evaporation Ratio = Kg steam / Kg fuel oil
hs = Enthalpy of Steam = 665 Kcal/Kg
hw = feed water enthalpy = 80 Kcal/Kg
Boiler Efficiency = 82%

ER = 0.82 x 10000 / (665-80) = 14.02 = Say 14 Kg steam / Kg fuel oil

Cost of fuel oil per KL = Rs.40,850/-
S.G. of fuel oil = 0.9
Cost of fuel oil per tonne = 40,850 / 0.9 = Rs.45,389/-

Fuel cost of steam per tonne = 45,389 / 14 = Rs.3242

N2 **In a food processing unit, 24,000 litres of water per day is to be heated from 25^{o}C to 55^{o}C. Presently this requirement is met by an electrical heater. The management is planning to install a vapour compression heat pump system having a COP of 2.3 which includes the compressor motor losses. The schematic of the heat pump hot water system is given below:**



Schematic of Heat Pump

	Hours of operation of water circulation pump = 24 hours/day **Evaporator fan operation = 20 hours/day** **Energy consumption of water circulation pump and evaporator fan per day = 50 kWh** **Compressor motor efficiency = 88 %** **Annual operating days of heat pump = 330 days** **Cost of electrical energy = Rs.10/kWh** **Heat loss in the condenser and hot water tank in addition to the heat load = 5%** **Investment for heat pump = Rs.15 Lakhs** **The compressor and evaporator fan are interlocked in operation.** **Find out** **i) Heat pump capacity in TR in terms of heat delivered** **ii) The payback period of investment towards heat pump** **iii) Evaporator capacity in TR**
ANS	i) Hot water requirement per day = 24000 litres = 24000 kgs. Inlet water temperature = 25^{o}C Outlet water temperature = 55^{o}C Energy required for electrical heating per day = 24000 (55 – 25) / 860 = 837.2 Kwh Heat load on the condenser per day including 5% loss (in the condenser & hot water tank) = 24000 (55 – 25) x 1.05 = 756000 Kcals/day Heat pump capacity based on delivered heat =756000/(24 x 3024) = 10.4 TR Electrical energy equivalent of heat delivered = 756000 / 860 = 879.07 Kwh Daily energy consumption in the heat pump with a COP of 2.3 = 879.07 / 2.3 = 382.2 Kwh Daily energy consumption in the circulating water pump and evaporator fan = 50 Kwh (given data) Total energy consumption for operation of heat pump per day = 432.2 Kwh Energy saving with heat pump compared to electrical heating per day = 837.2 – 432.2 = 405 Kwh Cost of electricity per kwh = Rs.10 Monetary saving per day = 405 x 10 = Rs.4,050/- Annual savings with 330 days operation = 4050 x 330 = Rs.13,36,500/- = Rs.13.365 lacs Investment for heat pump = Rs.15 lacs

Simple pay back period = 15 / 13.365 = 13 months

The investment is attractive and justifiable.

Evaporator capacity in tonne refrigeration

= Heat delivered at the condenser – Input energy to the compressor

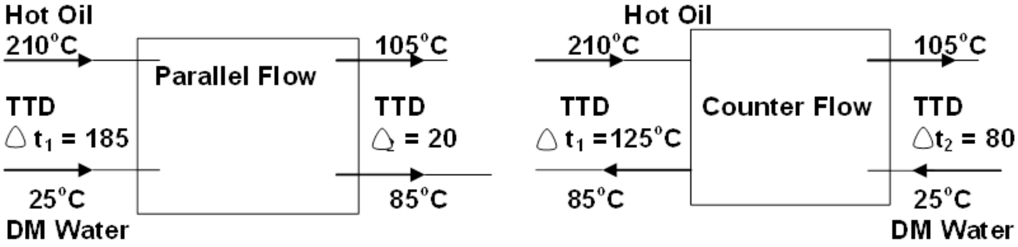
= [{879 – (382.17 x 0.88)} x 860] / (3024 x 20)

