ANNAMALAI UNIVERSITY

DEPARTMENT OF MECHANICAL ENGINEERING

FACULTY OF ENGINEERING AND TECHNOLOGY

VI SEM B.E MECHANICAL ENGINEERING

LABORATORY INSTRUCTION MANUAL CUM OBSERVATION NOTEBOOK

MECP607 – APPLIED THERMAL LABORATORY

NAME : ______________________________

ROLL No : ______________________________

SUBJECT : ______________________________

DEPARTMENT OF MECHANICAL ENGINEERING

VISION

The Mechanical Engineering Department endeavors to be recognized globally for outstanding education and research leading to well qualified engineers, who are innovative, entrepreneurial and successful in advanced fields of mechanical engineering to cater the ever changing industrial demands and social needs.

MISSION

The Mechanical Engineering program makes available a high quality, relevant engineering education. The Program dedicates itself to providing students with a set of skills, knowledge and attitudes that will permit its graduates to succeed and thrive as engineers and leaders. The Program strives to:

- Prepare the graduates to pursue life-long learning, serve the profession and meet intellectual, ethical and career challenges.
- Extend a vital, state-of-the-art infrastructure to the students and faculty with opportunities to create, interpret, apply and disseminate knowledge.
- Develop the student community with wider knowledge in the emerging fields of Mechanical Engineering.
- Provide set of skills, knowledge and attitude that will permit the graduates to succeed and thrive as engineers and leaders.
- Create a conducive and supportive environment for all round growth of the students, faculty & staff

PROGRAM EDUCATIONAL OBJECTIVES

1.	Prepare the graduates with a solid foundation in Engineering, Science and Technology for a successful career in Mechanical Engineering.
2.	Train the students to solve problems in Mechanical Engineering and related areas by engineering analysis, computation and experimentation, including understanding basic mathematical and scientific principles.
3.	Inculcate students with professional and ethical attitude, effective communication skills, team work skills and multidisciplinary approach
4.	Provide opportunity to the students to expand their horizon beyond mechanical engineering
5.	Develop the students to adapt to the rapidly changing environment in the areas of mechanical engineering and scale new heights in their profession through lifelong learning

ANNAMALAI UNIVERSITY

DEPARTMENT OF MECHANICAL ENGINEERING

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VI SEM. BE MECHANICAL ENGINEERING 2020-2021.

MECP607 – APPLIED THERMAL LABORATORY

I C ENGINES LAB

REFERENCE

GIVEN

Calorific value of Diesel	: 42,000 kJ/kg.
Specific Gravity of Diesel	: 0.835
Density of water	: 1000 kg/m^3

REFRIGERATION & AIR CONDITIONING LAB

INSTRUCTIONS TO THE STUDENTS

1. *Be regular and be punctual to classes*
2. *Come in proper uniform stipulated*
3. *Ensure safety to your body organs and laboratory equipment*

   – SAFETY FIRST DUTY NEXT
4. *Read in advance the contents of the instruction manual pertaining to the experiment due and come prepared. Understand the related basic principles.*
5. *Maintain separate observation and record note books for each laboratory portion of the course wherever justified.*
6. *Though you work in a batch to conduct experiment, equip yourself to do independently. This will benefit you at the time of tests and university examinations.*
7. *Independently do the calculations and sketching. If there is difficulty, consult your batch mate, classmate, teacher(s) and Laboratory in-charge.*
8. ***Do not attempt to simply copy down from others**. You may fulfill the formalities but you stand to loose learning and understanding*
9. *Obtain the signature of teacher (s) in the laboratory observation note book and record note book then and there during class hours (with in a week subsequent to experimentation).This will relieve the teacher (s) from giving reminder.*
10. *Help to maintain neatness in the laboratory.*
11. *Students are advised to retain the bonafide record notebook till they successfully complete the laboratory course.*

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Expt.No : Date:

LOAD TEST ON BATLIBOI ENGINE

Aim:

To conduct a load test on BATLIBOI engine by running the engine at different loads at 1500 rpm and to find the economic load. Also determine the load characteristics of the engine.

Instruments required:

- Tachometer to measure the speed of the engine
- Stop-watch to note the time for a definite volume of fuel consumption.

Specifications:

Type	:
No. of strokes per cycle	:
Type of cooling	:
Fuel used	:
Speed	:
Power	:
Bore	:
Stroke	:

Procedure:

1. After evaluating the full-load of the engine in kg_f with the help of specifications given, check the fuel level in fuel tank, level of lubricant in the sump as indicated by the dipstick, and no-load on the engine as indicated by the loading device etc, before starting the engine.

2. Start the engine by cranking and allow it to run for 5 to 10 minutes to attain steady condition at its rated *speed of 1500 rpm*.

3. Now, load the engine to 20 % of full-load. Then check and adjust for its rated speed and note down the actual load on the engine.

4. Note the time for 10 cc of fuel consumption twice at this load and average the values.
5. In the same way, maintain the speed at rated value and note the time for 10cc of fuel consumption at 40 %, 60 %, 80 % of full load, full load and at no load. After taking no load reading at last the engine is stopped by engaging the fuel cut off lever.

Preliminary calculations:

Full-load can be estimated by using the following equation.

$$BP_{rated} = \frac{W * N}{C}$$

Where,

BP_{rated} - Brake power (kW)
W_{max} - Maximum load applied on the hydraulic dynamometer (Newton)
N - Speed (rpm)
C - Dynamometer constant [29323.3]

$$W_{max} = \frac{BP * C}{N}$$

Observations:-

Speed to be maintained___________rpm

Sl. No	%of load	Calculated load (T_1-T_2)		Applied load (T_1-T_2)		Time taken for 10cc of fuel consumption in (sec)		
		N	kg_f	kg_f	N	t_1	t_2	t_{ave}
1								
2								
3								
4								
5								
6								

Note: *At the beginning of the experiment, the conditions of viscous friction will be more than that at steady running. Hence observation at no load if made at the beginning will result in arriving of incorrect higher fuel consumption value. In order to overcome this error observations at no load are to be made at the end of the experiment*

***Specimen calculations*:** (For ....% of load)

1. Fuel Consumption [FC], kg/hr

= Vol. flow rate, cc/s x density of fuel, kg/m^3 x 3600 s/hr.

$= \left(\frac{10}{t_{ave}}\right)$ x Sp. gravity of diesel x density of water in kg/m^3 x 3600

[1 cc $= 1 \times 10^{-6}$ m^3]

FC $= \left(\frac{10}{\qquad\qquad}\right) \times 10^{-6} \times 0.835 \times 1000 \times 3600 =$ __________kg/hr

2. Brake Power (kW) = $\frac{W * N}{C}$

3. Specific Fuel Consumption [SFC], (kg/kW-hr) = $\frac{FC}{BP}$

SFC = --------------- =.................... kg/kW-hr

4. Frictional Power [Fr. P], kW

To be obtained from the graph of BP Vs FC by extrapolation method. ***Frictional power is assumed to be constant at all loads.***

$F_r.P$ =

5. Indicated Power [IP], (kW) = BP+ Fr.P

IP =

6. Mechanical Efficiency (%) = $\frac{\text{Brake power}}{\text{Indicated power}}$ x 100

η_{Mech} =

7. Fuel Power [Fu.p] (or) Heat Input, (kW) $= \frac{FC.(\frac{kg}{hr}) x C.V.(\frac{kJ}{kg})}{3600}$

Fu P =

8. Brake Thermal Efficiency (%) = $\frac{BP}{\text{fuel power}}$x100

η_{Bth} =

9. Indicated Thermal Efficiency (%) = $\frac{IP}{\text{Fuel power}}$ x100

η_{Ith} =

10. Brake Mean Effective Pressure [BMEP],(bar) = $\frac{BP x 10^3 x 60}{10^5 x L x A x N' x n}$

$= \frac{BP x 60}{100 L A N' n}$ in bar

N' = Number of power strokes per minute. For **4 stroke engine N' =**$\frac{N}{2}$; For 2 stroke engine N' = N; n = Number of cylinders A = Area of bore(m^2)= $\frac{\pi d^2}{4}$(d = Dia of bore in m)= ....m^2; L = Length of stroke(m)

BMEP =

11. Indicated Mean Effective Pressure [IMEP] (bar) = $\frac{IP \times 60}{100 L A N' n}$

IMEP =

12. Torque, Nm = $\frac{BP \times 1000}{\omega}$ where ω = angular velocity

$$\omega = \frac{2\pi N}{60} \ rad/_{sec}$$

Where N-Speed of the engine.

Draw the following Graphs:

1. BP Vs SFC,
   B.Th. efficiency,

2. BP Vs I.Th.efficiency,
   Mech. efficiency,
   IMEP,
   BMEP ,
   Torque

RESULT TABULATION

Sl No	Appl.load	BP	F C	S F C	Fu.P	I P	$\eta_{B\ th}$	$\eta_{I\ th}$	η_{mech}	BMEP	IMEP	Torque
	N	kW	Kg/hr	$Kg/kW-hr$	kW	kW	%	%	%	bar	bar	Nm
1												
2												
3												
4												
5												
6												

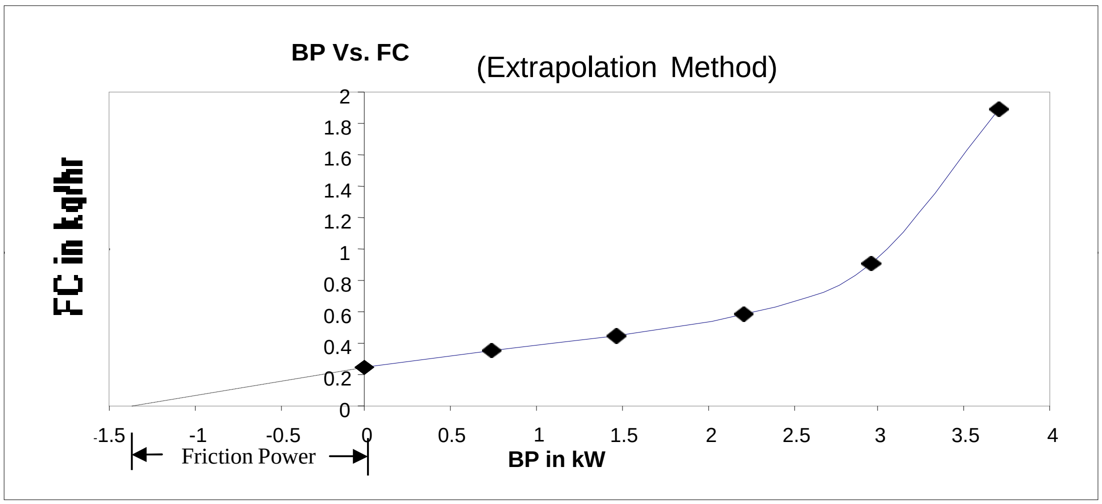
Result :

The Load test on BATLIBOI Engine was conducted at different load conditions, the economic load of engine was found at ____________rpm is _________kW and the corresponding performance characteristic curve were also drawn.

Extrapolation (or) Willan's line method:

This is a method of determining the friction power and hence the indicated power of engine. It is based on the fact that at part loads the combustion is completed within the engine cylinder. Hence at a given speed the rate of fuel consumption bears a linear relationship with power output/torque.

A plot therefore of rate of fuel consumption versus power output/torque at a particular speed will be a straight line in the light load region. This straight line is Willan's line. The amount of negative power output/torque obtained by extrapolation of the plot at zero rate of fuel consumption represents the **frictional power** (power required to overcome friction) of the engine at the specified speed.

