Class :2nd stage
Subject: thermodynamics
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Experiment No. 4: Determining the phase of the refrigerant at the beginning and end of each part of the compressor system.

The aim of this experiment: To recognize the parts of refrigeration system.

Apparatus: Refrigeration system, thermometer, heat sensors type (NiCr-Ni), timer.

Theory:

Refrigeration Cycle Heat flows in direction of decreasing temperature, i.e., from high-temperature to low temperature regions. The transfer of heat from a low-temperature to high-temperature requires a refrigerator and/or heat pump. Refrigerators and heat pumps are essentially the same device; they only differ in their objectives. The performance of refrigerators and heat pumps is expressed in terms of coefficient of performance (COP):

$$COP_R = \frac{Q_L}{W_{net,in}}$$

$$COP_{HP} = \frac{Q_H}{W_{net,in}}$$

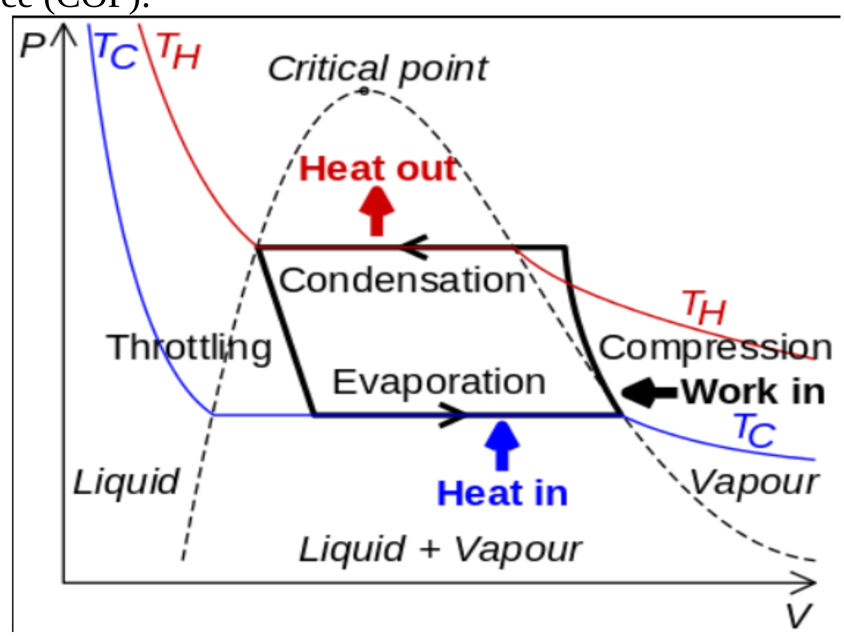

Figure (4-1): schematic diagram of refrigeration cycle.

