47.19 How much power is required to isentropically compress $100\frac{lb}{min}$ of air at atmospheric pressure and $80°F$ to $150psia$? Assume air is an ideal gas with constant specific heat capacity.

A. $50hp$

B. $200hp$

C. $290hp$

D. $1920hp$

Look up Constant Entropy Processes and find the formula relating temperature and pressure. Determine the temperature after the compression process, T_2. The ratio of specific heats may be taken as $k = 1.4$ since air is to be considered an ideal gas. Be sure to use the absolute temperature scale ie. Rankine rather than Farenheit.

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = (540°R)\left(\frac{150psia}{14.7psia}\right)^{\frac{1.4-1}{1.4}} = 1048.6°R = 588.6°F$$

The power for a compressor can be expressed most generally as the product of the mass flow rate and the change in enthalpy. If the gas being compressed has constant specific heats, it is valid to express the enthalpy change in terms of the change in temperature. Calculate the power required and convert the final units to horsepower to be consistent with the answer choices. Look up Measurement Relationships for unit conversions that may be useful.

$$\dot{W} = \dot{m}\Delta h = \dot{m}c_p\Delta T = \left(100\frac{lb}{min}\right)\left(0.24\frac{Btu}{lb°F}\right)(588.6°F - 80°F) = 12,207\frac{Btu}{min}$$

$$\dot{W} = 12,207\frac{Btu}{min}\left(\frac{1hp}{42.4\frac{Btu}{min}}\right) = 288hp$$

Answer C

47.20 A refrigeration cycle using R-123 operates between $75psia$ and $220psia$ with no sub-cooling. During isenthalpic expansion, what is the change in entropy of the refrigerant?

A. $0.001\frac{Btu}{lb\cdot^\circ F}$

B. $0.003\frac{Btu}{lb\cdot^\circ F}$

C. $0.01\frac{Btu}{lb\cdot^\circ F}$

D. $0.04\frac{Btu}{lb\cdot^\circ F}$

Sketch the process line from State 3 to State 4 representing the expansion process within a typical refrigeration cycle. Use the table for Refrigerant 123 to obtain the enthalpy and entropy at State 3. Since there is no sub-cooling, the refrigerant is a saturated liquid at State 3.

$$P_3 = 220psia$$

$$h_3 = h_f = 78.66\frac{Btu}{lb}$$

$$s_3 = s_f = 0.138\frac{Btu}{lb^\circ R}$$

The expansion from $3 \to 4$ is isenthalpic, therefore the enthalpy at State 4 is the same as the enthalpy at State 3.

$$h_4 = h_3 = 78.66\frac{Btu}{lb}$$

Since the expansion process line from $3 \to 4$ is vertically down on the Pressure-Enthalpy diagram, State 4 is observed to be a saturated mixture, as it is within the vapor dome. Use the Refrigerant 123 table again to obtain the enthalpy values h_f and h_{fg} at the lower pressure of State 4. Calculate the quality at State 4. Refer to Properties for Two-Phase (Vapor-Liquid) Systems for a reminder of the formulas involving quality.

$$P_4 = 75psia$$

$$h_f = 53.58\frac{Btu}{lb}$$

$$h_{fg} = 115.68\frac{Btu}{lb}$$

$$h_4 = h_f + \chi_4 h_{fg}$$

$$\chi_4 = \frac{h_4 - h_f}{h_{fg}} = \frac{78.66\frac{Btu}{lb} - 53.58\frac{Btu}{lb}}{115.68\frac{Btu}{lb}} = 0.404$$