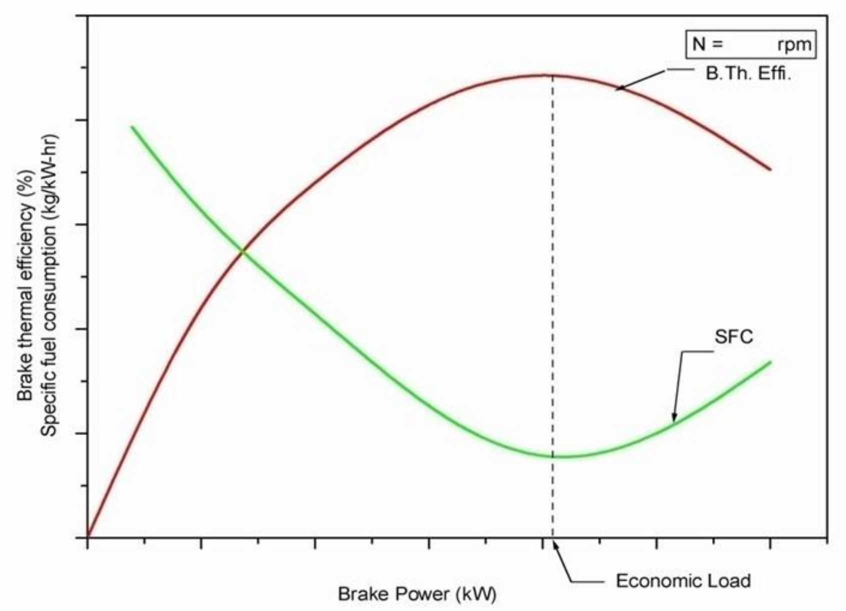


The rapid increase in the slope of Willan's line at high load denotes a reduction in combustion efficiency as more and more fuel is pumped in to the given volume of air.

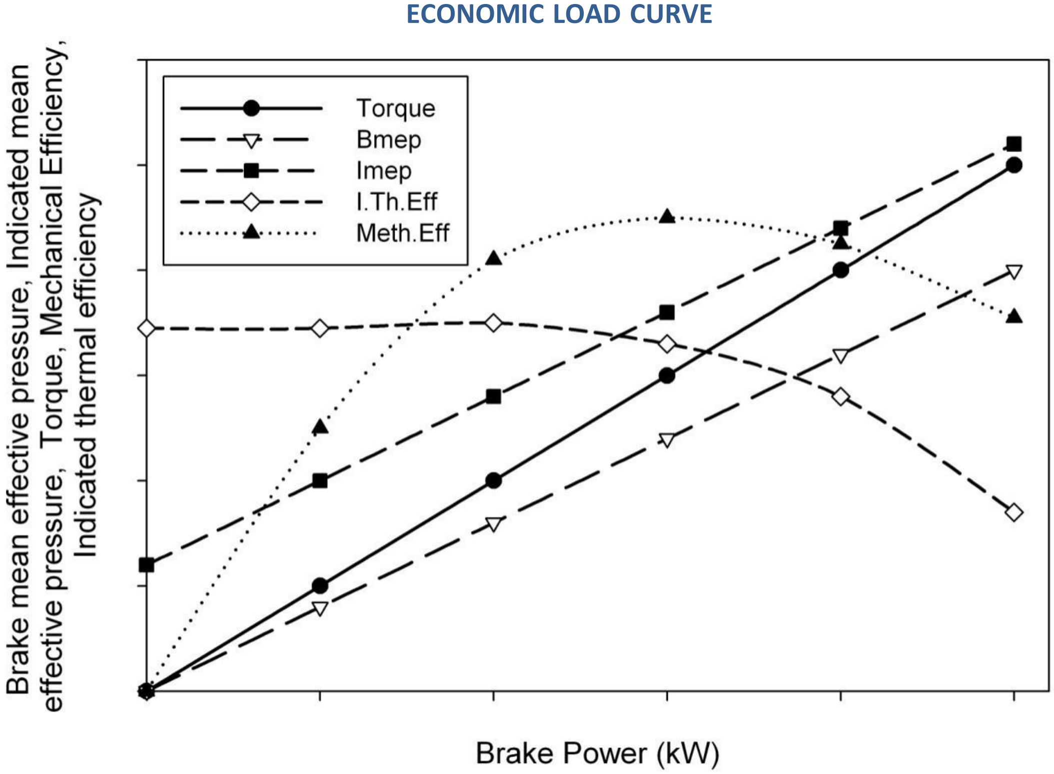
Since petrol engine is throttled to maintain a high fuel/air ratio with load, combustion is not complete with in the cylinder. In this case a plot of power output versus rate fuel consumption does not yield a straight line. Hence extrapolation is difficult and not suitable for use with petrol engines.

Note: Finding friction power in this method directly depends on the flow rate of fuel consumed. It has to be noted that any fuel leak in the fuel line will result in incorrect frictional power.

The general shape of characteristics curve are shown – For reference



ECONOMIC LOAD CURVE



Expt.No : Date :

STUDY AND PERFORMANCE TEST ON KAESER AIR COMPRESSOR

(A) Study on Kaeser Air compressor

CAIntroduction:-

Air Compressors are used to raise the pressure of air with the minimum expenditure of energy. An air-compressor sucks the air from the atmosphere, compresses it and delivers the same under high pressure to a storage tank.

Since the compression of air requires some work to be done on it, some form of prime mover must drive a compressor.

The compressed air is used for many purposes such as for operating pneumatic drills, rivets, road drills, paint spraying, air motors and in starting and supercharging of I.C. Engines etc. It is also utilized in the operation of lifts, rams, pumps and a variety of other devices. In heavy vehicle automobile, compressed air is also used for power brakes.

Air Compressors are classified into:

a) Reciprocating air compressors
b) Rotary air compressors.

Classification of Reciprocating Air Compressor:

(i) Single acting compressor,
(ii) Double acting compressor,
(iii) Single stage compressor,
(iv) Multi stage compressor

Single acting reciprocating compressor: In single acting compressor the air is compressed in the cylinder on one side of the piston.

Double acting compressor: In double acting compressor the air is compressed on both sides of the piston.

Single stage compressor: In single stage compressor, the air is compressed in a only one cylinder.

Multi stage compressor: In multistage compressor, the air is compressed in two or more cylinders. Multi stage compression is done to achieve high pressure ratio. In a compressor when compression ratio exceeds 5, generally multistage compression is adopted. The following arrangements are generally in practice for reciprocating compressors.

No. of stages	Delivery press
One	up to 5 bars
Two	5 to 35 bar
Three	35 to 85 bar
Four	above 85 bars

According to pressure range the compressors are also classified as:

Fans : Pressure ratio is 1 to 1.1
Blowers : Pressure ratio is 1.1 to 4.0
Compressors : Pressure ratio is above 4

*In this experiment the compressor given for study is Keaser air compressor, which is a **single acting, two stage, air cooled reciprocating air compressor** .The specifications of the compressor is also given below.*

Some Important parts and their functions

Low pressure cylinder: Air is compressed from atmospheric pressure to intermediate pressure in L.P. Cylinder.

High Pressure Cylinder: Air is compressed from intermediate pressure to delivery pressure in H.P Cylinder.

Inter Cooler: Air is cooled in between the two compression stages at constant pressure.

After Cooler: Air is cooled after the compression is over to accommodate more air in the receiver tank.

Air Filter: It filters dust particles from the air. Otherwise the dust particles will adhere the inner surface of the cylinder and thereby increases the friction between the cylinder and piston. Due to this more power loss, wear and tear will be taking place.

Orifice Meter: It is used to measure the actual flow of air for compression by measuring pressure difference across the orifice using manometer.

Air Stabilizing Tank: During suction stroke, the air from atmosphere is sent into the LP cylinder. During compression, air is sent to HP cylinder through inter cooler. The flow of air in the pipe line from atmosphere to the LP cylinder is not uniform (i.e. intermittent) due to the suction of the air taking place in the alternative strokes. To measure the flow rate of air, the flow must be uniform across the orifice. Otherwise the manometer reading will fluctuate. Hence an air stabilizing tank is introduced between orifice meter and LP cylinder. This stabilizes the flow of air between the air filter and stabilizing tank. While connecting the pipe line and the stabilizing tank , that these are connected in diametrically opposite. However, air stabilizing tank, is fitted only in the experimental air compressors to measure the flow rate of air.

Safety Valves: It releases the air when the pressure of air exceeds the desired limit.

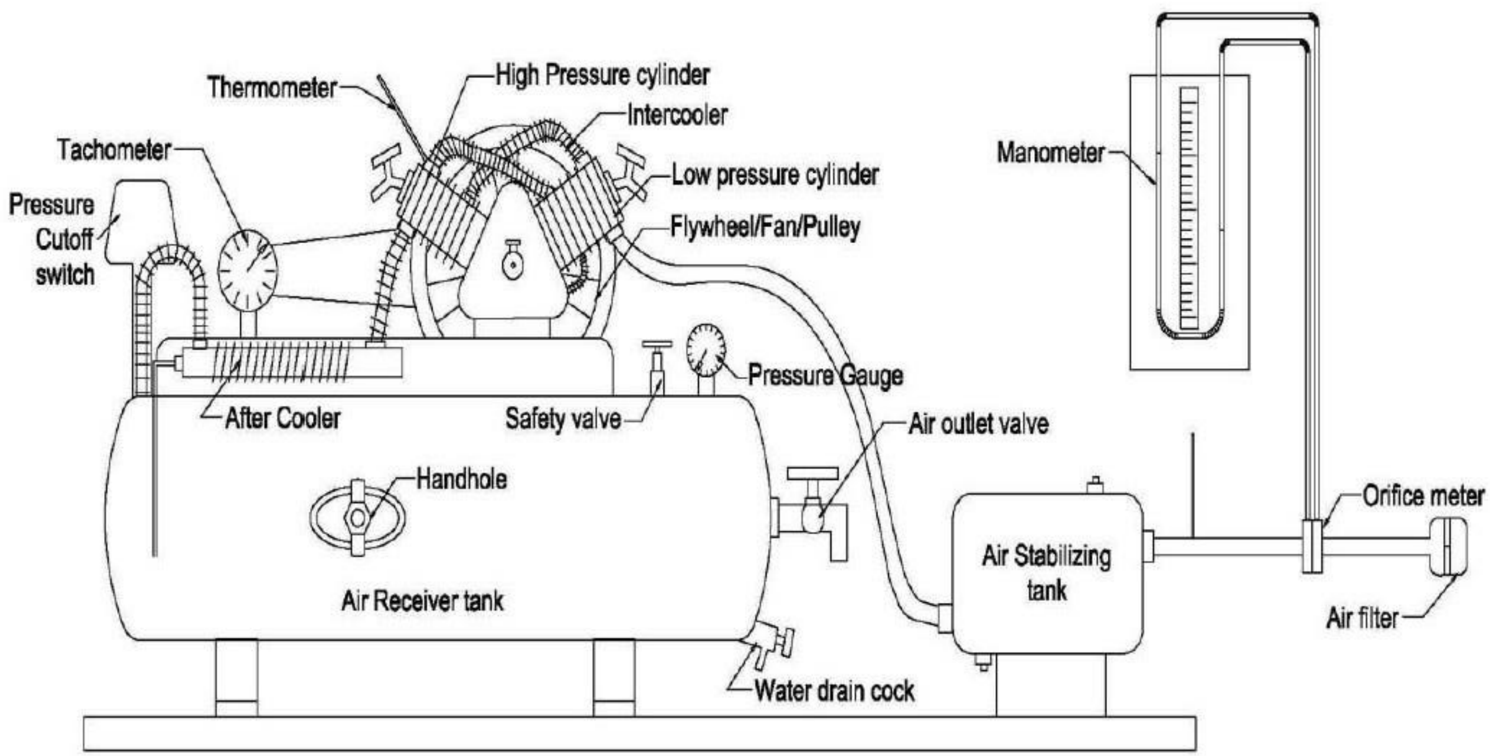
Pressure Cut off Switch: It is a device used to disconnect the electrical circuit, when the pressure of air in the receiver tank reaches the desired pressure. This disconnects the circuit of no volt coil in the Star-Delta Starter; thereby it switches off the motor.

The advantages with multistage compression are:

(i) Some work is saved.
(ii) Uniform torque is obtained with the result, that a smaller size flywheel is needed.
(iii) Volumetric efficiency is increased.
(iv) Light cylinders are required.
(v) The maximum working temperature is reduced thereby more effective lubrication is possible.

FIG 1

SCHEMATIC DIAGRAM OF KAESER AIR COMPRESSOR



Prime mover and Dynamometer: The prime mover used for the compressor is a trunnion type electrical motor. This motor itself is acts as dynamometer to measure the input power of the compressor.

