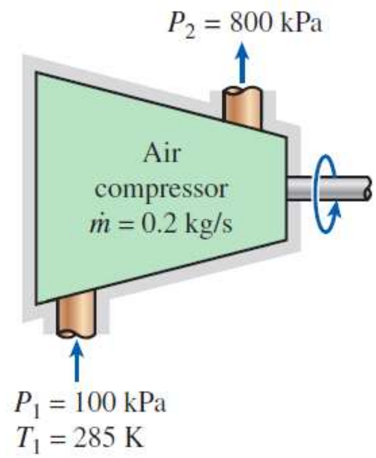
Given: $kJ := 1000J$

Air is compressed by an adiabatic compressor from 100 kPa and 12°C to a pressure of 800 kPa at a steady rate of 0.2 kg/s.

$$P_1 := 100kPa \qquad T_1 := 12\,°C \qquad P_2 := 800kPa \qquad m' := 0.2\frac{kg}{s}$$



Required:

If the isentropic efficiency is 80%, determine the air temperature at the exit and the required power input for the compressor.

Solution:

The isentropic efficiency is defined as

$$\eta_C := 80\%$$

Using the definition of the isentropic efficiency of a compressor, the enthalpy at the outlet may be found by

$$\eta_C = \frac{h_{2s} - h_1}{h_{2a} - h_1} \qquad \text{or} \qquad h_{2a} = \frac{h_{2s} - h_1}{\eta_C} + h_1$$

Going to Table A-17 @ $T_1 = 285.15K$ shows that interpolation is need but will be approximated by $T_1 = 285K$.

$$h_1 := 285.14\frac{kJ}{kg} \qquad P_{r1} := 1.1584$$

The relative pressure at state 2 may then be found by

$$P_{r2} := P_{r1}\cdot\left(\frac{P_2}{P_1}\right) = 9.267$$

Going to Table A-17 @ $P_{r2} = 9.267$ shows that interpolation is needed.

$$P_{ra} := 9.031 \qquad P_{rb} := 9.684$$

$$h_a := 513.32\frac{kJ}{kg} \qquad h_b := 523.63\frac{kJ}{kg}$$

$$h_{2s} := \frac{P_{r2} - P_{ra}}{P_{rb} - P_{ra}}\cdot\left(h_b - h_a\right) + h_a = 517.049\cdot\frac{kJ}{kg}$$

The actual enthalpy at the outlet may then be found by

$$h_{2a} := \frac{h_{2s} - h_1}{\eta_C} + h_1 = 575.027\cdot\frac{kJ}{kg}$$

Solution (contd.):

Going to Table A-17 @ $h_{2a} = 575.027\frac{kJ}{kg}$ shows interpolation is needed.

$h_a := 565.17\frac{kJ}{kg}$ $\qquad h_b := 575.59\frac{kJ}{kg}$

$T_a := 560K$ $\qquad T_b := 570K$

$$\boxed{T_{2a} := \frac{h_{2a} - h_a}{h_b - h_a}\cdot(T_b - T_a) + T_a = 569.5\,K} \qquad T_{2a} = 296.3\cdot°C$$

The required power is found by using the 1st Law for a steady flow device that is adiabatic, and has no ΔKE and ΔPE.

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

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

$$0 = m'_{in}\cdot h_{in} + W'_{in} - m'_{out}\cdot h_{out}$$

Realizing that the mass flow rates are equal to each other because there is only one inlet and only one outlet, the required power may be found by

$$0 = m'\cdot(h_{in} - h_{out}) + W'_{in}$$

$$W'_{in} = m'\cdot(h_{out} - h_{in})$$

$$\boxed{W'_{in} := m'\cdot(h_{2a} - h_1) = 57.98\cdot kW}$$