* Mechanical Heat Pump.
Experiment
Solution Sheet.

Name of the Experiment :

Study of Mechanical Heat pump.

Objective :

(i) Determination of power Input. Heat and coefficient of performance.

(ii) Production of Heat pump performance curves over a rang of Source and delivery tempuratures.

(iii) Comparision of Practical and Ideal cycles on a ph diagram and determination of enargy blance for Condenser and Compressor.

(iv) Production of heat pump performance curves based on the R134a properticees at a Variety of Evaporating and Compensating tempuratures.

(v) Estimation of the effect of compressor Pressure ratio on Volumetric efficiency.

Theory :

A Heat pump is a machine whose prime function is to absorb heat from a low grade. Source and to deliver heat at a useful tempurature, e.g. Suitable for Space heating or domestic hot water.

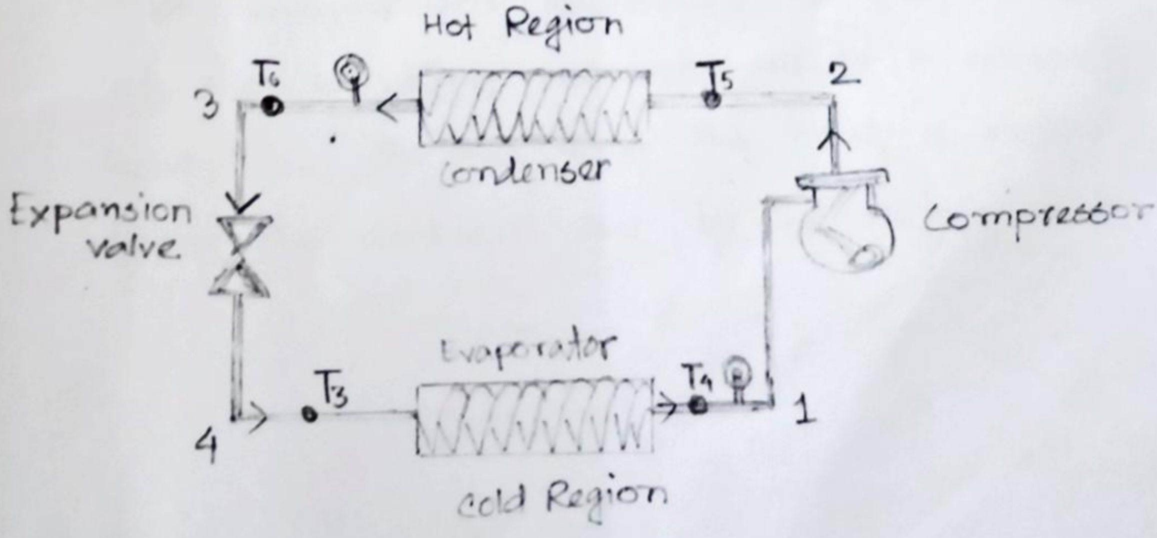
Although higher tempurature are possible in Special circumstances.

To do this, a heat pump requires,

(I) A Low grade input "this is usually free"

(II) A high grade energy input either in the from of work or as heat a high tempurature.

Practical Heat pump can deliver considerably more heat than is taken in as high grade energy and in suitable circumstance, can make a Valuable Contibution to energy consecvation.



A heat pump utilizes the Steam power station cyclic processes in reverse.
the result in the direction of the flow of heat also reversing.

I. A compressor compresses the vapours working medium, during this process mechanical energy win is absorbed.

II. In the condenser the heat Qout is drawn (at constant tempurature) from the working and medium condense. the heat can be used to heat water.

III. In Expansion valve the liquid working medium expands during this process it cools down.

IV. An Evaporator facilitates the evaporation of the working medium while it absorbs heat Qin. In this case the heat is drawn from the ambient air by the refrigerant.

- Procedure :

(i) Turn on the water supply to a high flow rate.

(ii) Ensure that the receiver inlet and outlet Values are open by being "Back Seated" anti-Clockwise.

(iii) Turn on the main switch.

(iv) Switch on fan for evaporator using switch.

(v) The Switch on the compressor.

(vi) After sort period of gassing in the R134a flow meter tube. the flow rate should stablize. the heat pump may now be set to operate at any conditions within its capability. the unit is ready for use as soon as tempuratures are sensibly constant.

