INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

Date....................FN / AN Time : 2 / 3 Hrs. Full Marks 60........ No. of Students 68..........

Autumn / Spring Semester, ...Deptt. Mechanical..................................... Sub. No. ME 40603.........

.... Yr. B.Tech. (H) / B.Arch. (H) / M.Sc. Sub. Name Applied Thermo Fluids - II........................

Instruction Steam Tables to be provided..

Answer all questions. All questions carry equal marks.

1. In an ideal Rankine cycle with superheat the temperature in the condenser is 45°C, saturated liquid exits the condenser, the temperature at turbine inlet is 500°C and the quality of steam at turbine exit is 0.95. What is the thermal efficiency of the cycle? Now if there is no condenser and the water is taken from a natural source at 25°C and the steam from the turbine exit is directly discharged to the atmosphere at 1 bar, define and calculate the thermal efficiency. Assume again that steam quality at turbine exit is 0.95 and temperature of steam at turbine inlet is 500°C.

2. Water circulates from the steam drum via the downcomer to a bottom header and up the riser where it partially boils, because of heating, and back to the steam drum. The void fraction α of the two-phase mixture in the riser is defined by

$$\alpha = \frac{\text{volume of vapour}}{\text{volume of vapour } + \text{ liquid}}$$

Prove that this is related to the quality of steam x flowing through the riser by

$$x = \frac{1}{1 + \left(\frac{1-\alpha}{\alpha}\right)\frac{1}{\psi}}$$

where

$$\psi = \frac{v_f}{v_g} S$$

v_f and v_g are the specific volumes of liquid and vapour and S the slip ratio is defined by

$$S = \frac{V_g}{V_f}$$

where V_f and V_g are the average liquid and vapour velocities at any cross-section of the riser. The density ρ_m of the two-phase mixture is given by

$$\rho_m = (1-\alpha)\rho_f + \alpha\rho_g$$

where ρ_f and ρ_g are densities of liquid and vapour. The average density in the riser is defined by

$$\bar{\rho}_r = \frac{1}{H}\int_0^H \rho_m(z)\, dz$$

where z is the axial distance from the bottom of the riser. Assuming uniform axial heating and that we have saturated liquid at the bottom of the riser, evaluate this integral, assuming ψ to be a constant, to obtain an expression for $\bar{\rho}_r$ in terms of the void fraction α_e at riser exit.

3. In a velocity compounded impulse turbine, if ${}_1V_1$ is the velocity of steam issuing from the nozzle, making an angle α_1 with the tangential direction and n is the number of rows of rotating blades, what is the optimum blade velocity u_{opt}? Assume that the blades in each row (both rotating and stationary) are equiangular, i.e., have equal inlet and exit angles and that there is no friction loss in the blades, so that the velocity coefficient $k = 1$. What is the work ratio between the different rows of moving blades assuming that the blade velocity has the optimum value?