PAPER-4 COLOUR CODE: GREEN

24th NATIONAL CERTIFICATION EXAMINATION

FOR ENERGY MANAGERS AND ENERGY AUDITORS – SEPTEMBER, 2024

PAPER -4 – ENERGY PERFORMANCE ASSESSMEN T FOR EQUIPMENT AND UTILITY SYSTEMS

SECTION –I : BRIEF QUESTIONS **Marks 10x1=10**

STATE TRUE OR FALSE (EACH QUESTION CARRIES 1 MARK)

1. The air velocity is uniform across the cross section of a circular duct. **- False**
2. A pump operating with VFD at a low speed to accommodate a high static head does not adhere to the affinity laws **- True**
3. Lower CO percentage in flue gas indicates better combustion efficiency **- True**
4. Higher power factor results in higher power loss in the power system**- False**
5. Increasing the condenser vacuum will increase the heat rate of a thermal power plant.**- False**
6. The excess air in cement kiln combustion can be assessed by measuring CO2 % in kiln exhaust- **False**
7. A higher solar cooling load factor results in a lower air-conditioning load.- **False**
8. For a 20 MW co-generation plant, a backpressure turbine system configuration will have less steam rate (kg/kWh) compared to an extraction condensing turbine **- False**
9. The heat transfer coefficient of a shell and tube heat exchanger is reduced solely due to changes in the temperatures of the cold and hot fluids. **- False**
10. For a given motor rating, stray losses as a percentage decrease with a change in the output kW of the motor. **- False**

******** End of Section -I ********

SECTION –II : SHORT NUMERICAL QUESTIONS **Marks: 2 x 5 = 10**

(i) Answer all the TWO questions
(ii) Each question carries Five marks

L-1

In a chemical plant, a cooling water pump supplies cooled water to both the process and the refrigeration system. During performance testing, the following operating parameters were recorded:

Measured Data:

Rated Flow	: 2124 m^3/hr
Rated Head	: 70 m
Running Pump Flow (Q)	: 1700 m^3/hr
Motor Input Parameters	: V = 440 V, I = 480 A, Power Factor = 0.89,
Motor losses	: 19.5 kW
Suction Head	: 8 m
Delivery Head	: 55 m

Calculate the following:

(a) Pump Efficiency (Hydraulic Efficiency)
(b) Overall Pump Set (Pump + Motor) Efficiency

Solution:

Flow Delivered by pump = 1700 m^3/hr = 0.47 m^3/s
Head Differential (h) = Delivery Head – Suction Head (m) = 55 – 8 = 47m

Hydraulic Power = $\rho\ x\ g\ x\ Q\ x\ h$
= 1000 x 9.81 x 0.47 x 47/1000 = 216.70 kW

Motor Input = 1.732 x V x I x Cos (phi) = 1.732 x 440 x 480 x 0.89/1000 = 325.5 kW
Motor Output = Motor Input – Motor Losses = 325.5 – 19.5 = 306 kW

Pump Input = Motor Output
(a) Pump Efficiency
Hydraulic Efficiency = Pump Output/Pump Input x 100
Hydraulic Efficiency = 216.70/306 x 100 = 70.82%
(b) Overall Efficiency
Overall Efficiency = Pump Output/Motor Input x 100
Overall Efficiency = 216.70/325 x 100 = 66.67%

L-2

A medium-sized re-rolling plant has installed a batch-type reheating furnace. The furnace operating details are as follows:

Average Furnace Oil Consumption : 1565 LPH
Average Production : 36 TPH
Cost of Furnace Oil : 55/kg
Cost of Electricity : Rs 9.25/kWh
Furnace Oil Density : 0.93 kg/liter
GCV of Furnace Oil : 10,200 kCal/kg
Billet Loading Temperature : 35 °C
Billet Reheat Temperature : 1250 °C
Mean Specific Heat of Billet : 0.13 kCal/kg°C

The plant management has proposed replacing the reheating furnace with a 95% efficient electric furnace.

Calculate the following:

a) Oil fired furnace efficiency.
b) The specific energy consumption for both the cases and comment on the plant management proposal based on the cost benefits.