- Shutting Down :

Before Shutting down, increase the Condenser water flow rate to maximum for two or three minutes, then switch off and turn off water supply.

The water should not be left running.

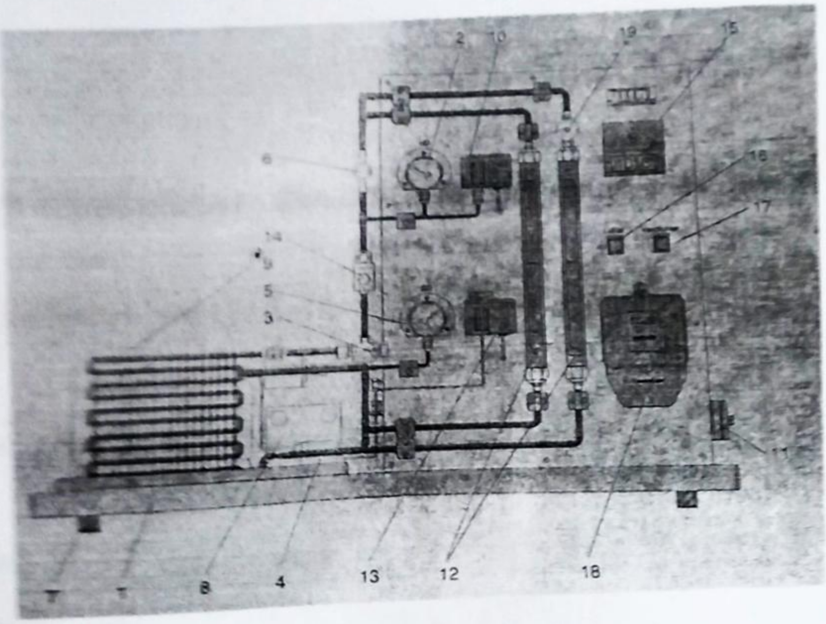


Fig: Layout of Mechanical Heat Pump

Diagram Key :

1. Base plate
2. Manometer for High pressure side.
3. Expansion Valve with Tempurature Sensor.
4. Tempurature Sensor with the thermostat.
5. Manometer for low Pressure side.
6. Sight glass for refrigerant
7. Evaporator,
8. Condenser
9. Compressor.
10. Pressostat
11. Master Switch
12. Flow meter
13. Thermostat
14. Solenoid value
15. Measuring point Switch.
16. Fan Switch.
17. Compressor Switch.
18. Single phase meter
19. Needle Valve.

Calculation :

(i) Electrical power Input $P_{el(10V)} = \frac{7200\ Ws}{t}$

(ii) Heat Supplied by Refrigerant from compressor,

$$Q_{comp} = m_{ref}(h_2 - h_1)\ W$$

(iii) Heat rejected by Refrigrant in Condenser,

$$Q_{cond} = m_{ref}(h_2 - h_3)\ W.$$

(iv) Heat absorbed by Refrigerant in Evaporator

$$Q_{Eva} = m_{ref}(h_1 - h_4)\ W.$$

(v) compressor Effiecency, $\eta = \frac{Q_{comp}}{P_{el}}$

(vi) Compressure pressure ratio, $\varphi = \frac{P_{2/3}}{P_{1/4}} = \frac{P_{HP}}{P_{LP}}$

(vii) Volumetric Effeciency, $\lambda = \frac{V_{Real}}{V_{theo}} \times 100\%$

Compressor flowrate = 2850 r.p.m

Cylinder Volumme = $12.05\ cm^3$.

$V_{Real} = \frac{m_{ref}}{\rho''_{ref}}$

[Saturated refrigerant steam ρ''_{ref} can be found in the Table]

(viii) Tempurature difference $\Delta T = T_1 - T_{Ambient}$.

(x) $COP = \frac{Q_{cond}}{P_{el}}$.

