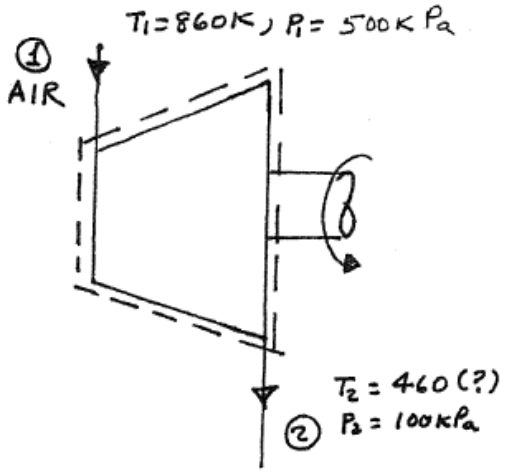
PROBLEM 6.97

Air enters a turbine operating at steady state at 500 kPa, 860 K and exits at 100 kPa. A temperature sensor indicates that the exit air temperature is 460 K. Stray heat transfer and kinetic and potential energy effects are negligible, and the air can be modeled as an ideal gas. Determine if the exit temperature reading can be correct. It yes, determine the power developed by the turbine for an expansion between these states, in kJ per kg of air flowing. If no, provide an explanation with supporting calculations.

SCHEMATIC & GIVEN DATA:



ENGR. MODEL:

1. The control volume shown in the sketch is at steady state.
2. For the control volume, stray heat transfer and kinetic and potential effects are negligible.
3. The air can be modeled as an ideal gas.

ANALYSIS: Apply an entropy rate balance:

$$0 = \sum \frac{\dot{Q}_j}{T_j}^{\,0} + \dot{m}(s_1 - s_2) + \dot{\sigma}_{cv}$$

$$\Rightarrow \dot{\sigma}_{cv} = \dot{m}(s_2 - s_1)$$

$$= \dot{m}\left(s_2^\circ - s_1^\circ - R \ln \frac{P_2}{P_1}\right)$$

or

$$\frac{\dot{\sigma}_{cv}}{\dot{m}} = s_2^\circ - s_1^\circ - R \ln \frac{P_2}{P_1}$$

$$= \left(2.13407 - 2.79783 - \frac{8.314}{28.97} \ln \frac{100}{500}\right) \frac{kJ}{kg \cdot K}$$

$$= -0.202 \frac{kJ}{kg \cdot K}$$

Since $\dot{\sigma}_{cv}/\dot{m}$ cannot be negative, the exit temperature reading cannot be correct.