Ref. No. **Ex/PG/PE/T/129A/2017**

M. POWER 1ST YR. 2ND SEM. EXAMINATION, 2017

SUBJECT: ***ADVANCED POWER CYCLES AND ECONOMICS***

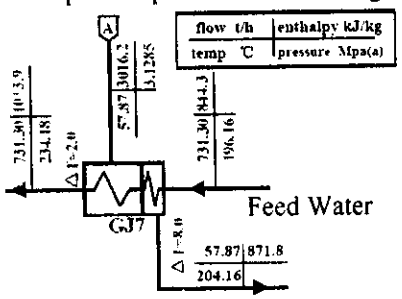
Time: Three Hours **(Full Marks 100)**

Answer any 5

1.

i. What is the difference between *restricted* and *absolute* dead states? If air contains 21.01% by volume of oxygen, evaluate the chemical exergy of 5 kg of pure oxygen gas at p_0 = 1 ata and T_0=298 K **2+4=6**

ii. The regenerative HP feed heater (surface type) of a power plant has the design parameters as described in the figure in the right. But, because of scale formation in the tubes, actual measurements show that the TTD and DCA have increased by 2 °C each (the bled steam (A) parameters have remained unchanged). If the cost of electricity produced by this power plant is Rs. 4.5/ kWh, estimate the net financial loss you would incur in one year if you decide not to carry out a proper maintenance to restore its performance. **9**



iii. In an industrial furnace, why is it important to match the source and the end-use temperatures? Why is co-generation a thermodynamically favorable option for plants that require process heat at low-temperature? **5**

2.

i. State the purpose of inlet fogging in GT. **2**

ii. Deduce an expression of an ideal regenerative GT cycle efficiency in terms of the pressure ratio r, adiabatic index γ, and temperature ratio t, and show that the cycle efficiency decreases as r increases. Deduce the expression of the pressure ratio, below which the purpose of regeneration is defeated. **8**

iii. Deduce the expression of efficiency of an actual regenerative GT cycle in terms of the three above parameters (r, γ, t), the combustion chamber efficiency (η_{cc}), and isentropic efficiencies of the turbine (η_T) and compressor (η_C). **10**

3.

A GTCC plant operates with simple GT cycle with HRSG. The GT, HRSG and ST operating parameters are as follows:

GT Cycle: Temperature ratio = 3.33; Pressure ratio = 6; Isentropic efficiencies for compressor and turbine are 85% and 90%, respectively; GT output = 100 MW; Ambient Air temperature = 25 °C.

HRSG: Pinch point temperature difference 20°C; Acid dew point = 170 °C. Exit gas temperature is to be maintained at least 5 °C above the acid dew point.

Steam Cycle: Simple Rankine cycle with boiler and condenser back pressures of 30 bar and 0.02 bars, respectively. Assume steam turbine expansion isentropic, and neglect pump work.

Determine, (i) GT cycle efficiency, (ii) ST cycle output, and (iii) Overall plant efficiency **20**

4.

i. What do you mean by EFGT? What is the salient advantage of EFGT over conventional GT cycle? **3**

ii. Draw a neat sketch of an EFGT-Combined cycle with gasifier and label different salient components of it. **5**

iii. In a supplementary fired GTCC plant, a fraction (x) of the total heat is supplied, in terms of vacuum residue fuels, to the duct burners of the HRSG. The open cycle GT operates in a simple cycle (consider ideal cycle) at a pressure ratio of 5, while the steam cycle has a net heat rate of 10,000 kJ/kWh. The efficiency of HRSG is 85%. (i) Derive an expression for the overall plant efficiency for the configuration and (ii) calculate its value for x=10%. 6+6 = 12

5.

i. Write down the basic steps of gasification process. 5

ii. What are the three basic types of gasifiers used in IGCC power plants? Which type of gasifier produces the highest temperature of flue gas? Which type of gasifier can burn the poorest grade of coal? 3+2=5

iii. With a neat sketch of the basic building blocks, explain the working procedure of an oxygen blown IGCC cycle. 7

iv. What is the rationale of using NH_3-water solution in Kalina cycle? 3

6.

As a project manager of a power project, you are to select a 250 MW (gross) steam turbine-generator set (including the turbine auxiliaries) out of the following 3 models of proposed by three TG manufacturing companies:

TG Model	TG Model A	TG Model B	TG Model C
GHR (Kcal/ kWh)	2080	2000	1950
Quoted price of TG set (Incl. taxes) (Rs. Millions)	1600	1800	2000
Incremental cost of interfacing equipment (assuming model B as the base case) (Rs. Millions)	20	0	60
Interfacing Boiler Efficiency	87%	87%	90%

Other data:

1. Landed cost of coal = Rs. 8 per kg, GCV of coal = 4000 kCal/ kg
2. Annual insurance to be paid on the cost of equipment @0.5%
3. Discounting rate applicable = 10%
4. Accounting period = 20 years.
5. Predicted plant load factor = 80%

Select the best model for the power plant. 20

7.

a) The input-output relationship of a thermal power plant is expressed as:

$$I = a_0 + a_1 L + a_2 L^2 + a_3 L^3,$$

while I = input and L = output (load) of the plant, expressed in the same unit. Explain the significance of a_0, a_1, a_2, and a_3. 3

b) Show that the best-efficiency point of operation of a power generating unit is obtained when the *Incremental Rate* on the machine is equal to the *Heat Rate*. 3

c) The input-output expressions for two coal-fired generating stations connected to the same grid are as follows:

Unit	Capacity (MW)	I/L curves (MW/ MW)	C.V. of Coal (kCal/ kg)	Cost of Coal (Rs. / 1000 kg)
A	60	$I_A = 12.0 + 0.5\ L_A + 0.03\ L_A^2$	4000	1200
B	40	$I_B = 25.0 + 0.3\ L_B + 0.05\ L_B^2$	3500	1000

What will be the load sharing between the units for a total load of 20 MW, 50 MW and 100 MW? **14**

8.

The salient project data (as per DPR) of a 500 MW_e (net) power project are given below:

(a) Project cost = Rs. 2500 Cr.
(b) Debt : Equity = 70:30 ; Interest rate = 10% ;
(c) Normative PLF = 75% ; Normative NPHR = 2500 kCal/kWh ; Normative Fuel Oil Consumption = 3.5 ml/kWh
(d) Incentive = 1% additional ROE for every 10% increase over the normative
(e) Cost of coal = Rs. 1500 per 1000 kg ; GCV of coal = 4000 kCal/kg
(f) Cost of Fuel Oil = Rs 100 per Lit ; GCV of Fuel Oil = 10000 kCal/lit

Calculate both (a) the monthly fixed and variable charges and (b) the tariff of electricity as per the GOI Notification (CEA Norm) if the plant is to operate at (i) 50% PLF, (ii) 75% PLF and (iii) 85% PLF.

Neglect the tax on income, and the interest on working capital. **20**