Fundamentals of Refrigeration

Changing the way you think about refrigeration

DAIKIN LEARNING
ADVANCING THE INDUSTRY

3 Refrigeration Cycles

A refrigeration system moves heat from a space, fluid or material for the purpose of lowering its temperature. In the past, this was done by collecting ice in the winter and using its specific heat to cool as the ice melted. When 1 pound of ice melts, it absorbs 144 Btu, as latent energy. When 1 ton (2000 lbs) melts over a 24-hour period:

Q = 2000 lbs × 144 Btu/lb/24 hrs = 12,000 Btu/h

This is the definition of 1 ton of refrigeration.

Ideal Basic Refrigeration Cycle

The ***ideal basic refrigeration cycle*** consists of four components, connected by piping with refrigerant flowing through the system. ***Figure 13*** shows the components in the cycle and ***Figure 14*** shows the basic cycle on the Ph diagram.

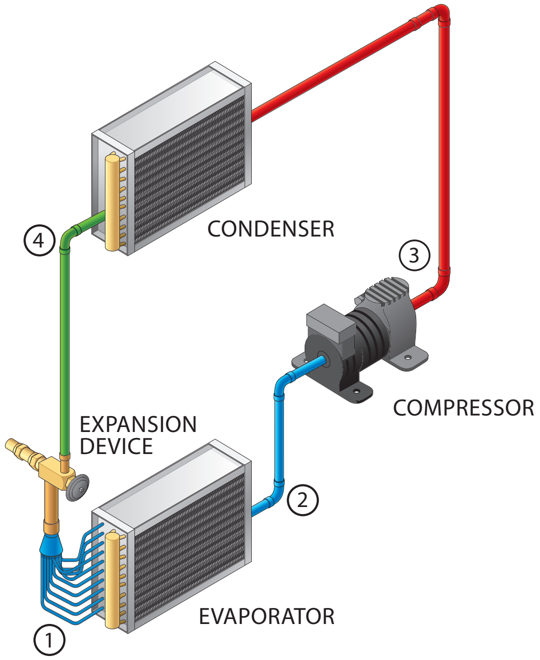
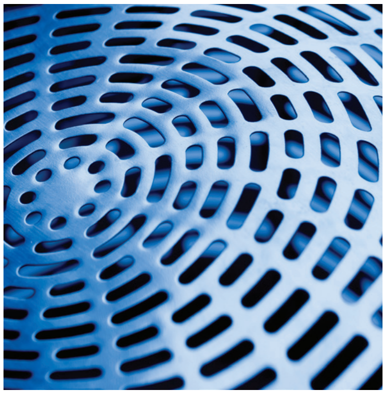


Figure 13
Basic Refrigeration Cycle

The ***evaporator*** is between points 1 and 2. In this component, the refrigerant starts as a cold, two-phase substance (part liquid, part vapor) and is boiled to a saturated gas by absorbing heat from the space/fluid/item that needs to be cooled.



1 ton of cooling is the effect of 1 ton of ice melting over a 24 hour period.

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In an ideal cycle, the expansion device is indicated as a vertical line on a Ph diagram because there is no change in enthalpy of the refrigerant. In a carnot cycle, the expansion process is both adiabatic and isentropic.

The ***compressor*** is between points 2 and 3. The compressor does work on the refrigeration system (consumes energy). It raises the pressure, temperature and enthalpy of the refrigerant by compressing the saturated gas, in an isentropic process, to a superheated gas (i.e. entropy is constant – reversible process).

The ***condenser*** is between points 3 and 4. It cools the refrigerant until it condenses back into a (high-pressure) liquid by rejecting heat from the refrigerant to the surroundings. When complete, the refrigerant is a saturated liquid. The condenser rejects not only the heat gained in the evaporator but also the work of compression added by the compressor.

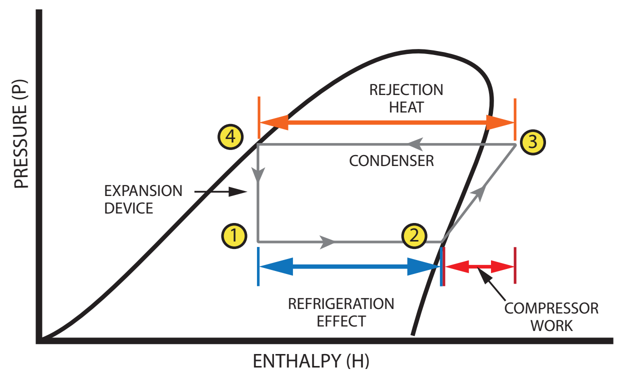
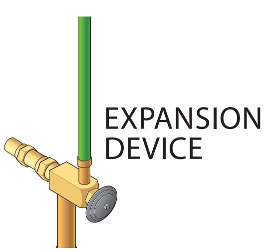


Figure 14
Ph Diagram For Basic Refrigeration Circuit

The ***expansion device*** is between points 4 and 1. In an ideal cycle, it drops the pressure and temperature of the refrigerant with no heat transfer to the surroundings (adiabatically).

Expansion Device



Point 4 can be identified by finding the properties of a saturated liquid at the condensing temperature or pressure. In an ideal cycle, the expansion process has constant enthalpy so the enthalpy at point 1 is the same as point 4. This can be used to calculate the quality of the refrigerant entering the evaporator.

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Expansion Device Example

An R-134a refrigeration system condenses at 95° F and evaporates at 45° F. The capacity is 100 tons.

Find the properties at point 4, the pressure drop across the expansion device, the quality of the refrigerant and properties at point 1.

Answer:

From ***Appendix C - Refrigerant Properties***, we can get the following information by looking at the saturated conditions for the two temperatures:

Temperature (° F)	45	95
Pressure (p) psia	54.75	128.6
Density (ρ) lb/ft³	79.32	72.88
Enthalpy (h_L) Btu/lb	26.51	43.39
Enthalpy (h_v) Btu/lb	109.5	115.7
Entropy (s_L) Btu/lb° R	0.05724	0.08877
Entropy (s_v) Btu/lb° R	0.2217	0.2192

The properties at point 4 can be found because they are the saturated liquid condition of the refrigerant at 95° F.

T_4 = 95° F

h_4 = 43.39 Btu/lb

s_4 = 0.08877 Btu/lb° R

p_4 = 128.6 psia

Pressure drop across the expansion device

ΔP = 128.6 - 54.75 = 73.85 psi

$$\text{Quality}\,(\chi) = \frac{(h - h_l)}{(h_v - h_l)}$$

Since an ideal expansion device is adiabatic, $h_1 = h_4$ = 43.39 Btu/lb

$$\chi = \frac{(43.39 - 26.51)}{(109.5 - 26.51)} = 0.203$$

The properties at point 1 can be found as follows;

T_1 = 45° F

h_1 = 43.39 Btu/lb

$s_1 = s_l + \chi\,(s_v - s_l)$ = 0.05724 + 0.203 × (0.2217 - 0.05724) = 0.0906 Btu/lb° R

p_1 = 54.75 psia