Work done on P-V diagram of compressor:

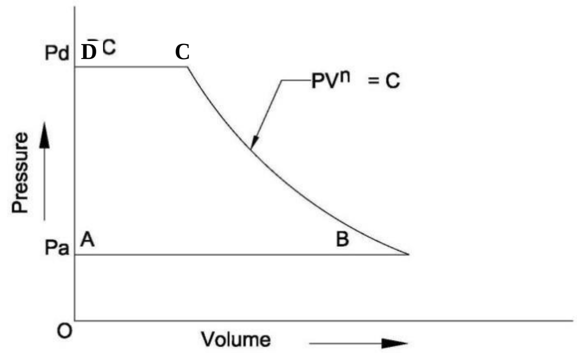


Fig.2 P-V diagram for Single stage air compressor.

The P-V diagram of a single stage reciprocating air compressor with zero clearance is shown in Fig.2 The air is sucked in from the atmosphere during the suction stroke AB at pressure Pa(i.e. at atmospheric pressure). At the end of suction stroke the air is compressed polytropically during the part of its return stroke (process BC). During compression stroke the pressure and temperature of air increases and volume decreases. This happens until the pressure P_d (delivery pressure) in the cylinder is sufficient to force open the delivery valve at C after which no more compression takes place. The delivery occurs during the remainder of the return stroke CD. The work done on the air per stage is area ABCDA. In the case of air compressors, the inlet and outlet valves are operated by pressure difference only. Not by any external means.

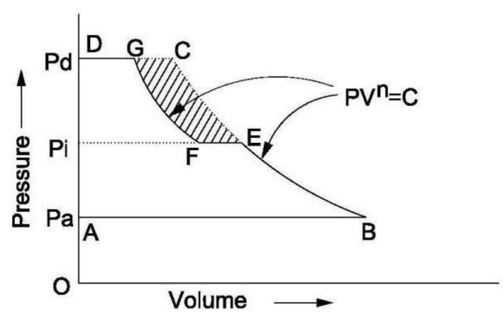


Fig.3 P-V diagram for two stage air compressor with inter cooling.

The air is sucked in LP cylinder during the suction stroke at intake pressure Pa and Temperature Ta. After compression in the first stage from B to E it is delivered to the intercooler, at a constant pressure Pi. The air is cooled in an intercooler, at a constant pressure Pi before passing it to second stage. The process of inter cooling is represented by the line EF. The air from the intercooler is then directed to the second stage ofcompression FG to the delivery pressure P_d. Then the air delivered to the receiver tank at constant pressure P_d. This process is represented by GD in the P-V diagram. The shaded area CEFGC shows the amount of work saved due to two stage compression with intercooling per cycle.

(B) *Performance test*

Aim: To determine the volumetric efficiency of the low pressure cylinder of Keaser Air Compressor at NTP condition, and to draw the performance characteristics curve of a compressor .

Specifications:

Type :

Speed :

Type of cooling :

Bore

L.P. cylinder :

H.P. cylinder :

Stroke :

Maximum pressure :

Motor output :

Free air delivered :

Precautions:

1. Before starting the experiment, the air which is already compressed if any in the reservoir is released out so that initial gauge pressure in compressor reservoir is zero/atmospheric.

2. The initial load on the motor while starting should be avoided by opening the valves provided at the top of the L.P. and H.P. cylinders.

3. The pin is inserted on the torque arm hole to prevent jerk while starting.

4. After starting the motor the pin is removed to get the correct load on the motor.

Procedure:

1. The motor is started using the automatic star-delta starter by pressing the green color button.

2. The valves provided at the top of the LP and HP cylinders, water drain cock and the air outlet valves are closed after the motor has gained its speed and attains 960 rpm. The increase in pressure of air in the receiver tank is indicated by the pressure gauge.

3. The pressure of air is maintained constant to the desired value (say 2 kgf /cm^2) by adjusting at the opening of the compressed air outlet valve in the reservoir manually.

4. The following observations are to be taken by keeping *reservoir pressure constant. Say* (2 kg_f / cm^2)

a) Speed (N)

b) Manometer reading (hw)(Pressure difference across orifice)

c) Temperature of air entry to LP cylinder [T_1]

d) Temperature of air entry to HP cylinder [T_2'] after attaining the steady state.

e) Load on the motor in kgf. [Tm_1-Tm_2]

5. The same procedure of observations are to be made for the other reservoir pressures [4,6,8,10,12 Kgf / cm^2]

6. Then the motor is switched off by pressing the red color (or off) button of the starter after removing the load on the motor. This can be done by opening the valves provided at the top of LP and HP cylinders.

.

Observations:

Room Temperature [T_a] :__________ °C Orifice dia. [d_o] :______mm.

Sl. No	Receiver pressure (P_3)		Speed (N)	Entry temp (˚C)		Manometer reading(h_w) in (mm)			Load on motor ($Tm_1 - Tm_2$)	
	kg_f/cm^2 (gauge)	bar (abs.)	rpm	LPC T_1	HPC $T_2{}^1$	L (left arm)	R (right arm)	L+R	N	Kg_f

Note :1 kg$_f$ / cm^2 (gauge) =** (1 x 0.981) + 1.013 bar [Absolute]* ***bar

***Note** : The load on the motor[Tm_1-Tm_2] has to be taken by keeping the torque arm horizontal and this position can be verified by inserting the pin into the torque arm hole.*

Specimen calculations: **(**For gauge pressure = kg/cm^2)

1. Density of air (ρ_a)$\left(\frac{kg}{m^3}\right) = \frac{P_a}{R_a T_a} = \frac{1.013 \times 10^5}{287 \times (273 + \quad)} =$

Where

P_a = Atmospheric pressure, 1.013 x 10^5 N/m^2

R_a = Universal Gas constant, 287 J/KgK

T_a = Room Temperature in (K)

2. Pressure head in terms of air (h_a), m

$$\rho_a h_a = \rho_w h_w$$

$$h_a = \frac{h_w \rho_w}{\rho_a} = \frac{\quad \times 1000}{\quad} =$$

where

ρ_w = density of water = 1000 kg/m^3

h_w = head of water in m=

3. Velocity of air through orifice, (V_a), m/sec. = $\sqrt{2gh_a}$

4. Area of orifice, (m^2) = (A_o) =$\frac{\pi d_o^2}{4}$ where d_o = dia of orifice= 18 mm = 0.018 m

$$= \frac{3.14 \times (0.018)^2}{4} = 2.54 \times 10^{-4}\, m$$

5. Volume flow rate of air at inlet condition (Q_a), (m^3/sec) = $Cd \times Ao \times Va$

Where C_d = Coefficient of discharge of orifice = 0.6

6. Volume of air compressed at NTP (Normal Temp. and Press.) (m^3/sec.)

$$Q_a \text{ at NTP} = Q_a \frac{273}{T_a}$$

7. Theoretical Volume of air (m^3 /sec) $Q_{th} = \frac{\pi D^2 LN}{4 \times 60}$

where

L = Stroke length of LP cylinder in (m)

N = Speed (rpm)

D = Diameter of LP Cylinder in (m)

8. Volumetric efficiency of the L.P. Cylinder (%) $= \frac{Q_a \; at\, NTP}{Q_{th}} \times 100$

9. Input power, (kW) = $\frac{2 \pi R N (T_{m1} - T_{m2})}{60x1000}$

Where, R = Torque arm length = Half the distance between the spring balance centers (m).
$Sub\ the\ value\ (Tm_1 - Tm_2)\ in\ Newton\ ; N = Speed\ of\ the\ motor\ in\ rpm$

10. Mass flow rate of air [M_a], kg/sec. = $Qa \times \rho a$

11. Isothermal power ,(kW) = $\frac{M_a\ xR_a\ xT_1}{1000}\ x\ ln\left(\frac{P_3}{P_1}\right)$

Where P_3 = Receiver pressure in bar

P_1= atmospheric pressure = 1.01325 bar

R_a = 287 J/KgK

T_1 = Atmospheric temperature in K

12. Isothermal efficiency (%) = $\frac{\text{Isothermal power}}{\text{Inputpower}}$ x 100

13. Adiabatic power in kW = $\left(\frac{\gamma}{\gamma-1}\right) \times \left(\frac{M_a \, x \, R_a}{1000}\right) x \left(T_1 + T_2'\right) \times \left\{\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{2\gamma}} - 1\right\}$

Where γ = 1.4 [Ratio of Specific heats]
T_1, T_2^1 are in K

14. Adiabatic efficiency,(%) = $\frac{\text{Adiabatic power}}{\text{Input power}}$

15. Free air delivered, $\left(\frac{m^3}{kW\,S}\right)$ = $\frac{Q_a}{\text{Input power}}$

16. Heat rejected in inter cooler,(kJ/sec). $= \left(m_a \times Cp_a \times \left(T_2 - T_2^1\right)\right)$

Where T_2 = Temperature of air entry to intercooler(K)

ie $T_2 = T_1 x \left[\frac{P_2}{P_1}\right]^{\frac{n-1}{n}}$

Where $n = 1.35$

T_1 = Atmospheric temperature in (K)

Where P_2 = Intermediate pressure assuming perfect intercooling, P_1 = Atmospheric pressure.

$P_2 = \sqrt{P_1 x P_3}$ bar.

C_p of air = 1.005 kJ/KgK

Draw the following performance characteristic curves graphs:

Receiver Pressure (P_3)

Vs Volumetric efficiency.
Vs Isothermal efficiency.
Vs Adiabatic efficiency.
Vs FAD.
Vs Heat lost in the intercooler.

RESULT

The performance test on Keaser air compressor was conducted and the volumetric efficiency of L.P cylinder at NTP conditions was determined at various receiver pressure, and the various performance characteristic curves of the were also drawn

INFERENCE

Result Tabulation:

Sl.No	Receiver Pr P_3 (bar) (abs.)	Q_a $\frac{m^3}{sec}$	Q_{th} $\frac{m^3}{sec}$	Vol.η %	I.P kW	Adiabatic		Isothermal		Heat rejected kJ/s	FAD $m^3/kW/sec$
						Power kW	η in %	Power kW	η in %		

FAD *– Free Air Delivered.(The FAD is actual volume delivered at the stated pressure reduced to intake temperature and pressure and is expressed in cubic meter per min).*

Expt.No: Date:

LOAD TEST ON KIRLOSKAR AV-I (Double arm) ENGINE

Aim:

To conduct a load test on Kirloskar AV-I engine by running the engine at different loads at 1500 rpm and to find the economic load. Also determine the load characteristics of the engine and generator.

Instruments required:

- Swing field [DC] generator/motor type dynamometer,
- AC-DC converter with starting device [panel board],
- Bank of electrical resistances to apply load,
- Tachogenerator with speed indicator to measure the speed of the engine,
- Stop-watch to note the time for a definite volume of fuel consumption.

Specifications:

Type :

No. of strokes per cycle :

Type of cooling :

Fuel used :

Speed :

Power :

Bore :

Stroke :

Preliminary calculations:

While conducting load test the speed is retained constant and the load is varied (viz, no load, light load, medium load & full load). *Normally six equi-distributed* loads are chosen in the range from no load to full load. Preliminary calculations are made to determine the net tension (T_1-T_2) or a tangential force (W) needed at the dynamometer to effect the desired power output (Load).

In this test setup the engine is coupled to a swing field DC shunt-wound generator/motor type dynamometer. There are provisions to measure both the electrical output of the generator and the mechanical output of the engine. When the electrical resistances are included in the output circuit, the generator and hence the engine gets loaded. The generator swings about the trunnion and force required to keep the torque arm horizontal is the measure of engine output.

The net tension (T_1-T_2) corresponding to the rated power output is calculated using the expression for brake power. Then the values of net tension for other part load outputs (0%,20%,40%,60%,80%) are calculated and tabulated in the observation table.

