EXPERIMENT

Title of the Experiment: Determination of COP of a Refrigeration System
Date of the Experiment:

OBJECTIVE [AIM] OF THE EXPERIMENT

To determine the [i] Theoretical COP, [ii] Experimental COP, [iii] Carnot COP, [iv] Relative COP on a refrigeration system.

FACILITIES REQUIRED AND PROCEDURE

a] Facilities required to do the experiment:

Sl. No.	Facilities required	Quantity
1.	Refrigeration test rig.	1

b] Description

Vapour compression cycle is widely used refrigeration cycle. The main object of the trainer is to demonstrate refrigeration system with basic components and necessary controls. The practical working is demonstrated in the system and considerable amount of theoretical analysis and performance can be studied.

The trainer consists of components of a refrigeration system viz. Hermetically sealed components, evaporator, condenser, capillary tube. The condenser is air cooled type for which a condenser fans and motor has been provided. Evaporator is water immersion type which is housed in a thermally insulated calorimeter. Calorimeter is provided with a electric heater which can be used for heating the water initially to be desired temperature.

In addition to capillary tube a thermostatic expansion valve is also provided. We have to select either a capillary tube or thermostatic expansion valve at a time. A toggle switch has been provided to facilitate this selection.

A temperature indicator with six point selection switch has been provided to get the various temperature of Freon – 12 viz. Compressor suction, compressor discharge after condenser and after expansion and water temperature.

Special gauges have been provides for indicating Freon – 12 pressure at above mentioned points except for colorimeter water.

An energy meter has been provided which indicates the consumption of energy of compressor. An additional energy meter has been provided to indicate the energy consumption of water heater.

The students are advised to find out the saturation temperature of F – 12 after knowing the pressures at various points and based on the saturation temperatures study the working of refrigeration considering the cycle based on

[a] Reversed Carnot cycle,

[b] Simple vapour compression cycle.

TABULATION

S. No.	Time [s]	Energy Meter Reading For 10 Rev. in sev.	Pressure				Temperature [^{0}C]				
			P_1	P_2	P_3	P_4	T_1	T_2	T_3	T_4	T_5
1..	2.15	176	25	195	150	20	20	52	22	-12	29.5
2.	2.25	186	22.5	195	150	20	20	53	24	-14	29
3.	2.35	191	24	195	160	22	22	54	23	-13	28
4.	2.45	201	24	200	160	22	22	55	24	-15	27
5.	2.55	206	25	200	160	25	22	53	24	-17	26
6.	3.05	209	24	200	165	25	24	51	26	-19	22
7.	3.15	212	24	200	170	24	26	49	23	-21	19
8.	3.25	208	24	200	170	22	20	46	27	-20	16

Quantity of water in tank: 10 kg.
Initial temperature of water: 30^0C.]

Pressure in bar:

Convert all the pressures in [PSIG] to bar [multiply the value in PSIG by 0.06894 and add 1.013 to convert to bar abs.]

P_1 = 25 x 0.06894 + 1.013 = 2.736 bar.
P_2 = 195 x 0.06894 + 1.013 = 14.456 bar.
P_3 = 150 x 0.06894 + 1.013 = 11.354 bar.
P_4 = 20 x 0.06894 + 1.013 = 2.391 bar.

[1] Total Refrigerant Effect:

$Q = mC_p \Delta T/\Delta t.$
Q = 10 x 4.186 x [30-16] / 60 x 60
Q = 0.1627 KJ/sec.

[2] Theoretical COP. = $[h_1 - h_3]/ [h_2 - h_1]$
h_1 corresponding to P_1 and T_1 = 370 KJ/kg.
h_2 corresponding to P_2 and T_2 = 382 KJ/kg.
$h_3 = h_4$ corresponding to P_3 and T_3 = 350 KJ/kg.
Where h_1, h_2, h_3 are enthalpies of refrigerant taken from p-h chart.
Theoretical COP = [370 – 350] / [382 – 370]
Theoretical C.O.P. = 1.667.

The interested students can also study the saturation temperature against the actual temperatures obtained during the experimentation and thus study the actual cycle of refrigeration system.

Specification:

[1] Compressor: Hermetically sealed compressor.
[2] Air cooled condenser.
[3] Expansion valve
    [a] Capillary tube.
    [b] Thermostatic Expansion valve.
[4] Evaporator.
[5] Rota meter: For liquid refrigerant flow rate.
[6] Refrigerant: Freon – 12.
[7] Energy meters for power measurement of compressor and the fans and heater.
[8] Pressure gauges – 4 Nos. [Two for H.P. and Two for L.P.]
[9] Temperature indicator.
[10] Solenoid valves.
[11] H.P. / L.P. cut out.
[12] Ammeter.
[13] Voltmeter.
[14] Thermostat.

c] Procedure for doing the experiment:

Step No.	Details of the Step
1.	Switch on the main.
2.	Switch on the fan motor and then compressor motor.
3.	Allow the plant to run to reach steady conditions. Take readings for every 10 minutes to know the steady state.
4.	Observe the readings in compressor motor energy meter. Freon flow meter, pressure gauges and thermometer and record it is a tubular form.
5.	Switch off the plant after experiment is over by switching off the compressor motor first. Allow the fan motors to run for 10 minutes and then switch off.

Specimen Calculations:

P_1 = Pressure of the Refrigerant before the compressor.
P_2 = Pressure of the Refrigerant after the compressor.
P_3 = Pressure of the Refrigerant before the expansion valve.
P_4 = Pressure of the Refrigerant after the expansion valve.

