Exercise 2.9

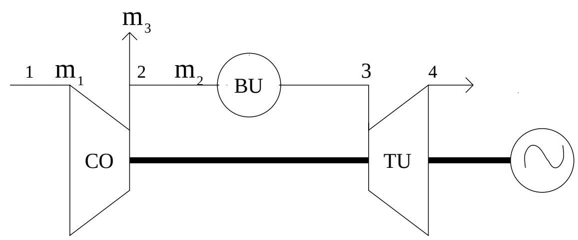

Figure 1: Auxiliary gas turbine

Problem definition: Air is bled from the main stream after the compressor.

Find:

A. Necessary mass flow to produce 200 kW when 1.5 kg/s air is bled at station 2.

B. Power with no bleed.

Solution:

a: The net power is:

$$W = \left(\underbrace{m_2 c_{p,g}(T_{03} - T_{04})}_{\text{Turbine power}} - \underbrace{\frac{m_1 c_{p,a}(T_{02} - T_{01})}{\eta_{m,rotor}}}_{\text{Power absorbed by compressor}} \right) \cdot \eta_{m,load} \tag{1}$$

where

$$m_2 = m_1 - m_3 = m_1 - 1.5$$

We have (C.R.S. p. 57):

$$\begin{cases} c_{p,a} = 1005 \text{ J/kg K} \ , \gamma_a = 1.40 \\ c_{p,g} = 1148 \text{ J/kg K} \ , \gamma_g = 1.333 \end{cases}$$

The compression and expansion obey (C.R.S. 2.11,2.12):

$$T_{02} - T_{01} = \frac{T_{01}}{\eta_c} \left(\left(\frac{P_{02}}{P_{01}} \right)^{\frac{\gamma_a - 1}{\gamma_a}} - 1 \right) \tag{2}$$

$$T_{03} - T_{04} = T_{03} \cdot \eta_t \left(1 - \frac{1}{\left(\frac{P_{03}}{P_{04}}\right)^{\frac{\gamma_g - 1}{\gamma_g}}} \right) \tag{3}$$

But we have that (pressure ratio on compressing side must equal pressure ratio on expanding side):

$$\frac{P_{02}}{P_{01}} = \frac{P_{03}}{P_{04}} + 0.12 = 3.80 \quad \Longrightarrow \quad \frac{P_{03}}{P_{04}} = 3.68$$

An introduction of the given data into 2 and 3 yields:

$$\begin{cases} T_{02} - T_{01} = 157.34 \text{ K} \\ T_{03} - T_{04} = 256.71 \text{ K} \end{cases}$$

Finally, 1 produces (solving for a power output of W = 200 kW):

$$m_1 = ... = 4.79 \text{ kg/s}$$

b: Setting $m_2 = m_1$ in 1 and using data from the previous exercise produces:

$$W = ... = 634 \text{ kW}$$