CHE 3172 EXAM III July 22, 1999

Solution

I. Isentropic base case:

$$\Delta S = 0 = R\int_{300}^{T_2'} C_p/R \frac{dT}{T} - R\ln\left(\frac{18}{1}\right) + \cancel{S_2^R}^{\,0} - \cancel{S_1^R}^{\,0}$$

$$0 = 1.424\ln\left(T_2/300\right) + 14.394\times10^{-3}\left(T_2-300\right) - \frac{4.392\times10^{-6}}{2}\left(T_2^2-300^2\right) - \ln 18$$

$$T_2' = 475.97\ K$$

$$W_s' = \Delta H' = R\int_{300}^{475.97} C_p/R\,dT + \cancel{H_2^R}^{\,0} - \cancel{H_1^R}^{\,0}$$

$$\Delta H' = 8.314\left[1.424(475.97-300) + \frac{14.394}{2}\times10^{-3}\left(475.97^2-300^2\right) - \frac{4.392}{3}\times10^{-6}\left(475.97^3-300^3\right)\right]$$

$$\Delta H' = 9269.93\ J/mole$$

$$W_{s,ACTUAL} = \Delta H'/\eta = 9269.93/0.8 = 11587.413\ J/mole$$

$$\Delta H_{ACTUAL} = 11587.413 = R\left[1.424(T_2-300) + \frac{14.394}{2}(\times10^{-3})\left(T_2^2-300^2\right) - \frac{4.392\times10^{-6}}{3}\left(T_2^3-300^3\right)\right]$$

$$T_{2,ACTUAL} = 513.29\ ^\circ K$$

$$\Delta S_{ACTUAL} = R\int_{300}^{513.29^\circ K} \frac{C_p}{R}\frac{dT}{T} - R\ln(18)$$

$$\Delta S_{ACTUAL} = 8.314\left[0.56359\right] = 4.68571\ J/mole\ ^\circ K$$

II. $T_1 = 650°C$ $P_1 = 11{,}000$

$H_1 = 3737.5$ kJ/kg

$S_1 = 6.9872$ kJ/kg K

Isentropic base case

at $P_2 = 50$ kPa $S_L = 1.0912$ $S_V = 7.5947$ saturated

$6.9872 = 7.5947x' + (1-x')(1.0912)$

$6.9872 - 1.0912 = (7.5947 - 1.0912)x'$

$x' = 0.90659$

$H_2' = (0.90659)(2646.0) + (1 - 0.90659)(340.564)$

$H_2' = 2430.6$ J/g $T_2' = 81.35$ (saturated)

$S_2' = 6.9872$

$\Delta H' = -3737.5 + 2430.6 = -1306.9$

$\Delta H_{ACTUAL} = (-1306.9)(0.85) = -1110.83$

$H_2 = 3737.5 - 1110.83 = 2626.67$

$P_2 = 50$ kPa

$T_2 = 81.35°C$ (saturated)

$2626.67 = x(2646.0) + (1-x)(340.564)$

$2626.67 - 340.564 = (2646.0 - 340.564)x$

$x = 0.9916$

$1.0912(1 - 0.9916) + (0.9916)(7.5947) = S_2$

$S_2 = 7.5402$ J/g °K

$\dot{W}_s = 1110.83$ kJ/kg $\times 10$ kg/min $= 11108.3$ kJ/min $\times$ 1 min/60 sec $= 185.13$ kW

$\dot{W}_s = 1.34102$ hp/kW $\times 185.13$ kW $= 248.3$ HP