EXPERIMENT-2

REFRIGERATION CYCLE

1. Introduction

Cooling systems generally have many applications in current life, industry and especially in preservation of food. The most common cooling system is vapor compression mechanical cooling system. This cooling system consists of four main components: compressor, condenser, expansion valve and evaporator. The vapor compression system employs a liquid refrigerant which evaporates and condenses readily. The system is a closed one since the refrigerant never leaves the system.

A compressor which compresses the vaporous working fluid and providing required mechanical energy $\dot{W}$ to the system.

A condenser that absorbs heat (at constant pressure) from the working medium and transfer it to the high temperature source.

An expansion valve that expands the liquid working medium during a constant enthalpy process.

An evaporator facilitates the evaporation of the working medium while it absorbs heat from the low temperature reservoir.

For thermal analysis of refrigeration cycle several diagrams such as T-s or p-h diagrams can be used.

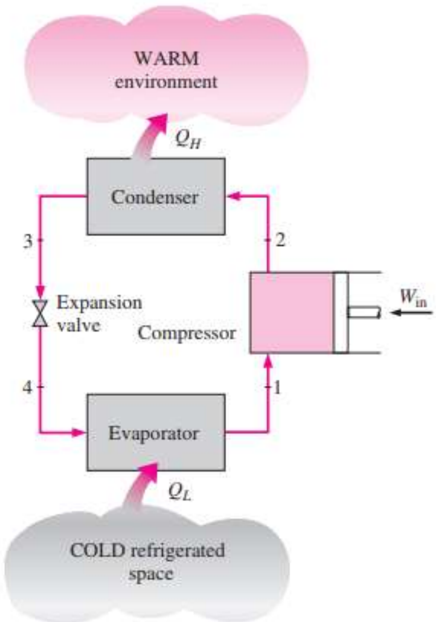

Figure 1. The ideal vapor-compression refrigeration cycle

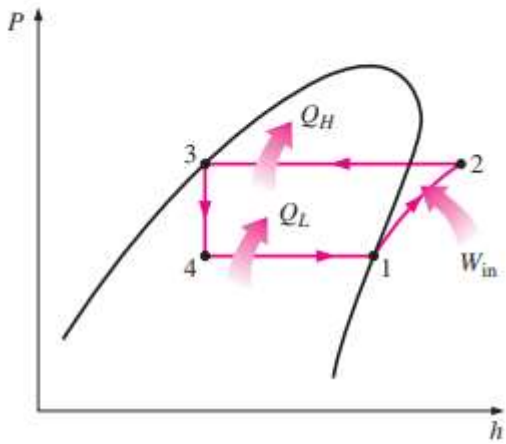

Figure 2. The P-h diagram of an ideal vapor-compression refrigeration cycle

Ideal Vapor-Compression Cycle

for refrigeration air conditioning and heat pumps processes:

- 1-2 (compressor) isentropic compression
- 1-3 (condenser) constant pressure heat rejection
- 3-4 (expansion valve) throttling, isenthalpic
- 4-1 (evaporator) constant pressure and temperature heat addition

In an ideal vapor-compression refrigeration cycle, the refrigerant enters the compressor at state 1 as saturated vapor and is compressed isentropically to the condenser pressure. The temperature of the refrigerant increases during this isentropic compression process to well above the temperature of the surrounding medium. The refrigerant then enters the condenser as superheated vapor at state 2 and leaves as saturated liquid at state 3 as a result of heat rejection to the surroundings. The temperature of the refrigerant at this state is still above the temperature of the surroundings. The saturated liquid refrigerant at state 3 is throttled to the evaporator pressure by passing it through an expansion valve or capillary tube. The temperature of the refrigerant drops below the temperature of the refrigerated space during this process. The refrigerant enters the evaporator at state 4 as a low-quality saturated mixture, and it completely evaporates by absorbing heat from the refrigerated space. The refrigerant leaves the evaporator as saturated vapor and reenters the compressor, completing the cycle.

To calculate the refrigerating capacity, $\dot{Q}_L$, the refrigerant mass flow rate $\dot{m}$ should be known beforehand. The specific volume v for the refrigerant is read from the p-h diagram. Using the volumetric flow rate read on the volumetric flow meter, $\dot{V}$, the mass flow rate is calculated:

$$\dot{m} = \frac{\dot{V}}{v} \qquad (1)$$

Consequently, the refrigeration capacity, $\dot{Q}_L$, is calculated as:

$$\dot{Q}_L = \dot{m}\, q_L = \dot{m}\,(h_1 - h_4) \qquad (2)$$

This value is identical to the heat which is transferred to the water cooled in the evaporator:

$$\dot{Q}_L = \dot{m}_w C\,(T_{in} - T_{out}) \qquad (3)$$

The compressor work $\dot{W}$ can be taken from the cyclic process plotted in the p-h diagram. It is given by the enthalpy difference between the working fluid states before and after the compressor.

$$\dot{W} = \dot{m}\,(h_2 - h_1) \qquad (4)$$

Another important parameter in analysis of refrigerators is the coefficient of performance (COP). COP is the ratio of useful energy, i.e., heat transfer from low temperature source $\dot{Q}_L$ to the costing energy, i.e., the energy consumption of the compressor, $\dot{W}$

$$COP = \frac{\dot{Q}_L}{\dot{W}} \quad (5) \qquad COP_R = \frac{q_L}{w_{net,in}} = \frac{h_1 - h_4}{h_2 - h_1} \quad (6)$$

$s_1 = s_2$

state 1 is saturated vapor

state 3 is saturated liquid

pressure in the condenser is constant ($P_2 = P_3$)

pressure and temperature in the evaporator are constant ($P_4 = P_1$ and $T_4 = T_1$)

Compressor: $w_{in} = h_2 - h_1$ use: $h_1 = h_{g\ @P1}$

Condenser: $q_{out} = h_2 - h_3$ use: $h_{3\ = hf\ @P3}$

Expansion Valve: $h_3 = h_4$ use: h_4 to find x_4

Evaporator: $q_{in} = h_1 - h_4$

2. Objective

The aims of this study;

- introducing the vapor compressed cooling system,
- specifying thermal capacities of evaporator and condenser,
- showing the refrigeration cycle in P-h diagram,
- calculating the Coefficient of Performance (COP) of system.