= 7.72 TR

N-3 **In an organic chemical industry 10 tonne per hour of hot oil is to be cooled from 210^{o}C to 105^{o}C by DM water. The DM water enters the heat exchanger at 25^{o}C and exits at 85^{o}C after which it is fed to the feed water storage tank of the boiler.**

- **i. Depict the heat exchanger process on a schematic for the parallel and counter flow indicating the hot and cold stream temperatures along with terminal temperature difference.**
- **ii. Find out the LMTD for parallel and counter flow heat exchange and justify the choice of the heat exchanger.**
- **iii. Estimate the DM water flow rate through the heat exchanger. The specific heat of oil is 0.8 kcal/kg^{o}C.**

Ans I)



ii)

$$\textbf{LMTD parallel flow} = \frac{\Delta t_1 - \Delta t_2}{\ln \ \Delta t_1 / \Delta t_2}$$

$$= (185 - 20) / \ln (185 / 20) = 74.19^{o}C$$

$$\text{LMTD Counter flow} = (125 - 80) / \ln (125/80) = 100.9^{o}C$$

Counter flow heat exchange will yield higher LMTD and hence heat exchanger area will be less and hence preferred.

iii)

m_c = mass flow rate of DM water

m_c x 1 x (85 – 25) = m_h x 0.8 x (210 – 105)

m_c x 1 x (85 – 25) = 10000 x 0.8 x (210 – 105)

m_c = 14,000 kg/hour

N-4 To attempt **ANY ONE OF THE FOLLOWING** among A, B, C and D

A **An energy audit was conducted on a 110 MW thermal power generating unit. The details of design parameters and operating parameters observed during the audit are given below.**

Parameters	Design	Operating
Generator output	110 MW	110 MW
Boiler outlet superheated steam temperature	540^{o}C	520^{o}C
Boiler outlet steam pressure	140 kg/cm^2(a)	130 kg/cm^2(a)
Feed water inlet temperature to Boiler	120 ^{o}C	120 ^{o}C
Feed water enthalpy	120 kcal/kg	120 kcal/kg
Boiler efficiency	87%	87%
GCV of coal	3650 kcal/Kg	3650 kcal/Kg
Turbine exhaust steam pressure	0.09 kg/cm^2(a)	0.12 kg/cm^2(a)
Dryness fraction of exhaust steam	88%	88%
Unit gross heat rate	2815 kcal/kWh	?
Efficiency of turbine & generator (including gear box)	-	90 %

Steam properties are as under:

Enthalpy of steam at 520^{o}C and 130 kg/cm^2(a) is 808.4 kcal/kg
Enthalpy of Exhaust steam at 0.12 kg/cm^2(a) is 550 kcal/kg

For the changed current operating parameters calculate the following..

I. **Steam flow rate to the Turbine**
II. **Specific steam consumption of Turbine**
III. **Specific coal consumption and unit gross heat rate**
IV. **Additional quantity of coal required based on 8000 hours/year of operation of the plant**
V. **Increase in annual coal cost due to increase in coal consumption at a cost of Rs. 4000 per tonne of coal.**

Ans

(i) Calculation of Steam flow rate to Turbine

Turbine output, KW = m x (Hs – Hf)/ 860

Where, m = steam flow to turbine, Kg/hr
Hs = Enthalpy of steam at 520 Deg.C& 130 Kg/cm2 = 808.4 Kcal/Kg
Hf = Enthalpy of turbine exhaust steam =550 Kcal/kg

Turbine output = Generator output/ Efficiency of Turbine & Generator
= 110 / 0.9 =122.2 MW

122.2 x 1000 = (m x (808.4 – 550))/860

Steam flow rate to Turbine, m = 406.7 Tonnes/hr

(ii) Calculation of specific steam consumption of Turbine, kg/kwh

Specific steam consumption = Steam flow to turbine, Kg/hr / Generator output, Kw
= 406.7 x 1000/(110 x 1000)
= 3.697 Kg/Kwh