Sensor Meter Reading:

T_1 = Temperature of Refrigerant before compression.
T_2 = Temperature of Refrigerant after compression.
T_3 = Temperature of Refrigerant before evaporation.
T_4 = Temperature of Refrigerant after evaporation.

[3] Experimental COP

Time for 10 rev. of energy meter, t = 208 sec.

t = 208 sec.

Energy consumed by the compressor

P = 10/t x 1/1500 x 3600 x 0.9 KW.

= 10/208 x 1/1500 x 3600 x 0.9

P = 0.104 KW.

Experimental COP = Actual Refrigeration effect / workdone

= Q / p = 0.1627 / 0.104

Experimental COP = 1.564.

[4] Carnot COP = $T_L / [T_H - T_L]$

$T_L = P_{min} = [P_1 + P_4] / 2 = [2.736 + 2.391] / 2 = 2.5635$ bar.

$T_H = P_{max} = [P_2 + P_3] / 2 = [14.456 + 2.391] / 2 = 12.905$ bar.

Lowest Temperature from table.

$T_L = -12^0C = 261$ K. Corresponding to P_{min}

Highest Temperature from table.

$T_H = 56^0C = 329$ K Corresponding to P_{max}

Carnot COP = $T_L/T_H - T_L$

= 261 / [329 – 261]

= 3.84.

[5] Relative COP = Actual COP / Carnot COP

= 1.564 / 3.84

= 0.407.

Formula:

[1] Total Refrigerating effect $Q = mC_p \Delta T/\Delta t$.

Where, m = Mass of water in kg.

C_p = Specific heat of water = 4.186 KJ/kg.

ΔT = Temperature drop in the water.

[2] Theoretical COP = $[h_1 - h_3]/ [h_2 - h_1]$

[Enthalpy is to be found out from the P-h diagram of R-12]

Where, h_1 = Enthalpy corresponding to pressure P_1 and refrigerant entering temperature at $T_1{}^0C$.

h_2 = Enthalpy corresponding to pressure P_2 and refrigerant leveling temperature at $T_2{}^0C$.

$h_4 = h_3$ = Enthalpy corresponding to pressure P_3 and refrigerant temperature after condensing at $T_3{}^0C$.

[3] Experimental COP = [Actual Refrigeration Effect/time] / Workdone.

Actual Refrigeration effect/time = $m\ C_p \Delta T/\Delta t$.

Where, m_w = mass of water in kg.

C_p = Specific heat of water = 4.186 KJ/kg.

ΔT = Temperature drop in the water.

Workdone = Energy consumed by the compressor motor to be found out from the energy meter.

Workdone = (10/t) x (3600/x} x 0.9.

Where, x = Energy meter constant = 1500 rev./Kw-hr.

t = Time taken in sec. for 10 revolutions of energy meter reading.

Experimental COP = $mC_p \Delta T/\Delta t$ / workdone.

[4] Carnot COP = $T_L / [T_H - T_L]$

$T_L = P_{min} = [P_1 + P_4] / 2$; $T_H = P_{max} = [P_2 + P_3] / 2$;

Where, T_L = Lower temperature to be maintained in the evaporator in absolute units [^0K]

T_H = Higher temperature to be maintained in the condenser in absolute units [^0K]

[5] Relative COP. = Actual COP / Carnot COP

d] Result:

The COP of the Refrigeration system were determined and tabulated.

Theortical COP.	Experimental [Actual] COP	Carnot COP	Relative COP
1.667	1.564	3.34	0.407

VIVA QUESTIONS

1. **Power requirement of a refrigerator is_____.**

   Inversely proportional to COP.

2. **In SI units, one ton of refrigeration is equal to_____.**

   210 kJ/min.

3. **Define tons of refrigeration and COP.**

   A tonne of refrigeration is defined as the quantity of heat required to be removed from one tonne of water [1000 kg] at 0^0C to convert that into ice at 0^0C in 24 hours. In actual practice,

   1 tonne of refrigeration = 210kJ/min = 3.5kW.

4. **The capacity of a domestic refrigerator is in the range of_____.**

   1 to 3 tonne.

5. **Name four important properties of a good refrigerant.**

   1. Low boiling point.
   2. High critical temperature & pressure.
   3. Low specific heat of liquid.

6. **What is the difference between air conditioning and refrigeration?**

   Refrigeration is the process of providing and maintaining the temperature in space below atmospheric temperature.

   Air conditioning is the process of supplying sufficient volume of clean air containing a specific amount of water vapour and maintaining the predetermined atmospheric condition with in a selected enclosure.

7. **Name any four commonly used refrigerants.**

   1. Ammonia [NH_3].
   2. Carbon dioxide [CO_2].
   3. Sulphur di oxide [SO_2].
   4. Freon – 12.

8. **What are the advantages and disadvantages of air refrigeration system?**

Advantages:

1. The refrigerant used namely air is cheap and easily available.
2. There is no danger of fire or toxic effects due to leakages.
3. The weight to tonne of refrigeration ratio is less as compared to other systems.

Disadvantages:

1. The quantity of refrigerant used per tonne of refrigeration is high as compared to other system.
2. The COP of the system is very low. Therefore running cost is high.
3. The danger of frosting at the expander valves is more as the air contains moisture content.

9. **What is net refrigerating effect of the refrigerant?**

Refrigerating effect is the total heat removed from the refrigerant in the evaporator.

COP = Refrigeration effect / Work done.

Refrigeration effect = COP x Work done.

10. **Define refrigerant.**

Any substance capable of absorbing heat from another required substance can be used as refrigerant.