Given: $kJ := 1000J$

The electrical heating systems used in many houses consist of a simple duct with resistance heaters. Air is heated as it flows over the resistance wires. Consider a 15 kW electric heating system where air enters at 100 kPa and 17°C with a flow rate of 150 m^3/min.

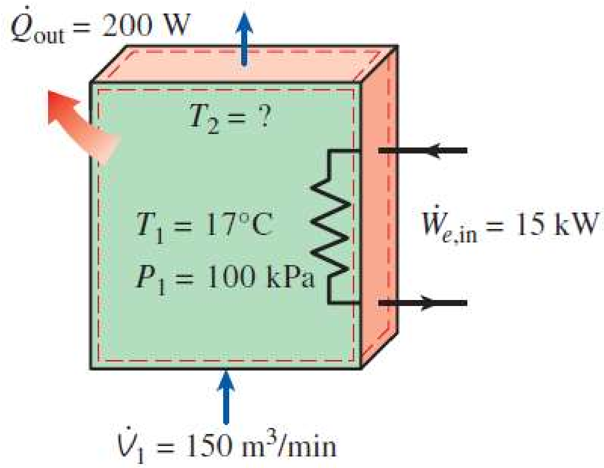
$$Q'_{out} := 200W$$

$$T_1 := 17\,°C$$

$$P_1 := 100kPa$$

$$W'_{e,in} := 15kW$$

$$V'_1 := 150\frac{m^3}{min}$$



Required:

If the rate of heat loss from the air duct to the surroundings is 200 W, determine the final temperature of the air.

Solution:

1st Law (for rigid, steady flow device with no changes in kinetic and potential energy)

$$E'_{in} = E'_{out}$$

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

Rearranging yields

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

Assuming the air behaves as an ideal gas in the process region and has a constant specific heat the first law becomes

$$W'_{in} - Q'_{out} = m'\cdot c_p\cdot\left(T_{out} - T_{in}\right)$$

Solving for the outlet temperature yields

$$T_{out} = \frac{W'_{in} - Q'_{out}}{m'\cdot c_p} + T_{in}$$

Using the ideal gas law, the mass flow rate may be found by

$$m' = \frac{P\cdot V'}{R\cdot T}$$

Going to Table A-2(a) @ air shows

$$R := 0.287\frac{kJ}{kg\cdot K} \qquad c_p := 1.005\frac{kJ}{kg\cdot K}$$

Solution (cont.):

The mass flow rate is then

$$m' := \frac{P_1 \cdot V'_1}{R \cdot T_1} = 3.002 \frac{kg}{s}$$

The outlet temperature is then

$$\boxed{T_2 := \frac{W'_{e,in} - Q'_{out}}{m' \cdot c_p} + T_1 = 21.9 \cdot °C}$$