Data Table:

a. Measure Values:

Obs.	$\dot{m}_{water}$ in g/s	T_1 in °C	T_2 in °C	T_3 in °C	T_4 in °C	T_5 in °C	T_6 in °C	p_{HP} in bar	p_{LP} in bar	$\dot{m}_{Ref}$ in g/s	T 10 Rounds in s
1	10	47.4	24	9	13.7	76.2	41.3	14	2.8	6	148
2	20	38.6	24.5	9.1	13.5	74.8	36.9	9.7	2.8	6.2	156
3	30	34	24.4	8.4	13.3	73.2	33.2	8.5	2.6	6.4	160
4	40	31.8	24.4	8.5	13.2	72	31.7	8	2.6	6.6	166
5	50	30.6	24.6	8.3	13	71.3	30.9	8	2.6	6.6	168

b. Calculated Values

Obs.	$\dot{m}_{water}$ in Kg/s	$\dot{m}_{Ref}$ in Kg/s	P_{el} in W	h_1 in KJ/KgK	h_2 in KJ/KgK	h_3 in KJ/KgK	h_4 in KJ/KgK
1	.01	.006	486.5	412	448	253	253
2	.02	.0062	461.5	402	455	248	248
3	.03	.0064	450	403	454	247	247
4	.04	.0066	434	403	453	246	246
5	.05	.0066	428.5	402	452	245	245

Obs.	$\dot{Q}_{Comp}$ in W	$\dot{Q}_{Eva}$ in W	$\dot{Q}_{Cond}$ in W	η	ψ	λ in %	ΔT in °C	COP
1	216	954	1170	0.44	5	14	23.2	2.4
2	328.6	954.8	1283	0.71	3.46	22.55	15.3	2.78
3	326.4	998	1324	0.72	3.27	26	10.7	2.94
4	330	1036.2	1366.2	0.76	3.07	29	8.5	3.14
5	316	1102	1419	0.73	3.07	25.8	7.3	3.31

\# For serial NO : 01 (observation - 1)

High pressure:

Absolute pressure = Gauge P + atm pressure

$= 14 + 1 = 15$ BAR

Low Pressure

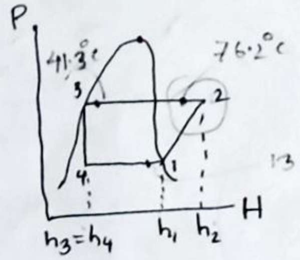
Absolute pressure = Gauge P + atm pressure

$= 2.8 + 1 = 3.8$ BAR

$h_1 = 412$ KJ/Kg

$h_2 = 448$ KJ/Kg

$h_4 = 253$ KJ/Kg



(i) Electrical power input, $P_{el} = \frac{7200}{14.88}$ Ws (14.8 per revol time)

$= 486.5$ W.

(ii) Heat Suplied by refrigerant from compressor

$Q_{comp} = m_r (h_2 - h_1)$

$= 0.006$ Kg/s $\times (448 - 412)$ KJ/kg

$= 0.216$ KJ/s $= 216$ W.

(iii) Heat Rejected by refrigerant in Condenser.

$Q_{cond} = m_r (h_2 - h_3)$

$= 0.006 (448 - 253)$

$= 1.17$ KJ/s

$= 1170$ W.

(iv) Heat absorbed by refrigerant in Evaporator.

$$Q_{Eva} = m_r (h_1 - h_4)$$
$$= 0.006 (412 - 253)$$
$$= 0.954 \text{ K.J/s.} = 954 \text{ W.}$$

(v) compressor efficiency $\eta = \frac{Q_{comp}}{P_{el}}$

$$= \frac{216}{486.5} = 0.44$$

(vi) Volumetric efficiency $\lambda = \frac{V_{Real}}{V_{theo}} \times 100$

$$V_{theo} = \frac{R.P.M \times V_{cyl}}{60}$$
$$= \frac{2850 \times 12.05 \times 10^{-5}}{60}$$
$$= 5.72 \times 10^{-4} \text{ m}^3/\text{s}$$

$$= \frac{8.42 \times 10^{-5}}{5.72 \times 10^{-4}}$$
$$= 0.147 \times 100$$
$$= 14.$$

$$V_{Real} = \frac{m_r}{\rho''_{ref}} = \frac{0.006}{71.24}$$
$$= 8.42 \times 10^{-5} \text{ m}^3/\text{s}$$

(vii) compressare pressure ratio: $\varphi = \frac{P_{2/3}}{P_{1/4}} = \frac{14}{2.8} = 5.$

(viii) Tempurature difference $\Delta T = T_1 - T_{ambient}$

$$= 47.4 - 23.3$$
$$= 23.2^\circ$$

(ix) $COP = \frac{Q_{cond}}{P_{el}} = \frac{1170}{486.5} = 2.4.$

For observation : 02

High pressure

Absolute pressure = Gauge P + atmospheric P.

