Given: $kJ := 1000J$

The power output of an adiabatic steam turbine is 5 MW. The inlet and the outlet conditions are shown in the figure below.

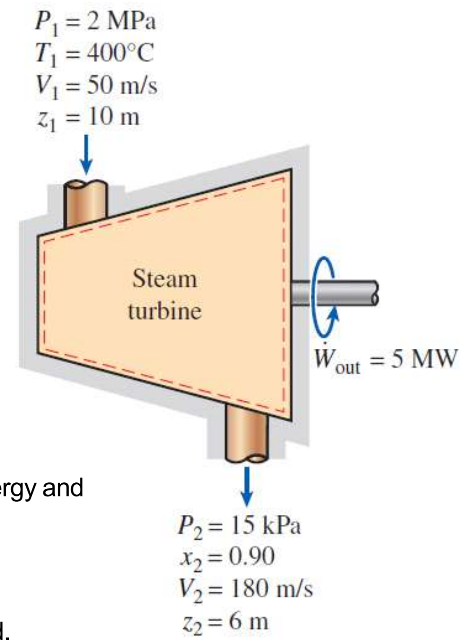
$W'_{out} := 5MW$

$P_1 := 2MPa$ $\quad P_2 := 15kPa$

$T_1 := 400\,°C$ $\quad x_2 := 0.9$

$V_1 := 50\frac{m}{s}$ $\quad V_2 := 180\frac{m}{s}$

$z_1 := 10m$ $\quad z_2 := 6m$



Required:

Determine

(a) The changes in specific enthalpy, kinetic energy, and potential energy and

(b) The mass flow rate of the steam.

Solution:

Going to Table A-5 @ $P_1 = 2 \cdot MPa$ shows that the state is superheated.

Going to Table A-6 @ $P_1 = 2 \cdot MPa$ & $T_1 = 400 \cdot °C$ shows

$$h_1 := 3248.4\frac{kJ}{kg}$$

Since a quality is given for the outlet, the state is in the two phase region. Going to Table A-5 @ $P_2 = 15 \cdot kPa$ shows

$$h_f := 225.94\frac{kJ}{kg} \qquad h_g := 2598.3\frac{kJ}{kg}$$

$$h_2 := h_f + x_2 \cdot (h_g - h_f) = 2361.1 \cdot \frac{kJ}{kg}$$

The change in specific enthalpy is then given by

$$\boxed{\Delta h := h_2 - h_1 = -887.3 \cdot \frac{kJ}{kg}} \quad \text{(a)}$$

The change in specific kinetic energy is given by

$$\boxed{\Delta ke := \frac{V_2^{\,2} - V_1^{\,2}}{2} = 14.95 \cdot \frac{kJ}{kg}} \quad \text{(a)}$$

The change in specific potential energy is given by

$$\boxed{\Delta pe := g \cdot (z_2 - z_1) = -39.23 \cdot \frac{J}{kg}} \quad \text{(a)}$$

Solution (contd.):

Beginning with the 1st Law

$$\frac{d}{dt}E_{sys} = \Sigma E'_{in} - \Sigma E'_{out}$$

For a steady flow device the 1st Law becomes

$$0 = \Sigma E'_{in} - \Sigma E'_{out}$$

For an adiabatic, rigid turbine the expression becomes

$$0 = m'_{in}\cdot\left(h_{in} + \frac{V_{in}^{\ 2}}{2} + g\cdot z_{in}\right) - W'_{out} - m'_{out}\cdot\left(h_{out} + \frac{V_{out}^{\ 2}}{2} + g\cdot z_{out}\right)$$

Knowing $m'_{in} = m'_{out} = m'$, and rearraging yields

$$m' = \frac{-W'_{out}}{h_{out} - h_{in} + \frac{V_2^{\ 2} - V_1^{\ 2}}{2} + g\cdot(z_2 - z_1)} \quad \text{or} \quad \boxed{m' := \frac{-W'_{out}}{\Delta h + \Delta ke + \Delta pe} = 5.731\,\frac{kg}{s}} \quad \text{(b)}$$