39.13 Steam with a quality of 90% expands isentropically from $350psia$ to $120psia$. What is the change in enthalpy?

A. $40\frac{Btu}{lb}$

B. $80\frac{Btu}{lb}$

C. $90\frac{Btu}{lb}$

D. $120\frac{Btu}{lb}$

Look up the Properties of Saturated Water and Steam in the Reference Handbook organized by pressure and find $350psia$. Call this State 1. From the table, $h_f = 409.8\frac{Btu}{lb}$ and $h_{fg} = 794.62\frac{Btu}{lb}$. Calculate the enthalpy at State 1:

$$h_1 = h_f + \chi h_{fg} = 409.8\frac{Btu}{lb} + (0.9)\left(794.62\frac{Btu}{lb}\right) = 1125\frac{Btu}{lb}$$

Also gather entropy values from the same line in the table, $s_f = 0.6059\frac{Btu}{lb_m \cdot {}^\circ F}$ and $s_{fg} = 0.8914\frac{Btu}{lb_m \cdot {}^\circ F}$. Calculate the entropy at State 1:

$$s_1 = s_f + \chi s_{fg} = 0.6059\frac{Btu}{lb_m \cdot {}^\circ F} + (0.9)\left(0.8914\frac{Btu}{lb_m \cdot {}^\circ F}\right) = 1.408\frac{Btu}{lb_m \cdot {}^\circ F}$$

Since the expansion from State 1 to State 2 is isentropic:

$$s_2 = s_1 = 1.408\frac{Btu}{lb_m \cdot {}^\circ F}$$

Gather entropy values from the table for State 2, which has a pressure of $P_2 = 120psia$. $s_f = 0.4919\frac{Btu}{lb_m \cdot {}^\circ F}$ and $s_{fg} = 1.0965\frac{Btu}{lb_m \cdot {}^\circ F}$. Find the quality at State 2 (after the isentropic expansion):

$$\chi = \frac{s_2 - s_f}{s_{fg}} = \frac{\left(1.408\frac{Btu}{lb_m \cdot {}^\circ F}\right) - \left(0.4919\frac{Btu}{lb_m \cdot {}^\circ F}\right)}{\left(1.0965\frac{Btu}{lb_m \cdot {}^\circ F}\right)} = 0.835$$

Gather enthalpy values from the table for State 2. $h_f = 312.55\frac{Btu}{lb}$ and $h_{fg} = 878.2\frac{Btu}{lb}$. Calculate the enthalpy at State 2:

$$h_2 = h_f + \chi h_{fg} = 312.55\frac{Btu}{lb} + (0.835)\left(878.2\frac{Btu}{lb}\right) = 1046\frac{Btu}{lb}$$

Finally, calculate the change in enthalpy from State 1 to State 2:

$$\Delta h = h_1 - h_2 = 1125\frac{Btu}{lb} - 1046\frac{Btu}{lb} = 79\frac{Btu}{lb}$$

Answer B

39.14 A Carnot heat pump operates between $20°F$ and $70°F$. What is the coefficient of performance?

A. 0.4

B. 1.4

C. 9.6

D. 10.6

Look up the Carnot Cycle in the reference handbook and find the Coefficient of Performance formulas. A Carnot heat pump operates at the upper limit of COP, which is a function of the temperatures of the hot and cold reservoirs which the heat pump is operating between.

$$COP_{HP,carnot} = \frac{T_H}{(T_H - T_L)}$$

The temperatures must be in absolute terms i.e. Rankine, so add 460 to $°F$ before substituting into the formula. (Technically, there is no need to change to absolute in the denominator since the difference will remain unchanged.)

$$COP_{HP,carnot} = \frac{T_H}{(T_H - T_L)} = \frac{(70 + 460)}{(70 - 20)} = \frac{530R}{50R} = 10.6$$

Answer D

39.15 In a Carnot heat pump, R-22 evaporates at $31psia$ and condenses at $211psia$. What is the coefficient of performance?

A. 0.9

B. 4.3

C. 5.1

D. 6.8

Lookup the Pressure Versus Enthalpy Curves for Refrigerant 22 and read from the chart the temperatures for the evaporator and condenser based on the pressures given. These correspond to the low and high temperature reservoirs, respectively, for the heat pump:

$$T_L = T_{evaporator@P=31psia} \approx -10°F + 460 = 450°R$$

$$T_H = T_{condenser@P=211psia} \approx 100°F + 460 = 560°R$$

Look up the Carnot Cycle in the reference handbook and find the coefficient of performance formula:

$$COP_{HP,carnot} = \frac{T_H}{(T_H - T_L)} = \frac{560°R}{560°R - 450°R} = 5.1$$

Answer C