

The force between any two molecules is weakly attractive at long distances and strongly repulsive at short distances. Under most (though not all) conditions the attraction dominates; then $U_{\text{potential}}$ is negative, but becomes less negative as the pressure drops and the distance between molecules increases. To compensate for the increase in potential energy, the kinetic energy generally drops, and the fluid cools as desired.

If we use the fact that $H_4 = H_3$ in the refrigeration cycle, the coefficient of performance (4.14) simplifies to

$$\text{COP} = \frac{H_1 - H_3}{H_2 - H_1} \tag{4.20}$$

Now one only has to look up three enthalpies. Tables 4.3 and 4.4 give enthalpy and entropy values for the refrigerant HFC-134a.

Problem 4.29. Liquid HFC-134a at its boiling point at 12 bars pressure is throttled to 1 bar pressure. What is the final temperature? What fraction of the liquid vaporizes?

P (bar)	T (°C)	H_{liquid} (kJ)	H_{gas} (kJ)	S_{liquid} (kJ/K)	S_{gas} (kJ/K)
1.0	-26.4	16	231	0.068	0.940
1.4	-18.8	26	236	0.106	0.932
2.0	-10.1	37	241	0.148	0.925
4.0	8.9	62	252	0.240	0.915
6.0	21.6	79	259	0.300	0.910
8.0	31.3	93	264	0.346	0.907
10.0	39.4	105	268	0.384	0.904
12.0	46.3	116	271	0.416	0.902

Table 4.3. Properties of the refrigerant HFC-134a under saturated conditions (at its boiling point for each pressure). All values are for 1 kg of fluid, and are measured relative to an arbitrarily chosen reference state, the saturated liquid at -40°C . Excerpted from Moran and Shapiro (1995).

P (bar)		Temperature (°C)		
		40	50	60
8.0	H (kJ)	274	284	295
	S (kJ/K)	0.937	0.971	1.003
10.0	H (kJ)	269	280	291
	S (kJ/K)	0.907	0.943	0.977
12.0	H (kJ)		276	287
	S (kJ/K)		0.916	0.953

Table 4.4. Properties of superheated (gaseous) refrigerant HFC-134a. All values are for 1 kg of fluid, and are measured relative to the same reference state as in Table 4.3. Excerpted from Moran and Shapiro (1995).