We know that

Brake power (BP) = Torque x Angular Velocity

BP $= (T_1 - T_2)\, R_e \times \frac{2\pi N}{60}$

Where,

BP = Brake Power (kW)

(T_1 - T_2) = Load or net tensions (Newton)

N = Speed of the engine (rpm)

R_e = Effective Torque arm length (m) = $\frac{R}{2}$

{R = Torque arm length = Distance between the center lines of the spring balances}

Hence $R_e = \frac{R}{2}$ (m)

The equation to find BP is:

BP in kW $= \frac{2\pi R_e N (T_1 - T_2)}{60 \times 1000}$

Hence (T_1- T_2) $= \frac{B.P \times 60 \times 1000}{2\pi Re\, N}$ in Newton

- *The value for '**B.P**' and '**N**' are to be taken from the specifications of the engine.*
- *The value obtained for (T_1- T_2) from the above equation is the full load of the engine in Newton.*

(T_1- T_2) = ... = in N

(T_1- T_2) = N

(T_1- T_2)= $\frac{(T_1 - T_2)\, in\, N}{9.81}$ in kg_f

Precautions:-

a) Ensure that the electrical main switches (one in the panel board intended for running the DC machine as a motor to find friction power and the other in the resistance load bank intended for loading the DC machine as generator during load test) are in OFF position.

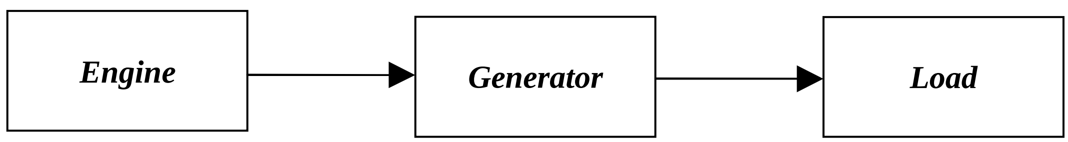
b) Electrical starter has to be in OFF position.

c) Speed regulator knob shall be set for minimum position.

Procedure:

1. After evaluating the loads to be applied on the engine, check the fuel level in fuel tank, flow of cooling water to the engine, level of lubricant in the sump as indicated by the dipstick and no-load on the engine as indicated by the loading device etc.

The DC machine coupled to the engine is run as a generator and the applied load is varied by altering the load resistances.



2. After observing all the precautions, the engine has to be started.

<u>Starting Procedure:-</u>

i. *The decompression lever located at the rocker box is turned to the vertical upward position. [Decompression On]*
ii. *The starting handle is inserted on the cam shaft*
iii. *The cam shaft is manually rotated faster in clockwise direction.*
iv. *After the engine shaft has gained sufficient momentum, the decompression lever is brought to the horizontal position [Decompression Off]. Then the engine gets started.*

3. Allow the engine to run for 5 to 10 minutes to attain steady condition at its rated speed of 1500 rpm.

4. Now, load the engine approximately to 20 % of full-load by switching on the load mains and suitable electrical resistances.

5. The speed of the engine is to be maintained at 1500 rpm. The generator output voltage is also to be maintained at 220 V by adjusting the field rheostat.

6. The actual spring balance readings are noted after the generator torque arm to its horizontal position by adjusting the hand wheels located above the spring balance

7. Note the time for 10 cc of fuel consumption twice at this load and average the values.

8. Ammeter reading is also to be noted for the same load.

9. In the same way, maintain the speed at rated value and note the time for 10cc of fuel consumption at 40 %, 60 %, 80 % of full load, full load and at no load.

10. After taking all the readings, the engine is switched off at no load by pulling the control rod of the fuel injection pump.

Observations:-

Speed to be maintained:_________rpm

Sl. No.	%of load	Cal. Load (T_1-T_2)		App. load (T_1-T_2)		Voltmeter reading in ($volts$)	Ammeter reading in ($amps$)	Time taken for 10 cc of fuel consumption in (sec)		
		N	kgf	kgf	N			t_1	t_2	t_{ave}

Note: *At the beginning of the experiment, the conditions of viscous friction will be more than that at steady running. Hence observation at no load if made at the beginning will result in arriving of incorrect higher fuel consumption value. In order to overcome this error observations at no load are to be made at the end of the experiment*

***Specimen calculations*:** (For ....% of load)

1. Fuel Consumption [FC], kg/hr

= Vol. flow rate, cc/s x density of fuel, kg/m^3 x 3600 s/hr.

$= \left(\frac{10}{t_{ave}}\right)$ x Sp. gravity of diesel x density of water in kg/m^3 x 3600

$[\,1\text{ cc} = 1 \times 10^{-6}\text{ m}^3\,]$

$$FC = \left(\frac{10}{\qquad\qquad}\right) \times 10^{-6} \times 0.835 \times 1000 \times 3600 = \_\_\_\_\_\_\_\_\_\_\text{kg/hr}$$

2. Brake Power [BP], (kW) = $\frac{2\,\pi R_e N(T_1 - T_2)}{60 \times 1000}$

Subsituite $(T_1 - T_2)$ *Valve in* "Newton"

BP = $\frac{2\,\pi \times \qquad\qquad \times 1500\,(\qquad\qquad)}{60 \times 1000}$ =

3. Specific Fuel Consumption [SFC], (kg/kW-hr) = $\frac{FC}{BP}$

SFC =

4. Frictional Power [Fr. P], kW

To be obtained from the graph of BP Vs FC by extrapolation method. ***Frictional power is assumed to be constant at all loads****.*

F_r.P =

5. Indicated Power [IP], (kW) = BP+ Fr.P

IP =

6. Mechanical Efficiency (%) $= \frac{\text{Brake power}}{\text{Indicated power}} \times 100$

$\eta_{Mech} =$

7. Fuel Power [Fu.p] (or) Heat Input, (kW) $= \frac{FC\left(\frac{kg}{hr}\right) x C.V.\left(\frac{kJ}{kg}\right)}{3600}$

Fu P =

8. Brake Thermal Efficiency (%) $= \frac{BP}{\text{fuel power}} x100$

$\eta_{Bth} =$

9. Indicated Thermal Efficiency (%) $= \frac{IP}{\text{Fuel power}} x100$

$\eta_{Ith} =$

10. Brake Mean Effective Pressure [BMEP],(bar) = $\frac{BP x 10^3 x 60}{10^5 x L x A x N' x n}$

$= \frac{BP \times 60}{100 L\ A\ N'\ n}$ in bar

N' = Number of power strokes per minute.

For **4 stroke engine N' =** $\frac{N}{2}$; For 2 stroke engine N' = N; n = Number of cylinders

A = Area of bore(m^2)= $\frac{\pi d^2}{4}$(d = Dia of bore in m)= ....m^2; L = Length of stroke,m

BMEP =

11. Indicated Mean Effective Pressure [IMEP] (bar) = $\frac{IPx60}{100LAN'n}$

IMEP =

12. Torque (Nm) = $(T_1 - T_2) \times R_e$

Torque =

13. Generator power output, (kW) = $\frac{V \times I}{1000}$

$= \frac{\qquad}{1000}$ kW

14. Generator efficiency (%) = $\frac{\text{Generator power output}}{\text{BrakePower of the engine}} \times 100$

η_{gen} =

Draw the following Graphs:

1. BP Vs SFC,
   B.Th. efficiency,

2. BP Vs I.Th.efficiency,
   Mech. efficiency,
   IMEP,
   BMEP ,
   Torque and
   Generator Efficiency.

RESULT TABULATION

Sl. No.	B.P	F.C	SFC	Fu.P	I.P	I.Th.η	B.Th.η	Mech.η	BMEP	IMEP	Torque	Generator Efficiency
	kW	kg/hr	$kg/kw.hr$	kW	kW	%	%	%	bar	bar	Nm	%

Result:

The Load test on KIRLOSKAR AV I Engine was conducted at different load conditions, the economic load of engine was found at ____________rpm is_________kW - and the corresponding performance characteristic curve were also drawn.

Expt.No :   Date:

HEAT BALANCE TEST ON FIELD MARSHAL 6 HP ENGINE

Aim:

To conduct a HEAT BALANCE test on Field marshal 6 HP engine , and to draw the heat balance chart on percentage basis.

Instruments required:

- Friction brake to indicate the load,
- Digital tachometer to measure the speed of the engine.
- Stop-watch to note the time for a definite volume of fuel consumption.

Specifications:

Type :

No. of strokes per cycle :

Type of cooling :

Fuel used :

Speed :

Power :

Bore :

Stroke :

Procedure:

1. After evaluating the full-load of the engine in kg_f with the help of specifications given, check the fuel level in fuel tank, flow of cooling water to the engine, level of lubricant in the sump as indicated by the dipstick, and no-load on the engine as indicated by the loading device etc., before starting the engine.

2. Note down the initial thermometer readings of exhaust gas, cooling water inlet and outlet and room temperature before starting the engine.

3. Adjust the cooling water flow rate to get appreciable temperature difference between cooling water inlet and outlet. (Approximately 6 to 8 lit/min)

4. After ensuring the no load on the dynamometer dial, start the engine by cranking and allow it to run at its rated speed of 660 rpm for 5 to 10 minutes to attain steady state conditions.

5. Note down the following observations after attaining the steady state conditions at no load.

(i) Temperature of cooling water inlet , Twi in °C

(ii) Temperature of cooling water outlet, Two in °C

(iii) Temperature of exhaust gas , Tg in °C

(iv) The flow rate of cooling water , Mw in Kg/sec

(v) Time for`10'cc of fuel consumption in secs

6. In the same way note down the above observations at 20%, 40%, 60%, 80% of full load and at the full load.

7. After taking all the readings, the load on the engine is to be reduced to no load. The flow of cooling water to the brake drum is to be cut off. Then the engine is to be stopped by engaging fuel cut off lever.

Preliminary calculations:

The loading device attached to this Engine is ***Mechanical Brake drum*** type.

We know that ,

Brake power (BP) = Torque x Angular Velocity

BP $=(T_1 - T_2)\, R_e \times \frac{2\pi N}{60}$

Where, BP = Brake Power in kilowatts

$(T_1 - T_2)$ = Load or net tensions in Newton

N = Speed of the engine in rpm

R_e = Effective radius of brake drum in meters = $(R + \frac{t}{2})$

(Where ‘R’ is the radius of the brake drum , obtained from its circumference and ‘t’ is the thickness of the belt = 8 mm = 0.008 m)

Circumference of the brake drum, $2\pi R$ =

(*To be obtained from Engine brake drum)*

R =

Hence R_e =

The equation to find BP is: BP in kW = $\frac{2\pi R_e N(T_1 - T_2)}{60 \times 1000}$

$$\text{Hence } (T_1 - T_2) = \frac{B.P \times 60 \times 1000}{2 \pi Re N} \quad \text{in Newton's}$$

- *The value for '**B.P'** and '**N'** are to be taken from the specifications of the engine.*

Initial observations:-

1. Room temperature /Atmospheric air temp. (Ta) :
2. Initial thermometer reading of cooling water inlet (Twi) :
3. Initial thermometer reading of cooling water outlet (Two) :
4. Initial thermometer reading of exhaust (Tg) :
5. Orifice dia (do) :

Speed to be maintained:___________rpm

Observation :

Sl. No.	% of load	Calculated Load (T_1-T_2)		Applied Load (T_1-T_2)		Time taken for 10cc of fuel consumption in (sec)			Cooling Water Temp ^{0}C		Exhaust gas Temp ^{0}C		Vol. Flow rate of water (Qw) lit./min.	Manometer reading (h_w) mm
		N	kgf	kgf	N	t_1	t_2	t_{avg}	t_{wi}	t_{wo}	t_g	Tg_c		hw

Specimen Calculations: (For ....% of load)

1. Fuel Consumption [FC], kg/hr

= Vol. flow rate, cc/sec x density of fuel, kg/m^3 .

$= \left(\frac{10}{t_{ave}}\right)$ x Sp. gravity of diesel x density of water in kg/m^3 x 3600

[1 cc $= 1 \times 10^{-6}$ m^3]

FC = $\left(\frac{10}{\qquad\qquad}\right) \times 10^{-6} \times$ 0.835 x 1000 = __________ kg/sec

2. Brake Power [BP], (kW) = $\frac{2\pi R_e N(T_1 - T_2)}{60 \times 1000}$

Subsituite $(T_1 - T_2)$ *Valve in* '"Newton" "

BP = $\frac{2\pi \times \qquad \times N \times (\qquad\qquad)}{60 \times 1000}$ =

3. Heat input, (kJ/Sec) = FC, (kg/sec) x Calorific value of fuel, (kJ/kg)

[CV of Diesel =42,000$\frac{kJ}{kg}$]

4. Useful shaft work in heat units, (kJ/sec) = BP

5. Heat carried away by cooling water, (kJ/sec) = $M_w x Cp_w x (Tw_o - Tw_i)$

$= M_w \left({}^{kg}/_{sec} \right) x Cp_w \left({}^{kJ}/_{kg\,K} \right) x (Tw_o - Tw_i)\ K$

where M_w = mass flow rate of cooling water, kg/sec.

