Paper-4 Code: Green

25^{TH} NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS - SEPTEMBER 2025

PAPER – 4: ENERGY PERFORMANCE ASSESSMENT FOR EQUIPMENT AND UTILITY SYSTEMS

Date: 28.09.2025 Timings: 14:00-16:00 HRS Duration: 2 HRS Max. Marks: 100

General instructions:

- *Please check that this question paper contains **6** printed pages*
- *Please check that this question paper contains **16** questions*
- *The question paper is divided into three sections*
- *All questions in all three sections are compulsory*
- *All parts of a question should be answered in one place*
- *Time management guidance: Section - I & II: 10 Minutes each, Section - III: 100 Minutes*

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

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

1.	Evaporation ratio is based on actual performance data (steam output and fuel input) and does not depend on whether efficiency is expressed on GCV or NCV basis.	True
2.	Isentropic efficiency of a back-pressure turbine will be more if extraction temperature is higher than steam temperature at back-pressure condition.	False
3.	Profitability Index (PI) will be greater than 1 for projects with positive NPV, but its value varies with cash flow patterns and is not always higher for all positive NPV projects.	True
4.	In an integrated iron & steel plant, all the rolling mills consume more energy compared to energy consumed for iron making.	False
5.	In indirect method of boiler efficiency calculations, blowdown losses are also considered.	False
6.	Lower the TTD (Terminal Temperature Difference) and DCA (Drain Cooler Approach) for feedwater heaters, the higher will be the efficiency of the cycle.	True
7.	If wet steam is generated, the high Evaporation ratio indicates high efficiency of boiler.	False
8.	The only reason for installing condensate recovery systems is to reduce makeup water.	False
9.	The heat rate of a thermal power plant can be improved by decreasing the condenser cooling water temperature.	True
10.	In a cement rotary kiln, the highest heat loss occurs through clinker discharge.	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 petrochemical industry, both the Low-Pressure (LP) boiler and the High-Pressure (HP) boiler operate with the same evaporation ratio of 14, using the same fuel oil. The operating details are provided below:

Particulars	LP Boiler	HP Boiler
Pressure	10 kg/cm^2a	32 kg/cm^2a
Temperature	Saturated steam	400 °C
Enthalpy of steam	665 kcal/kg	732 kcal/kg
Temperature of feed water	80 °C	105 °C
Evaporation Ratio	14	14

If the efficiency of the LP boiler is 82%, calculate the efficiency of the HP boiler.

L-1 Ans

Effy η = ER. (hg – hf) / GCV

EffyL.P η_1 = 0.82 = 14 x(665 – 80) / GCV

EffyH.P η_2 = 14 x(732 – 105) / GCV

EffyH.P η_2 / EffyL.P η_1 = (732 – 105)0.82 / (665 – 80) = 0. 8789 =87.89%

Or

EffyL.P η_1= 0.82 = 14 x(665 – 80) / GCV

GCV= 14x(665-80) / 0.82 = 9987.8 kcal/kg

EffyH.P η_2 = 14 x(732 – 105) / GCV

= 14 x(732 – 105) / 9987.8 = 0.8789 = 87.89 %

L-2 During the assessment year 2024–25, one of the thermal power plants reported a gross heat rate of 2300 kCal/kWh and an auxiliary power consumption of 9%, while the baseline net heat rate was 2600 kCal/kWh.

If the baseline generation is 5000 MU and considering that 1 kg of oil equivalent = 10,000 kCal and 1 e-Certificate = 1 ton of oil equivalent (TOE), calculate the reduction in net heat rate compared to the baseline and determine the expected number of e-Certificates.

