PROBLEM 7.103

KNOWN: From an input of electricity, a furnace delivers energy by heat transfer at a rate of $\dot{Q}_u$ at a use temperature of $T_u$. The furnace operates at steady state.

FIND: (a) Derive an exergetic efficiency. (b) Plot this efficiency versus $T_u$ ranging from 300 to 900K.

SCHEMATIC & GIVEN DATA:

ENERG. MODEL: (1) The closed system is at steady state. (2) There are no significant energy transfers other than those shown. (3) For the environment, $T_e = 20^\circ C = 293K$.

ANALYSIS: (a) At steady state, the energy balance with assumption 2 reads

$$0 = \dot{W}_e - \left[1 - \frac{I_0}{I_{tu}}\right] \dot{Q}_u - \dot{E}_d$$

where the quantities $\dot{W}_e$ and $\dot{Q}_u$ have been taken as positive in the direction of the arrows. Rearranging

$$\dot{W}_e = \left[1 - \frac{I_0}{I_{tu}}\right] \dot{Q}_u + \dot{E}_d$$

An exergetic efficiency in the form output/input is

$$\varepsilon = \frac{\left[1 - \frac{I_0}{I_{tu}}\right] \dot{Q}_u}{\dot{W}_e}$$

With $\dot{Q}_u = \dot{W}_e$ from an energy balance at steady state

$$\varepsilon = \left[1 - \frac{I_0}{I_{tu}}\right]$$

(b) The following plot is generated using IT with $T_e = 293K$:

From the plot, we observe that as $T_u \to T_e$, $\varepsilon \to 0$. Also, $\varepsilon$ increases rapidly with $T_u$. 