$= \frac{Q_w}{60}$ x density of water in kg/lit. $= \frac{\quad}{60}$ x1 = $(1000\ lts = 1\ m^3)$

$Q_w = flow\ rate\ of\ water\ in\ (liters/min)$

Cp_w= sp.heat of cooling water = 4.184 kJ/kgK

Tw_i,= Inlet temp. of cooling water (K) , Tw_o =Outlet temp. of cooling water (K)

6. Heat carried away by exhaust gas, (kJ/ sec) = $M_g x Cp_g x (Tg_c - T_a)$

where M_g = Mass flow rate of exhaust gas, kg/sec.

= Mass flow rate of fuel + mass flow of air. = (Fc + M_a)

Where M_a = mass flow of air = $\rho_a \times Q_a$

$$\rho_a = \frac{P_a}{R_a x T_a} =$$

To evaluate the mass of air M_a

Where	P_a	= Atmospheric pressure [1.013 x $10^5, \frac{N}{m^2}$]
	Ra	= Universal gas constant [287,J/KgK]
	Ta	= Room temperature in (K)
	Cp_g	= Specific heat of exhaust gas= (1.005 kJ/kgK)
	Tg_c	= Temperature of exhaust gas (corrected) , K
	T_a	= Temperature of air, K

Pressure head in term of air,

$$\rho_a \times h_a = \rho_w \times h_w$$

$$h_a = \frac{\rho_w \times h_w}{\rho_a}$$

Where ρ_w = density of water = 1000 kg/m^3

h_w = corrected manometer reading

Velocity of air through orifice $V_a = \sqrt{2gh_a}$ m/sec.

Area of orifice $A_o = \frac{\pi}{4} d^2$, m^2

Where d = diameter of the air drum orifice.

Volume flow of air inlet condition $Q_a = C_d \times A_o \times V_a$

Where C_d = Co - efficient of discharge of orifice = 0.6

$M_g = (Fc + M_a)$ ie., $M_{g1} = (Fc_1 + M_a)$, $M_{g2} = (Fc_2 + M_a)$ like wise

Now, Heat carried away by exhaust gas,(kJ/ sec) = $M_g x Cp_g x (Tg_c - T_a)$

7. Heat unaccounted =

{Heat input - (Heat to shaft work + Heat carr. by cool. water + Heat carr. by ex.gas)}

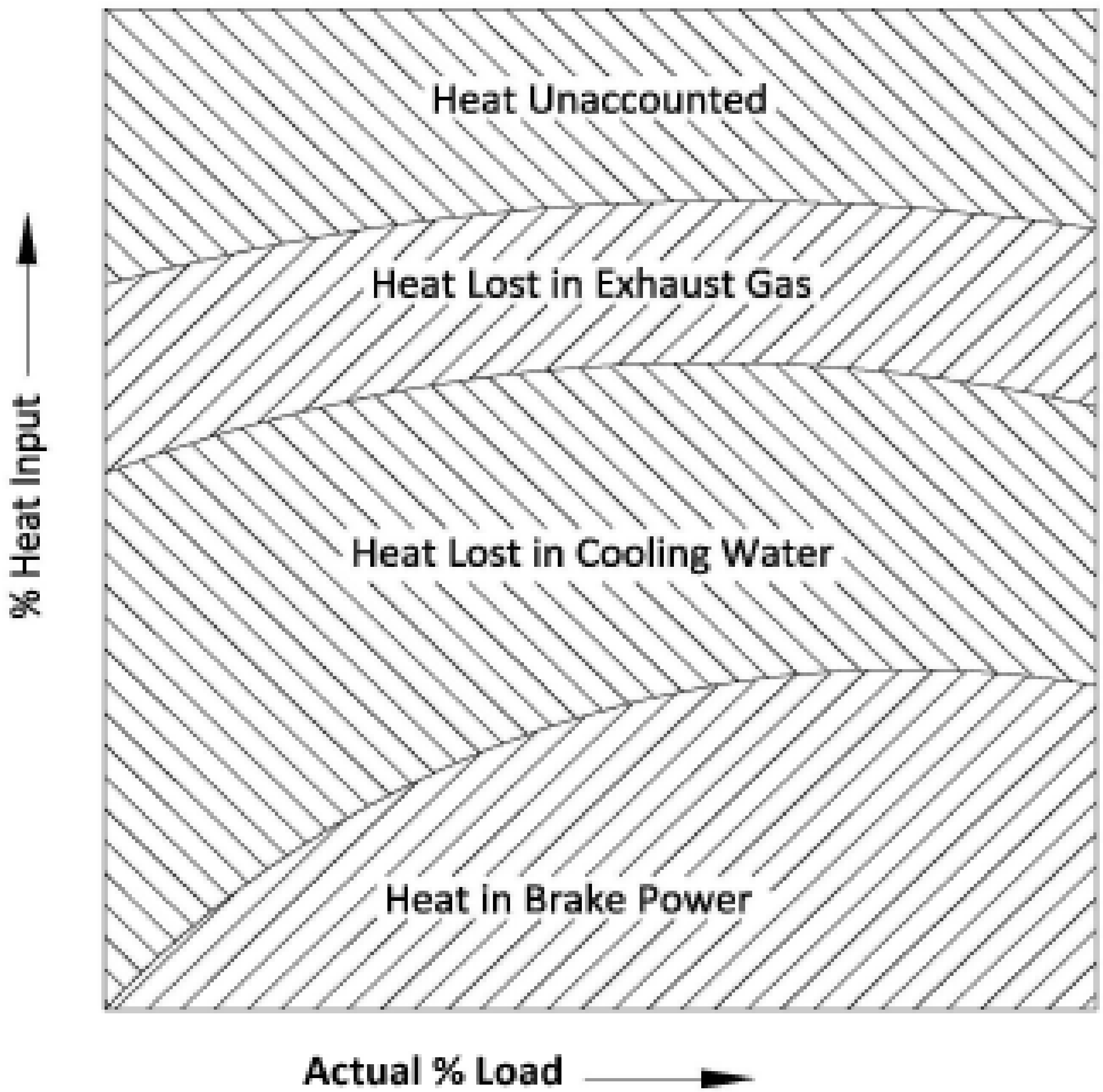
Result

The heat balance test on Field Marshal 6 HP ENGINE was conducted and heat balance chart was drawn on percentage basis .

RESULT TABULATION :

Sl no	Actual Load	Heat input	Heat to useful shaft work		Heat to Cooling water		Heat to Exhaust gas		Heat Unaccounted	
	%	kJ/sec	kJ/sec	% of heat input	kJ/sec	% of heat input	kJ/sec	% of heat input	kJ/sec	% of heat input

Typical heat balance chart for an I.C Engine.



Ex. No. :
Date :

EXPERIMENTAL CENTRAL AIR CONDITIONING PLANT

Aim:

1. To conduct the Performance Test on the Air-conditioning system

Description:

This plant consists of three circuits.

1. Cooling water circuit.

2. Refrigerent circuit.

3. Air circuit.

Cooling Water Circuit:

The water from the bottom tank of the cooling tower is pumped to the condenser by means of condenser pump. It removes the heat from the refrigerant and gets heated and then goes to the top of the cooling tower and the water is sprayed from the top with help of sprayers. The heated water gets cooled and collected at the bottom tank. The cycle is repeated.

Refrigerant Circuit:

The R-22 vapour is compressed in the compressor and then sent to the condenser where it gets cooled and the liquid R-22 goes to the cooling coil through a thermo static expansion valve . The liquid R 22 removes the heat from the air to be conditioned and the R-22 vapour to the compressor for the next cycle of operation.

Air circuit:

The air from the A/C room and from the atmosphere is sucked and passes through a pre heater and then through an Air Filter by the vacuum created by the blower . There is a damper to regulate the air flow drawn into the blower. On its way, the conditioned air is humidified with the help of a humidifying sprayer . The humidifying sprayer sprays water which is pumped by means of humidifying pump . The pump draws water from the sump. The water is collected at the bottom in a tray after spraying and the collected water is sent to the sump.

The conditioned air is circulated through duct by blower and passes through a reheater , enters the room to be conditioned. The duct through which the conditioned air flows is lagged by thermocole to prevent heat transfer from the surroundings.

CENTRAL STATION AIR-CONDITIONING SYSTEM:

In a central station air-conditioning system, all the components of the system are grouped together in one central room and conditioned air is distributed from the central room to the required places through extensive duct work. The central air- conditioning system is generally used for the load above 25 tons of refrigeration and 2500 m^3/min. of conditioned air. The unitary system can be more economically used for low capacity (below 25 tons) units.

The central plants require the following components and all the components are assembled on the site.

1. Cooling and Dehumidifying coils.

2. Heating coils.

3. Blower with motor.

4. Spray for cooling, dehumidifying or washing.

5. Air-cleaning equipments

6. Control Device

The central system serves different rooms through extensive duct work with individual control. The system may use one of the following methods to supply the conditioned air.

(a) Air is conditioned in the central conditioned room and is supplied to the required rooms with controlled air discharge in each room.

(b) The water is chilled in the central conditioned room and is supplied to the required rooms with individual flow control.

(c) Individual evaporators in each room with thermostatic flow control or direct expansion system.

Advantages:

1) The capital cost and running cost are less per unit of refrigeration.

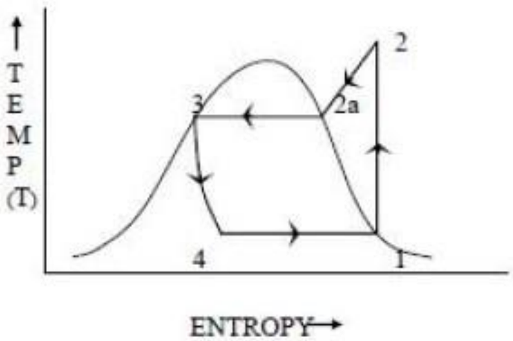
2) It can be located away from the air-conditioned places which is useful and less costly.

3) Noise and vibration troubles are less to the people leaving in air-conditioned places as the air conditioning plant is far away from the air conditioned places.

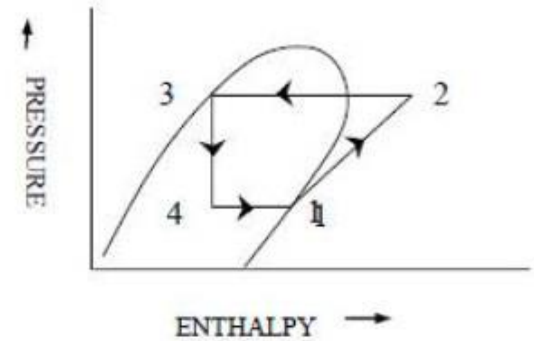
4) Better accessibility for maintenance.

The Central Air Conditioning System works on vapour compression cycle. The p-h and T-s diagram of a vapour compression cycle is given below.

T-s Diagram:



p- h Diagram:



Process 1 to 2 ----------- Compression Process 2 to 3 ----------- Condensation Process 3 to 4 ----------- Expansion Process 4 to 1 ----------- Evaporation

EXPERIMENTAL AIR CONDITIONING PLANT.

Observations:

1. Dry Bulb and Wet Bulb temperatures before the cooling coil - $\mathbf{S_1}$

2. Dry Bulb and Wet Bulb temperatures after the cooling coil- $\mathbf{S_2}$

3. Area of outlet grill in Airconditioned room - $\mathbf{A_1 =}$ [0.91 x 0.15 m^2]

4. Velocity of air using anemometer at A_1 - $\mathbf{V_1}$ = m/sec

5. Quantity of water circulated through the condensor – **Q =** lit/min

6. Temperature of cooling water at inlet and outlet of condenser = t_1 °C and t_2 °C respectively.

7. Dry Bulb & Wet Bulb temperature of air entering the Air-Conditioned room - $\mathbf{S_3}$

8. Dry Bulb & Wet Bulb temperatture of air in Air-conditioned room - $\mathbf{S_4}$

9. Ambient air Dry Bulb & Wet Bulb temperatures - $\mathbf{S_5}$

10. Time for 10 revolutions of Compressor Energy Meter reading -

    Meter constant -

CALCULATIONS:

From Psychrometric chart,

1. Enthalpy of air before cooling coil corresponding to S_1 - **A** kJ/kg

   Enthalpy of air after cooling coil corresponding to S_2 - **B** kJ/kg

Mass of Air flow through coil - (M_a) = $\dfrac{\text{Volume of Air } (V_a) \text{ in kg/sec}}{\text{Sp. Volume } (v_a)}$

Volume of air(V_a) = Average Velocity of air at outlet grill × Area of grill ----m^3/sec

Sp. volume from Psychrometric chart corresponding to S_3 --- m^3/kg

Capacity of the plant (C) = $\dfrac{M_a\ [A - B]}{3.5}$ Tonne of refrigeration.