L-2 Ans

Assessment Year Net Heat Rate = 2300/ (100-9)/100
= 2527.47 kCal/kWh

Reduction in net heat rate = Baseline – Assessment year Net Heat Rate
= 2600 – 2527.47
= 72.53 kCal/kWh

Expected E-certs = 5000 x 10^6 x 72.53 / 10000 x 1000
= 36,263.74 e-Certificates

………… 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 pharmaceutical manufacturing plant operates a central chilled water system that serves both cleanroom AHUs and a process cooling water loop for tablet coating machines. The process cooling water passes through a counterflow heat exchanger, entering at 20 °C and leaving at 14 °C with a flow rate of 166 m^3/h. On the other side, the chilled water enters at 7 °C and leaves at 12 °C, with a flow rate of 200 m^3/h. The heat exchanger has an overall heat transfer coefficient of 2.8 kW/m^2 °C. The chilled and condenser cooling water loops are each served by centrifugal pumps with operating efficiencies of 78 % and 80 %, respectively and with a head of 18 m. The cooling tower is fitted with an induced-draft axial fan delivering 28 m^3/s of air at 42.83 mmWC total pressure, with a fan efficiency of 62 %. All pumps and the fan are driven by directly coupled three-phase induction motors with an efficiency of 92 %. The plant's HVAC system operates for 300 days annually, running 18 hours per day, to handle an average cooling load of 850 kW with an ISEER value of 4.4 Calculate the following: a) Estimate the required heat exchanger surface area. (6 marks) b) Determine the combined electrical load in kW of both pumps and the cooling tower fan, if condenser cooling water flow is 600 m^3/h. (6 marks) c) Determine the Specific Energy Consumption (SEC) of the chiller in kWh/TR and calculate the overall SEC. (4 marks) d) Calculate the annual energy consumption in kWh and the annual operating cost in ₹. Lakhs if electricity is charged at ₹7.5 per kWh. (4 marks)
N-1 Sol	a) Heat Exchanger Surface Area (6 Marks) - Process water flow rate: 166 m^3/h = 46.1 kg/s - ΔT = 20 - 14 °C = 6 °C - Heat load (Q): Q = ṁ × cp × ΔT = 1156 kW - LMTD (counterflow): ΔT1 = 8 °C, ΔT2 = 7 °C, LMTD = 7.49 °C - Area: A = Q / (U × LMTD) = 1156 / (2.8 × 7.49) = 55.2 m^2 b) Combined Electrical Load of Pumps and Fan (6 Marks) Chilled water pump (200 m^3/h, 18 m head): - Hydraulic power = 9.81 kW - Motor input = 13.7 kW Condenser pump (600 m^3/h, 18 m head): - Hydraulic power = 29.43 kW - Motor input = 40.0 kW Cooling tower fan (28 m^3/s, 42.83 mmWC): - Air power = 11.76 kW - Motor input = 20.6 kW Total auxiliary load = 13.7 + 40.0 + 20.6 = 74.3 kW c) Specific Energy Consumption (SEC) (4 Marks) - Cooling load = 850 kW = 242 TR - Chiller input = 193.2 kW (ISEER = 4.4)