$= 9.7 + 1$

$= 10.7$ BAR

Low pressure,

Absolute pressure = Gauge P + atm P.

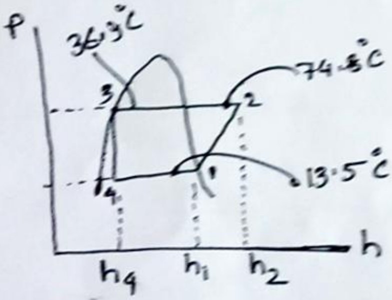
$= 2.8 + 1$

$= 3.8$ BAR

$h_1 = 402$ KJ/kg

$h_2 = 455$ KJ/kg

$h_3 = h_4 = 248$ KJ/kg



(i) Electrical power input $P_{el} = \frac{7200\,ws}{t}$

$= \frac{7200}{15.6} = 461.5$ W

(ii) Heat Supplied by refrigerant from compressor

$Q_{comp} = m_r (h_2 - h_1)$

$= 0.0062 (h_2 - h_3)$

$= 328.6$ W.

(iii) Heat Rejected by refrigeration in condenser.

$Q_{cond} = m_r (h_2 - h_3)$

$= 0.0062 (455 - 248)$

$= 1283$ W

(iv) Heat absorbed by refrigeration in Evaporator

$$Q_{Eva} = m_r (h_1 - h_4)$$
$$= 0.0062 (402 - 248)$$
$$= 954.8 \text{ W.}$$

(v) compressor efficiency $\eta = \frac{Q_{comp}}{P_{el}}$

$$= \frac{328.6}{461} = 0.71.$$

(vi) Compressor pressure ratio: $\psi = \frac{P_{2/3}}{P_{1/4}} = \frac{9.7}{2.8} = 3.46.$

(vii) Volumetric efficiency $\lambda = \frac{V_{Real}}{V_{theo}} \times 100.$

$$V_{theo} = \frac{RPM \times V_{cyl}}{60}$$
$$= \frac{2850 \times 12.05 \times 10^{-5}}{60}$$
$$= 5.72 \times 10^{-4} \text{ m}^3/\text{s}$$

$$V_{Real} = \frac{m_r}{\rho_{ref}} = \frac{0.0062}{48}$$
$$= 1.29 \times 10^{-4} \text{ m}^3/\text{s}$$

$$= \frac{1.29 \times 10^{-4}}{5.72 \times 10^{-4}} \times 100$$
$$= 22.55.$$

(viii) Tempurature difference $\Delta T = T_1 - T_{ambient}$

$$= 38.6 - 23.3$$
$$= 15.3^\circ C$$

(ix) $COP = \frac{Q_{cond}}{P_{el}}$

$$= \frac{1283}{461.5} = 2.78.$$

For observation : 3

High pressure

Absolute Pressure = Gauge P + atm P.

= 8.5 + 1 = 9.5 BAR

Low pressur

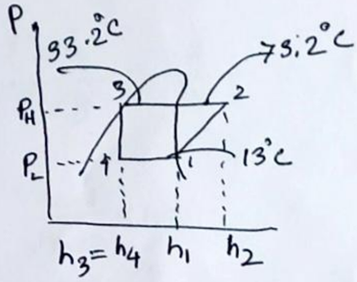
Absolute Pressure = Gauge P + atm P.

= 2.6 + 1 = 3.6 BAR.

$h_1 = 403$ KJ/kg

$h_2 = 454$ KJ/kg

$h_4 = 247$ KJ/kg



(i) Electrical power input, $P_{el} = \frac{7200}{16s} = 450$ W.