2. Net Refrigerating effect = $M_a\ [A - B]$ kJ/sec

3. Input to the compressor = $\dfrac{10 \times 3600}{Meter\ Constant \times t}\ \eta_m\ ----kW$

   Assume (η_m) Motor efficiency = 0.9

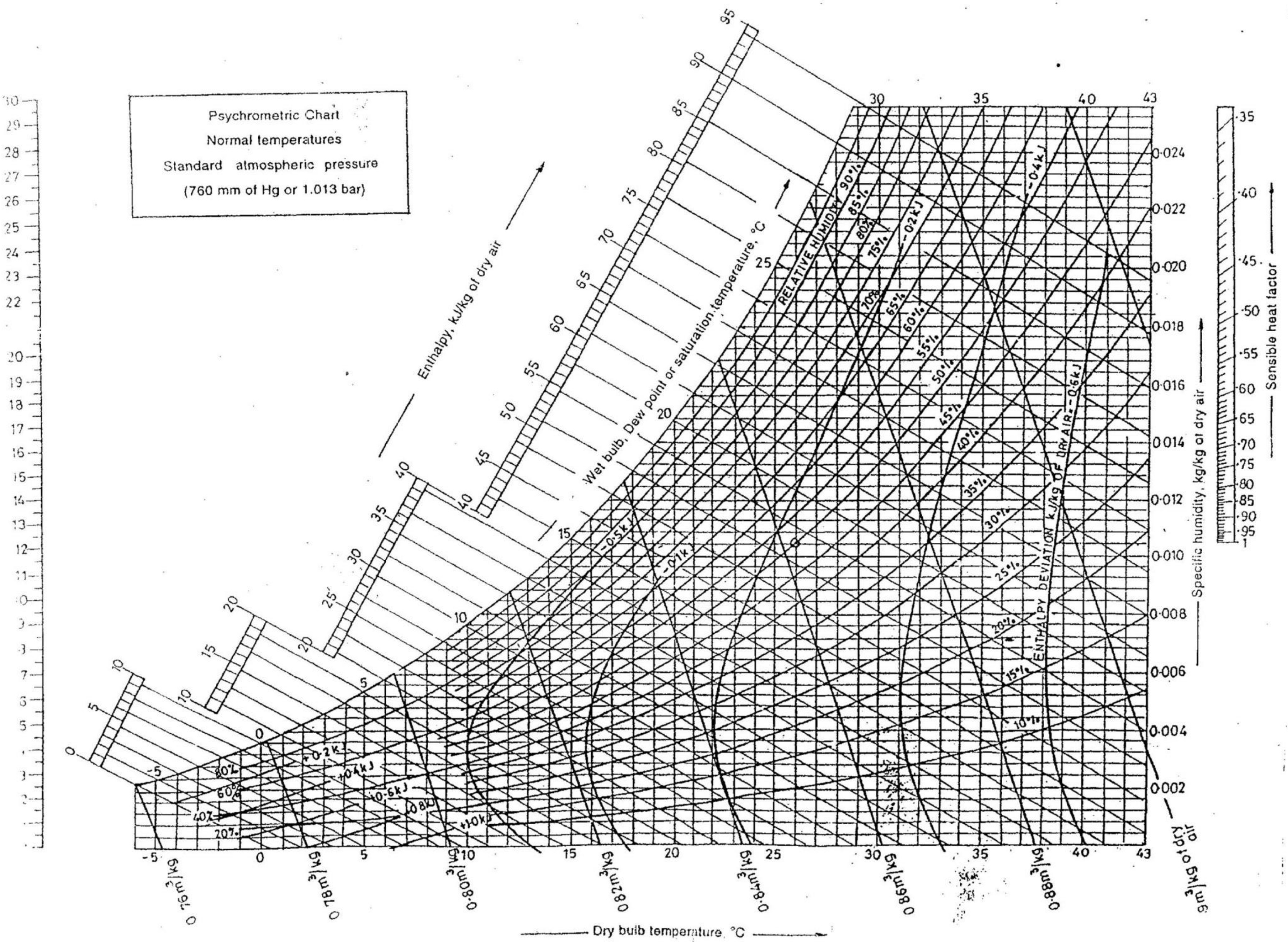
   t = time taken for 10 revolutions in seconds.

4. Actual C.O.P. of Refrigerating Plant

$$= \frac{\text{Net Refrigerating effect in kW (or) kJ / sec}}{\text{Act. work of compression in kW}}$$

5. Actual heat removed by condenser = $Q \times Cp_w \times [t_2 - t_1]$ kJ/min

   = Refrigerating effect plus actual work of compressor minus losses from the compressor



Psychrometric Chart
Normal temperatures
Standard atmospheric pressure
(760 mm of Hg or 1.013 bar)
Enthalpy, kJ/kg of dry air
Wet bulb, Dew point or saturation temperature, °C
RELATIVE HUMIDITY
ENTHALPY DEVIATION kJ/kg OF DRY AIR
Specific humidity, kg/kg of dry air
Sensible heat factor
Dry bulb temperature, °C
0·76m³/kg
0·78m³/kg
0·80m³/kg
0·82m³/kg
0·84m³/kg
0·86m³/kg
0·88m³/kg
0·9m³/kg of dry air

PERFORMANCE TEST ON WINDOW AIR CONDITIONER

AIM:

To study the various component & working and to conduct the performance test on window air conditioner.

SPECIFICATIONS:

1. Cooling capacity	:	18900 kJ/hr
2. Refrigerant/Weight	:	R22/940 g
3. Test pressure	:	24 ksc (G)
4. Compressor	:	Rotary type
5. Condenser	:	Air- cooled (forced)
6. Expansion valve	:	Capillary tube
7. Evaporator	:	Dry expansion type
8. Electrical supply	:	230 V/9.9 A/1

DESCRIPTION:

The Air conditioner, which is installed in the window of a room, is called window type Air conditioner.

The Window Air conditioner consists of a steel chassis. In the center of it, a hermetic sealed compressor motor unit is fitted. The rotary type compressor is used in it, a discharge line, fin and tube type condenser and capillary tube are fitted at one end and suction line fin and tube type evaporator on the opposite end. The complete refrigeration system is charged with Freon – 22 refrigerant.

The shaft is fitted on the both side of the sealed motor. A blower is fitted behind the evaporator on one side of the motor shaft and on the other end; a fan is fitted behind the condenser. The evaporator and blower housing are insulated with the felt insulation. The bottom tray of the evaporator is connected with the condenser tray by means of rubber tube for draining the condensed water. A grill is fitted on the front portion of the air conditioner, which is having a provision for changing the direction of the air.

The blower draws the air through the air filter and evaporator and discharges the cooled air into the room through the grill. The condenser fan draws the air through the grill and forces it through the center of the condenser.

Room air conditioners are available in capacities of ½ to 3 tons.

EXPERIMENTAL PROCEDURE:

1. The Air conditioned room should kept closed before starting the experiment.
2. Switch on the main in the control panel
3. Keep the cooling fan switch in fan position and then start the unit.
4. Keep the cooling fan switch according to the required condition (super quiet/High cool/Super cool).
5. Keep the thermostat position according to the required position.
6. Take the pressure and temperature readings for every 10 min.

Where

t_1= Temperature before compression

t_2= Temperature after compression

t_3= Temperature before Expansion

t_4= Temperature after Expansion

Temperatures of points (1 – 4) have been taken using temperature indicator

P_1=Pressure before Compression

P_2=Pressure after Compression

P_3=Pressure before Expansion

P_4=Pressure after Expansion

The Pressure (1 – 4) have been taken using pressure gauges

7. The dry bulb and wet bulb temperatures of supply air, room air, and outside air using a sling Psychrometer.
8. Take down the Voltmeter and Ammeter readings
9. Measure the air velocities at supply air grill and return air grill using anemometer.
10. Continue the observations up to one hour till the steady state condition is reached.

Condition of Testing

During a test fix the thermostat position at the required (1 – 10) and analyze the performance under different fan positions. (Super quiet/High cool/Super cool).

Tabulate the observations in the table given

EXPERIMENTAL WINDOW AIR CONDITIONER

OBSERVATION TABLE:

Time of Starting :

Time of Closing :

Time	Temperature (°C)				Pressure (PSIG)				Psychrometer Reading (°C)						Air Velocity (m / s)	Energy meter reading for 10 rev (s)
									Supply air		Room air		Outdoor air		Supply air	
	t_1	t_2	t_3	t_4	P_1	P_2	P_3	P_4	t_{d2}	t_{w2}	t_{d1}	t_{w1}	t_{d3}	t_{w3}	v	

SPECIMEN CALCULATION[#]

1. Enthalpy of room air (h_{a1}) kJ/kg (from psychrometric chart)

Enthalpy of room air, h_{a1} =

,

2. Enthalpy of cooling coil outlet air (h_{a2}) kJ/kg (from psychrometric chart)

Enthalpy of cooling coil outlet air, h_{a2} =

(h_{a1} & h_{a2} values are taken from psychometric chart corresponding to t_{db1} & t_{wb1}, t_{db2} & t_{wb2} of room air and supply air)

3. Volume flow rate of air (V_a) = Velocity of air at the grill × area of the grill

Area of the grill (A) m^2

$= 16 \times 27$ cm

$= 16/100 \times 27/100\ m^2$

$= 0.0432\ m^2$

Average velocity of air at the grill (v) = $(v_1 + v_2 + v_3) / 3$ (m/s)

=

$\therefore$ Volume flow rate of air 'V_a' = $A \times v$ (m^3/s)

=

Specific volume (v_{s1}) m^3/kg

(From psychometric chart corresponding to supply air dry & wet bulb temperature)

Supply Air : t_{db2} = t_{wb2} =

v_{s1} =

4. Mass flow rate of air

through coil (m_a) $= \dfrac{Volume \quad flow \quad rate \quad of \quad air}{Specific \quad volume \quad of \quad air}$ (kg/s)

=

Mass flow rate of air through coil (m_a) =

5. Capacity of the Plant (C) = $\dfrac{m_a \left[h_{a1} - h_{a2}\right]}{3.5}$ (TR)

(C) =

6. Net refrigeration effect = $m_a \left[h_{a1} - h_{a2}\right]$ kJ/s

7. Input to the Compressor = $\dfrac{10 \times 3600 \times \eta_m}{\text{Energy meter constant} \times \text{Energy meter reading for 10 rev. (s)}}$, (kW)

$$\text{Energy meter Constant} = 600 \frac{revolutions}{kW - hr}.$$

Time for 10 rev. of energy meter =

Assume $\eta_m = 0.9$

Input to the Compressor =

8. Experimental COP of refrigerant unit

$$= \frac{\text{Net refrigeration effect}}{\text{Actual work of compression } (kW)}$$

(COP) $_{\text{Experimental}}$ =

9. Theoretical COP $= \dfrac{h_{r1} - h_{r4}}{h_{r2} - h_{r1}}$

(From pH chart of R-22 find the value of enthalpies h_{r1} h_{r2} h_{r3} h_{r4})

[To convert PSIG to bar absolute = (PSIG $\times$ 0.06894 + 1.013)]

Where

h_{r1} = Enthalpy Corresponding to Pressure P_1 & t_1 (kJ/kg)

h_{r2} = Enthalpy Corresponding to Pressure P_2 & t_2 (kJ/kg)

h_{r4} = h_{r3} =Enthalpy Corresponding to Pressure P_3 & t_3 (kJ/kg)