	Chiller SEC = 193.2 / 242 = 0.79 kWh/TR System SEC = (193.2 + 74.3) / 242 = 1.106 kWh/TR d) Annual Energy & Cost (4 Marks) Total power demand = 193.2+74.3 = 267.46 kW - Annual energy consumption = 267.46 × 18 x 300 = 1444304.94 kWh/year - Annual cost (@ ₹7.5/kWh) = 1444304.94 × 7.5 /100000 = ₹ 108.32 lakh/year
N-2	A boiler is fired with 200 kg/hr of a hydrogen-enriched hydrocarbon fuel ($C_nH_m–H_2$) at atmospheric pressure and a temperature of 20 °C. The flue gas, leaving the boiler at atmospheric pressure and 300 °C, has the following dry composition by weight: • CO_2 = 12% • O_2 = 3% • N_2 = 85% Based on this information, determine: a) The main constituents of the fuel (carbon and hydrogen) 12 Marks b) The percentage composition of each constituent in the fuel 4 Marks c) The total mass flow rate (kg/hr) of the dry flue gas. 4 Marks
N-2 Sol	Assumptions (per 100 kg dry flue gas): Nitrogen -85 kg/hr, Oxygen – 3 kg/hr, CO_2 – 12 kg/hr Take air O_2 mass fraction = 0.23 and N_2 mass fraction = 0.77. Carbon in the fuel (from CO_2): $CO_2 \rightarrow C$: $$m_C = 12kg\ CO2 \times \frac{12}{44} = \frac{144}{44} = \frac{36}{11}\ \text{kg}$$ m_C=36/11=3.2727 kg/h of carbon/ per 100 kg/hr of flue gas Actual air supplied: Air mass = $\frac{N_2}{N_2 \text{ mass fraction in air}} = \frac{85}{0.77}$ = 110.39 kg/hr of air / 100 kg/hr of flur gas O_2 supplied with that air: $O_2^{supplied}$=0.23 ×110.39 =25.39 kg/hr / 100 kg/hr of flue gas O_2 consumed (used in combustion) = supplied − residual in flue gas $$O_2^{consumed} = 25.39 - 3 = 22.39 \text{ kg/hr /100 kg/hr of flue gas}$$ O_2 used to oxidize carbon (to form CO_2): Stoichiometry: $C + O_2 \rightarrow CO_2 \rightarrow$ mass factor = $\frac{32}{12} = \frac{8}{3}$. $$O_2 \text{ for } C = \frac{8}{3} \times m_C = \frac{8}{3} \times \frac{36}{11} = \frac{288}{33} = 8.73\ \text{kg/hr/100kg/hr of flue gas}$$ O_2 available for hydrogen: $$O_2 \text{ for } H = O_2^{consumed} - O_2 \text{ for } C = 22.39 - 8.73 = 13.66\ \text{kg/hr/100kg/hr of flue gas}$$ Each kg H requires 8 kg O_2 to form H_2O, so H mass: $$m_H = \frac{13.66}{8} = 1.70779\ \text{kg/hr}$$ Fuel mass & composition (per 100 kg dry flue gas): Total fuel mass (C + H): $$m_{fuel} = m_C + m_H = 3.2727 + 1.70779 = 4.9805\text{kg/hr}$$ Mass fractions: $$\%C = \frac{3.2727}{4.9805} \times 100 = 65.732663\% \ (\approx 65.73\%)$$ $$\%H = \frac{1.7077}{4.9805} \times 100 = 34.267337\% \ (\approx 34.27\%)$$ If fuel flow = 200 kg/h: Carbon: $$m_C(200) = 200 \times 0.6573 = 131.465326\ \text{kg/h}$$

= 131.46 kg/hr

Hydrogen:

$$m_H(200) = 200 \times 0.3426 = 68.534674 \text{ kg/h}$$
= 68.54 kg /hr

c) The total Mass Flow rate of Dry Flue gas in kg/hr:

Carbon (C) = 131.46 kg/h
Hydrogen (H) = 68.54 kg/h

Mass of dry flue gas = Mass of wet flue gas – Mass of H_2O
= 200 + Actual Air – 9* 68.54
= Actual Air – 416.86
Actual Air = Ta +Ea

Ta = (2.67 x131.46 + 8x68.54) / 23%
= 3910 kg/hr

Ea = E% x Ta

E% = O2%/ (21% - O2%)

O2%= 3/32 / (12/44 + 3/32 + 85/28)

= 2.75%

E% = 2.75% / (21%- 2.75%)

= 15.07%
Ea = 15.07% x 3910 kg/hr

= 589.24 kg/hr

Therefore, Actual Air = Ta +Ea
= 3910 kg/hr + 589.24 kg /hr
= 4499.24 kg/hr

Mass of Dry flue gas = 4499.24 – 416.86
= 4082.38 kg/hr

N-3 i) A small Topping Cycle Gas Turbine cogeneration plant has the following operating parameters. Estimate the power generation in kW and the steam supplied from the HRSG in TPH. The Energy Auditor has suggested that the HRSG exit flue gas temperature can be maintained at 95 °C by recovering more heat from the HRSG. If the HRSG exit flue gas temperature is maintained at 95 °C, estimate the additional steam generation and also the EUF with improved steam generation. The operating parameters are given below:

