ME 316 Mech. Eng. Lab.

COP Measurement in Refrigeration Unit

OBJECT

The purpose of the experiment is the measurement of Coefficient of Performance(COP) of a refrigeration unit which is operated under different test conditions.

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.

Thermodynamic Aspects of Refrigeration

- 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.

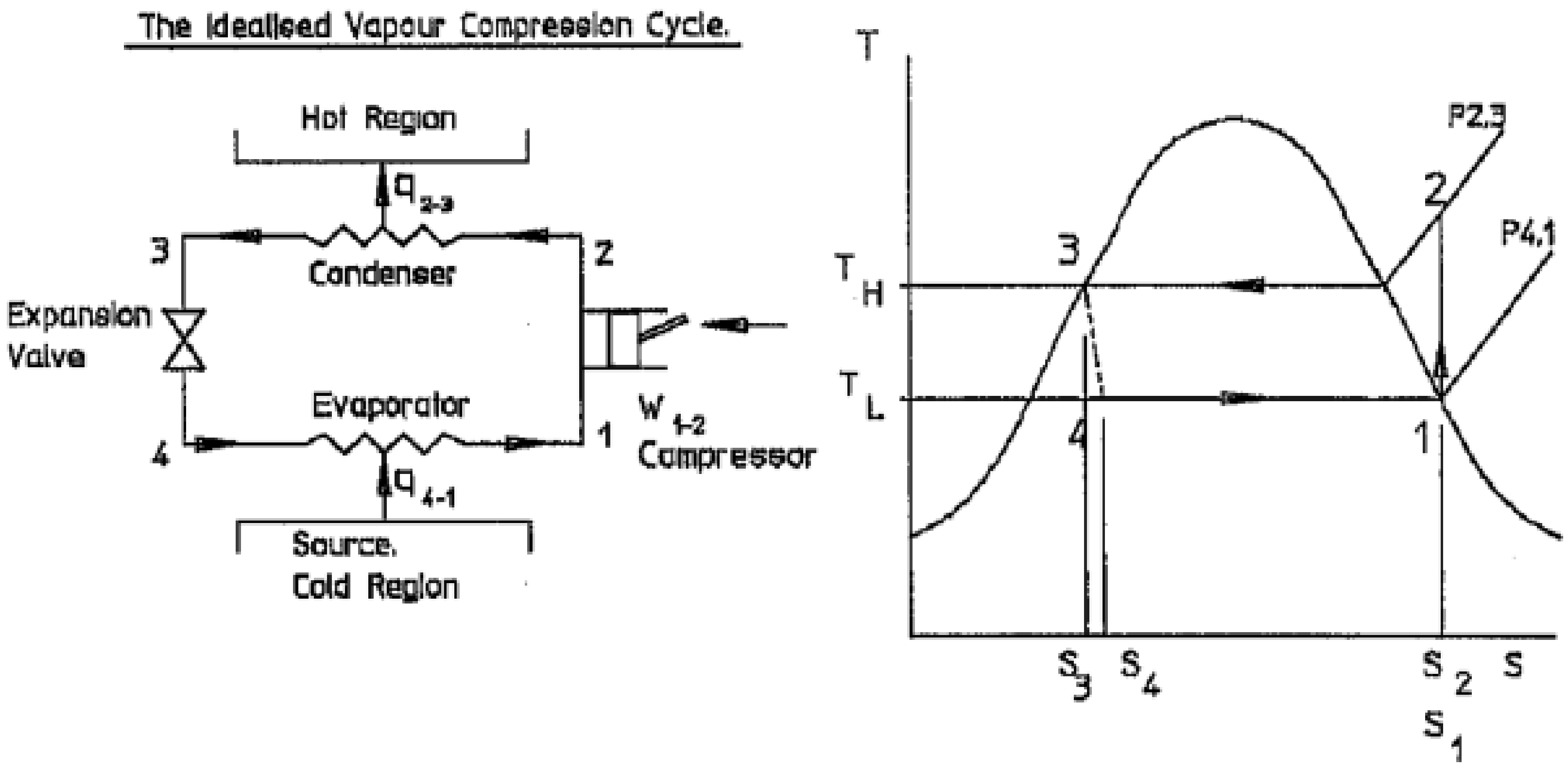
Q_{in} (Cold Region) + W_C (Work Input) = Q_{out} (Hot Region)

Thermodynamic Aspects of Refrigeration

- Physical meaning of COP :

