ESO201A

Solution of
Quiz # 2 (Set A)
2022-23-I

1. Assumptions

For compressor: (i) steady state
(ii) $V_1 = 0$ (since V_1 is low)
(iii) $q = 0$
(iv) $\Delta PE = 0$
(1 point)

For aftercooler: (i) steady state
(ii) $W = 0$ (rigid boundary and no shaft or electrical work)
(iii) $\Delta PE = 0$
(iv) $\Delta KE = 0$ ($V_2 = V_3$)
(1 point)

In addition, CO_2 is treated as an ideal gas and flows are single stream. $h = f(T)$ only since CO_2 is considered as an ideal gas.

The schematic diagram of the combined system is shown in Fig. 1.

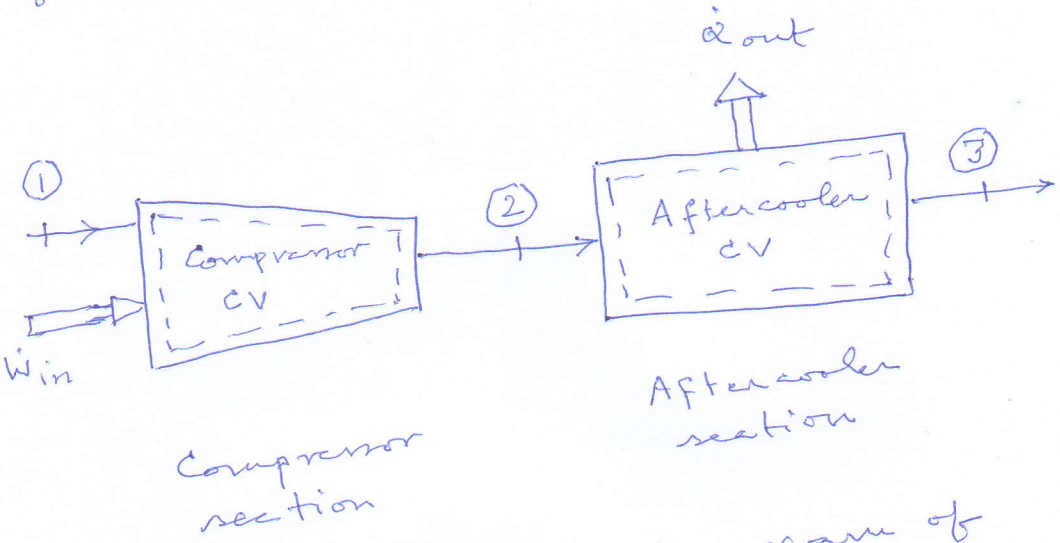

Fig. 1 Schematic diagram of the combined system

3 points for the diagram.
2 points for CVs.

Compressor

Applying the first law to the CV,

$$h_1 + q_{in} + w_{in} + \frac{1}{2}V_1^2 = q_{out} + w_{out} + \frac{1}{2}V_2^2 + h_2$$

$$\Rightarrow (q_{in}^{\,0} - q_{out}^{\,0}) - (w_{out}^{\,0} - w_{in}) + h_1 = \frac{1}{2}(V_2^2 - V_1^{2\,0}) + h_2$$

$$\Rightarrow w_{in} = (h_2 - h_1) + \frac{1}{2}v_2^2$$

$$= (401.5 - 198) + \frac{(25)^2}{2 \times 1000}$$

$$= 203.5 + 0.3125$$

$$= 203.8125$$

$$\simeq 203.8 \text{ kJ/kg} \quad (3 \text{ points})$$

Note:

$1 \frac{m^2}{s^2} = 1 \text{ J/kg}$

$= \frac{1}{1000} \text{ kJ/kg}$

$$\dot{m} = \frac{\dot{W}_{in}}{w_{in}} = \frac{50}{203.8} = 0.245 \text{ kg/s}$$

(1 point)

Aftercooler

Applying the first law to the CV,

$$q_{in} + w_{in} + \frac{1}{2}v_2^2 + h_2 = h_3 + \frac{1}{2}v_3^2 + q_{out} + w_{out}$$

$$\Rightarrow \cancel{q_{in}}^{\,0} - q_{out} = h_3 - h_2 \quad (\because v_2 = v_3,\ w_{in} = 0,\ w_{out} = 0)$$

$$\Rightarrow -q_{out} = 257.9 - 401.5$$

$$= -143.6$$

$$\Rightarrow q_{out} = 143.6 \text{ kJ/kg} \quad (3 \text{ points})$$

Hence, $\dot{Q}_{out} = \dot{m} q_{out}$

$$= 0.245 (143.6)$$

$$= 35.182$$

$$\simeq \boxed{35.2 \text{ kW}}$$

(1 point)