12 Marks

Parameter	Value
Natural Gas Fuel Firing Rate	1500 Sm^3/hr
Lower Heating Value (LHV)	9600 kcal/Sm^3
Exhaust Gas Flow Rate	16.35 kg/s
Exhaust Gas Temperature	525 °C
Mean Specific Heat of Gas (Cp)	0.265 kcal/kg·°C
Specific Power Generation	3.044 kWh/Sm^3
HRSG Inlet Temperature	520 °C
HRSG Exit Temperature	135 °C
Steam Pressure	10 kg/cm^2
Saturated Steam Temperature	179 °C
Steam Enthalpy	663 kcal/kg
Feedwater Temperature	105 °C
HRSG Efficiency	80 %

ii) A coal-fired boiler operates with the following parameters. 8 Marks

Parameter	Value
Hours of Operation	24 hours
Feed Water Temperature	140 °C
Steam Enthalpy	805 kcal/kg

GCV of Coal	4200 kcal/kg
Evaporation Ratio	5.7
Steam Flow Rate	265 TPH

Calculate the Boiler Efficiency and Coal Consumption per hour. If the boiler efficiency is improved by 2% relative to the existing efficiency, then estimate the coal savings per day.

N-3 Ans

a)
Power Generation
Power = Fuel rate × Specific power generation
= 1500 × 3.044 = 4566 kW
Steam Generation at Baseline (Exit 135 °C)
Heat recovered = 48,04,153.20 kcal/hr
Steam generated = 8609.6 kg/hr = 8.61 TPH
Steam Generation at Improved Condition (Exit 95 °C)
Heat recovered = 53,03,286 kcal/hr
Steam generated = 9504 kg/hr = 9.5 TPH
Additional steam = 9504 – 8609.6 = 894.5 kg/hr = 0.89 TPH
Energy Utilization Factor (EUF)
Fuel input = 16,747.2 kW
Useful output = Power (4566) + Steam thermal (5587.23) = 10,153.23 kW
EUF = 10,153.23 / 16,747.2 = 60.63 %

Determination of EUF at improved Condition (Exit 95 °C)
New Useful output = Power (4566) + Steam thermal (6167.72) = 10,733.72 kW
EUF = 10,733.72 / 16,747.2 = 64.09 %

b)
Step 1: Data Given
- Steam flow = 265 TPH = 265,000 kg/hr
- Steam enthalpy = 805 kcal/kg
- Feedwater enthalpy ≈ 140 kcal/kg
- GCV of coal = 4200 kcal/kg
- Evaporation ratio = 5.7

Step 2: Heat Output
Net enthalpy gain = 805 – 140 = 665 kcal/kg
Q_{out} = 265,000 × 665 = 17,62,25,000 kcal/hr

Step 3: Coal Consumption (from ER)
Coal/hr = 265,000 ÷ 5.7 = 46,491 kg/hr = 46.491 TPH

Step 4: Heat Input
Q_{in} = 46,491 × 4200 = 19,52,62,200 kcal/hr

Step 5: Boiler Efficiency
$\eta = Q_{out} \div Q_{in} \times 100 = (17{,}62{,}25{,}000 \div 19{,}52{,}62{,}200) \times 100 = 90.25\%$

Step 6: Improved Efficiency (relative 2%)
$\eta_{new} = 90.25 \times 1.02 = 92.055\%$

Step 7: New Coal Consumption
$Coal_{new} = Q_{out} \div (\eta_{new} \times GCV)$
$Coal_{new}$ = 17,62,25,000 ÷ (0.92055 × 4200) = 45,580.70 kg/hr = 45.58 TPH

Step 8: Coal Savings
ΔCoal/hr = 46.491 – 45.580 = 910 .53 kg/hr
Daily Saving = 910.53× 24 = 21,852.77 kg/day ≈ 21.85 TPD