(OR)

ALTERNATE PROCEDURE

Specific steam consumption = 860/((Hs – Hf) x Efficiency of Turbine & Generator)
= 860/((808.4 – 550) x 0.9)
= 3.697 Kg/Kwh

(iii) Calculation of specific coal consumption, Kg/kwh

Boiler efficiency = m kg/hr (Hs – Hw) Kcal/kg / (Q x GCV)------------(2)
0.87 = (406.7 x1000 (808.4 – 120))/ (Q X 3650)
Coal consumption Q = 88166 Kg/hr

Specific coal consumption = Coal consumption, Kg/hr / Generator output, Kw
Specific coal consumption = 88166/ (110 x 1000)= 0.801 Kg /Kwh
Unit gross Heat rate= 0.801x3650=2923.6 kcal/kWh

(iv) Additional quantity of coal required

Specific coal consumption at design conditions = unit heat rate / GCV of coal
2815/3650 =0.771 kg/kwh

Additional coal consumption/year = (0.801 – 0.771) x 110 x 1000 x 8000 =26400000 kg
Additional quantity of coal required /year = 26400 Tonnes

(v) Annual increase in coal cost

Additional cost of coal = 26400Tonnes x 4000 Rs/Tonne
=Rs. 10,56,00,000

B

During the conduct of heat balance of a 5 stage inline calciner Kiln of a cement plant , the following data were measured at **preheater outlet** using pitot tube and flue gas analyser.

Temp	Static Pressure	Avg. Dynamic Pressure	Oxygen	CO_2	CO	Duct Area
°C	(P_s) mm WC	(P_d) mm WC	% (v/v) dry	% (v/v) dry	% (v/v) dry	m^2
350	-435	16.9	6.0	19.2	0.06	3.098

Note: take Pitot tube constant as 0.85, reference temperature as 20 °C and atmospheric pressure same as at sea level i.e. 10334 mm WC.

Other Data obtained

Kiln Feed	Clinker Production	Return Dust in PH gas	NCV of Coal	Cost of coal	Annual Operation

TPH	TPH	% of Kiln Feed	kcal/kg	~~INR~~ (Rs)/tonne	hrs
88.5	55	6.8	5356	6950	8000

C_p of PH gas = 0.25 kcal/kg ^oC) , (C_p of return dust = 0.23 kcal/kg ^oC)

Calculate the following:

a. Specific volume of Preheater gas (Nm^3/kg clinker)
b. Heat loss in pre-heater exit gas (kcal/kg clinker)
c. Heat loss in pre-heater return dust (kcal/kg clinker)
d. Heat loss due to CO formation (kcal/kg clinker)
e. Reduction in above mentioned heat losses (kcal/kg clinker) and the annual thermal monitory savings if the Preheater exit gas temperature is reduced to 330 ^oC and there is no CO formation in the system.

Ans :

a. Density of Pre-heater gas at STP:

$$\rho_{STP} = \frac{(O_2\% X MW_{O_2}) + (CO_2\% X MW_{CO_2}) + ((N_2 + CO)\% X MW_{CO})}{22.4 X 100}$$

$$\rho_{STP} = \frac{(6.0 X 32) + (19.2 X 44) + ((74.74 + 0.06) X 28)}{22.4 X 100} = \mathbf{1.398\ kg/Nm^3}$$

$$\rho_{T,P} = \rho_{STP}\ X \frac{273 X (10334 + P_S)}{(273 + T) X 10334}$$

$$\rho_{T,P} = 1.393 X \frac{273 X (10334 - 435)}{(273 + 350) X 10334} = \mathbf{0.587\ kg/m^3}$$