P_1 =

P_2 =

P_3 =

P_4 =

h_{r1} =

h_{r2} =

h_{r4} = h_{r3} =

Theoretical COP =

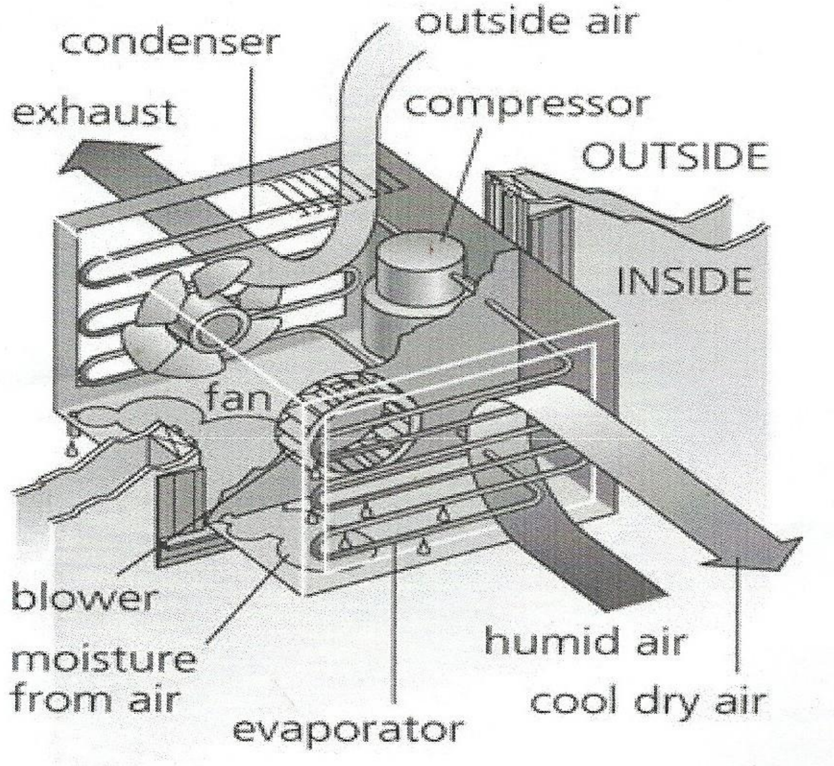


Fig.1 Schematic diagram of Window Air conditioner

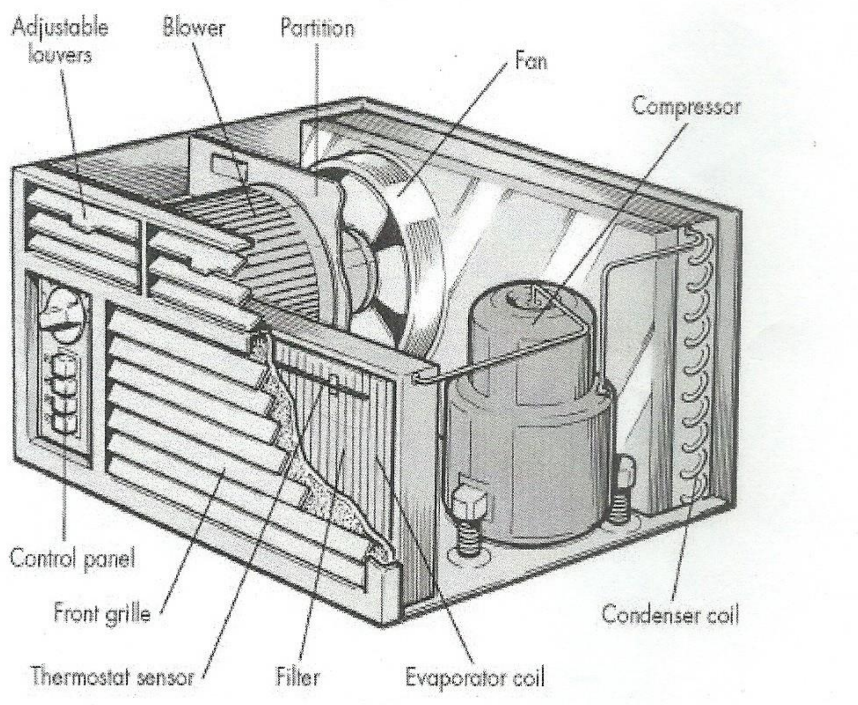


Fig.2 Schematic diagram of Window Air conditioner components

10. Carnot C.O.P = $\dfrac{T_L}{T_H - T_L}$

Where

T_L = Lower temperature corresponding to lower pressure P_L
T_H = Higher temperature corresponding to higher pressure P_H
P_L = Average pressure of P_1 & P_4
P_H = Average pressure of P_2 & P_3

T_L =

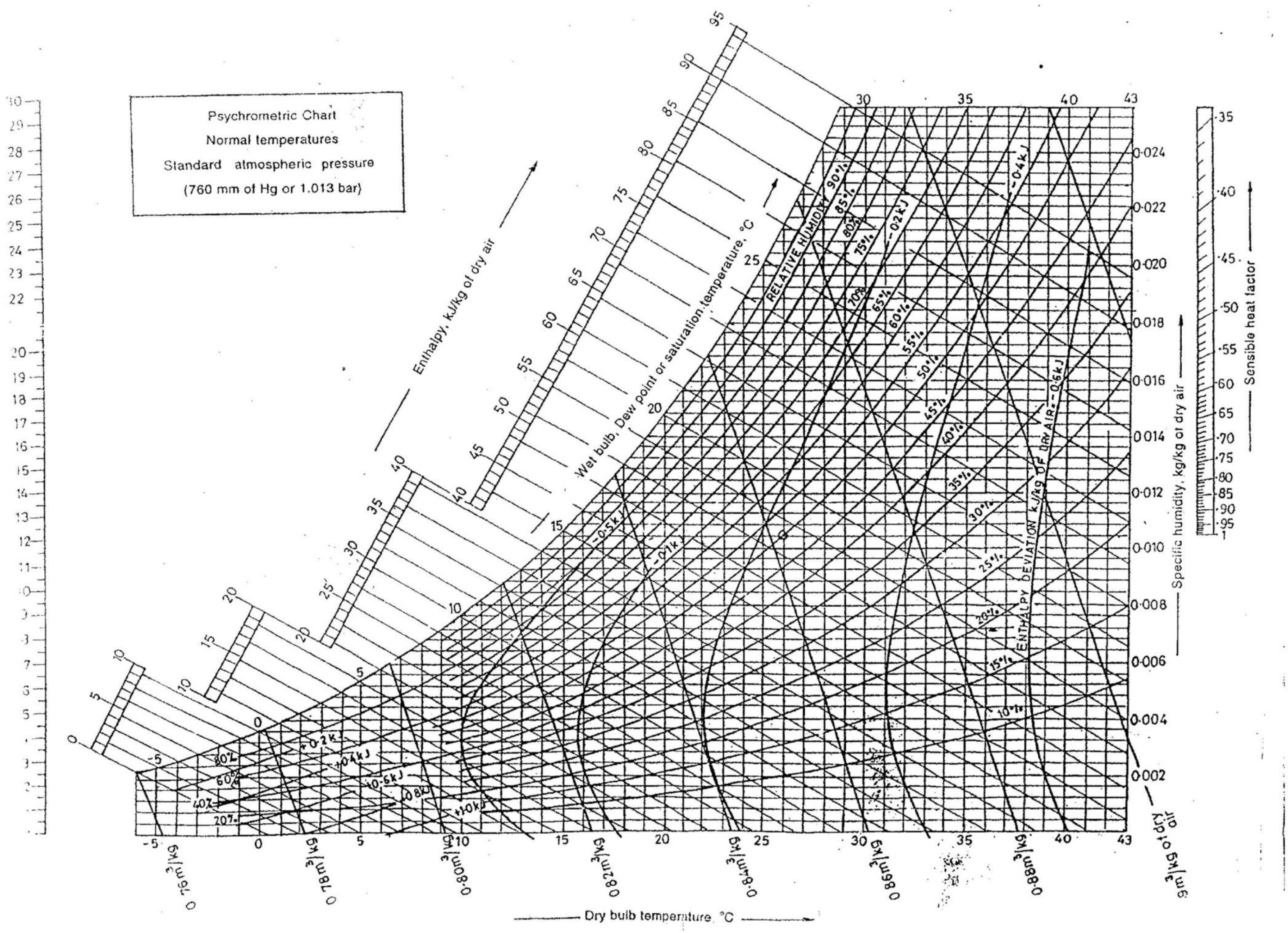
T_H =

T_L & T_H values are taken from R-22 table corresponding to pressure P_L and P_H

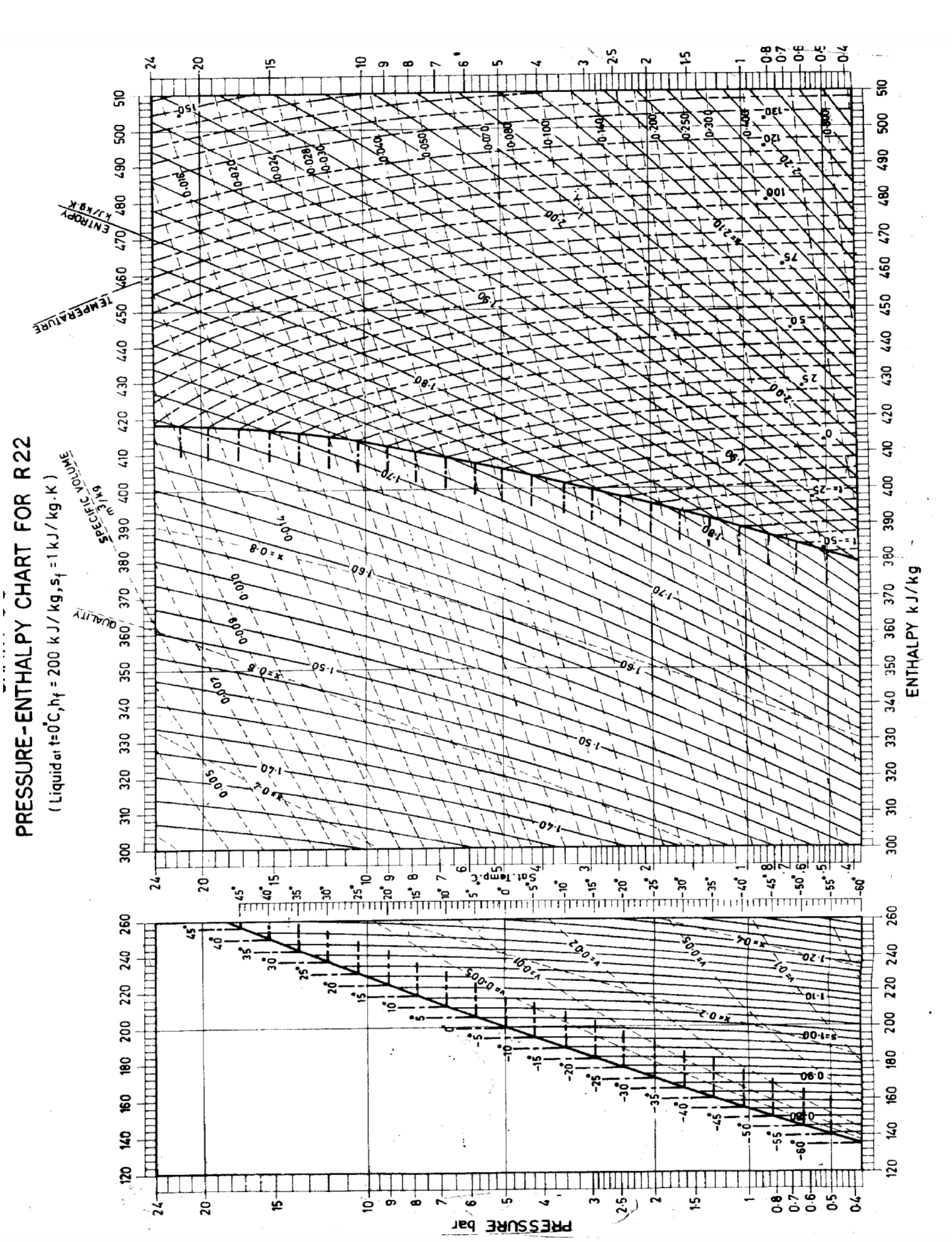
Carnot C.O.P =

RESULTS TABULATION:

Sl. No.	**C.O.P**			**Capacity TR**
	Carnot	**Actual**	**Theoretical**	



Psychrometric Chart
Normal temperatures
Standard atmospheric pressure
(760 mm of Hg or 1.013 bar)
Enthalpy, kJ/kg of dry air
Wet bulb, Dew point or saturation temperature, °C
RELATIVE HUMIDITY
ENTHALPY DEVIATION kJ/kg OF DRY AIR
Specific humidity, kg/kg of dry air
Sensible heat factor
Dry bulb temperature, °C


PRESSURE-ENTHALPY CHART FOR R22
(Liquid at t=0°C, h_f = 200 kJ/kg, s_f = 1 kJ/kg.K)
ENTROPY kJ/kg.K
TEMPERATURE
SPECIFIC VOLUME m³/kg
QUALITY
Sat. Temp. °C
ENTHALPY kJ/kg
PRESSURE bar

PERFORMANCE TEST ON VAPOUR ABSORPTION REFRIGERATION TRAINER

AIM: To conduct performance test on vapour absorption refrigeration system.