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

N-4 (A)	A 10,000 TPD cement plant purchases power from the grid, operates an 18 MW Captive Power Plant (CPP) and also has a Waste Heat Recovery (WHR) system with a 9 MW turbine. Electricity is used for cement production and also supplied to the colony and other utilities. The plant also exports excess energy to the grid. The annual energy and production data are given below:

Parameter	Value
Annual operating hours	8,300 hrs
Energy imported	60,210,000 kWh
Energy exported	3,150,000 kWh
Energy supplied to colony & others	3,500,000 kWh
CPP average generation	18 MW
CPP heat rate	3100 kcal/kWh
WHR turbine average generation	9 MW
WHR turbine heat rate	3600 kcal/kWh
Indian coal consumption	96,000 MT (GCV 4500 kcal/kg)
Pet coke consumption	80,000 MT (GCV 7500 kcal/kg)
Imported coal consumption	198,000 MT (GCV 7200 kcal/kg)
Biomass consumption	10,000 MT (GCV 2850 kcal/kg)
Clinker produced	2,700,000 MT
Clinker-to-cement ratio	1.4

Calculate the following:

a) Specific Electrical Energy Consumption (SEEC) in kWh/ton of cement. (8 Marks)

b) Estimate the Specific Thermal Energy Consumption (STEC) in kcal/kg of clinker (7 Marks)

c) If the CPP is operated using only Indian coal and Imported coal, calculate the coal blending ratio by weight required to achieve a blended coal GCV of 6000 kcal/kg. (5 Marks)

N-4 (A) Sol

Solution

Specific Electrical Energy Consumption (SEEC) – 8 Marks

Energy Input

CPP generation = 18 × 8300 × 1000 = 149,400,000 kWh

WHR generation = 9 × 8300 × 1000 = 74,700,000 kWh

Grid import = 60,210,000 kWh

Total Input = 284,310,000 kWh

Deductions

Export to grid = 3,150,000 kWh

Colony & others = 3,500,000 kWh

Net for cement production = 284,310,000 – 3,150,000 – 3,500,000 = 277,660,000 kWh

Cement Production

Clinker produced = 2,700,000 MT

Cement produced = 2,700,000 × 1.4 = 37,80,000 MT

SEEC

SEEC = 277,660,000 ÷ 37,80,000 = 73.46 kWh/ton cement

Specific Thermal Energy Consumption (STEC) – 7 Marks

Fuel Heat Input

Indian coal = 96,000 × 4500 = 432 × 10^9 kcal

Pet coke = 80,000 × 7500 = 600 × 10^9 kcal

Imported coal = 198,000 × 7200 = 1425.6 × 10^9 kcal

Biomass = 10,000 × 2850 = 28.5 × 10^9 kcal

Total Heat Input = 2486.1 × 10^9 kcal

Heat to Kiln

As per PAT convention (no CPP deduction applied)

Heat to kiln = 2486.1 × 10^9 kcal

STEC

Clinker produced = 2,700,000 MT = 2,700,000,000 kg

STEC = 2486.1 × 10^9 ÷ 2,700,000,000 = 920.78 kcal/kg clinker

Coal Blending Ratio – 5 Marks

Define ratio

Let x = fraction of Indian coal, (1–x) = fraction of Imported coal

Equation

6000 = 4500x + 7200(1–x)

6000 = 4500x + 7200 – 7200x

6000 = 7200 – 2700x

2700x = 1200
x = 0.444 (44.4%)
Step 4: Ratio (1 Mark)
Indian coal = 44.4%, Imported coal = 55.6%
Coal Blending Ratio = 44 : 56