(ii) Heat Supplied by refrigerant in Compressor.

$$Q_{comp} = m_r (h_2 - h_1)$$
$$= 0.0064 (454 - 403)$$
$$= 326.4 \text{ W}.$$

(iii) Heat Rejected by refrigerant in condenser.

$$Q_{cond} = m_r (h_2 - h_3)$$
$$= 0.0064 (454 - 247) \text{ KJ/s}.$$
$$= 1.324 \times 1000$$
$$= 1324 \text{ W}.$$

(iv) Heat absorbed by refrigerant in Evaporator.

$$Q_{EVA} = m_r (h_1 - h_4)$$
$$= 0.0064 (403 - 247)$$
$$= 998.4 \text{ W}$$

(v) Compressor efficiency $\eta = \dfrac{Q_{comp}}{P_{el}}$

$$= \frac{326.4}{450} = 0.72$$

(vi) compressor ratio: $\varphi = \dfrac{P_{2/3}}{P_{1/4}} = \dfrac{8.5}{2.6} = 3.27$

(vii) Volumetric efficiency $\lambda = \dfrac{V_{Real}}{V_{theo}} \times 100$

$$V_{theo} = \frac{2850 \times 12.05 \text{ cm}^2}{60}$$
$$= 5.72 \times 10^{-4} \text{ m/s}$$

$$V_{Real} = \frac{m_r}{\rho'_{ref}} = \frac{0.0064}{41.85}$$
$$= 1.5 \times 10^{-4} \text{ m}^3/\text{s}$$

$$= \frac{1.5 \times 10^{-4}}{5.7 \times 10^{-4}} \times 100$$
$$= 0.26 \times 100$$
$$= 26.$$

(viii) Temperature difference $\Delta T = T_1 - T_{ambient}$

$$= 34 - 23.3$$
$$= 10.7$$

(ix) $$C.O.P = \frac{Q_{cond}}{P_{el}}$$
$$= \frac{1324}{450}$$
$$= 2.94.$$

(iv) Heat absorbed by refrigerant in Evaporator.

$$Q_{EVA} = m_r(h_1 - h_4)$$
$$= 0.0064(403 - 247)$$
$$= 998.4 \text{ W}$$

(v) compressor efficiency $\eta = \frac{Q_{comp}}{P_{el}}$

$$= \frac{326.4}{450} = 0.72$$

(vi) compressor ratio: $\varphi = \frac{P_{2/3}}{P_{1/4}} = \frac{8.5}{2.6} = 3.27$

(vii) Volumetric efficiency $\lambda = \frac{V_{Real}}{V_{theo}} \times 100$

$$V_{theo} = \frac{2850 \times 12.05 \text{ cm}^2}{60}$$
$$= 5.72 \times 10^{-4} \text{ m/s}$$

$$V_{Real} = \frac{m_r}{\rho'_{ref}} = \frac{0.0064}{41.85}$$
$$= 1.5 \times 10^{-4} \text{ m}^3/\text{s}$$

$$= \frac{1.5 \times 10^{-4}}{5.7 \times 10^{-4}} \times 100$$
$$= 0.26 \times 100$$
$$= 26.$$

(viii) Temperature difference $\Delta T = T_1 - T_{ambient}$

$$= 34 - 23.3$$
$$= 10.7$$

(ix) $C.O.P = \frac{Q_{cond}}{P_{el}}$

$$= \frac{1324}{450}$$
$$= 2.94.$$

For observation 4:

High pressure

Absolute pressure = Gauge Pressure + atm P.

= 8+1 = 9 BAR

Low pressure,

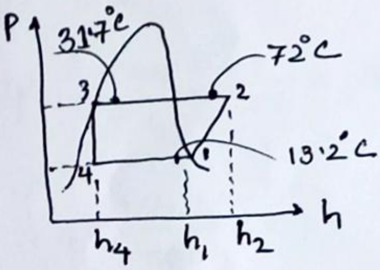
Absolute pressure = Gauge P + atm P.

= 2.8 + 1 = 3.8 BAR

$h_1 = 403$ KJ/kg

$h_2 = 453$ KJ/kg

$h_3 = h_4 = 246$ KJ/kg.



(i) Electrical power input (P_{el}) = $\frac{7200 \text{ WS}}{t}$

= $\frac{7200 \text{ WS}}{16.6}$ = 434 W

(ii) Heat Supplied by refrigerant from compressor.

