Thermodynamics Qualifiers
Spring 2021

(Total Points : 100)

1. Steam enters the first-stage turbine shown in Fig. 1 at 40 bar and 500°C with a volumetric flow rate of 90 m^3/min. Steam exits the turbine at 20 bar and 400°C. The steam is then reheated at constant pressure to 500°C before entering the second-stage turbine. Steam leaves the second stage as saturated vapor at 0.6 bar. For operation at steady state, and ignoring stray heat transfer and kinetic and potential energy effects, determine the
(a) mass flow rate of the steam, in kg/h.
(b) total power produced by the two stages of the turbine, in kW.
(c) rate of heat transfer to the steam flowing through the reheater, in kW.

(30 points)

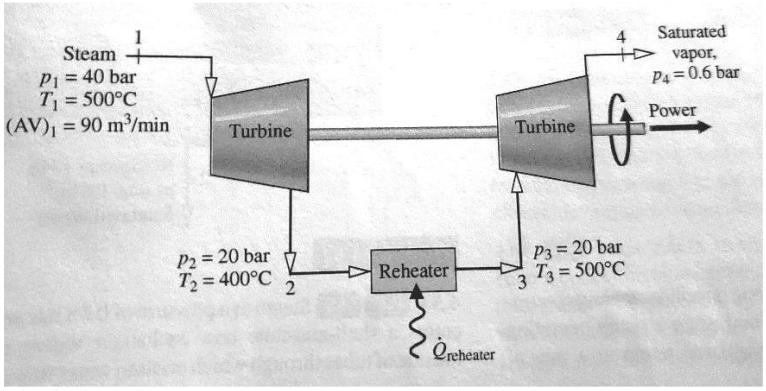

Fig.1 Schematic sketch of proposed system

2. An inventor claims that at steady state the device shown in Fig. 2 develops power from entering and exiting streams of water at a rate of 1638 kW. The accompanying table provides data for inlet 1 and 2 and exit 4. The pressure at exit 3 is 3 bar. Stray heat transfer and kinetic and potential energy effects are negligible. Evaluate the inventor's claim.

(25 points)

State	$\dot{m}$ (kg/s)	p (bar)	T (°C)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg·K)
1	5	3	500	1.1870	3130.0	3486.0	8.3251
2	1	1	320	2.7320	2841.5	3114	8.2849
4	3	4	400	0.7730	2964.4	3273.4	7.8985

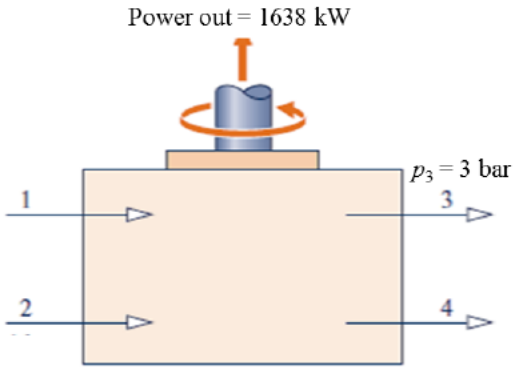

Fig. 2

3. A heating system must maintain the interior of a building at TH = 20 °C when the outside temperature is TC = 2 °C. If the rate of heat transfer from the building through its walls and roof is 16.4 kW, determine the electrical power required, in kW, to heat the building using (a) electrical-resistance heating (b) a heat pump whose coefficient of performance is 3.0, (c) a reversible heat pump operating between hot and cold reservoirs at 20°C and 2°C.

(20 points)

4. Air at pressure p=300kPa, temperature T=77 °C flows in a straight pipe at a rate of 18kg/min with a velocity of 25 m/s. Determine (a) the diameter of the pipe in m, (b) the rate of energy transport in kW including kinetic energy, (c) the error in rate of energy transport when the kinetic energy is neglected.

(25 points)