Or

N-4 (B) The following data was collected from a 500 MW turbine unit during an energy audit. The power plant operates with a main steam (MS) flow of 1561 TPH at a pressure of 166 kg/cm^2 and temperature of 529°C. The hot reheat (HRH) flow is 1413 TPH, with steam conditions of 42.4 kg/cm^2 and 540°C, while the cold reheat (CRH) section records a pressure of 44.3 kg/cm^2 and temperature of 341°C. The feed water enters at 246°C, whereas the MS, CRH, and HRH enthalpies are 806.47 kCal/kg°C, 730.71 kCal/kg°C, and 844.28 kCal/kg°C, respectively. These optimized steam cycle parameters enable the generator to deliver a substantial power output of 501 MW with a boiler efficiency of 88%. The turbine cycle heater operating parameters are as below:

Heater Reference	Steam				Feed Water in		Feed Water out		Design Values	
	Temp (°C)	Pressure (kg/cm²)	Saturation Temp (°C)	Drain Temp (°C)	Temp (°C)	Pressure (kg/cm²)	Temp (°C)	Pressure (kg/cm²)	TTD	DCA
LP Heater 1	92.5	-0.23	93.07	64.2	47.2	13.7	63.6	12.6	2.88	4.8
LP Heater 2	140	0.49	111.23	70.4	-	-	105	11.5	2.95	4.95
LP Heater 3	209	1.97	132.9	110	-	-	130	10.4	2.95	4.95
HP Heater 5	416	17.4	207.33	171	170	202	210	199	0	5
HP Heater 6	335	43	254.94	212	-	-	255	197	0.1	5

Neglect temperature loss in the feedwater line between heaters and calculate the following:

a. Calculate the Turbine Heat Rate and the Unit Heat Rate. 8 Marks
b. Determine the loss or gain in the Turbine Heat Rate due to deviations of the TTD (Terminal Temperature Difference) and DCA (Drain Cooler Approach) of the LP/HP Heater systems from their design values. 12 Marks
Consider the following criteria:

- For every 0.56°C increase or decrease in TTD from the design value, the Heat Rate will increase or decrease by 0.014%.
- For every 0.56°C increase or decrease in DCA from the design value, the Heat Rate will increase or decrease by 0.005%.

N-4 (B) Ans

Turbine Heat Rate:
Turbine: HR: {(1561000 X (806.47-246))+ (1413000 X (844.27 – 730.714))}/ (501000)
= 2066.57 kCal/kWh

Unit Heat Rate:
= 2066.57 / 88%
= 2348.38 kCal/kWh

From the Above data, the following heater data can be inferred

Heater Ref.	Feed water Inlet Temp ^{0}C	Feed water Inlet Temp ^{0}C	Steam Inlet temp ^{0}C	Inlet steam Saturation Temp ^{0}C	Drain temp ^{0}C
LP Heater -1	47.2	63.6	92.5	93.07	64.2
LP Heater-2	63.6	105	140	111.23	70.4
LP Heater -3	105	130	209	132.9	110
HP heater-5	170	210	416	207.33	171
HP Heater -6	210	255	335	254.94	212

So
TTD (Terminal Temperature Difference) = Inlet Steam Saturation Temp ^{0}C – Feed Outlet Temp ^{0}C
DCA (Drain Cooler Approach = Drain temperature ^{o}C – Feed Water Inlet Temperature ^{o}C

Heater Ref.	TTD ^{o}C (Design)	DCA ^{0}C (Design)	TTD ^{o}C (Calculated)	DCA ^{0}C (Calculated)
LP Heater -1	2.88	4.8	29.47	17

LP Heater-2	2.95	4.95	6.23	6.8
LP Heater -3	2.95	4.95	2.9	5
HP heater-5	0	5	-2.67	1
HP Heater -6	0.1	5	-0.06	2

Difference Between design values and Operating values of TTD and DCA of Heaters.