Solution:

Heat to Billet = $m\ c_p\ \Delta t$

Production	36	TPH
Production	36000	Kg/T
Sp Heat of Billet	0.13	kcal/kg
Billet Final Temperature	1250	Deg°c
Billet Loading temperature	35	Deg°c
Heat required for the Billet(mcpΔT)	5686200	kCal/hr
Furnace oil Consumption	1565	LPH
Density	0.93	
Furnace oil Consumption	1455.45	Kg/hr
GCV of Furnace Oil	10200	Kcal/Kg
Heat Input	14845590	Kcal/Hr
Oil fired Furnace Efficiency	**38.3**	**%**
SEC Oil	***43.5***	***Ltrs/T***
	40.43	***Kg/Ton of billet***
Cost/ton with FO	***=40.43x 55***	***Rs/ton***

	=2223.6	
Electrical furnace Efficiency	95	%
Heat to billet	5686200	Kcal/hr
Electricity Heat	860	Kcal/kwh
Equivalent kWh required	6611.86	Kwh
kWh at 95 % Furnace Efficiency	6960	Kwh
SEC Electrical	***193.3***	***Kwh/Ton***
Cost/ton with electrical furnace	***1788***	***Rs***

Conversion to Electrical is Economical.

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

SECTION –III: LONG NUMERICAL QUESTIONS **Marks 4 x 20 = 80**

(i) Answer all the Four questions
(ii) Each question carries Twenty marks

N-1

A medium-sized textile processing plant has installed a 20 TPH traveling grate coal-fired boiler. As part of a green energy initiative and to optimize steam costs, the plant management has proposed replacing the coal-fired boiler with a paddy husk boiler. The ultimate analysis of paddy husk and other boiler operating parameters are provided below.

Average Monthly Steam Demand : 10800 Tonnes
Operating hours per month : 720 Hours
Coal-Fired Boiler Efficiency : 67 %
Steam Generation Pressure : 12 kg/cm ^{2}
Steam Enthalpy : 665 kcal/kg
Ambient temperature :32 °c
Feed Water temperature : 84 °C
Exit Flue Gas temperature after APH : 225 °C
Oxygen % In Flue gas before APH with Coal as Fuel : 8%
Oxygen % In Flue gas before APH with Paddy husk as Fuel: 6%
Radiation loss accounted for Husk Boiler :1.6%
Humidity factor : 0.025 Kg/Kg dry air
GCV of Coal : 4200 kcal/kg
GCV of Paddy Husk : 3500 kcal/Kg

Cost of Coal	: Rs 12000/Tonne
Cost of Rice Husk	: Rs 6700/ Tonne
Auxiliary Cost for coal fired boiler	: Rs 750/tonne
Auxiliary Cost for paddy husk boiler	: Rs 550/tonne

Ultimate Analysis of Paddy Husk (%):

Moisture	:10.79
Mineral Matter	:16.73
Carbon	:33.95
Hydrogen	:5.01
Nitrogen	:0.91
Sulphur	:0.09
Oxygen	:32.52

Calculate the following:

a) Evaporation ratio of the coal-fired boiler
b) Steam cost (fuel cost + auxiliary cost) of the coal-fired boiler in Rs/tonne
c) Efficiency of the paddy husk boiler using the indirect method
d) Evaporation ratio of the paddy husk boiler
e) Steam cost (fuel cost + auxiliary cost) of the paddy husk boiler in Rs/tonne

Solution for N2

Coal Fired Boiler Efficiency	= 67 %
GCV of Coal	= 4200 Kcal/kg
Steam Generation Pressure	= 12 kg/Cm ^{2}
Steam Enthalpy	= 665 kcal/kg
Feed Water temperature	= 84 °C
Evaporation Ratio	= (4200 x 0.67)/ (665-84)
	= 4.84
Cost of Coal	= 12000/Tonne
Cost of Coal Fired Boiler Steam	=12000/4.84
	= Rs2479/Tonne
Auxiliary cost	= Rs 750/Tonne
Total cost of steam from Coal Boiler	*= Rs(2479+750) = Rs 3,229/Tonne*

Efficiency of Paddy Husk Boiler:

