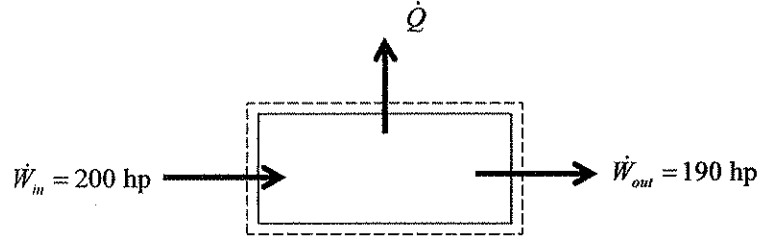19. An operating gearbox (transmission) has 200. hp at its input shaft while 190. hp are delivered to the output shaft. The gearbox has a steady state surface temperature of 140.°F. Determine the rate of entropy production by the gearbox.

The Second Law for the closed system (rate form) is,

$$\frac{\dot{Q}}{T} + \dot{S}_P = \frac{dS_{sys}}{dt}$$

The transmission is operating at steady state. Therefore, the entropy production is,

$$\dot{S}_P = -\frac{\dot{Q}}{T}$$

The heat transfer rate is determined from the First Law,

$$\dot{Q} - \dot{W} = \frac{dE_{sys}}{dt} \qquad \rightarrow \qquad \dot{Q} = \dot{W}$$

Therefore,

$$\dot{Q} = \dot{W}_{out} + \dot{W}_{in} = 190 \text{ hp} + (-200 \text{ hp}) = -10 \text{ hp}$$

Now, we can find the entropy production rate,

$$\dot{S}_P = -\frac{\dot{Q}}{T} = -\frac{-10 \text{ hp}}{(140 + 459.67)\text{R}} \left| \frac{2545 \text{ Btu}}{\text{hp-hr}} \right. = 42.4 \frac{\text{Btu}}{\text{hr-R}}$$