Heater Ref.	$TTD_{Operating} - TTD_{Design}$	$DCA_{Operating} - DCA_{Design}$
LP Heater -1	26.59	12.2
LP Heater-2	3.28	1.85
LP Heater -3	-0.05	0.05
HP heater-5	-2.67	-4
HP Heater -6	-0.16	-3
Total Difference	**26.66**	**7.1**

Change in Heat rate because of deviation in TTD =

(Net Change in TTD for All heaters X 0.014%/0.56°C)

Since given, for every 0.56°C change in TTD HR will increase by 0.014%

So Increase in HR because of TTD deviation= 26.66°C X 0.014 / 0.56 = 0.67475 %

Change in Heat rate because of deviation in DCA =

(Net Change in DCA for All heaters X 0.005%/0.56°C)

Since given, for every 0.56°C change in TTD HR will increase by 0.005%

So Increase in HR because of DCA deviation
7.1 X 0.005 / 0.56 = 0.064 %

Total % Increase in Turbine HR because of deviation in operation of TTD and DCA of Heaters from Design Values
= 0.7381 %.
=0.7381 X 2066.57 = 15.25 kCal/kWh

Or

N-4 (C) A DRI-route steel plant operates a DRI unit and a Steel Melting Shop (SMS). The plant also has a coal-based captive power plant (CPP). Any shortfall in electrical energy is met by imported grid power. On average, the plant imports 1,20,000 kWh/day and the operational parameters are given below:

Description	Parameter	Value
DRI Unit	Rated capacity	500 TPD
	Capacity utilization	70%
	Specific coal consumption	1.25 t coal / t sponge iron
	Specific power consumption	95 kWh / t sponge iron
	Coal GCV	5000 kcal/kg
SMS	Yield	85%
	Specific power consumption	830 kWh / t liquid steel
CPP	Gross efficiency	27%
	Auxiliary power consumption	8% of gross generation
	Coal GCV	5000 kcal/kg
Grid	Grid electricity heat rate	2700 kCal/ kWh

Calculate the following:

a) The daily production of sponge iron and liquid steel in TPD. (2 marks)
b) DRI coal consumption in TPD and its thermal input in Million kcal/day. (2 marks)
c) Total daily electrical energy demand of DRI and SMS in kWh/day. (3 marks)
d) The CPP gross generation in kWh/day, CPP heat rate in kCal/kWh, CPP thermal input in Million kcal/day and the CPP coal consumption in TPD. (6 marks)
e) The overall specific energy consumption (SEC) in Million kcal per tonne of liquid steel. (4 marks)
f) Compare your SEC with a benchmark of 6.5 Million kcal/t of liquid steel, and comment briefly on performance. (3 marks)

N-4 (C) Ans

1) Daily Production (2 marks)
Sponge iron = 500 × 70% = 350 TPD
Liquid steel = 350 × 0.85 = 297.5 TPD
2) DRI Coal & Heat Input (2marks)
Coal = 1.25 × 350 = 437.5 TPD
Thermal input = 437.5 × 5,000 × 1000 = 2,187.5 Million kcal/day
3) Electrical Demand (3 marks)
DRI = 95 × 350 = 33,250 kWh/day
SMS = 830 × 297.5 = 246925 kWh/day
Total = 280,175 kWh/day
4) CPP Generation & Coal (6 marks)
CPP net = 280175 – 120,000 = 160175 kWh/day
CPP gross = 160175/ 0.92 = 174103.26 kWh/day
Heat rate = 860 / 0.27 = 3,185.2 kcal/kWh
Thermal input = 174103.26 × 3,185.2 = 554.55 Million kcal/day
CPP coal = 554.55 ×10^6 / 5000 = 110.91 TPD
5) Overall SEC (4 marks)
Total heat input = Thermal input to DRI + Thermal input to CPP + Thermal Input of Import
Imported electricity thermal eq. = 120,000 × 2700 = 324.0 Million kcal/day
Total heat input = 2,187.5 + 554.55 + 324.0 = 3066.05 Million kcal/day
SEC = 3066.05 / 297.5 = 10.31 Million kcal/t
6) Benchmark Comparison & Comment (3 marks)
Benchmark = 6.5 Million kcal/t;
Actual = 10.31 Million kcal/t (~58.6% higher)
Comments:
Need reduction in DRI coal use,
improved SMS SPC,
better CPP efficiency,
adoption of WHR, and auxiliary load reduction.

