Ref. No. Ex /PE/T/322/2019

B.E. POWER ENGINEERING THIRD YEAR SECOND SEMESTER EXAMINATION, 2019

SUBJECT: **POWER PLANT CYCLES AND SYSTEMS**

Time: Three Hours **100 Marks**

Part 1: 10 Marks

1.

(a) What are the merits of an ORC over steam Rankine cycle? For what types of applications ORCs are used? **4**

(b) Modern high-capacity steam power plants are mostly designed to operate at supercritical pressure - why? **2**

(c) What is the purpose of reheating in a steam power plant? How does reheating influence the cycle efficiency? When is double-reheating used? **1+1+2=4**

OR

(a) What is the purpose of GT inlet fogging? Where is the fogging done? **2**

(b) A mercury-steam binary cycle uses a conventional fuel-fired boiler that has an efficiency of 90%. 70% of the utilized heat in the boiler goes to the topping cycle, while 30% goes to the superheater and economizer sections of the steam cycle. The mercury-condenser doubles as the evaporator for the steam cycle. The bottoming cycle rejects heat directly to the surroundings. Find the overall efficiency of the combined cycle if the mercury and steam cycles have efficiencies of 25% and 30%, respectively. **6**

(c) What do you mean by IGCC? What is the most striking advantage of IGCC? **2**

Part II: Answer any 2 (40 Marks)

2.

A non-reheat regenerative vapor power cycle for a 100 MW nuclear power plant operates between a boiler pressure of 100 bar and a condenser back pressure of 0.1 bar. The steam exiting from the turbine is dry saturated. The cycle employs two direct contact type feedwater heaters that receive bled steam from the turbine. Find out the optimum extraction pressures that will produce the maximum cycle efficiency. At what temperature would the feed water enter the economizer section of the boiler? What will be the corresponding cycle heat rate? Neglect Pump work in your analysis. **20**

3.

(a) Deduce the expression of a regenerative GT cycle efficiency in terms of the pressure ratio r, adiabatic index γ, temperature ratio t, combustion chamber efficiency η_{cc}, and the isentropic efficiencies η_c of the compressor and η_T of the turbine, and the heat exchanger effectiveness R. Also deduce the expression for work ratio. **14**

(b) The following data refers to the gas turbine set described above: Isentropic efficiency of the compressor: 82%, Isentropic efficiency of the turbine: 85%, pressure ratio: 7:1, Maximum cycle temperature: 1000 K, Combustion efficiency: 97%, Calorific value of fuel: 43.1 MJ/kg, Air mass flow rate: 20 kg/s, Effectiveness of the regenerator: 75%, Ambient temperature and pressure: 327 K, 1 bar. Calculate the output, specific fuel consumption and overall thermal efficiency of the cycle. **6**

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100 Marks

4.

Consider the HBD of a 330 MW steam power plant operating under VWO operation with 3% make-up (See the figure attached at the end). Find (a) the Gross Heat Rates as per ASME PTC 6, (b) Isentropic efficiency of the HP Turbine-Control valve system taken together, (c) specific steam consumption, (d) heat rate penalty due to cycle make-up. (e) Total heat rejected from the cycle, (f) Dryness fraction of the steam at LPT exhaust, (g) Feed water temperature rise in the heater with pumped ahead configuration, (h) BFP and CEP powers if the combined mechanical and electrical efficiency of the drives for both is 95%, (i) pressure at the outermost sealing pocket of the turbine gland, (j) flow capacity of the boiler feed control station. Power consumed by the TG auxiliaries = 520 kW, Generator excitation power = 980 kW. Electric output at the generator terminal under VWO operation is 343425 kW. **20**

Part III (Answer any one 20 Marks)

5.

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

GT Cycle: T_{max} = 1050 K, T_{amb} = 300 K, r_p = 6, isentropic efficiencies for compressor and turbine are 85% and 90%, respectively, GT output = 150 MW

HRSG: Pinch point temperature difference 20 °C, Acid dew point = 160 °C. Exit gas temperature is to be maintained at least 10 °C above the acid dew point.

