$$\frac{dS}{dt} = \frac{1}{T_{eq}}\left(\cancel{\frac{đQ}{dt}} + \frac{đW^{i}_{irr}}{dt}\right) = \left.\frac{dS}{dt}\right|_{m} = \frac{9.7 \cdot 10^{8}\ \text{ft lb}_f/\text{hr}}{520\ \text{R} \cdot 778\ \text{ft lb}_f/\text{BTU}} = 2.4 \cdot 10^{3}\ \text{BTU/(hr R)}$$

The part of the ship's power that was used to overcome hull-water friction resulted in immediate entropy production. That part of the power that went into wave making was initially reversibly converted to kinetic and potential energy in the bow and stern wave. But this energy is subsequently dissipated as the wave action is damped.

B. Thermal Entropy Production

Since heat can enter or leave a system, dS_{th}, unlike dS_m, is not pure production. Indeed thermal entropy change contains both a reversible and irreversible component. Since our purpose is to identify production sources, it is desirable that we separate the two components. We begin by observing that heat interactions require a differential between the boundary, T_B, and system, T_{eq}, temperatures. We define

$$\delta T_{neq} \equiv T_B - T_{eq} \qquad \text{(IIIB-25)}$$

If this definition is substituted into eqn. IIIB-22a, we obtain

$$dS_{th} = \frac{đQ}{T_B} + \frac{đQ\ \delta T_{neq}}{T_{eq}\ T_B} \qquad \text{(IIIB-26)}$$

Exercise 9. Substitute eqn. IIIB-25 into eqn. IIIB-24a to derive eqn. IIIB-26.

Now consider the sign of the second term. If heat is to leave the system, $dQ < 0$, the interior must be hotter than the boundary, $\delta T_{neq} < 0$. The term is positive. Conversely, if heat enters the system both $đQ > 0$ and $\delta T_{neq} > 0$; the term remains positive. This is a positive semidefinite component. It is the thermal entropy production.

$$dS_{th,irr} = \frac{đQ\ \delta T_{neq}}{T_{eq}\ T_B} \geq 0 \qquad \text{(IIIB-27)}$$

Ans. 6. Refer to eqn. IIIB-21, or 22. (a) When Q is positive system entropy must increase. (b) When Q is negative entropy could decrease; it depends on the magnitude of W^{i}_{irr}. Can't tell. (c) Still can't tell, since W^{i}_{irr} is still unknown. (d) Q is negative and larger than W^{i}_{irr}; decreases. (e) Q is negative but less than W^{i}_{irr}; increases.

Ans. 7. (a) $\Delta S_{univ} \geq 0$. So for this process $\Delta S_{surr} \geq 2$ J/K. (b) a decrease in entropy in a closed system can only occur due to heat rejection.

Ans. 8. (a) Entropy is a property. The change in all properties between two specified equilibrium states is the same for all paths. (b) The entropy of the universe cannot decrease. For the reversible process $\Delta S_{univ} = 0$. For the irreversible process $\Delta S_{univ} > 0$.