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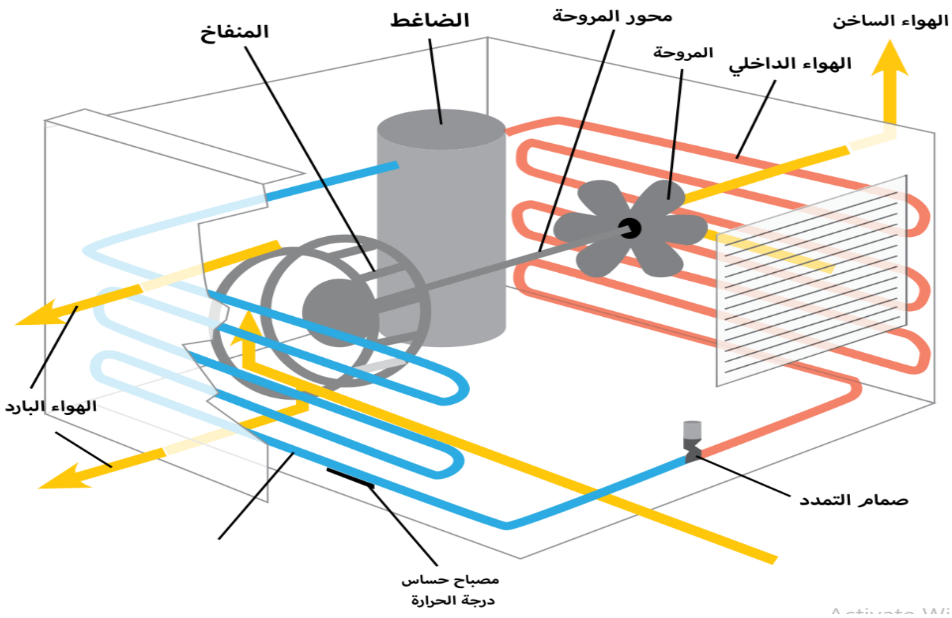
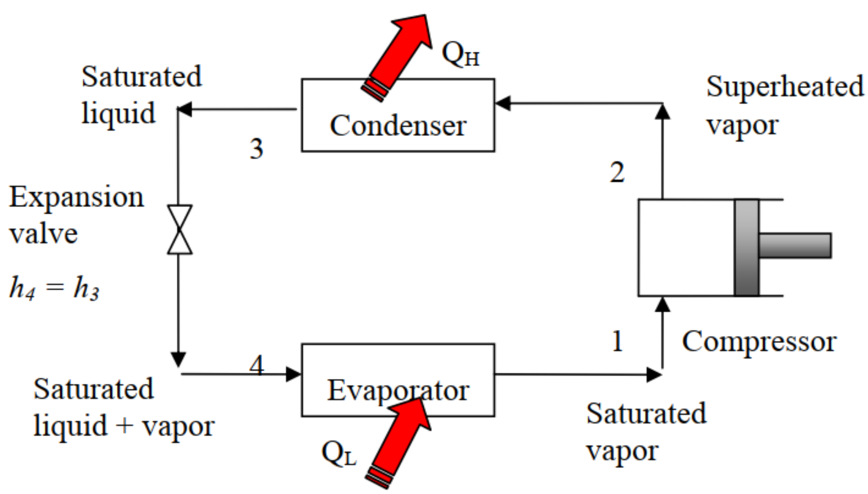


Figure (4-2): Heat pump system.

The Ideal Vapor- Compression Refrigeration Cycle The vapor-compression refrigeration is the most widely used cycle for refrigerators, air conditioners, and heat pumps.



Figure(4-3): Schematic for ideal vapor-compression refrigeration cycle.

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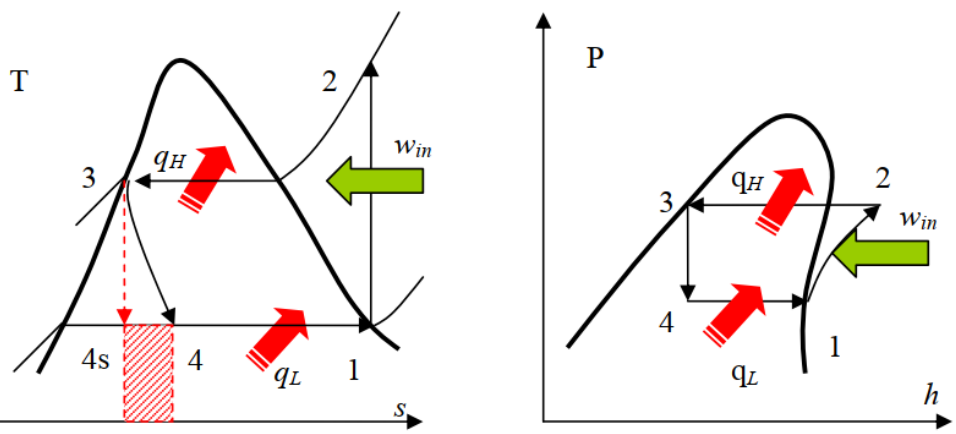
Assumptions for ideal vapor-compression cycle:

- Irreversibility within the evaporator, condenser and compressor are ignored
- No frictional pressure drops
- Refrigerant flows at constant pressure through the two heat exchangers (evaporator and condenser)
- Heat losses to the surroundings are ignored
- Compression process is isentropic



Figure(4-4): T-s and P-h diagrams for an ideal vapor-compression refrigeration cycle.

1-2: A reversible, adiabatic (isentropic) compression of the refrigerant. The saturated vapor at state 1 is superheated to state 2.