Theoretical air required for complete combustion Paddy Husk

= {11.6. C + [34.8 (H_2 – O_2/8)] + 4.35 S} / 100

= {11.6 x 33.52 [34.8 (5.01 –32.53/8)] + 4.35 x 0.09} / 100 = 4.27 Kg/ Kg of Husk

% O_2 in fuel gas = 6

% Excess air = [%O_2 / (21 - % O_2)] x 100 = [6 / (21 –6)] x 100 = 40%

Actual Air Supplied (ASS) = (1 + 0.4) x 4.27 = 5.98 Kg/Kg fuel

Mass of dry flue gas = mdfg

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 Mdfg = 0. 3395x (44 / 12) + 0.0009 x (64 / 32) + [(5.98 – 4.27) x (23 / 100)] + 5.98 x (77/100) Mdfg = 6.165 Kg/Kg fuel

Alternatively, Mdfg. = (AAS+1) – (9xH_2) – Mmoist = (5.98+1) – (9 x 0.0501) - 0.1079 = 6.34 kg/kg fuel

% heat loss in dry flue gas = mdfg x Cpf x (Tg – Ta) / GCV of fuel

Tg = flue gas temperature = 225°c

Ta = ambient temperature = 32°c

Cp = SP ht of flue gas = 0.24 Kcal/KgC (Value referred from the guidebook)

GCV = Gross Calorific Value of Paddy Husk =3500 Kcal/kg

L1 = % heat loss in dry flue gases = [(6.34 x 0.24 x (225-32))/3500] X 100 = 8.4 %

Heat loss due to evaporation of water due to H_2 in fuel = {9 x H_2 [584 + CPS (Tg – Ta)]} / GCV

CPS = Specific heat of superheated steam = 0.43 Kcal/Kg (Value referred from the guidebook)

L2 = {9 x 0.0501 [584 + 0.43 (225 – 32)] / 3500} x 100 = 8.59%

L3 = % heat loss due to moisture in fuel == M x[584 + CPS (Tg – Ta)/GCV

L3=0.1079 x (584+0.43(225-32)/3500=2.06 %

L4 = AAS x humidity factor x CPS x (Tg – Ta) / GCV Humidity factor = 0.025 Kg/Kg dry air

L4 = {[5.98 x 0.025 x 0.43 (225-32)] / 3500} x 100 = 0.35%

L5 = Radiation and convection loss from the boiler = 1.6% (given data)

Total losses in the boiler in %= L1 + L2 + L3 + L4 + L5 = 8.4+8.59+2.06+0.35+1.6=21
Efficiency of boiler by indirect method = 100 – 21% = 79 %
Evaporation Ratio of Paddy Husk Boiler = 3500 X 0.79/ (665-84) = 4.76

Cost of Husk = Rs 6700

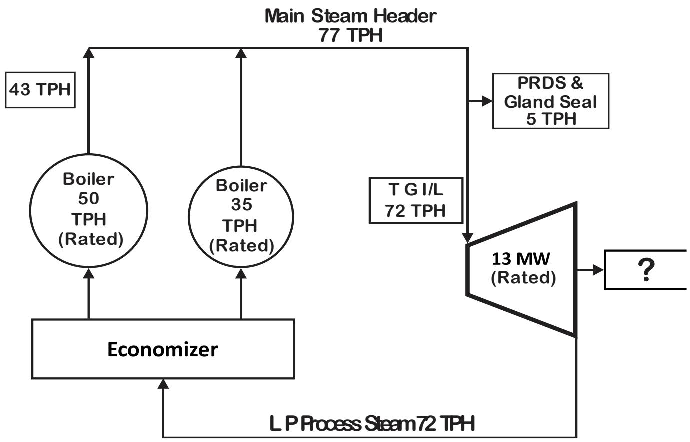
Cost of steam from paddy Husk Boiler = 6700/4.76 = Rs1407.6/Tonne

Auxiliary Cost = Rs 550/tonne

Total Steam Cost with Paddy husk Boiler = Rs 1957.6/Tonne

N-2

One of the sugar plant, operating at 4,000 TCD (Tonnes of Crushing per day), has installed a 13 MW back pressure turbine co-generation system. The co-generation plant comprises of one old bagasse-fired boilers with a capacity of 50 TPH and another with 35 TPH. This co-generation plant meets both the steam and power demands of the sugar plant and exports power to the grid during the crushing season. The power required for the sugar plant is 29 kW per tonne of crushing. The schematic of the present system is given below:



