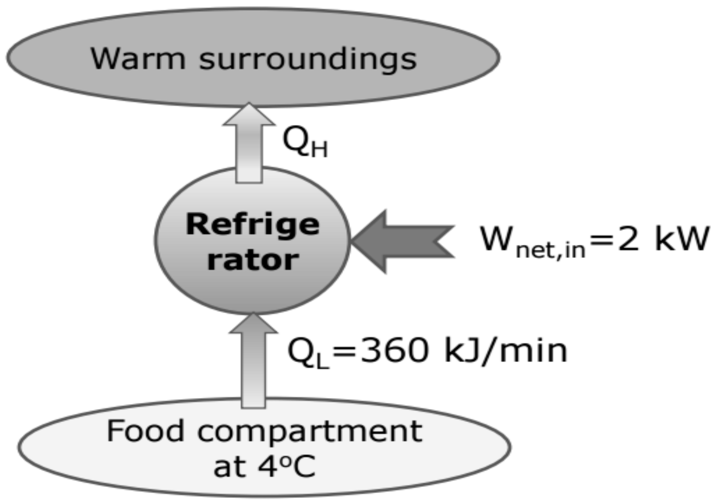
FAQs/Problems

1. The food compartment of a refrigerator is maintained at 4°C by removing heat from it at a rate of 360 kJ/min. If the required power input to the refrigerator is 2 kW, determine (a) the coefficient of performance of the refrigerator and (b) the rate of heat rejection to the room that houses the refrigerator.

Solution: Block diagram of heat input and output is:



COP of the refrigerator, COP_R
=Desired effect/work input
=Q_L/Wnet,in
=(360/60 kJ/s)/2 = 3

The COP of the refrigerator is 3 (3 kJ of heat is removed per kJ of work supplied).
The rate of heat rejection can be obtained by applying the first law of thermodynamics
$Q_H = Q_L + W_{net,in}$=6 kW + 2 KW = 8 kW

2. Carnot refrigeration cycle absorbs heat at 270 K and rejects heat at 300 K.

(a) Calculate the coefficient of performance of this refrigeration cycle.
(b) If the cycle is absorbing 1130 kJ/min at 270 K, how many kJ of work is required per second.

Given: T1 = 270 K; T2 = 300 K
(a) Coefficient of performance of Carnot refrigeration cycle
We know that coefficient of performance of Carnot refrigeration cycle,

$$\mathrm{COP_R} = \frac{\mathrm{T_1}}{\mathrm{T_2} - \mathrm{T_1}} = \frac{270}{300 - 270} = 9$$

(b) Work required per second

Let WR = Work required per second

Heat absorbed at 270 K (i.e. T_1),

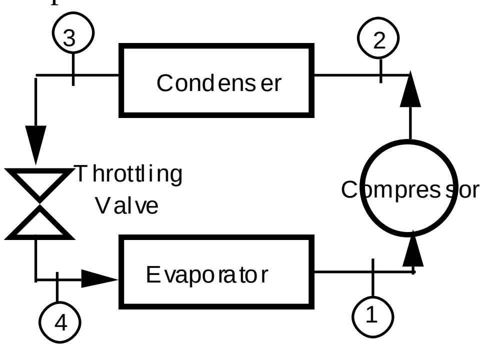
Q_1 = ll30 kJ/min= 18.83 kJ/s

We know that $COP_R = \frac{Q_1}{W_R}$

$\because W_R = \frac{Q_1}{COP_R} = \frac{18.83}{9}$

$W_R = 2.1\ kJ/s$

3. A 300 kJ/min refrigeration system operates on a vapor-compression refrigeration cycle with refrigerant 134a as the working fluid and an isentropic efficiency of 85 percent for the compressor. The refrigerant enters the compressor as a saturated vapor at 140 kPa and is compressed to 800 kPa. Determine (a) the quality of the refrigerant at the end of the throttling process, (b) the coefficient of performance and (c) the power input to the compressor.



The state points for the cycle are shown on the diagram. For the ideal cycle there is no pressure drop or work in a heat transfer device so $P_1 = P_4$ = 140 kPa and $P_2 = P_3$ = 800 kPa. The ideal compressor is assumed to be isentropic so $s_{2,s} = s_1$. State 1 is a saturated vapor and state 3 is a saturated liquid.