3. Test System and Experimental Procedure

3.1. Test System

Figure 1 shows the test system. There are compressor, condenser, three types of reduction valves (thermostatic expansion valve, automatic expansion valve and capillary tube) and evaporator in refrigeration cycle. R 134a is used as refrigerant fluid. While the temperatures are measured by thermometers placed into some points of the systems, the pressures of low and high pressure regions is read through manometers of the system.

3.2. Experimental Procedure

1) After controlling of the close position of compressor switch, electrical connection of system is provided.
2) Before activation of system, the valve of at least one expansion mechanism must be open.
3) Condenser ventilator, evaporator ventilator and compressor is activated through switches on the system, respectively.
4) Data are recorded when the system reaches to steady-state.
5) All procedures are done for every expansion mechanism.
6) At the end of the experiment, compressor and then all switches are closed and electrical connection is cut off.

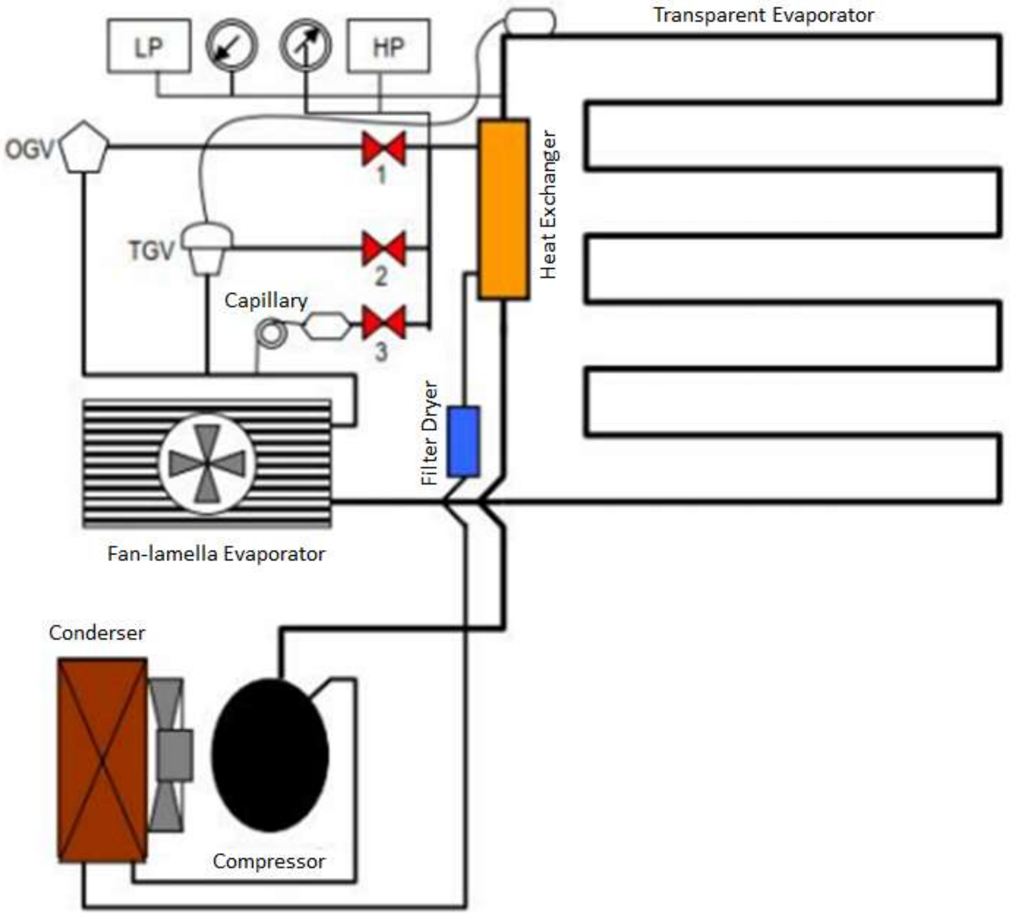

Figure 3. Vapor compressed refrigeration cycle

4. Calculations

1) Compare all data and ideal condition for every test by using on P-H diagram.
2) Calculate thermal capacities of evaporator and condenser.
3) Calculate the Coefficient of Performance (COP) of the system.
4) Discuss the ideal refrigerant cycle behaviour and differences of test system.

5. References

Çengel, Y.A., Boles, M.A., 2006, Thermodynamics An Engineering Approach, 5th Edition, McGraw-Hill.

http://www.sfu.ca/~mbahrami/ENSC%20388/Lab/Experimrnt%202/Vapor%20Compression%20Refrigeration%20Cycle.pdf date accessed: 27.09.18

Paknezhad, Mi., 2006, Thermodynamic cycle and machinery of vapor compression heat pump and refrigerator, Engineering Thermodynamics 2 Lab Report.

Yadav, G.M., RajendraPrasad, P., Veeresh, G., Experimental analysis of vapour compression refrigeration system with liquid line suction line heat exhanger by using R134A and R404A, International Journal of Scientific Researh and Management Studies, 1(12): 382-395.