$Q_{comp} = m_r (h_2 - h_1)$

$= 0.0066 (453 - 403)$

$= 330$ W

(iii) Heat rejected by refrigerant in Condenser.

$Q_{cond} = m_r (h_2 - h_3)$

$= 0.0066 (453 - 246)$

$= 1366.2$ W.

Heat absorbed by refrigerant in Evaporator

$$Q_{EVA} = m_r (h_1 - h_4)$$
$$= 0.0066 (403 - 246)$$
$$= 1036.2 \text{ W.}$$

Compressor efficiency $\eta = \dfrac{Q_{comp}}{P_{el}}$

$$= \frac{330}{434} = 0.76$$

Compressure pressure ratio $\psi = \dfrac{P_{2/3}}{P_{1/4}} = \dfrac{8}{2.6} = 3.076$

Volumetric efficiency $\lambda = \dfrac{V_{Real}}{V_{theo}} \times 100$

$$V_{theo} = \frac{RPM \times V_{cyl}}{60}$$
$$= \frac{2550 \times 12.05 \times 10^{-5} m^3}{60}$$
$$= 5.72 \times 10^{-4} \, m^3/s$$

$$= \frac{1.67 \times 10^{-4}}{5.72 \times 10^{-4}}$$
$$= 0.29 \times 100$$
$$= 29$$

$$V_{Real} = \frac{m_r}{\rho_{ef}} = \frac{0.0066}{39.32}$$
$$= 1.67 \times 10^{-4} \, m^3/s$$

Temperature difference $\Delta T = T_1 - T_{ambient}$

$$= 31.8 - 23.3$$
$$= 8.5$$

$$COP = \frac{Q_{cond}}{P_{el}} = \frac{1366.2}{434} = 3.14.$$

Heat absorbed by refrigerant in Evaporator

$$Q_{EVA} = m_r (h_1 - h_4)$$
$$= 0.0066 (403 - 246)$$
$$= 1036.2 \text{ W.}$$

Compressor efficiency $\eta = \frac{Q_{comp}}{P_{el}}$
$$= \frac{330}{434} = 0.76$$

Compressure pressure ratio $\psi = \frac{P_{2/3}}{P_{1/4}} = \frac{8}{2.6} = 3.076$

Volumetric efficiency $\lambda = \frac{V_{Real}}{V_{theo}} \times 100$

$$V_{theo} = \frac{RPM \times V_{cyl}}{60}$$
$$= \frac{2350 \times 12.05 \times 10^{-5} m^3}{60}$$
$$= 5.72 \times 10^{-4} \; m^3/s$$

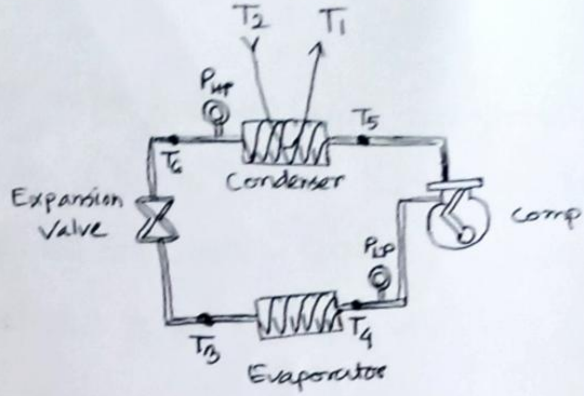
$$= \frac{1.67 \times 10^{-4}}{5.72 \times 10^{-4}}$$
$$= 0.29 \times 100$$
$$= 29$$

$$V_{Real} = \frac{m_r}{\rho_{ref}} = \frac{0.0066}{39.32}$$
$$= 1.67 \times 10^{-4} m^3/s$$

Temperature difference $\Delta T = T_1 - T_{ambient}$
$$= 31.8 - 23.3$$
$$= 8.5$$

$$COP = \frac{Q_{cond}}{P_{el}} = \frac{1366.2}{434} = 3.14.$$

Observation : 05.



For High Pressure,

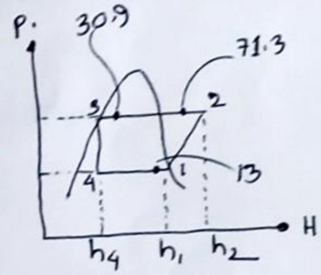
Absolute pressure = Gauge P + atmospheric P.

