AIR CONDITIONER IN REAL LIFE

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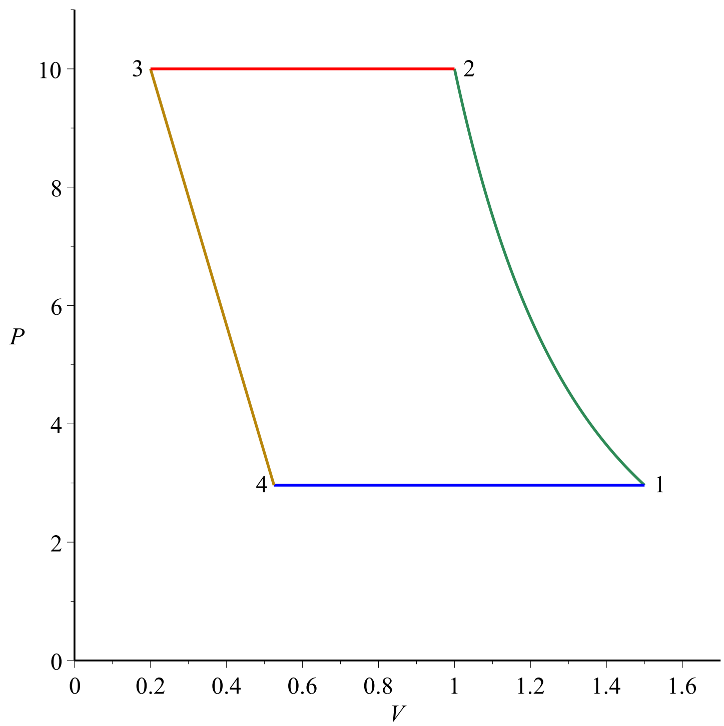
Reference: Daniel V. Schroeder, *An Introduction to Thermal Physics*, (Addison-Wesley, 2000) - Problem 4.32.

Suppose we want to use the refrigeration cycle discussed in an earlier post to design an air conditioner using the coolant fluid HFC-134a as before. The cycle looks like this:



The COP for this cycle is

$$\text{COP} = \frac{H_1 - H_3}{H_2 - H_1} \tag{0.1}$$

where we've used the fact that the enthalpy is constant along the throttling edge $3 \to 4$ so $H_4 = H_3$.

Using Schroeder's Tables 4.3 and 4.4, a reasonable temperature range for an air conditioner would be a high temperature of $T_h = 46.3^\circ$ C with corresponding pressure $P_3 = 12$ bars. This temperature is hotter than any outdoor temperature (at least in populated areas), so heat will be able to flow from the air conditioner into the outdoor environment. A typical indoor temperature is around 20° C so we need the cold temperature of the air conditioner to be less than this so it can absorb heat from the room. Using $T_c = 8.9^\circ$ C is probably a bit too much, but it's the best we can get from Table 4.3. This corresponds to a low pressure of $P_4 = 4$ bars.

The fluid is 100% liquid at point 3, 100% saturated gas at point 1, and superheated gas at point 2. Point 4 is a mixture of saturated liquid and gas. From the tables we have

$$H_4 = H_3 = 116 \text{ kJ} \tag{0.2}$$

$$H_1 = 252 \text{ kJ} \tag{0.3}$$

To find H_2, we use the fact that the path $1 \to 2$ is adiabatic so entropy is constant. From the table, $S_1 = 0.915$ kJ K^{-1} so we need to find an entry in Table 4.4 with the same entropy at a pressure of 12 bars. This value is slightly less than S for $T = 50^\circ$ C but since no value is given for any lower temperature and the values are almost the same we can use this value for the superheated temperature. The corresponding enthalpy is $H_2 = 276$ kJ. This gives a COP of

$$\text{COP} = 5.67 \tag{0.4}$$

A Carnot refrigeratoroperating between $T_c = 8.9^\circ$ C and $T_h = 46.3^\circ$ C has a COP of

$$\text{COP} = \frac{273 + 8.9}{46.3 - 8.9} = 7.54 \tag{0.5}$$