31.17 A 60% efficient steam generating turbine system generates $5MW$ using $1100psia$ steam at $850°F$. The exhaust pressure is $200psia$. What mass flow rate of steam is required for the cycle?

A. $150,000\frac{lb}{hr}$

B. $250,000\frac{lb}{hr}$

C. $420,000\frac{lb}{hr}$

D. $660,000\frac{lb}{hr}$

The work done by a Turbine is most generally given by $\dot{W}_T = \dot{m}\Delta h$. The Δh must be the *actual* change in enthalpy obtained by applying the efficiency to the *ideal* change in enthalpy which would occur if the expansion was isentropic. Let the inlet conditions be considered State 1 and the exit conditions be considered State 2. Start by finding the enthalpy and entropy for State 1 using the Properties of Superheated Steam table.

$$P_1 = 1100psia$$

$$T_1 = 850°F$$

$$h_1 \approx 1415\frac{Btu}{lb}$$

$$s_1 \approx 1.578\frac{Btu}{lb \cdot °F}$$

To find the ideal change in enthalpy, temporarily assume isentropic expansion. Therefore, when finding h_2,it is valid to let $s_2 = s_1$. Using the steam table again, notice the steam is still superheated at $P_2 = 200psia$. Interpolate to find h_2.

$h\left[\frac{Btu}{lb}\right]$	$s\left[\frac{Btu}{lb \cdot °F}\right]$
1223.2	1.574
h_2	1.578
1235.2	1.588

$$\frac{h_2 - 1223.2}{1235.2 - 1223.2} = \frac{1.578 - 1.574}{1.588 - 1.574}$$

$$h_2 = 1226.6\frac{Btu}{lb}$$

The ideal change in enthalpy (if the expansion was isentropic) would be:

$$\Delta h_{ideal} = h_1 - h_2 = 1415\frac{Btu}{lb} - 1226.6\frac{Btu}{lb} = 188.4\frac{Btu}{lb}$$

However, the actual change in enthalpy is less than the ideal, as an outcome of the efficiency.

$$\eta = \frac{\Delta h_{actual}}{\Delta h_{ideal}}$$

$$\Delta h_{actual} = \eta \Delta h_{ideal} = (0.60)\left(188.4 \frac{Btu}{lb}\right) = 113 \frac{Btu}{lb}$$

Solve for the mass flow rate, converting units as necessary.

$$\dot{W}_T = \dot{m} \Delta h$$

$$\dot{m} = \frac{\dot{W}_T}{\Delta h_{actual}} = \frac{\left(5 \times 10^6 W\right)\left(3.412 \frac{Btu}{hr \cdot W}\right)}{113 \frac{Btu}{lb}} = 151,000 \frac{lb}{hr}$$

Answer A