= 8+1 = 9 BAR

For Low Pressure,

Absolute pressure = Gauge P + atm P.

= 2·6+1 = 3.6 BAR



* $h_1 = 402$ KJ/kg

$h_2 = 452$ KJ/kg

$h_3 = h_4 = 245$ KJ/kg.

(I) Electrical power input $P_{el} = \frac{7200}{t}$

∴ $P_{el} = \frac{7200 \text{ W.}\cancel{s}}{16.8 \ \cancel{s}}$

$= 428.5$ W

* T = 500 U = 1 KWh = 1 unit

or, 500 U = 1 KWh

= (1000 × 60 × 60) WS

$U = \frac{1000 \times 60 \times 60}{500}$ WS

U = 7200 S.

* Energy metre reading Per revolation time = 16·8 S.

(ii) Heat supplied by refrigerant from compressor.

$$Q_{comp} = m_r (h_2 - h_1)$$
$$= 0.0066 (452 - 402)$$
$$= 0.33 \text{ K.J/s} = 330 \text{ W.}$$

(iii) Heat rejected by refrigerant in condenser.

$$Q_{cond} = m_r (h_2 - h_3)$$
$$= 0.0066 (452 - 245)$$
$$= 1366.2 \text{ W}$$

(iv) Heat absorbed by refrigerant in Evaporator.

$$Q_{eva} = m_r (h_1 - h_4)$$
$$= 0.0066 (402 - 245)$$
$$= 1036.2 \text{ W.}$$

(v) Compressor efficiency $\eta = \frac{comp}{P_{el}}$

$$= \frac{330}{428.5}$$
$$= 0.77.$$

(vi) compressure pressure ratio $\varphi = \frac{P_{2/3}}{P_{1/4}}$

$= \frac{8}{2.6}$

$= 3.076$

(vii) Volumetric efficiency $\lambda = \frac{V_{Real}}{V_{theo}} \times 100.$

$V_{real} = \frac{M_r}{\rho'_{ref}} = \frac{0.0066}{39.32}$ $= \frac{1.67 \times 10^{-4}}{5.72 \times 10^{-4}}$

$= 1.67 \times 10^{-4} m^3/s$ $= 0.29.$

$V_{theo} = \frac{RPM \times V_{cyl}}{60}$

$= 5.72 \times 10^{-4}$

$RPM = 2850.$
$V_{cyl} = 12.05 cm^3$

(viii) Tempurature difference $\Delta T = T_1 - T_{ambient}$

$= 30.6 - 23.6$

$= 7$

(ix) $COP = \frac{Q_{cond}}{P_{el}}$

$= \frac{1366.2}{428.5} = 3.18.$

Technical Data :

T_1 — water exit tempurature

T_2 — water inlet tempurature.

T_3 — Evaporator inlet temp.

T_4 — Evaporator outlet temp.

T_5 — Condenser inlet tempurature

T_6 — Condenser outlet tempurature.

V_{geo} — Compressor Volumetric displacement

V_{theo} — theoritical Volumatric flow

V_{real} — Real Volumetric flow of the compressor.

n_{comp} — compressor Speed

η = compressor efficiency

ψ = compressor pressure ratio.

λ = Volumetric efficiency

ρ_{ref} — Density of Saturated refrigerant Steam.

P_{el} — electrical power consumption of comp.