The plant management has conducted an energy audit of the sugar plant and the co-generation system. The energy auditor has recommended replacing the existing co-generation system with a high-pressure boiler of 80 TPH and a back pressure steam turbine to increase power export. The operating details for both the existing and proposed systems are presented in the table below:

Description	Units	Present Co-Gen System	Proposed Co-Gen System
Bagasse GCV	kCal/kg	2270	2270
Boiler steam generation pressure	kg/cm²(g)	42	85
Boiler super heat steam temperature	°C	485	520
Main steam pressure enthalpy	kCal/kg	815	823
Feed water temperature	°C	95	105

Turbine inlet steam pressure	$kg/cm^2(g)$	42	85
Turbine inlet steam temperature	°C	480	520
Turbine inlet steam flow	TPH	72	72
Inlet steam enthalpy	kCal/kg	812	823
Turbine back pressure	$kg/cm^2(g)$	1.5	1.5
Back pressure steam enthalpy	kCal/kg	676	676
Back pressure steam temperature	°C	178	178
Boilers operating efficiency	%	67 (Avg)	74
Turbine efficiency	%	90	92
Alternator efficiency	%	96	96
Cost realised for exported power	Rs./kWh	4.25	4.25
Auxiliary power consumption for the co-generation plant	%	6	6
Steam consumption for PRDS & Gland Seal	TPH	5	5

Calculate the following:

a) Power generation in the present and proposed system.

b) Power export with the present and proposed system.

c) Bagasse consumption in the present and proposed system.

d) Savings in bagasse with the proposed system.

e) Heat-to-power ratio (kW_{th}/kW_e) of the present and proposed co-generation system.

f) Heat-to-power ratio (kW_{th}/kW_e) of the sugar plant.

g) Steam rate (kg of steam per kW) for the present and proposed system.

h) Energy Utilization Factor (EUF) in the present and proposed system.

Solution:

Daily Crushing Load = 4000TCD

Crushing Load/Hour = 4000/24 =166.6 TPH

Power required = 29 kW /Tonne

= 29x166.66= 4833 Kw

Power Generation

Stem inlet to turbine = 72 TPH

Inlet Enthalpy = 812 Kcal/kg

Backpressure Enthalpy = 676 Kcal/kg

Power Generation potential in kW = 72 x1000 x (812-676)/860= 11386 Kw

Turbine and alternator efficiency = 11386 x 0.9 x0.96 = 9837 Kw (Gross Gen)

Auxiliary Power Consumption in Co-Gen: 6% of gross generation

Sugar Plant = 4833 kW

Power Export in Present System = (0.94*9837)-4833 = 4413.78 kW

Steam Rate Kg/kw = 72000/9837= 7.32 kg/kW

Present boiler Efficiency = 67 %

Bagasse Required = 77 x1000 (815-95)/2270 x 0.67

= 36.45 TPH

Heat to power ratio of cogenator =

kW Thermal = 72 x1000 x (676-95)/860 = 48641.86 kW

kW Electrical = 9837

Kwth/Kwe = 48641.86/9837= 4.94

Energy Utilisation Factor in Present system= (Q Elect+ Q ther)/ Q Fuel

= (9837x860+72000x(676-95))/ (36.35x1000 x2270) x100

= 60.95%

Heat to power ratio of Sugar Plant

Kw Thermal = (72 x1000 x (676-95))/860=48641.86 Kw

Kw Electrical = 4833

Kwth/Kwe = 48641.86/4833 = 10.1

Power generation with High Pressure Cogeneration System

= (72000 x(823-676))/860= 12307 Kw

Applying Turbine and Alternator Eff Actual Power Generation

= 0.92 x0.96 x 12307= 10869 kw

Steam Rate Kg/kw = 72000/ 10869 = 6.62 kg/kW

Export with High Pressure Cogeneration=(0.94*10869)-4833- Kw= 5383.86 kW

Additional Export with High Pressure Cogeneration Plant = 5383.86-4413.78= 970.08 Kw

