(Example 9, continued) entropy change. What is the net rate of entropy change of the styrofoam? What is the rate of increase of the entropy of the universe as a result of this process?

The styrofoam acquires reversible entropy at its outside boundary and loses it at its inside boundary. The net result is

$$\frac{1}{A}\frac{dS}{dt}\bigg|_{th,rev} = \frac{\dot{Q}}{A}\left(\frac{1}{T_o}-\frac{1}{T_i}\right) = 10\ \text{BTU/(hr ft}^2)\cdot\left(\frac{1}{540\ \text{R}}-\frac{1}{492\ \text{R}}\right) = -0.0018\ \text{BTU/(hr ft}^2\text{R)}$$

Notice that this term represents a decreasing system entropy. To find the thermal production, we must determine T_{eq}. In this system we expect a linear temperature distribution. Thus

$$T_{eq} = \frac{T_o + T_i}{2} = \frac{(32 + 80)°\text{F}}{2} = 56°\text{F} = 516\ \text{R}$$

Heat crosses the boundary on both surfaces so there are also two components to the thermal entropy production.

$$\frac{1}{A}\frac{dS}{dt}\bigg|_{th,irr} = \frac{\dot{Q}_o}{A}\ \frac{(T_o - T_{eq})}{T_o\ T_{eq}} + \frac{\dot{Q}_i}{A}\ \frac{(T_i - T_{eq})}{T_i\ T_{eq}}$$

$$= \frac{10\ \text{BTU/(hr ft}^2)\cdot(24\ \text{R})}{540\ \text{R}\cdot 516\ \text{R}} + \frac{-10\ \text{BTU/(hr ft}^2)\cdot(-24\ \text{R})}{492\ \text{R}\cdot 516\ \text{R}} = 0.0018\ \text{BTU/(hr ft}^2\text{R)}$$

Notice the cancellation of the reversible and irreversible components

$$\frac{1}{A}\frac{dS}{dt}\bigg|_{th} = \frac{1}{A}\frac{dS}{dt}\bigg|_{th,rev} + \frac{1}{A}\frac{dS}{dt}\bigg|_{th,irr} = 0$$

The system is in steady state. All properties are time invariant. The production occurs in the surroundings. (We assume they are uniform in temperature and are thermally reversible.)

$$\frac{1}{A}\frac{dS}{dt}\bigg|_{surr} = \frac{1}{A}\frac{dS}{dt}\bigg|_{o,surr} + \frac{1}{A}\frac{dS}{dt}\bigg|_{i,surr} = \frac{Q}{A}\left(-\frac{1}{T_o}+\frac{1}{T_i}\right) = 0.0018\ \text{BTU/(hr ft}^2\text{R)}$$

and the net production for this process is

$$\frac{1}{A}\frac{dS}{dt}\bigg|_{univ} = \frac{1}{A}\left(\cancel{\frac{dS}{dt}\bigg|_{syst}} + \frac{dS}{dt}\bigg|_{surr}\right) = 0.0018\ \text{BTU/(hr ft}^2\text{R)}$$

The entropy of the universe is growing— the process is irreversible. If the production could be reduced would the design be better? Yes, thicker or better insulation would reduce $\dot{Q}/A$ and, therefore, reduce production. A final redesign decision would of course include consideration of cost and profit.

The preceding example illustrates for a system dependent primarily on heat effects what we saw earlier for work dominated systems, that minimization of production is a useful design concept. The examples that we have used to illustrate this principle have been too obvious to illustrate its full significance. But when two quite different design

Ans. 10. For heat out, $\delta T_{neq} < 0$ (see eqn. IIIB-25), and $dS_{th,rev} < 0$ (see eqn. IIIB-29b). Thus $dQ_{irr} > 0$. For heat in both δT_{neq} and $dS_{th,rev}$ are positive.