$w_c = h_2 - h_1$

2-3: An internally, reversible, constant pressure heat rejection in which the working substance is de-superheated and then condensed to a saturated liquid at 3.

During this process, the working substance rejects most of its energy to the condenser cooling water.

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$q_h = h2 - h3$

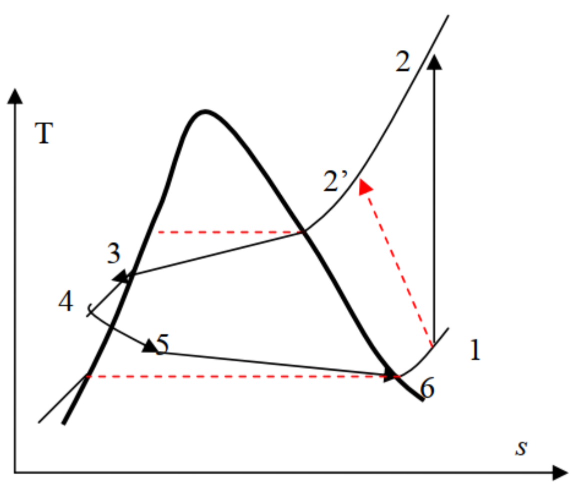
3-4: An irreversible throttling process in which the temperature and pressure decrease at constant enthalpy. The refrigerant enters the evaporator at state 4 as a low-quality saturated mixture.

$h3 = h4$

4-1: An internally, reversible, constant pressure heat interaction in which the refrigerant (two-phase mixture) is evaporated to a saturated vapor at state point 1. The latent enthalpy necessary for evaporation is supplied by the refrigerated space surrounding the evaporator. The amount of heat transferred to the working fluid in the evaporator is called the refrigeration load.

$qL = h1 - h4$

Actual Vapor- Compression Refrigeration Cycle



Figure(4-5): T-s diagram for actual vapor-compression cycle.

Most of the differences between the ideal and the actual cycles are because of the irreversibility in various components which are:

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1-In practice, the refrigerant enters the compressor at state 1, slightly superheated vapor, instead of saturated vapor in the ideal cycle.

2- The suction line (the line connecting the evaporator to the compressor) is very long. Thus pressure drop and heat transfer to the surroundings can be significant, process 6-1.

3- The compressor is not internally reversible in practice, which increase entropy.

However, using a multi-stage compressor with intercooler, or cooling the refrigerant during the compression process, will result in lower entropy, state 2'.

4- In reality, the refrigerant leaves condenser as sub-cooled liquid. The sub-cooling process is shown by 3-4 in Fig.(4-5). Sub-cooling increases the cooling capacity and will prevent entering any vapor (bubbles) to the expansion valve.

5- Heat rejection and addition in the condenser and evaporator do not occur in constant pressure (and temperature) as a result of pressure drop in the refrigerant.
Selecting the Right Refrigerant

When designing a refrigeration system, there are several refrigerants from which to choose. The right choice of refrigerant depends on the situation at hand. The most common refrigerants are: R-11, R-12, R-22, R-134a, and R-502.

R12: CCl2F2 dichlorofluoromethane, used for refrigeration systems at higher temperature levels- typically, water chillers and air conditioning (banned due to ozone layer effects)

R22: CHClF2 has less chlorine, a little better for the environment than R12 - used for lower temperature applications

R134a: CFH2CF3 tetrafluorethane - no chlorine- went into production in 1991- replacement for R12

Ammonia NH3: corrosive and toxic- used in absorption systems-cheap- high COP

R744: CO2 behaves in the supercritical region- low efficiency

R290: propane combustible.

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Procedure:

1.Fill the two storages with water to (4L) at each one.

2. Record temperature of laboratory, then run on the equipment and record the temperature of each storage every (30 s), repeat this step several times.

3.Plot graphic between temperature (^{o}C) on y-axis, and time (S) on x-axis.

4.Calculate efficiency from $\eta = Q/W$

W: work for heat pump (W=15 watt =150J/s) = i.v.t at t=10s

Q: heat flow = m.C.slop

m : mass of water on each storage = 4L= 4kg

C: specific heat of water = 4185J/kg.^{o}C