Bagasse required for High pressure Cogeneration system= 77000*(823-105)/(2270 x0.74)

= 32.91 TPH

Savings in Bagasse =36.45-32.91 = 3.54 TPH

Energy utilisation with High Pressure Cogeneration= =(Q Elect+ Q therm)/ Q Fuel

= (10869x860+72000x(676-105))/ (32.91x1000 x2270) x100

= 67.5%

N-3

A steam turbine power plant utilizes a Circulating Water (CW) system with an Induced Draft Cooling Tower (IDCT) for condenser cooling. The steam flow rate to the condenser is 440 T/hr. It is observed that 45 m^3 of CW is needed to condense 1 T of steam.

To compensate for the water loss from the IDCT sump, two makeup water pumps each with a capacity of 220 m^3/hr are available in parallel. During operation, it was observed that a single pump delivers 200 m^3/hr and both pumps operating in parallel deliver 350 m^3/hr together. One pump operates continuously and the second pump switches on when the IDCT sump level falls below 90% of its full capacity. The second pump is switched off once the sump is full.

The TDS of circulating water is 2,000 ppm and the TDS of the makeup water is 500 ppm. The cooling tower operates with an effectiveness of 63% and an approach of 4°C. The size of the IDCT sump is 100 m x 15 m x 40 m and to maintain proper water chemistry, a continuous blowdown from the sump is given.

During steady state operation, calculate the following:

a) Evaporative loss in m^3/hr, blow down in m^3/hr and draw mass flow diagram of the system with all the flow rates and losses. **10 Marks**

b) What is the time period in hours for which only one IDCT makeup pump is in service? **5 Marks**

c) What is the time period in hours for which both the IDCT makeup pumps are in service? **5 Marks**

Solution:

Total CW flow = 440 * 45 = 19800 m^3/hr

Effectiveness = Range / (Range + Approach)

Range = (4*0.63)/(1-0.63) = 6.81^{0}C

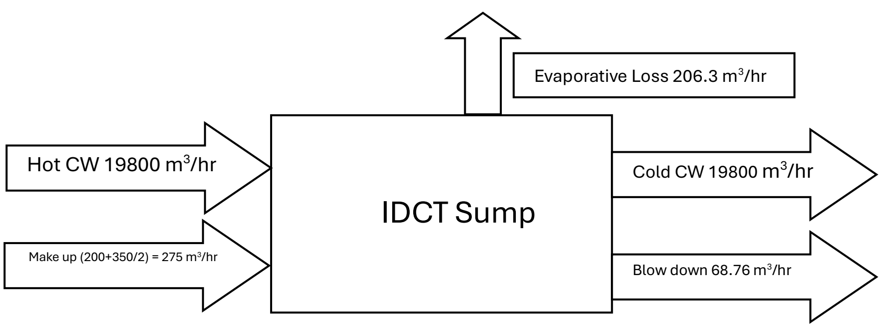
Evaporative loss = 0.00085*1.8*19800*6.81 = 206.3 m^3/hr

COC = 2000/500 = 4

Blow down from CT sump = Evaporation Loss/ (COC-1)

= 68.76 m^3/hr

Mass flow diagram of the system:



CT make up (one pump) = 200 m^3/hr

a) Calculation of time period for which only one pump is in service

Total volume of sump = 100*15*40 = 60000m^3

Volume change needed before 2nd make up pump is stared= (100-90)*60000 = 6000 m^3

Volume change in sump from mass flow diagram = 200-206.3-68.76 = -75 m^3/hr

Time period for which only one pump is in service = 6000/75= **80 hrs**

b) Calculation of time period for which both pumps are in service

When two pumps are in service, total make up flow will become 350m^3/hr, All other flows remain same

Volume change needed before 2nd make up pump is stopped= (100-90)*60000 = 6000 m^3

Volume change in sump from mass flow diagram = 350-206.3-68.76 = 75 m^3/hr

Time period for which both pumps are in service = 6000/75= **80hrs**

Answer any ONE of the following among four questions given below:

N4- (A)

i) A 500 MW power plant is operated with the turbine back pressure of 0.14 ata and after improving the condenser cooling system the turbine back pressure is maintained at 0.11 ata. The design heat rate of the turbine at backpressure of 0.14 ata is 2040 kcal/kwh and at 0.11 Back pressure will be 2000 kcal/kWh. The operating turbine efficiency is 93 % and the alternator efficiency is 96 % and the boiler efficiency is 87 %. The coal used in Power plant is having GCV of 5500 kCal/kg.