Velocity of Preheater gas

$$v = P_t \sqrt{\frac{2 g P_d}{\rho_{T,P}}}$$

$$v = 0.85 \sqrt{\frac{2 X 9.8 X 16.9}{0.585}} = \mathbf{20.19\ m/sec}$$

Volumetric flow rate of PH gas = velocity x duct cross-sectional area
= 20.22 x 3.098
= 62.55 m^3/sec
= 62.55 x 3600
= 225180 m^3/hr
= 225180 x 0.587/1.398
= 94550 Nm^3/hr

Specific volume of PH gas = 94550/55000 = **1.72 Nm^3/kg clinker**

b. Heat loss in pre-heater exit gas

$Q1 = m_{ph}\ c_p\ \Delta T$ (C$_p$ of PH gas = 0.25 kcal/kg ^oC)

Q1= 1.72 x 1.398 x 0.25 (350-20)

= 198.37 kcal/kg clinker

c. Heat loss in return dust

$Q2 = m_{dust}\ c_p\ \Delta T$ (C$_p$ of return dust = 0.23 kcal/kg ^oC)

m_{dust} = clinker factor x % return dust/100

= (88.5/55) x (6.8/100)

= 1.609 x 0.068

= 0.1094 kg dust/ kg clinker

Q2= 0.1094 x 0.23 x (350-20)

= 8.3 kcal/kg clinker

d. Heat Loss due to CO Formation

Q3= m_{co} X 67636

$$m_{co} = \frac{CO\%}{22.4 X 100} X\ sp.volume of\ PH Gas$$

= [0.06/(22.4 x100)] x 1.72

Q3= 2.68 x 10^{-5} x 1.72 x 67636

= 3.12 kcal/kg clinker

e. At exit temperature 330 ^oC the above losses would be

Q1'= 1.72 x 1.398 x 0.25 x (330-20)

= **186.35 kcal/clinker**

Thermal saving = Q1- Q1'= 197.95 – 186.35 = 12.02 kcal/kg clinker

Q2'= 0.1094 x 0.23 x (330-20)

= **7.8 kcal/kg clinker**

Thermal Saving = Q2 – Q2' = 8.3 – 7.8 = 0.5 kcal/kg clinker

Overall Thermal Savings = 12.02 + 0.5 + 3.12

= 15.64 kcal/kg clinker

Equivalent coal saving = 14.56/5356 = 0.0029 kg coal/kg clinker

Coal saving in one hour = 0.0029 x 55 = 0.1595 TPH

Annual Coal Saving = 0.1595 x 8000= 1276 tons of coal

Annual Monitory Saving = 1276 x 6950 = INR 88,68,200

or

C

In a textile process house a new stenter is being installed with a feed rate of 1000 kg/hr of wet cloth having a moisture content of 55%. The outlet (final) moisture of the dried cloth is 7%. The inlet and outlet temperature of the cloth is 25^oC and 75^oC respectively. The drying efficiency of the stenter is 50%. It is proposed to connect the stenter to the existing thermic fluid heater of 20,00,000 kcal/hr capacity, which is already loaded to 60% of its capacity. The thermic fluid heater has an efficiency of 75%. Check whether the thermic fluid heater will be able to cater to the input heat requirements of the stenter.

Ans

Feed rate of wet cloth to the stenter = 1000 Kg/hr
Initial moisture = 55%
Quantity of moisture at inlet = 0.55 x 1000 = 550 Kg/hr
Wt of bone dry cloth = 1000 – 550 = 450 Kg/hr
Final moisture in outlet cloth = 7%
Quantity of moisture (final) at outlet = (450 / 0.93)– 450 = 483.87 – 450 = 33.87 Kg/hr
m_i = inlet moisture in bone dry cloth = 550 / 450 = 1.22 kg moisture / kg cloth
m_o = Outlet (final) moisture in bone dry cloth = 33.87 / 450 = 0.0753 Kg moisture/Kg cloth

Heat load of the stenter for drying process = W x (m_i – m_o) x [(T_{in} – T_{out}) + 540]
W = Wt of bone dry cloth Kg/hr
T_{in} = Inlet temperature of cloth to stenter
T_{out} = Outlet temperature of cloth from stenter
Latent heat of evaporation of water = 540 Kcal/Kg

Heat load of the stenter for drying = 450 (1.22 – 0.0753) x [(75 – 25) + 540]
= 303917.85 Kcal/hr.

