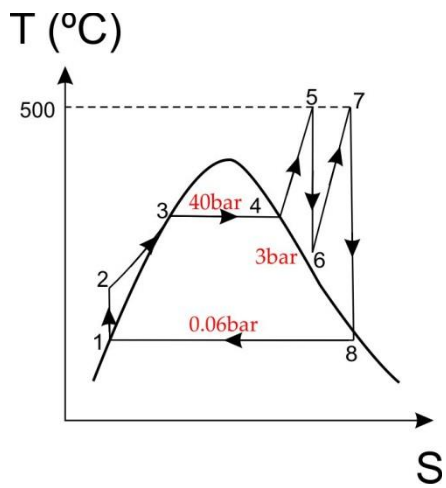
Example 3C

Steam is supplied to a two-stage turbine at 40bar and 500°C. In the first stage the steam expands isentropically to 3bar at which pressure 2500kg/h of steam is extracted for process work. The reminder is reheated to 500°C and then expanded isentropically to 0.06bar. The by-product power from the plant is required to be 6000kW. Calculate the amount of steam required from the boiler and the heat supplied. <u>Neglect feed-pump terms</u>, and assume that the process condensate returns at the saturation temperature to mix adiabatically with the condensate from the condenser.



$$h_{5@500^{o}C,40bar,\,superheated\ vapor} = 3445.3\,kJ/kg$$

Considering;

$$s_{5@500^{o}C,40bar,\,superheated\ vapor} = s_{6@3bar} = 7.069\,kJ/kg.K$$
$$s_{sat@3bar} = 6.9919\,kJ/kg.K < 7.069\,kJ/kg.K$$
$$\therefore \text{Point 6 at superheated vapour}$$

$$h_{6@3bar} = 2757.69\,kJ/kg$$

$$h_{7@3bar,500^{o}C} = 3486\,kJ/kg$$

$$s_{7@3bar,500^{o}C} = 8.3251\,kJ/kgK = s_{8@0.06bar}$$

$$s_{8@0.06bar,f} = 0.5209\,kJ/kgK$$
$$s_{8@0.06bar,g} = 8.3306\,kJ/kgK$$
$$s = s_f + xs_g$$
$$8.3251 = 0.5209 + x8.3306$$
$$x = 0.9368$$

$$h_{8@0.06bar,f} = 151.506\,\text{kJ/kgK}$$
$$h_{8@0.06bar,g} = 2567.38\,\text{kJ/kgK}$$
$$h = h_f + xh_g$$
$$= 151.506 + (0.9368 \times 2567.38)$$
$$h_8 = 2556.63\,\text{kJ/kg}$$

$$h_{1@0.06bar,f} = 151.506\,\text{kJ/kgK}$$

$$W_{out} = (h_5 - h_6) + (h_7 - h_8)$$
$$= (3445.3 - 2757.69) + (3486 - 2556.63) = 1617\,\text{kJ/kg}$$
$$= (687.61) + (929.37) = 1617\,\text{kJ/kg}$$
$$q_{in} = (h_5 - h_1) + (h_7 - h_6) = (3445.3 - 151.506) + (3486 - 2757.69) = 4022.104\text{kJ/kg}$$

$$P_{total} = (\dot{m}_{w,out,1} \times w_{out,1}) + (\dot{m}_{w,out,2} \times w_{out,2})$$
$$6000\text{kW} = (\dot{m}_{w,out,1} \times 687.61) + \left(\left(2500 \times \frac{1}{60 \times 60}\right) \times 929.37\right)$$
$$\dot{m}_{w,out,1} = 7.787\,\text{kg/s}$$

$$P_{q,in} = (\dot{m}_{w,out,1} \times q_{in}) = 7.787 \times 4022.104 = 31320.12\text{kW}$$