Calculate the following:

1. Condenser vacuum in mmHg at 0.14 ata turbine Back pressure 2 Marks
2. Condenser vacuum in mmHg at 0.11 ata turbine Back pressure 2 Marks
3. Improvement in gross heat Rate 4 Marks
4. At 74 % Power Plant Loading what will be the coal savings per day 4 Marks

ii)

The operating Details of a 1000 MW thermal power plant are given below:

Plant Load Factor	: 76 %
Annual Operating Hours	: 7200 hours
Annual Coal Consumption	: 40,45,400 MT
Annual Furnace oil Consumption (Support Fuel)	: 3,500 MT
Annual HSD Consumption (Earthmoving Equipment)	: 150 MT

Coal GCV	: 5,500 kCal/ kg
Furnace Oil GCV	: 10,200 kCal/kg
HSD GCV	: 10,500 kCal/kg

Calculate the following:

1. Annual power generation in Million kWh. 2 Marks
2. Gross Heat Rate kCal/kWh, 3 Marks
3. Net Heat Rate kCal/kWh, if auxiliary power consumption is 8% of the running Load. 3 Marks

Solution:

i)

1. Condenser vacuum in mmHg = 0.14 x 1.0332 kg/cm^2 =0.145 kg/cm^2 = 109.93 mm Hg

= 760-109.93 = 650 mmHg

2.Condenser vacuum in mmHg = 0.11 x 1.0332 kg/cm^2 =0.114 Kg/cm^2 = 86.37 mm Hg

=760-86.37= 674mmHg

3.Improvement in gross heat Rate
Gross Heat Rate with turbine Pressure O.14 ata = 2040/(0.87)= 2345 kCal/kW

Gross Heat Rate with O.11 ata = 2000/(0.87)= 2299 kCal/kW

Improvement = 2345-2299 = 46 Kcal/kWh

4.Heat savings at 74 % Loading = 500 X1000x 0.74 x (46) Kcal/Hr

= 17020000 kCal/hr

Coal savings = 17020000/5500 = 3094.55 kg/Hr
Daily Coal savings= 3094.55 kg x 24 hrs= 74.27 Ton/ Day

Solution:

ii)

Operating Load = 1000 x0.76 = 760 MW

Annual Units Generated = (760 x 1000 x7200)/1000000= 5472 million Units

Gross Heat Rate =[((4045400*1000)x 5500) + (3500*1000x10200))]/ 5472 million units

= 4073.64 kCal/kWh

Net Heat Rate = 4073.64/ (1-0.08)

= 4427.87 kCal/kg

(Or)

N4- (B)

A textile processing unit currently operates a 5-chamber stenter with a dryer efficiency of 40%. The average amount of dry cloth processed by this stenter is 1,500 kg/hr, containing 4% moisture. The incoming cloth to the stenter has a moisture content of 42%, with a feed temperature of 37°C, and exits at 89°C. The management plans to upgrade to an 8-chamber stenter, which has a dryer efficiency of 58%. The heat required for both stenters is supplied by a thermic fluid heating system powered by furnace oil, which operates at an efficiency of 80%. The furnace oil has a gross calorific value (GCV) of 10,000 kcal/kg and a density of 0.92 kg/liter.

Calculate the following:

1. The dryer heat input (kcal/kg) for both the 5-chamber and 8-chamber stenters.

   12 Marks

2. The amount of furnace oil required (in liters per hour) for the thermic fluid heater when using the 5-chamber stenter and when using the 8-chamber stenter.