$P_{HP} = P_{2/3}$ — condenser exit

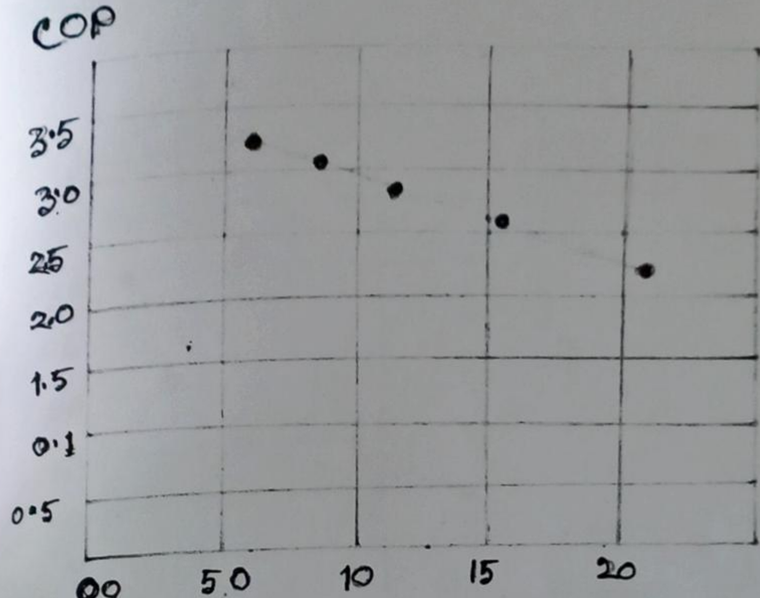
$P_{LP} = P_{1/4}$ — compressor inlet pressure.

Q_{cond} — removed heat from condenser

Q_{comp} — Supplied heat from to compressor

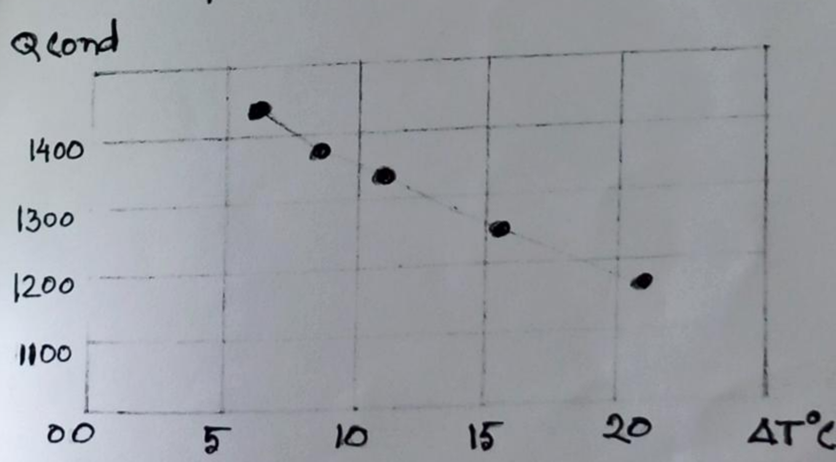
Q_{Eva} — Supplied heat to Evaporator.

Grap : 01



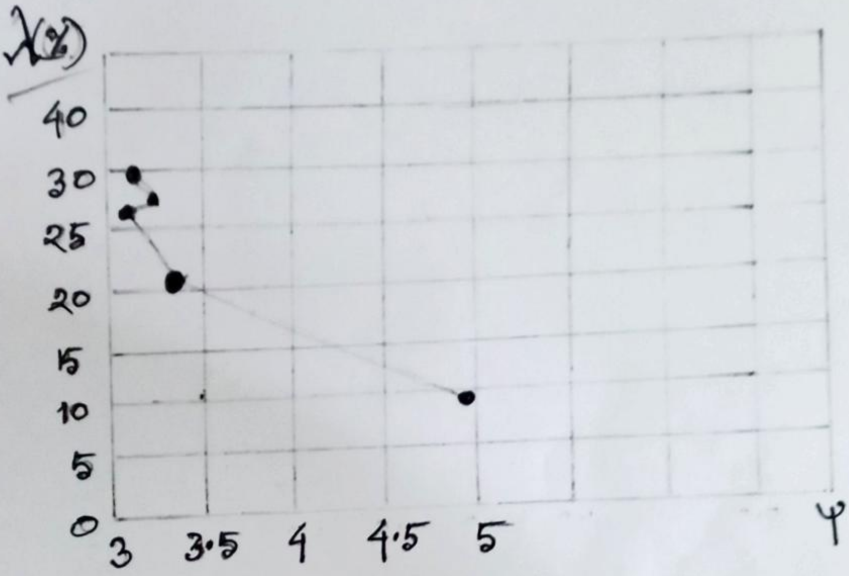
COP Vs ΔT

Grap : 02



Qcond Vs ΔT°C

Grap : 03.



Graph :
volumetric efficiency λ as a function of the compressor pressure ratio φ

λ vs φ.