Steam Cycle: Simple Rankine cycle with boiler and condenser back pressures of 20 bar and 0.05 bars, respectively. Assume steam turbine expansion isentropic, and neglect pump work.

Draw the cycle arrangement and the T-Q diagram for the HRSG. Also determine, (i) GT cycle efficiency, (ii) mass flow rates of the GT and ST cycles, (iii) ST cycle output, and (iii) Overall plant efficiency **20**

6.

(a) Draw a neat sketch of a PFBC-GTCC plant and deduce the expression of its efficiency in terms of the individual cycle efficiency, fraction of heat utilized in the GT and the overall steam generator efficiency. **10**

(b) What is the major advantage of the PFBC-GTCC plant over a regular GTCC? **2**

(b) Why dual pressure steam cycles often preferred in GTCC plants? **5**

(c) What is the purpose of supplementary firing in HRSG? Does it lead to an improvement in efficiency? **3**

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Part IV: <u>any two</u> (30 Marks)

7.

(a) Draw a neat diagram of a deaerator and explain its principle of operation. **6**

(b) How are the TTD and DCA of a surface-type feed water heater defined? Can the TTD be negative? **4**

(c) What do you mean by "cold-end optimization" of a steam turbine cycle? **5**

8.

(a) Draw a neat sketch of the HP-LP Bypass system of a modern steam power plant. What are the capabilities of a 100% HP-LP Bypass station? **5+2=7**

(c) Why is it often necessary to go for attemperation of SH and RH steam? Why is it more detrimental to have RH spray than the SH spray? **2+3=5**

(d) What are the possible sources of cycle fluid loss in a modern steam power plant? Why does a make-up flow inevitably leads to an increase in cycle heat rate? **2+1=3**

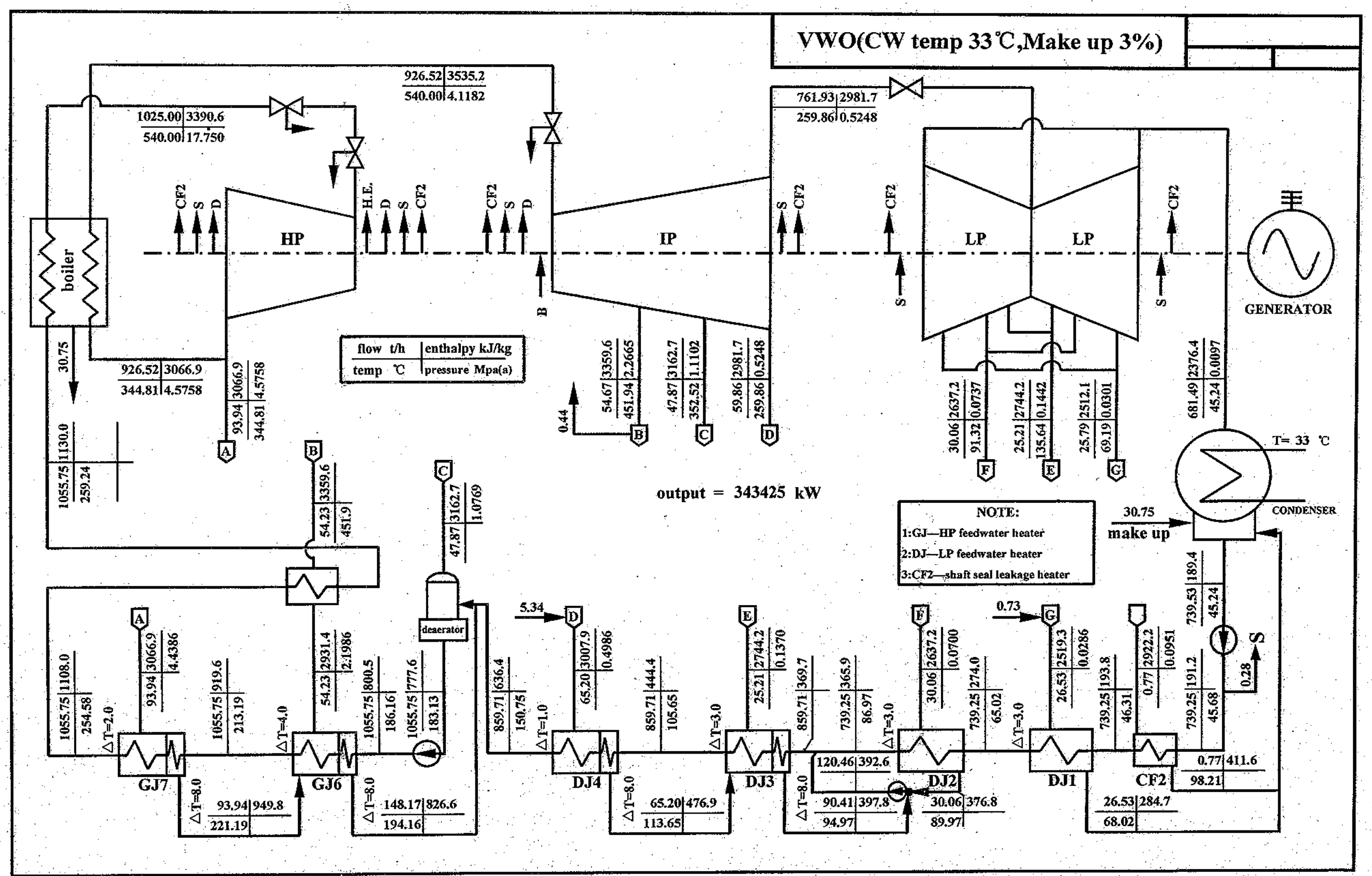
9.

(a) How does the heat rate of a power plant change with load? What is the "best-efficiency" load of a steam power plant **3+1=4**

(b) What do you mean by PG Test of a power plant? When are they conducted? **4**

(c) What do you mean by STEP Factor? How are they evaluated for an operating power plant? **4**

(d) Define cooling tower range, approach and cooling range. **3**



VWO(CW temp 33℃,Make up 3%)
HP
IP
LP
LP
GENERATOR
CONDENSER
T= 33 ℃
boiler
deaerator
output = 343425 kW
flow t/h | enthalpy kJ/kg
temp ℃ | pressure Mpa(a)
NOTE:
1:GJ—HP feedwater heater
2:DJ—LP feedwater heater
3:CF2—shaft seal leakage heater
30.75
make up
1025.00 3390.6
540.00 17.750
926.52 3535.2
540.00 4.1182
926.52 3066.9
344.81 4.5758
761.93 2981.7
259.86 0.5248
93.94 3066.9
344.81 4.5758
54.67 3359.6
451.94 2.2665
47.87 3162.7
352.52 1.1102
59.86 2981.7
259.86 0.5248
30.06 2637.2
91.32 0.0737
25.21 2744.2
135.64 0.1442
25.79 2512.1
69.19 0.0301
681.49 2376.4
45.24 0.0097
1055.75 1130.0
259.24
54.23 3359.6
451.9
47.87 3162.7
1.0769
1055.75 1108.0
254.58
93.94 3066.9
4.4386
1055.75 919.6
213.19
54.23 2931.4
2.1986
1055.75 800.5
186.16
1055.75 777.6
183.13
859.71 636.4
150.75
65.20 3007.9
0.4986
859.71 444.4
105.65
25.21 2744.2
0.1370
859.71 369.7
739.25 365.9
86.97
30.06 2637.2
0.0700
739.25 274.0
65.02
26.53 2519.3
0.0286
739.25 193.8
46.31
0.77 2922.2
0.0951
739.25 191.2
45.68
739.53 189.4
45.24
0.77 411.6
98.21
26.53 284.7
68.02
30.06 376.8
89.97
90.41 397.8
94.97
120.46 392.6
65.20 476.9
113.65
148.17 826.6
194.16
93.94 949.8
221.19
GJ7
GJ6
DJ4
DJ3
DJ2
DJ1
CF2
ΔT=2.0
ΔT=4.0
ΔT=1.0
ΔT=3.0
ΔT=8.0
0.44
5.34
0.73
0.28
H.E.