Input heat requirement of the stenter with 50% efficiency for drying (heat to be supplied) = 303917.85 / 0.5 = 607835.7 Kcal/hr.

Capacity of the thermic flue heater = 2000000 Kcal/hr
Existing load = 60% x 2000000 = 12,00,000 Kcal/hr
Balance capacity = 8,00,000 Kcal/hr.

The thermic fluid heater capacity is sufficient to cater to the input heat requirement of the new stenter.

D

In a steel plant, daily sponge iron production is 500 tons. The sponge iron is further processed in a steel melting shop for production of ingots. The yield from converting sponge iron into ingots is 88%. The plant has a coal fired captive power station to meet the entire power demand of the steel plant.

The base year (2011) and current year (2012) energy consumption data are given below:

Parameters	Base Year (2011)	Current Year (2012)
Sponge iron production	500 T/day	500 T/day
Specific coal consumption for sponge iron production	1.2 T/ T of Sponge Iron	1.1 T/T of Sponge Iron

Specific power consumption for sponge iron production	120 kWh/ T of Sponge Iron	100 kWh/ T of Sponge Iron
Yield ,in converting sponge iron into ingot in steel melting shop	91%	91%
Specific power consumption in steel melting shop to produce ingots	950 kWh / T of Ingot	900 kWh / T of Ingot
Captive power station heat rate	3500 kcal/ kWh	3200 kcal / kWh
GCV of coal	5000 kcal /kg	5000 kcal /kg

i) Calculate the specific energy consumption of the plant in Million kcals / Ton of finished product (Ingot) for the base year as well as for the current year

ii) Reduction in Coal consumption per day in current year compared to base year for the plant

Ans

i) specific energy consumption of the plant

For Base Year

Specific energy consumption for sponge iron	= 1200 kgx 5000 + 120 Kwhx 3500 = 6.42 million K Cal/ Ton of SI
Total energy consumption for sponge iron /day	6.42 X 500=3210 million K Cal/day
Actual production considering 88% yield from sponge iron to ingot conversion	= 500 Tons x 0.91 = 455 Tons / day
Specific energy consumption for ingot	= 950 Kwhx 3500 = 3.325 million Kcal/ ton of ingot
Total energy consumption for ingot production per day	3.325X 455= 1512.87 million K Cal/day
Plant specific energy consumption for production of finished product (ingot) during base year	= (3210+1512.87)/455 = 10.38million Kcal/ ton

For Current Year

Specific energy consumption for sponge iron	= 1100 kgx 5000 + 100 Kwhx 3200 = 5.82 million K Cal Ton of SI
Total energy consumption for sponge iron /day	5.82 X 500=2910 million KCal/day
Actual production considering 88% yield from sponge iron to ingot conversion	= 500 T X 0.91 = 455 Tons / day
Specific energy consumption for ingot	= 900Kwh x 3200 = 2.88 million Kcal/ ton of ingot
Total energy consumption for ingot production per day	2.88 X 455= 1310.4 million KCal/day
Plant specific energy consumption for production of finished product (ingot) during current year	=(2910+1310.4)/455 = 9.27 million Kcal/ ton

ii) Reduction in coal consumption

	Energy saving in sponge iron plant = (6.42-5.82) x500 = 300 million Kcals/day Energy saving in steel melting plant = (3.325-2.88) x 455 = 202.5 million Kcal/day Total energy saving = 300 + 202.5 = 502.5 million Kcals/day Equivalent coal reduction(saving) = 495.8 x 10^6 /5000 = 100.5 Tons per day

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