ME 316 Mechanical Engineering Laboratory
COP Measurement in Refrigeration Unit

1. OBJECT

The purpose of the experiment is the measurement of coefficient of performance of a refrigeration unit which is operated under different test conditions.

2. THEORY

2.1. Thermodynamic Aspects of Refrigeration

The Second Law of Thermodynamics includes the statement, "It is impossible to transfer heat from a region at a low temperature to another at a higher temperature without the aid of an external agency".

Refrigerators and Heat Pumps are examples of machines which transfer heat from a low to a high temperature region and the "external agency" employed may be either work or high grade heat.

The First Law of Thermodynamics states that in a cycle the net heat transfer is equal to the net work transfer. Thus, for a refrigerator, Heat transfer at low temperature + Heat transfer at high temperature = Work transfer. (The normal sign convention must, of course, be applied.)

In the case of a refrigerator (or heat pump) using a work input, (i.e. the vapour compression cycle), it follows that heat transfer at low temperature + work input = heat transfer at high temperature.

If the external agency is high grade heat (i.e. the absorption cycle), then heat transfer at low temperature + heat transfers at higher temperatures = 0.

2.2. Idealised Vapour Compression Cycle

Although no refrigerator or heat pump can have a coefficient of performance higher than that of a Reversed Carnot Cycle operating between the same source and sink temperatures, the Carnot Cycle is unattractive. This is largely because of the practical problems associated with the design of an expander which would take in high pressure liquid and pass out very wet vapour at a low pressure while producing a small work output.

There would also, of course, be irreversibilities in any practical attempt to make a Carnot Cycle.

In the modern Vapour Compression Cycle, a throttling process is substituted for the isentropic expansion process 3-4 in the Carnot Cycle and although the coefficient of performance suffers due to the introduction of this highly irreversible process, the reliability and simplicity gained far outweigh the small increase of work input required.

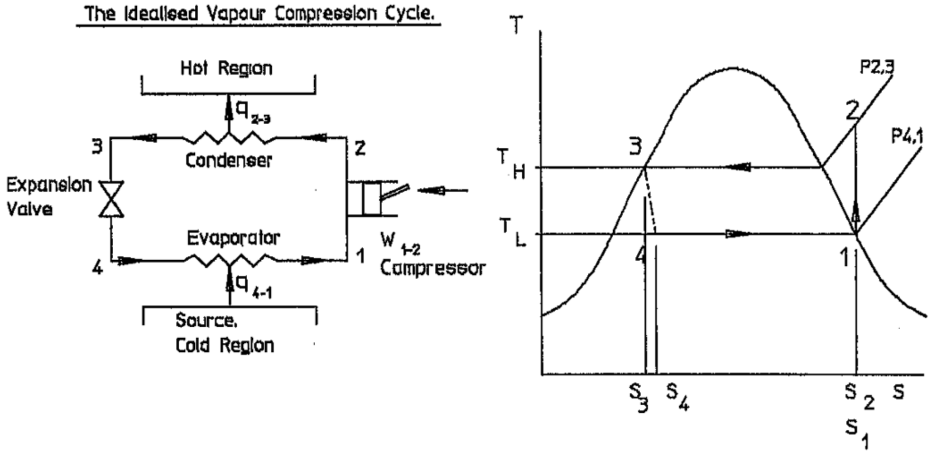


Fig 2.1 Vapour Compression Cycle.

2.3. Practical Vapour Compression Cycle

The practical cycle differs from the idealised cycle in the following ways:

- Due to friction, there will be a small pressure drop between the compressor discharge and expansion valve inlet, and between the expansion valve outlet and the compressor suction.
- The compression process is neither adiabatic nor reversible. (There will usually be a heat loss from the compressor and, obviously, there are frictional effects.)
- The vapour leaving the evaporator is usually slightly superheated. (This makes possible automatic control of the expansion valve and also improves compressor performance.)
- The liquid leaving the condenser is usually slightly sub-cooled, i.e. it is reduced below the saturation temperature corresponding with its pressure. (This improves the COP and reduces the possibility of the formation of vapour due to the pressure drop in the pipe leading to the expansion valve.)