We apply the first law for open systems assuming steady flow and negligible changes in kinetic and potential energies; each device has one inlet and one outlet. Thus our first law for each device is $\dot{Q} = \dot{W} + \dot{m}(h_{out} - h_{in})$

We can find the enthalpy values from tables A-11 to A-13.

$h_1 = h_g(P_{evap}$ = 140 kPa) = 239.16 kJ/kg $\qquad s_1 = s_g(P_{evap}$ = 140 kPa) = 0.94456 kJ/kg·K

$h_{2,s} = h(P_2 = P_{cond}$ = 800 kPa, $s_{2,s} = s_1$= 0.9322 kJ/kg·K) = 275.39 kJ/kg·K by interpolation.

Since the compressor is a work input device, we can find the actual value of h_2 by the equation $h_2 = h_1 - (h_1 - h_{2,s})/\square_s$ = 239.16 kJ/kg – (239.16 kJ/kg – 275.39 kJ/kg·K)/(85%) = 278.40 kJ/kg.

$h_3 = h_f(P_{cond} = 800 \text{ kPa}) = 93.42$ kJ/kg

For the throttling valve, $h_4 = h_3$ so, $h_4 = h_f(P_{cond} = 800 \text{ kPa}) = 95.47$ kJ/kg

We can find the quality at the throttling valve exit as follows.

$$x_4 = \frac{h_4 - h_f(P_4 = 140\ kPa)}{h_{fg}(P_4 = 140\ kPa)} = \frac{\frac{95.47\ kJ}{kg} - \frac{27.08\ kJ}{kg}}{\frac{212.08\ kJ}{kg}} \qquad \text{x4} = 32.2\%.$$

We find the COP from the usual equation in terms of the cycle enthalpy values.

$$COP = \frac{|q_{evap}|}{|w_{comp}|} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{\frac{239.16\ kJ}{kg} - \frac{95.47\ kJ}{kg}}{\frac{281.78\ kJ}{kg} - \frac{239.16\ kJ}{kg}} \qquad \text{COP} = 3.37.$$

The required power input to the compressor is found from the refrigerant heat load and the cop.

$$|\dot{W}_{comp}| = \frac{|\dot{Q}_{evap}|}{cop} = \frac{\frac{300\ kJ}{\min}\ \frac{\min}{60\ s}\ \frac{kW \cdot s}{1\ kJ}}{3.37} \qquad \boxed{|\dot{W}_{comp}| = 1.48\ kW}$$

4. Which is the most common refrigeration cycle?

Ans. Vapor compression cycle

5. What is the difference between azeotropic and zeotropic mixture?

Ans. Azeotrope- A mixture made up of two or more refrigerants with similar boiling points that act as a single fluid. The components of azeotropic mixtures will not separate under normal operating conditions and can be charged as a vapor or liquid. Zeotrope - A mixture made up of two or more refrigerants with different boiling points. Zeotropic mixtures are similar to near-azeotropic mixtures with the exception of having a temperature glide greater than 10° F. Zeotropic mixtures should be charged in the liquid state.

6. Why thermal conductivity of a refrigerant should be high?

Ans. To reduce the area of heat transfer in evaporator and condenser and for higher heat transfer coefficients

7. What is the difference between heat pump and refrigerator?

Ans. Heat pumps gives heat by taking work input on the other hand refrigerator ejects heat by taking heat input.

8. Why Reversed Carnot Cycle is not possible practically?

Ans. It is not because adiabatic processes are not possible to obtain due to losses in the pipes condensers, compressors and evaporator.

9. How defrosting is done in a refrigerator?

Ans. Defrosting is done by stopping the compressor for a short time.

10. What is the basis of refrigeration system?

Ans. Second law of thermodynamics

11. How to improve refrigeration effect?

Ans.By applying superheating and subcooling

12. What is the advantage of vapor compression refrigeration system?

Ans. Smaller size for a given refrigeration effect, Higher COP, Lower power consumption, Less Complicated in design and operation.

13. The relative coefficient of performance is

Ans. Actual COP/ Theoretical COP

14. Why the critical pressure of a refrigerant should be high?

Ans. Because otherwise the zone of condensation decreases and the heat rejection occurs

15. What is the advantage of vapor compression refrigeration system?

Ans. Smaller size for a given refrigeration effect , Higher COP, Lower power consumption, Less Complicated in design and operation.