   8 Marks

Solution:

	Bone dry cloth weight	=1500*0.96	1440	kg/hr
	Inlet cloth weight with Moisture	=1440/(1-0.42)	2483	Kg/hr
	Inlet Moisture/kg dry cloth	=2483*0.42/1440	0.724	Kg moisture/Kg dry cloth
	Outlet Moisture/kg dry cloth	=1500*0.04/1440	0.042	Kg moisture/Kg dry cloth
	Mass of moisture evaporated	=1440*(0.724-0.042)	982	kg/hr

	Heat Load to stenter	=982*((89-37)+540)	581344	kCal/hr
	Five Chamber stenter drying Efficiency		40	%
1a	Input heat to stenter	=581344/0.4	1453360	kCal/hr
	Thermopack efficiency		80	%
	Heat Input to Thermopack	=1453360/0.8	1816700	kCal/hr
	Furnace Oil GCV		10000	Kcal/kg
	Furnace oil qty	=1816700/10000	181.67	Kg/hr
	Furnace oil density		0.92	Kg/lit
2a	Furnace oil required	=181.67/0.92	197	LPH
	Eight Chamber stenter drying efficiency		58	%
1b	Input heat required for 8 chamber stenter	=581344/0.58	1002317.24	kCal/hr
	Thermopack Efficiency		80	%
	Heat Input at Thermopack	=1002317.24/0.8	1252896.55	kCal/hr
	Furnace Oil GCV		10000	Kcl/kg
	Furnace oil qty	=1252896.55/10000	125.29	Kg/hr
	Furnace oil density		0.92	Kg/lit
2b	Furnace oil required	=125.29/0.92	136.18	LPH

(Or)

N4 – (C)

The management of a cement plant with a capacity of 7200 TPD has decided to install waste heat recovery boilers (WHRB) to generate steam from preheater gas and clinker cooler gas for power generation. The relevant data is given below:

Raw meal feed Rate	7200	TPD
Clinker Output	62	% of feed
Preheater Outlet temp	325	°c
Clinker Cooler Outlet temp	310	°c
WHRB Exit temperature	160	°c
Preheater Gas heat availability	152	Kcal/kg of clinker
Cooler gas heat availability	120	Kcal/kg of clinker
Enthalpy of Main Steam	815	Kcal/kg
Feed Water temperature	95	°c
Power plant Condensate return Temperature	46	°c
Heat recovery potential in WHRB	75	%
Turbine Cycle Efficiency	36	%

Gear Box Efficiency	95	%
Alternator Efficiency	96	%

The chemical analysis of clinker (Loss-free basis) is given below:

Constituents	%
SiO_2	***22.68***
Fe_2O3	***5.92***
Al_2O3	***5.29***
CaO	***63.00***
MgO	***1.25***

Calculate the following:

1. The power output from the co-generation plant in MW. (15 Marks)
2. The heat of formation of the clinker. (5 Marks)

Solution :

Clinker Output	= (7200x0.62/ 24hrs)	186	TPH
Heat in Pre Heater-Gas	= 152x186 x1000	28272000	kcal/kg/hr
Heat In cooler gas	= 120 x186x1000	22320000	kcal/kg/hr
Steam Enthalpy	given	815	Kcal/Kg
Feed Water temperature	given	95	°c
Power plant Condensate return Temp	given	46	°c
Heat recovery potential in WHRB	given	75	%
Steam from Preheater	=28272000x0.75/(815-95)/1000	29.48	TPH
Steam From Cooler gas	=22320000x0.75/(815-95)/1000	23.25	TPH
Total Steam Generation	=29.48 + 23.25	52.7	TPH
Turbine Cycle Efficiency	given	36	%
Gear Box Efficiency	given	95	%
Alternator Efficiency	given	96	%
Power generation	= 52.7x1000x(815-95)x0.36x0.95x0.96/860/1000	14.48	MW

Heat of Formation of clinker

$= 2.22 \times Al_2O_3 + 6.48\ MgO + 7.646\ CaO - 5.116 \times SiO_2 - 0.59 \times Fe_2O_3$

$= 2.22 \times 5.29 + 6.48 \times 1.25 + 7.646 \times 63 - 5.116 \times 22.68 - 0.59 \times 5.92$

= 382 kCal/kg of clinker

(Or)

N4 – (D)