Or

N-4 (D)

A composite textile mill uses stenters for drying and heat-setting applications, currently the stenter system is running on a coal-fired boiler, and there is a proposal to modify the system to a biomass-fired thermic fluid heater. The relevant data is given below:

Parameter	Value
Cloth inlet temperature	32 °C
Cloth outlet temperature	78 °C
Cloth inlet moisture	65 %
Cloth outlet moisture	6 %
Stenter output	1250 kg/hr
Stenter Efficiency	48%
Latent heat of inlet steam to stenter at 10 bar	477 kcal/kg
Sensible heat of inlet steam to stenter at 10 bar	184 kcal/kg
Dryness fraction of inlet steam	0.95
Condensate temperature	87 °C
Boiler efficiency (coal-fired)	72 %
Distribution line losses – Boiler	5 %
Cost of coal	Rs. 7000/ton
GCV of Coal	4200 kCal/kg
Operating hours per annum	7200 hours
Thermic fluid heater efficiency	70 %
Distribution line losses – Thermic Fluid Heater	6 %
Biomass cost	Rs. 4000/ton
GCV of Biomass	3800 kCal/kg

Calculate the following:

a) Steam and coal required for the current coal-fired boiler. 8 Marks

b) If the system is converted to a biomass-fired thermic fluid heater, calculate the biomass required and its associated cost per hour. 8 Marks

	c) Estimate the difference in annual fuel cost savings. 4 Marks

N-4 (D) Ans

a) Steam and Coal Required for the Coal-Fired Boiler

Dry cloth mass:
m_dry = 1,250 × (1 − 0.06) = 1,175 kg/h

Wet inlet mass and moisture evaporated:
m_inlet = 1,175 / 0.35 = 3,357 kg/h
Moisture evaporated = 3,357 − 1,250 = 2,107 kg/h

Heat required to evaporate moisture:
Q_evap = 2,107x[540 +(78-32)]
= 2,107 × 586 = 12,34,702 kcal/h

Heat input to stenter (48% efficiency):
Q_stenter = 12,34,702 / 0.48 = 25,72,296 kcal/h

Steam required:
h_steam = 0.95 × 477 + 184 = 637.15 kcal/kg
Also condensate leaves at 87°C = 87 kCal/kg
Required Steam = 2,567,490 / (637.15-87) = 4675 kg/h

Boiler output required (5% distribution loss):
Q_boiler_out = 25,72,296 / 0.95 = 27,07,680 kcal/h

Boiler heat input (72% efficiency):
Q_boiler_in = 27,07,680 / 0.72 = 37,60,666 kcal/h

Coal required:
Coal = 37,60,666 / 4,200 = 895.4 kg/h = 0.895 t/h

Coal cost per hour:
Cost = 0.895 × 7,000 = Rs. 6265 Rs/hr

b) Biomass Required & Cost per Hour – Thermic Fluid Heater (6% Loss)

Heater output required (6% distribution loss):
Q_heater_out = 25,72,296 / 0.94 = 2,736,485.106383 kcal/h

TFH thermal input (70% efficiency):
Q_TFH_in = 2,736,485.106383 / 0.70 = 3,909,264.437689 kcal/h

Biomass required:
Biomass = 3,909,264.437689/ 3,800 ≈ 1,028.22485255 kg/h = 1.028 t/h

Biomass cost per hour:
Cost = 1.028 × 4,000 = Rs. 4112 Rs/hr

c) Annual Fuel Cost Savings
Hourly Fuel Saving:
Saving = 6265 − 4112 = Rs. 2153 Rs/hr

Annual Saving (7,200 h/year):
Annual Saving = 2153 × 7,200 = Rs. 1,55,01,600 ≈ Rs. 1.55 crore/year

………… **End of Section - III** …………