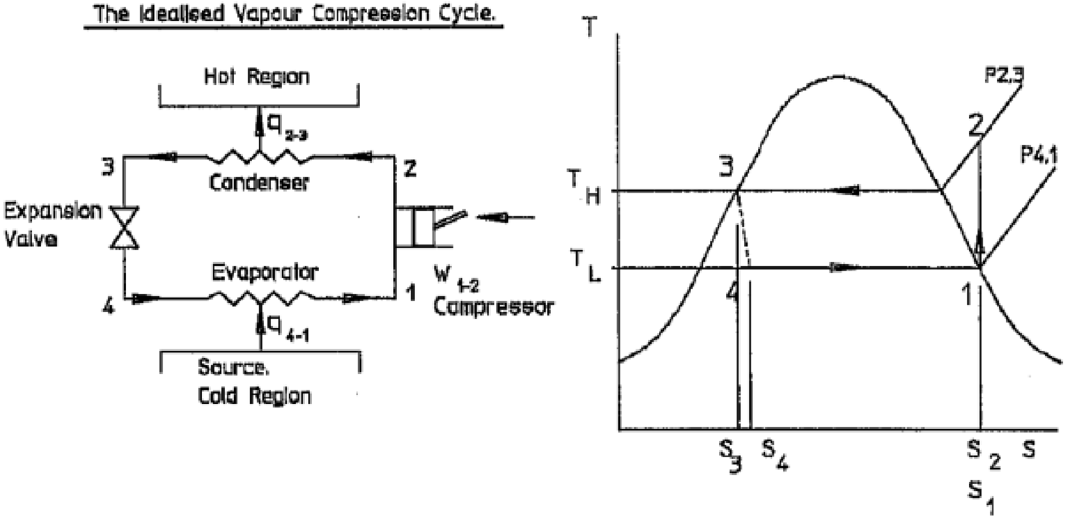
This is the Ratio : $\frac{\textit{Refrigerater Rate or Duty}}{\textit{Power Input}} = Q_{in} / W_C$

Idealised Vapour Compression Cycle



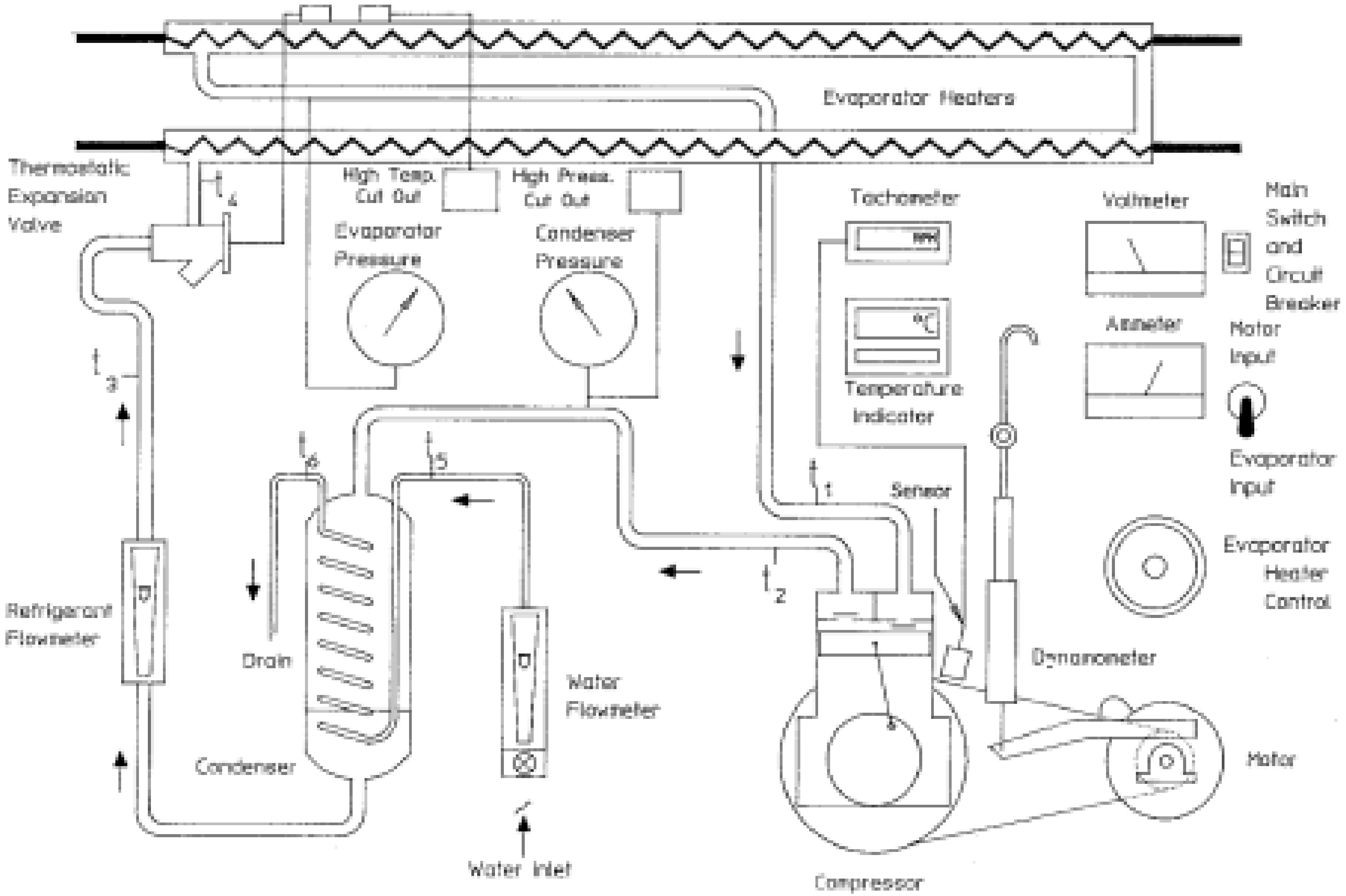
Idealised Vapour Compression Cycle.