SPECIFICATION:

Model	:	EA 3140
Type	:	MF20-60
Grass volume	:	41 ltrs
Mains Operation	:	220-240 volts AC
Input	:	90W
Energy Consumption	:	1.07 kWhr
Refrigerant	:	245 $NH_3 + H_2O$

SYSTEM COMPONENTS:

Volt meter	:	0 - 300V AC
Ammeter	:	0 - 20A AC
Temperature Indicator	:	-50 to +150 degree C
TSS	:	Thermocouple selector switch (8way)
Thermocouple	:	K type (Cr-Al)

Toggle switches for Heater and Condenser fan

INTRODUCTION:

Vapour Absorption Refrigeration system (VARS) belong to the class of vapour cycle similar to vapour compression refrigeration systems. However, unlike vapour compression refrigeration systems, the required input to absorption systems is in the form of heat. Hence these systems are also called as heat operated or thermal energy driven systems. Since conventional absorption systems use liquids for absorption of refrigerant, these are also sometimes called as wet absorption systems.

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Similar to vapour compression refrigeration systems, vapour absorption refrigeration systems have also been commercialized and are widely used in various refrigeration and air conditioning applications. Since these systems run on low-grade thermal energy, they are preferred when low-grade energy such as waste heat or solar energy is available. Since conventional absorption systems use natural refrigerants such as water on ammonia they are environment friendly.

In the above Figure (a) and (b) show a continuous output vapours compression refrigeration system and a continuous output vapour absorption refrigeration system. As shown in the figure in a continuous absorption system, low temperature and low pressure refrigerant with low quality enters the evaporator and vaporizes by producing useful refrigeration **Qe**.

From the evaporator, the low temperature, low pressure refrigerant vapour enters the absorber where it comes in contact with a solution that is weak in refrigerant. The weak solution absorbs the refrigerant and becomes strong in refrigerant. The heat of absorption is rejected to the external heat sink at **To.**

The solution that is now rich in refrigerant is fed to the generator. In the generator heat at high temperature **Tg** is supplied, as a result refrigerant vapour is generated at high pressure. This high pressure vapour is then condensed in the condenser by rejecting heat of condensation to the external heat sink to **To.**

The condensed refrigerant liquid is then throttled in the expansion device and is then fed to the evaporator to complete the refrigerant cycle.

On the solution side, the hot, high-pressure solution that is weak in refrigerant is throttled to the absorber pressure in the solution expansion valve and fed to the absorber where it comes in contact with the refrigerant vapour from evaporator. Thus continuous refrigeration is produced at evaporator, while heat at high temperature is continuously supplied to the generator. Heat rejection to the external heat sink takes place at absorber and condenser. If we neglect pressure drops, then the absorption system operates between the condenser and evaporator pressures. Pressure in absorber is same as the pressure in evaporator and pressure in generator is same as the pressure in Condenser.

It can be seen from Fig, that as far as the condenser, expansion valve and evaporators are concerned both compression and absorption systems are identical. However, the difference lies in the way the refrigerant is compressed to condenser pressure. In vapour compression refrigeration systems the vapour is compressed mechanically using the compressor, where as in absorption system the vapour is first converted into a liquid and then the liquid is pumped to condenser pressure using the solution pump. Since for the same pressure difference, work input required to pump a liquid (solution) is much les than the work required for compressing a vapour due to vey small specific volume of liquid, the mechanical energy required to operate vapour absorption refrigeration system is much less than that required to operate a compression system.

However, the absorption system requires a relatively large amount of low-grade thermal energy at generator temperature to generate refrigerant vapour from the solution in generator. Thus while the energy input is in the form of mechanical energy in vapour compression refrigeration systems, it is mainly in the form of thermal energy in case of absorption systems. The solution pump work is often negligible compared to the generator heat input. Thus the COPs for compression and absorption systems are given by:

$$COP(VCRS) = \frac{Qe}{Wc}$$

$$COP(VCRS) = \frac{Qe}{Qg} = \frac{Te}{(Tc-Te)} \times \frac{(Tg-Tc)}{Tg}$$

Thus absorption systems are advantageous where a large quantity of low-grade thermal energy is available freely at required temperature. However, it will be seen that for the refrigeration and heat rejection temperatures, the COP of vapour compression refrigeration system will be much higher than the COP of an absorption system as a high grade mechanical energy is used in the former, while a low-grade thermal energy is used in the latter.

Maximum COP of ideal absorption refrigeration system

In case of a single stage compression refrigeration system operating between constant evaporator and condenser temperatures, the maximum possible COP is given by

$$\text{Carnot COP (VARS)} = \frac{Te}{(Tc-Te)}$$

If we assume that heat rejection at the absorber and condenser takes place at Same external heat sink temperature **To**, then a vapour absorption refrigeration system operates between three temperature levels, **Tg**, **To** and **Te**.

The maximum possible COP of a refrigeration system operating between three temperatures levels can be obtained by applying first and second laws of thermodynamics to the system. Figure shows the various energy transfers and the corresponding temperatures in an absorption refrigeration system.

WORKING PRINCIPLE (VARS – 245 $NH_3 + H_2O$):

The domestic absorption type refrigerator was developed from an invention by CarlMunters and Baltzer Von Platen. This system is often called Munters Platen system. Ammonia is used as a refrigerant. The operation of this system is based on the concept of Dalton’s Law.

The ammonia vapour in the condenser is condensed to liquid and flows to evaporator by gravity. The whole part is charged to a pressure of about 15bar. In the evaporator, the liquid ammonia meets an atmosphere of hydrogen at about 12 bar. Thus the partial pressure of ammonia falls to about 3 bar, keeping the same total pressure, and the temperature falls to about -10^{o} C.

The vaporization of ammonia at this temperature produces refrigeration. Water is used as a solvent for ammonia which absorbs ammonia readily. If liquid ammonia is introduced at the top of the system, it passes on to the evaporator and vaporizes. Hydrogen flows upwards in the evaporator counter-flows to liquid ammonia that falls from the top. The ammonia vapour and hydrogen leave the top of the evaporator and flow through the gas heat exchange getting warmed by the warmer hydrogen flowing through the evaporator. Both the gases flow to the absorber. Weak aqua ammonia solution enters at the top of the absorber and absorbs ammonia gas as it passes counter-flow through the absorber. The hydrogen is not soluble in weak aqua ammonia solution and gets separated and flows up to the evaporator through the heat exchanger. Strong aqua ammonia solution leaves the bottom of the absorber and passes on the generator.

Heat is supplied to the generator from external source by an electric heater, expelling ammonia vapour out from the strong solution. Here the problem is to raise the elevation of weak solution of ammonia also so that it can pass to the separator and flow back to the absorber. Principle of bubble pump is used here. The delivery tube from the generator is immersed below the liquid level in the generator.

Thus as ammonia vaporizes in the tube, they carry slugs of weak solution also into the separation vessel. From the separating vessel, weak solution flows to the absorber and ammonia vapour passes on to the condenser.

Thus cycle is completed. The total pressure in the condenser is approximately the same as in evaporator. Since, in the condenser, there is a pure ammonia, the vapour pressure there is more or less same as the total pressure. In the evaporator, there exists a mixture of ammonia vapour and hydrogen gas. Thus ammonia vapour pressure is much less, this being equal to total pressure minus the partial pressure of hydrogen. Being at a pressure below saturation pressure, the ammonia readily evaporates in the evaporator and refrigerates. Thus temperature equal to the its saturation temperature of ammonia at its partial pressure is theoretically obtained in the evaporator.

OPERATING PROCEDURE:

1. Fill the water in overhead tank
2. Put the main switch ON.
3. Now, the digital panel meters display their respective readings.
4. Now switch on the heater and condenser fan.
5. Heater ON/OFF durations : (Automatic)

   ON for 15 seconds

   OFF for 10 seconds

   (Off – ON ratio = 2/3)

6. Wait for 30 - 45 min (approx.) to get cooling effect (The door of the refrigerator should be kept close always)

7. Check the temperatures at different points using TSS

8. When the evaporator temperature T_4 reduces 5 degree C, put the measuring jar inside the refrigerator chamber, put the thermocouple in to the jar. Now allow the water from the over head tank by opening the ball valve provided. The water flow through a copper pipe wound around the evaporator pipe.

9. Now note down the temperatures at different positions, voltmeter & ammeter readings when it reach steady state (say 10 or 15 min. approx.)

10. Check the quantity of water collected with respect to time

11. Now switch off the heater, condenser fan and mains.

TABULAR COLUMN:

Sl.No	**V**	**I**	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**	**M_w**

OBSERVATIONS:

V = Voltage in volts
I = Current in Amps
T_1 = Refrigerant temperature at inlet of generator in degree C
T_2 = Refrigerant temperature at outlet generator
T_3 = Refrigerant temperature at outlet of condenser
T_4 = Refrigerant temperature at inlet of evaporator (after expansion)
T_5 = Refrigerant temperature at outlet of evaporator
T_6 = Water inlet temperature at collecting measuring jar
T_7 = Water outlet temperature at over head tank
T_8 = Outlet temperature of air
M_w= mass of water collected in measuring jar
t = time taken for Mw of water collection.

SPECIMEN CALCULATION:

1. THEORITICAL COP

$$\text{COP th} = \frac{Qe}{Qg} = \frac{Te}{(Tc-Te)} \times \frac{(Tg-Tc)}{Tg}$$

Tg = T_2 = Generator Temperature in **K =**

Tc = T_3 = Condenser outlet Temperature in **K =**

Te = T_4 = Evaporator inlet Temperature in **K =**

$$= \frac{Te}{(Tc-Te)} \times \frac{(Tg-Tc)}{Tg}$$

=

2. CARNOT COP

$$\text{Carnot COP} = \frac{Te}{Tc-Te}$$

Where,

Te = T_4 in K =

Tc = T_3 in K =

$$= \frac{Te}{Tc-Te}$$

=

3. REFRIGERATING EFFECT:

$Qe = Mw \times CPw \times (T_7 - T_6)$ kW

Where,

M_w = mass of water collected in the jar in kg/sec

$= \dfrac{Vw \times 10^{-6} \times 1000}{t}$ = ...kg /sec

CPw = Specific heat of water in kJ/kg K = 4.186 kJ/kg K

T_6 = Water temperature in the jar = ……………….

T_7 = Water temperature in the over head tank = ………….

t = time taken in seconds = ……………

$Qe = Mw \times CPw \times (T_7 - T_6)$

=

4. POWER INPUT

$Qg = \dfrac{V \times I}{1000} \times time\ ratio \quad kW$

=

Where,

V = Voltage in volts

I = Current in Amps

*Time ratio = 2/3.

***NOTE:** Heater ON for 15 secs & OFF for 10 secs
Suppose duration of the test is 5 min (300 seconds) then the heater ON time will be 180 seconds, therefore, time ratio = 2/3.

5. ACTUAL COP

$$COP = \frac{Refrigeration\ Effect}{Power\ input}$$

$$= \frac{Qe}{Qg}$$

$$=$$

RESULT: