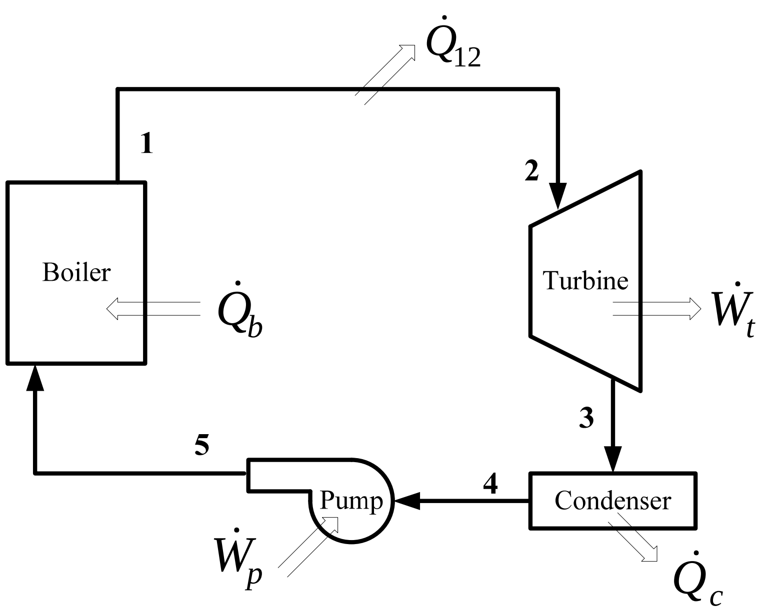
ENSC 388 Week # 5, Tutorial # 4–Energy Analysis of Control Volumes

Problem 1: Consider the simple steam power plant, as shown in the figure. The following data are for such a power plant.

Location	**Pressure**	**Temperature or Quality**
Leaving boiler	2.0 MPa	300°C
Entering turbine	1.9 MPa	290°C
Leaving turbine, entering condenser	15 kPa	90%
Leaving condenser, entering pump	14 kPa	45°C
Pump work = 4 kJ/kg		

Determine the following quantities per kilogram flowing through the unit:

a. Heat transfer in the line between boiler and turbine.
b. Turbine work.
c. Heat transfer in condenser.
d. Heat transfer in boiler.



Solution

Step 1: Write out what you are required to solve for (this is so you don't forget to answer everything the question is asking for)

Find:

a) q_{12} - Heat transfer in the line between boiler and turbine.
b) w_{23} - Turbine work.
c) q_{34} - Heat transfer in condenser.
d) q_{51} - Heat transfer in boiler.

Step 2: Prepare a data table

Data	Value	Data	Value
P_1	$2\ [MPa]$	T_1	$300\ [^\circ C]$
P_2	$1.9\ [MPa]$	T_2	$290\ [^\circ C]$
P_3	$15\ [kPa]$	x_3	0.9
P_4	$14\ [kPa]$	T_4	$45\ [^\circ C]$
w_p	$-4\ [kJ/kg]$		

Step 3: State your assumptions (you may have to add to your list of assumptions as you proceed in the problem)

Assumptions:

1) All processes are steady-state.
2) Changes in kinetic and potential energies are negligible.

Step 4: Calculations

There is a certain advantage in assigning a number to various points in the cycle. For this reason the subscripts i and e in the steady-state energy equation are often replaced by appropriate numbers.
Using the notation of the cycle, we have:

$$
\begin{cases}
h_1 = 3024.2 \left[{}^{kJ}\!/\!{}_{kg}\right] \\
h_2 = 3002.5 \left[{}^{kJ}\!/\!{}_{kg}\right]
\end{cases} \text{: from Table A - 6}
$$

$$h_3 = h_{f3} + x_3\, h_{fg3} = 225.94 + 0.9\,(2372.3) = 2361.0 \left[{}^{kJ}\!/\!{}_{kg}\right] \text{: from Table A - 5}$$

$$h_4 = h_f \,@\, 45^\circ C = 188.44 \left[{}^{kJ}\!/\!{}_{kg}\right] \qquad \text{: from Table A - 4}$$

a) For the control volume for the pipe line between the boiler and the turbine, the first law and solution are

$$q_{12} + h_1 = h_2 \Rightarrow\; q_{12} = h_2 - h_1 = 3002.5 - 3024.2 = -21.7\; kJ/kg \qquad \text{(Eq1)}$$

Note: in most application, pipes are well insulated to prevent (or minimize) heat losses to the surroundings; thus theses losses can be neglected.

b) A turbine is essentially an adiabatic machine. Therefore, it is reasonable to neglect heat transfer in the first law, so that

$$-w_{23} + h_2 = h_3 \Rightarrow\; w_{23} = h_2 - h_3 = 3002.5 - 2361.0 = 641.5\; kJ/kg \qquad \text{(Eq2)}$$

c) There is no work for the control volume enclosing the condenser. Therefore, the first law and solution are

$$q_{34} + h_3 = h_4 \Rightarrow\; q_{34} = h_4 - h_3 = 188.44 - 2361.0 = -2172.56\; kJ/kg \qquad \text{(Eq3)}$$

d) If we consider a control volume enclosing the boiler, the work is equal to zero, so that the first law becomes

$$q_{51} + h_5 = h_1 \qquad \text{(Eq4)}$$

The above equation requires the value of h_5, which can be found by taking a control volume around the pump.

$$-w_{45} + h_4 = h_5 \Rightarrow \; h_5 = -(-4) + 188.44 = 192.44 \; kJ/kg \qquad \text{(Eq5)}$$

Therefore, for the boiler,

$$q_{51} + h_5 = h_1 \Rightarrow \; q_{51} = h_1 - h_5 = 3024.2 - 192.44 = 2831.76 \; kJ/kg \qquad \text{(Eq6)}$$