There may be small heat inputs or losses to and from the surroundings to all parts of the circuit depending upon their temperature relative to the surroundings. The net effect of these "losses" or irreversibilities on the cycle diagram is shown below.

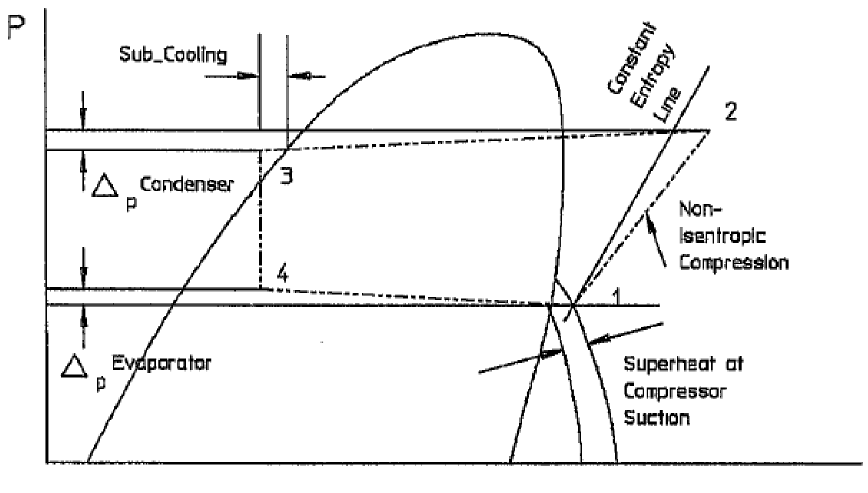
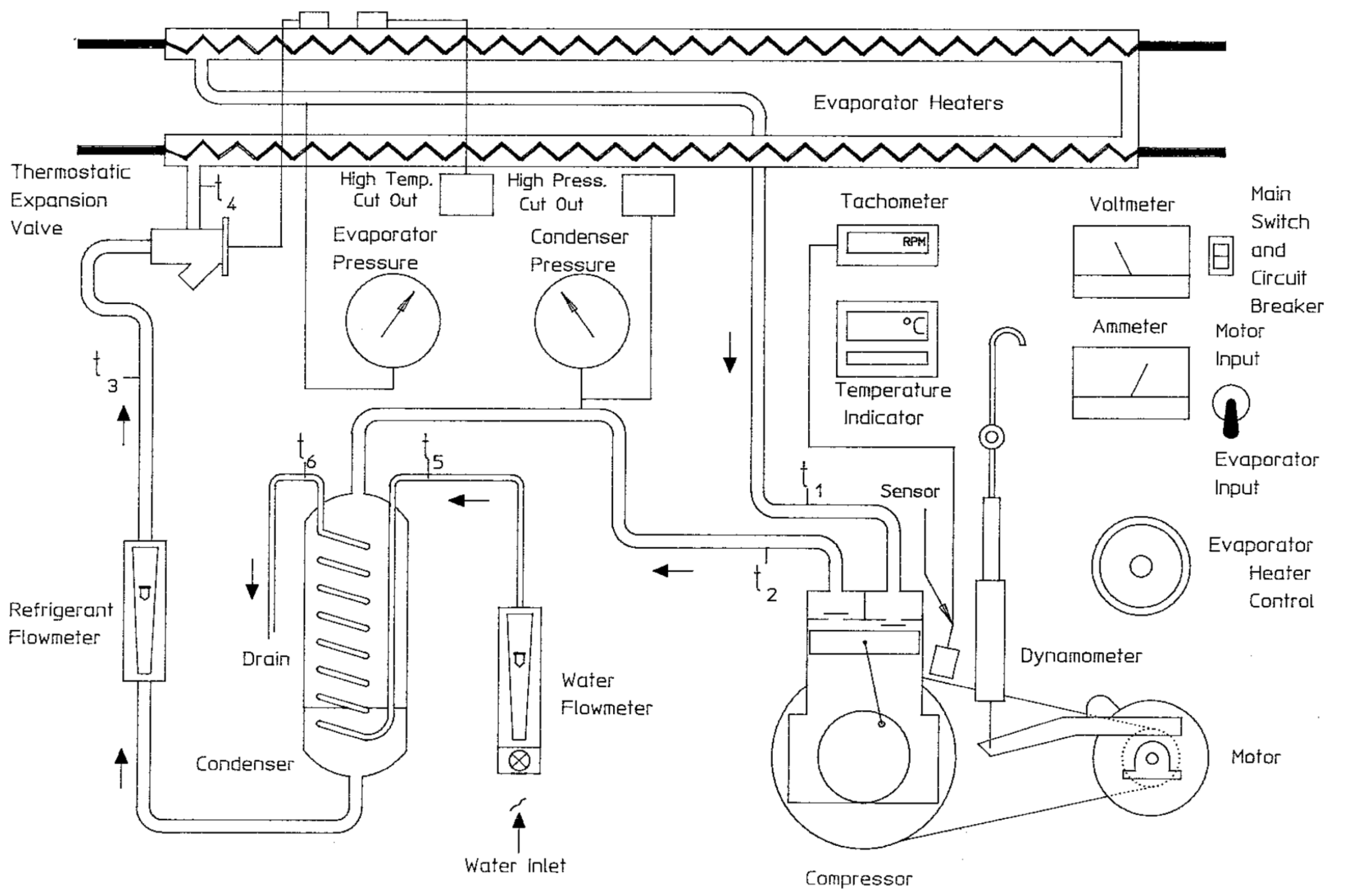