The production data for a steel plant using the Direct Reduced Iron (DRI) route is outlined below. The DRI unit has a daily production capacity of 500 tonnes of sponge iron but operates at 60% of this capacity. The produced sponge iron is transported to the Steel Melting Shop (SMS) where it is processed into ingots, the final product. The plant also operates a captive power station to fulfill its energy requirements. The operational parameters for both the baseline year and the assessment year are provided as follows:

Parameter	Unit	Base Year (2022)	Assessment Year (2023)
Sponge Iron Full Production Capacity	T/Day	500	500
Plant operating Capacity	%	60	60
Specific Coal Consumption of DRI	T/T	1.3	1.15
Specific Power Consumption of DRI	kWh/T	110	95
Yield of Steel Melting Shop	%	85	88
SEC of Steel Melting Shop	kWh/Ton	850	830
Captive Power Station Efficiency	%	26.06	27.74
GCV of Coal	kCal/kg	6000	6200

Calculate the following:

(1) Specific Energy Consumption of the plant in Million kCal/Tonne of Finished Product for Base Year. 8 Marks
(2) Specific Energy Consumption of the plant in Million kCal/Tonne of finished product for assessment year. 8 Marks
(3) Reduction in coal consumption considering both DRI and captive power plant in tonnes per day for the assessment year. 4 Marks

Solution :

1. **Base Year Performance**

Specific Energy Consumption	= 1300 kg x 6000 + 110 kWh x 3300 = 8.163 million kCal/Tonne of SI

Plant Capacity	= 500 T/day
Plant Actual Running Capacity	= 60% = 0.6 x 500 = 300 Tonnes
Total Energy Consumption of Sponge Iron /day	= 300 x 8.163 = 2448.9 million kCal
Total production of Ingots from Sponge Iron considering	=300 x 0.85 = 255 Tonnes/Day
Heat Rate of the Captive Power Station	=860/0.2606 = 3300 kCal/kWh
Specific Energy Consumption for Ingot	=850 x 3300 = 2.805 million kCal/Tonne of Ingot
Total Specific Energy Consumption for Ingot Production per year	= 2.805 x 255 = 715.275 million kcal
Plant Specific Energy Consumption for production of finished product (ingot) during base year	= (2448.9+ 715.275)/255 = 12.41 million kcal/tonne

2. Assessment Year Performance

Revised Parameter

Specific Power Consumption	= (1 – 0.1363) x 110 = 95 kWh/Tonne
Yield	= (1 + 0.0352) x 85 = 88 %
The Specific Energy Consumption of SMS	= (1-0.0235) x 850 = 830 kwh/tonne
Plant Heat Rate	=3300 – 200 = 3100 kCal/kWh
GCV of Coal	=6200 kCal/kg

Specific Energy Consumption	= 1150 kg x 6200 + 95 kWh x 3100 =7.425 million kCal/Tonne of SI
Plant Capacity	= 500 T/day
Plant Actual Running Capacity	= 60% = 0.6 x 500 = 300 Tonnes
Total Energy Consumption of Sponge Iron /day	= 300 x 7.425 = 2227.5 million kCal
Total production of Ingots from Sponge Iron considering	= 300 x 0.88 = 264 Tonnes/Day
Heat Rate of the Captive Power Station during assessment year	= 860/0.2774 = 3100 kCal/kWh
Specific Energy Consumption for Ingot	= 830 x 3100 = 2.573 million kCal/Tonne of Ingot
Total Specific Energy Consumption for Ingot Production per year	= 2.573 x 264 = 679.27 million kcal
Plant Specific Energy Consumption for production of finished product (ingot) during base year	= (2227.5+679.27)/264 = 11.01 million kcal/tonne

3. Reduction in Coal Consumption

Energy Saving in Sponge Iron Plant	= (8.163 – 7.425) x 300 = 221.4 million kCal/day
Energy Saving in Steel Melting Plant	= (2.805 x 255 – 2.573 x 264) = 38.07 million kCal/day
Total Energy Saving	= 221.4 + 38.07 = 259.47 million kCal
Equivalent Coal Reduction (Saving)	= 259.47 x 10^6/ (6200 x 10^3) = 41.85 Tonnes per Day

Comment: The coal consumption is reduced by 41.85 Tonnes / Day

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