Test Equipment



Idealised Vapour Compression Cycle.

R713 REFRIGERATION LABORATORY UNIT



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.

REFRIGERATION LABORATORY UNIT TEST OBSERVATIONS

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_e /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 $\cos\phi = 0.57$

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.

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 milimeter paper.

e) Discuss your results and add a conclusion.

Example

SERIES / TEST No.		3
Condenser pressure (abs.)	p_c/kN m^{-2}	993
Evaporator pressure (abs.)	p_e/kN m^{-2}	248
Compressor suction	t_1/°C	16.1
Compressor delivery	t_2/°C	65.8
Liquid leaving condenser	t_3/°C	29.1
Evaporator inlet	t_4/°C	-7.6
Water inlet	t_5/°C	15.0
Water outlet	t_6/°C	27.6
Water flow rate	$\dot{m}_w$/g s^{-1}	17.3

R134a flow rate	$\dot{m}_r$/g s^{-1}	4.4
Evaporator Volts	V_e/V	161
Evaporator Amps	I_e/A	4.7
Motor Volts	V_m/V	247
Motor Amps	I_m/A	3.76
Spring Balance	F/N	10.8
Compressor speed	n_c/rpm	480
Motor speed ($n_m = n_c$ x pulley ratio)	n_m/rpm	1478

Example

a) Calculating of the heat input to the evaporator.

- $\dot{Q} = \dot{m}_{R134a} * (h_1 - h_4)$

b) Calculating of the heat transfer to the cooling water.

- $\dot{Q} = \dot{m}_{water} * (h_6 - h_5)$

The heat transfer rate of water in the condenser is equal to the heat transfer rate of the refregeration in the condenser so ,we can calculate the heat transfer rate to cooling water from the following :

- $\dot{Q} = \dot{m}_{R134a} * (h_2 - h_3)$

Example

a) Calculating the shaft power

$$P = T * \omega$$

Take r= 0,165 [m]

- Shaft power $P_s = 0.165*F*2\pi*N_m/60$.

Where F is the Spring balance in (N) , and N_m is the motor speed in rpm.

- Friction power $P_f = 0.165*F_f*2\pi*N_m/60$.
- Compressor indicated power $P_i = P_s - P_f$

Take Ff=5 N

- Electric power $P_e = V_{motor}*I_{motor}*\cos\varnothing$

Example

b) Calculating the COP of the refregeration unit :

- This is the Ratio : $\frac{\boldsymbol{Refrigerater\ Rate\ or\ Duty}}{\boldsymbol{Power\ Input}}$

$$COP_{sys} = \frac{\mathbf{Q\ in/m}}{\boldsymbol{Wc/m}} = (h_1 - h_4) / (h_2 - h_1)$$

Example

c) The COP based on electrical input :

- $COP_{electric\ power} = Q_{in}\ /\ P_e\ = m_{134a}\,(h_1 - h_4)\ /\ P_e$

Example

d) The COP based on shaft power:

- $COP_{shaft\ power} = Q_{in} / P_s = m_{134a} (h_1 - h_4) / P_s$

Example

e) The COP based on indicated power:

- $COP_{indicated\ power} = Q_{in} \ / \ P_i = m_{134a}(h_1 - h_4) \ / \ P_i$