Fig 2.2 P-h Diagram for Simple Practical Vapour Compression Cycle

R713 REFRIGERATION LABORATORY UNIT



3. EXPERIMENTAL PROCEDURE

Start the unit and adjust the evaporator heat input control and, to set the evaporating pressure adjust the condenser cooling water to give the required condenser pressure and hence saturation temperature.

For performance curves start with a small duty, say 250W and increase this in increments of about 250W until the maximum duty is reached.

The unit will respond quickly after the load change and stabilise within 5-6 minutes, although it may take a little longer at light loads. Stability is reached when changes in pressure, temperature, flow, etc., have ceased.

Note: If the mains voltage or the mains water pressure tends to fluctuate, it will be necessary to make small adjustments to the heat input control and/or the water flow rate control to achieve absolute stability.

Shutting Down at End of Test

Reduce the refrigeration load (evaporator heat input control) to zero. After about one minute switch off at mains switch and turn off the cooling water.

4. CALCULATIONS

a) Calculate the heat input to the evaporator.

b) Calculate the heat transfer to cooling water.

c) Calculate the shaft power.

d) Calculate the COP of the refrigeration unit, and draw the performance curve with respect to condenser saturation temperature.

5. REPORT

In your laboratory reports must have the followings;

a) Cover

b) Include a short introduction

c) Make all the necessary calculations using measured data.

d) Draw a COP table on a milimetric paper.

e) Discuss your results and add a conclusion.

Series Test	1	2	3	4	5	6
Condenser pressure (abs.) P_0 /kN m^{-2}						
Evaporator pressure (abs.) P_0 /kN m^{-2}						
Compression suction t_1/°C						
Compressor delivery t_2/°C						
Liquid leaving condenser t_3/°C						
Evaporator inlet t_4/°C						
Water inlet t_5/°C						
Water outlet t_6/°C						
Water flowrate m_w/g s^{-1}						
R134a flowrate m_r/g s^{-1}						
Evaporator Volts V_e /V						
Evaporator Amps I_m / A						
Motor Volts V_m / V						
Motor Amps I_m / A						
Spring balance F / N						
Compressor speed n_o/rpm						
Motor speed n_m/rpm						

Note: Power factor of the electric motor is to be taken as Cosφ = 0.57