INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Mid-Autumn Semester 2017-18

Date of Examination: ____________ **Session (FN/AN)** ____ **Duration** 2 hrs **Full Marks** 100

Subject No.: ME40701/ME40603 ____________ **Subject : Applied Thermofluids-2**

Department/Center/School: Mechanical Engineering

Specific charts, graph paper, log book etc., required No

Special Instructions (if any) : No

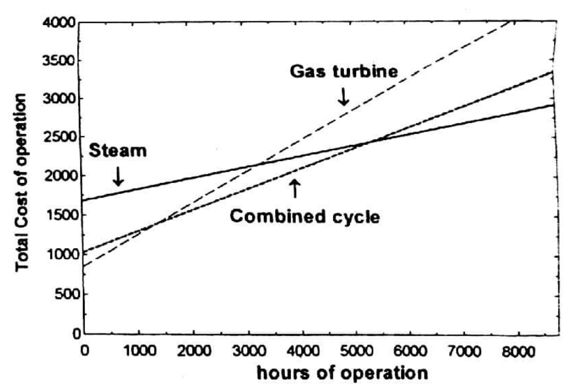
Answer all questions. Make suitable assumptions, if required, but state them clearly

Part-A (60 marks)

1. With the help of suitable figures and equations, and using the concept of **entropic mean temperature of heat addition**, prove that the efficiency of a standard Rankine cycle is always lower than that of a Carnot cycle operating between the same minimum and maximum cycle temperatures. State the modification(s) that are made to this Rankine cycle which **positively improve(s)** the efficiency of the cycle. **(10)**

2. For an ideal Brayton cycle operating between minimum and maximum cycle temperatures of T_1 & T_3, respectively, find expressions for **a)** the maximum possible pressure ratio for finite net work output, **b)** the pressure ratio at which net work output is maximum, and **c)** the expressions for thermal efficiencies corresponding to cases (a) and (b). All the expressions should be in terms of T_1, T_3 and γ ($\gamma = c_p/c_v$) only. **(15)**

3. *Explain briefly* with the help of a **neat sketch** what you understand *by a* **combined cycle power plant**. Shown here is a graph that gives *comparison between steam cycles, gas turbine cycles and combined cycles in terms of total cost of operation (in some arbitrary units) vs* hours of operation. What **conclusions** can be drawn from this graph and how they can be put to practical use in planning power generation systems? **(10)**



4. Define adiabatic flame temperature for a combustion reaction and state the factors which affect this temperature. Find the adiabatic flame temperature for combustion of **carbon** with **200 %** theoretical air in a **furnace** using the data given below. Assume that both the fuel and air are at standard state. **(10)**

Standard enthalpy of formation: CO_2 = **–8946.1 kJ/kg**; c_p: CO_2: **1.322** kJ/kg.K; O_2: **1.031** kJ/kg.K; N_2: **1.113** kJ/kg.K

5. A **15 m tall**, rectangular, natural circulation type power plant boiler has **1** downcomer and **2** risers (in parallel). The inner diameters of downcomer and riser tubes are **150 mm** and **60 mm**, respectively. Water flowing through the downcomer has a density of **580 kg/m³**, while the average density of the 2-phase mixture in the riser tubes is **350 kg/m³**. At steady state the buoyancy head developed due to density difference is balanced by frictional pressure drop through the system and pressure losses due to momentum change. **a)** If the frictional pressure drop of water through the downcomer tube is **25%** of the total pressure loss, find the mass flow rate of water through the system under steady

state. **b)** If the quality of the water at riser exit is **0.15**, what is the rate at which heat is transferred to the riser tubes? **c)** Find the average overall heat transfer coefficient of the riser tubes if the average flue gas temperature is **1200°C**, and boiling taking place at **346°C**.

Take the enthalpy values of water as: **1650 kJ/kg** (saturated liquid) & **2580 kJ/kg** (saturated vapour). For calculating frictional pressure drop, Δp_f, through the downcomer tube, use the Darcy-Weisbach equation given below, taking the value of friction factor, f as **0.02**. Acceleration due to gravity = **9.81 m/s²**.

$$\Delta p_f = \left(\frac{fL}{D}\right)\frac{\rho V^2}{2}$$

In the above equation, L is the length of the tube, D is the diameter, ρ is the density and V is the fluid velocity. **(15)**

End of Part-A

Part-B (40 marks)

Density of water **1000 kg/m³**, acceleration due to gravity **9.81 m/sec²**.

Make suitable assumptions whenever necessary and underline them.

6. In a gas turbine, there are m stages each having the same stage pressure ratio (p_s). The static pressure at the inlet to the turbine is p_1 whereas the static pressure at the outlet is p_{m+1}. The stage efficiency is η_s whereas the turbine overall efficiency is η_t. The ratio of the specific heats is given by γ. (a) Draw the process in the h-s plane. (b) Derive an expression for the turbine overall efficiency η_t as a function of stage pressure ratio (p_s), stage efficiency η_s, number of stages (m). **4+8=12**

7. A pump is required to raise water in a tank situated at a height of **80 m**. The water flow rate in the delivery pipe of diameter **40 mm** is **7.5 liter per second**. Due to pipe friction, the equivalent length for head loss is **75 m**. The pipe friction factor can be taken as **0.024**. The leakage loss in the pump is **0.2 liter per second**. The hydraulic efficiency in the pump is **93%** and the mechanical efficiency is **92%**. (a) Draw a schematic diagram showing the losses at each stage. (b) Find out the power at each stage of the calculation and (c) find out the power required by the motor to drive the impeller. **4+6+4=14**

8. A hydraulic turbine power house is located **110 m** down a water reservoir dam. Due to the pipe friction losses in the penstock, **10 m** of water head loss has occurred. The water flow rate is **15 m³/s** out of which **0.3 m³/s** leakage has occurred. The hydraulic efficiency and the mechanical efficiencies are **93%** and **91%** respectively. The turbine rotational speed is **750 rpm**. (a) Find out the output power of the turbine. (b) Among flow coefficient, head coefficient and power coefficient, which are relevant to calculate turbine specific speed? (c) Derive the turbine specific speed from the non-dimensional numbers. (d) Find out the specific speed of the turbine in rad/s. **4+2+4+4=14**

End of the paper