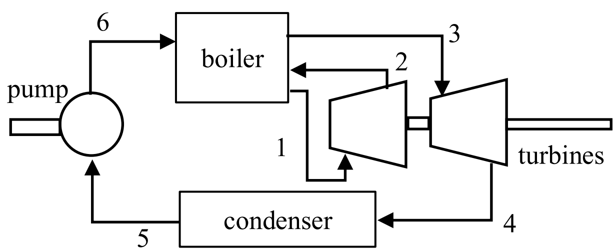
Consider a vapor power cycle with reheat where the working fluid is water. The pump and turbines operate adiabatically. At the exit of both turbines, the water exits as saturated water vapor. The mass flow rate through the system is 2.1 kg/s.

a. Determine the net power developed by the cycle, in kW.
b. Determine the thermal efficiency of the power cycle.
c. Sketch the cycle on a *T-s* plot, indicating states, paths, and isobars. You needn't include numerical values for the properties.

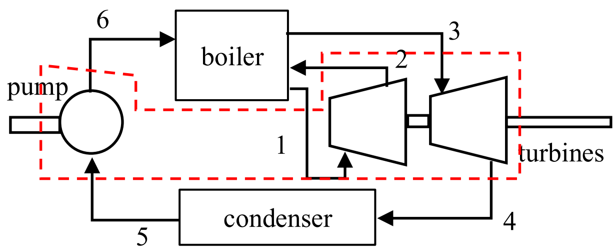


State	*p* [bar (abs)]	*h* [kJ/kg]	*x*
1	160	3355.6	-
2	15	2791.0	1
3	15	3169.8	-
4	1.5	2693.1	1
5	1.5	466.97	0
6	160	486.74	-

SOLUTION:
Applying Conservation of Mass to individual control volumes surrounding each component and assuming steady flow gives,

$$\dot{m} = \dot{m}_1 = \dot{m}_2 = \dot{m}_3 = \dot{m}_4 = \dot{m}_5 = \dot{m}_6. \quad (1)$$

Apply the 1st Law to a control volume that surrounds both turbines and the pump.



$$\frac{dE_{CV}}{dt} = \dot{Q}_{into\ CV} - \dot{W}_{by\ CV} + \sum_{in} \dot{m}\left(h + \tfrac{1}{2}V^2 + gz\right) - \sum_{out} \dot{m}\left(h + \tfrac{1}{2}V^2 + gz\right), \quad (2)$$

where,

$$\frac{dE_{CV}}{dt} = 0 \text{ (Assuming steady state operation.)}, \quad (3)$$

$$\dot{Q}_{into\ CV} = 0 \text{ (Assuming adiabatic operation.)}, \quad (4)$$

$$\sum_{in} \dot{m}\left(h + \tfrac{1}{2}V^2 + gz\right) - \sum_{out} \dot{m}\left(h + \tfrac{1}{2}V^2 + gz\right) = \dot{m}(h_5 - h_6 + h_1 - h_2 + h_3 - h_4). \quad (5)$$

(The changes in kinetic and potential energies are assumed to be negligibly small.)

Substitute and simplify,

$$\dot{W}_{by\ CV} = \dot{m}(h_5 - h_6 + h_1 - h_2 + h_3 - h_4), \quad (6)$$

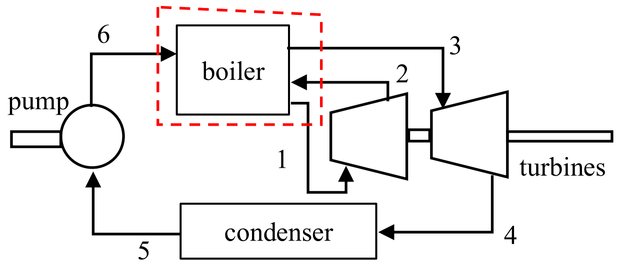
Using the given data,

$$\boxed{\dot{W}_{by\ CV} = 2150 \text{ kW}}.$$

The thermal efficiency of the power cycle is given by,

$$\eta \equiv \frac{\dot{W}_{net}}{\dot{Q}_{into}}. \quad (7)$$

To find the heat added to the power cycle, apply the 1st Law to a control volume that surrounds the boiler,



$$\frac{dE_{CV}}{dt} = \dot{Q}_{into\ CV} - \dot{W}_{by\ CV} + \sum_{in} \dot{m}\left(h + \tfrac{1}{2}V^2 + gz\right) - \sum_{out} \dot{m}\left(h + \tfrac{1}{2}V^2 + gz\right), \quad (8)$$

where,

$$\frac{dE_{CV}}{dt} = 0 \text{ (Assuming steady state operation.)}, \quad (9)$$

$$\dot{W}_{by\ CV} = 0 \text{ (The boiler is a passive device.)}, \quad (10)$$

$$\sum_{in} \dot{m}\left(h + \tfrac{1}{2}V^2 + gz\right) - \sum_{out} \dot{m}\left(h + \tfrac{1}{2}V^2 + gz\right) = \dot{m}(h_6 - h_1 + h_2 - h_3). \quad (11)$$

(The changes in kinetic and potential energies are assumed to be negligibly small.)

Substitute and simplify,

$$\dot{Q}_{into\ CV} = \dot{m}(h_1 - h_6 + h_3 - h_2), \quad (12)$$

Using the given data,

$\dot{Q}_{into\ CV}$ = 6820 kW.

Substituting values into Eq. (7) gives the power cycle thermal efficiency,

$\eta = 0.315$.