Expt.No: 1

Study of determination of Calorific Value of Fuels & Specific heat of a solid by using Bomb calorimeters

Aim: -

A. To study determination of Calorific Value of Fuels by using Bomb calorimeter.

Apparatus: - Bomb Calorimeter

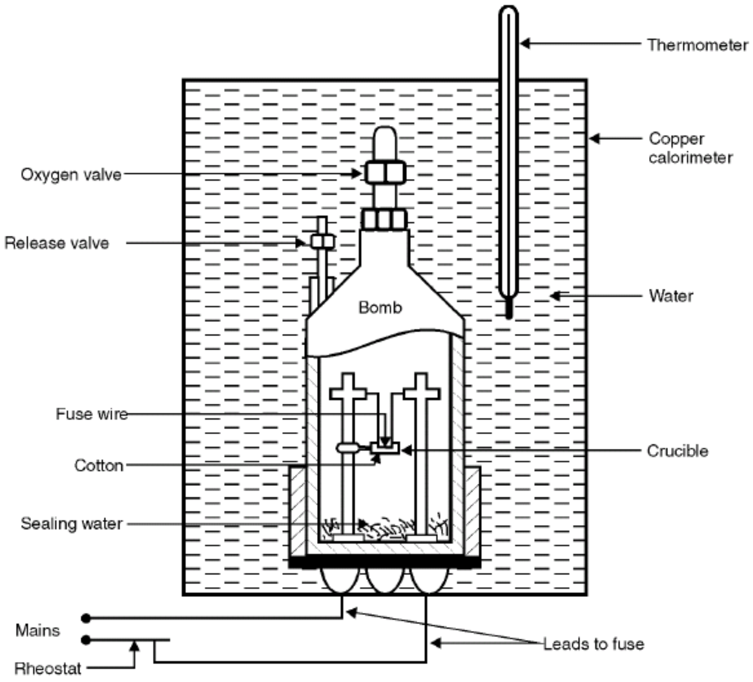
Theory:-

The "calorific value or heating value" of the fuel is defined as the energy liberated by the complete oxidation of a unit mass or volume of a fuel. It is expressed in kJ/kg for solid and liquid fuels and kJ/m^3 for gases. The higher heating value, HHV, is obtained when the water formed by combustion is completely condensed. The lower heating value, LHV, is obtained when the water formed by combustion exists completely in the vapour phase.

Bomb calorimeter:

The calorific value of solid and liquid fuels is determined in the laboratory by 'Bomb calorimeter'. It is so named because its shape resembles that of a bomb. Fig. 1 shows the schematic sketch of a bomb calorimeter. The calorimeter is made of austenitic steel which provides considerable resistance to corrosion and enables it to withstand high pressure. In the calorimeter is a strong cylindrical bomb in which combustion occurs. The bomb has two valves at the top. One supplies oxygen to the bomb and other releases the exhaust gases. A crucible in which a weighted quantity of fuel sample is burnt is arranged between the two electrodes as shown in Fig. 1. The calorimeter is fitted with water jacket which surrounds the bomb. To reduce the losses due to radiation, calorimeter is further provided with a jacket of water and air. A stirrer for keeping the temperature of water uniform and a thermometer to measure the temperature up to an accuracy of 0.001°C are fitted through the lid of the calorimeter.

Figure 1: Bomb calorimeter.



Procedure:

To start with, about 1 gm of fuel sample is accurately weighed into the crucible and a fuse wire (whose weight is known) is stretched between the electrodes. It should be ensured that wire is in close contact with the fuel. To absorb the combustion products of sulphur and nitrogen 2 ml of water is poured in the bomb. Bomb is then supplied with pure oxygen through the valve to an amount of 25 atmosphere. The bomb is then placed in the weighed quantity of water, in the calorimeter. The stirring is started after making necessary electrical connections, and when the thermometer indicates a steady temperature fuel is fired and temperature readings are recorded after 1/2 minute intervals until maximum temperature is attained. The bomb is then removed; the pressure slowly released through the exhaust valve and the contents of the bomb are carefully weighed for further analysis. The heat released by the fuel on combustion is absorbed by the surrounding water and the calorimeter.

From the above data the calorific value of the fuel can be found in the following way:
Let W_f = Weight of fuel sample (kg),
W = Weight of water (kg),
C = Calorific value (higher) of the fuel (kJ/kg),
W_e = Water equivalent of calorimeter (kg),
T_1 = Initial temperature of water and calorimeter,
T_2 = Final temperature of water and calorimeter,
T_c = Radiation corrections, and
c = Specific heat of water.
Heat released by the fuel sample = $W_f \times C$
Heat received by water and calorimeter
= $(W_w + W_e) \times c \times [(T_2 - T_1) + T_c]$.
Heat lost = Heat gained
$W_f \times C = (W + W_e) \times c \times [(T_2 + T_1) + T_c]$
i.e., 2 1 ( ) [( )] e c f W W c T T T C W □ □ □ □ □ □
[Value of c is 4.18 in SI units and unity in MKS units.]

Note:

1. Corrections pertain to the heat of oxidation of fuse wire, heat liberated as a result of formation of sulphuric and nitric acids in the bomb itself.

2. It should be noted that bomb calorimeter measures the higher or gross calorific value because the fuel sample is burnt at a constant volume in the bomb. Further the bomb calorimeter will measure the H.C.V. directly if the bomb contains adequate amount of water before firing to saturate the oxygen. Any water formed from combustion of hydrogen will, therefore, be condensed. The procedure of determining calorific values of liquid fuels is similar to that described above. However, if the liquid fuel sample is volatile, it is weighed in a glass bulb and broken in a tray just before the bomb is closed. In this way the loss of volatile constituents of fuels during weighing operation is prevented.

RESULT: Hence we study the Bomb calorimeter for determination of calorific value of the given fuel.

Expt.No: 2 Thermal Conductivity Measurement By GuardedPlate Method

AIM

To determine the thermal conductivity of a poor conducting material, say Asbestos sheet.

RELEVANT THEORY

Thermal conductivity is a specific property of conducting material which is defined below for a homogeneous solid as the quantity of heat conducted across a unit area normal to the flow direction in unit time and for unit temperature gradient along the flow.

$$K = q\, dL / A\, dT$$

Where,

q = heat conducted in watts
dL = thickness [m]
A = Area of conduction heat transfer, m^2
dT = temperature difference across the length dL [^{0}C]

MEASUREMENT:

Experimental measurement of thermal conductivities of solids can be accomplished by a variety of methods, all based on the observation of the temperature gradient across a given area of the material conducting heat at a known rate. Each of these methods has certain unique limitations, and the choice of one over another is governed by the general temperature level at which K is measured, by the physical structure of the material in question and by whether the material is a good or poor conductor.

In measuring the thermal conductivity of poor conductors, the specimens are taken in the form of sheets in order that the heat flow path is short and the conducting area large. [low dL, higher A].

FACILITIES REQUIRED AND PROCEDURE

a] Facilities required to do the experiment

Sl. No.	Facilities required	Quantity
1.	Guarded plate apparatus	1

SPECIFICATIONS:

Material	= Asbestos sheet [commercial grade]
Specimen diameter [d]	= 150 mm or 0.15 m.
Specimen thickness dL	= 12 mm or 0.012 m.
Area of specimen	= $\pi / 4 \times [0.15]^2$ m^2
Heat input	= VI watts [q]

b] Guarded Hot Plate method [Solids]

The apparatus consists of a Guarded Hot Plate, the arrangement along with thermocouple positions [T3, T4] across the specimen and T5, T6 guarded heater temperature [only for check] [T1, T2] Top and Bottom pad temperatures.

The panel consists of voltmeter, ammeter, temperature indicator [all digital], dimmer controls, voltmeter and ammeter selector [common switch, thermocouple selector switch].

c] Operation:

a] Connect the three pin plug top to 230 V, 50 Hz, 5 Amps power supply socket, dimmers in OFF position.

b] Keep the voltmeter and ammeter switch in 1 position. Turn the dimmer in clockwise and adjust the power input to main heater to any desired value by looking at voltmeter and ammeter.

c] Turn the voltmeter and ammeter switch to position marked 2 and check the voltage & current are same for ring heater.

d] Allow the unit to stabilize [approx 30 minutes].

e] Note down the temperature indicated by the digital temperature indicator by turning the thermocouple selector switch clockwise step by step [1, 2, 3, 4, 5, and 6].

f] Repeat the experiment for different power inputs to the heater. g] Tabulate all the readings and calculate for different conditions

h] After the experiment is over turn all the dimmer knobs anti clockwise, direction to zero. i] Disconnect the three pin plug top from the mains.

CAUTION:

The equipment should be operated between 0 and 150 V.

d] Procedure for doing the experiment:

Step No.	**Details of the Step**
1.	Supply a small quantity of energy to the source ‘H’ [the main heater MH].
2.	Now adjust the input to the guard heaters such that the temperature is same as that of the main heater
3.	Allow water through the cooling circuit slowly.
4.	Allow 30 – 60 minutes for the temperatures to st abilize.
5.	Note down all the parameter
6.	Repeat the experiment at different temperature values by adjusting appropriately the input conditions.

OBSERVATION:

MINIMUM 40 VOLTS [BOTH]

S. No.	Volts	Amps	Volts	Amps	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
1.	39	0.18	44.1	0.14	34.2	32.3	41.3	80.9	62.5	92.1	98.4	42.0	34.6

2.	36	0.16	41	0.13	22.6	34.5	44.4	85.0	66.4	95.6	102.8	44.9	37.4
3.	32	0.14	36	0.12	23.8	35.0	44.5	82.5	65.4	92.0	98.7	45.0	38.2

CALCULATION:

Insulating material : Asbestos sheet [commercial grade]

Specimen diameter = 150 mm = 0.15 m.

Area of specimen = $\pi / 4 \times [0.15]^2 = 0.018\ m^2$.

Specimen thickness = ΔL = 12 mm = 0.012 m.

Volts = 32

Amps = 0.14 Main heater

Volts = 36

Amps = 0.12 Ring heater

Heat input q = q [main heater] + q [guard heater]

= [32 x 0.14 x 0.86] + [36 x 0.12 x 0.86]

= 3.85 + 3.71

= 7.56 kcal/hr.

It should be noted that out of this heat input, ideally only a half will pass through each of the specimens [top and bottom].

Hence q = q / 2 = 7.56 / 2 = 3.78 kcal/hr.

$\Delta T = \{[T_4 - T_3] + [T_7 - T_8]\} / 2$

$= \{[82.5 - 44.5] + [98.7 - 45.0]\} / 2$

$= [38 + 53.7] / 2$

$= 91.7 / 2 = 45.85^0C$.

Thermal conductivity of specimen

$K = q \Delta L / A \Delta T$

$= 3.78 \times 0.012 / 0.018 \times 45.85$

$0.04536 / 0.8253 = 0.05496$ kcal/hr m^0C.

Result:

Thus the thermal conductivity of a poor conducting material [Asbestos sheet] is determined.

K= 0.05496 Kcal / hr m^0C.

Expt.No:3 Effectiveness Of Parallel / Counter Flow HeatExchanger

AIM

To determine the overall heat transfer co-efficient on the given double pipe parallel flow and counter flow heat exchanger.

FACILITIES REQUIRED AND PROCEDURE

a] Facilities required to do the experiment:

Sl. No.	Facilities required	Quantity
1.	Parallel/Counter flow heat exchanger apparatus.	1

b] Theory:

A heat exchanger is defined as equipment which transfers the heat from a hot fluid to a cold fluid.

Types of Heat Exchanger

There are several types of heat exchangers which may be classified on the basis of

I. Nature of heat exchange process
II. Relative direction of fluid motion
III. Design and constructional features
IV. Physical state of fluids.

I. Nature of heat exchange process

On the basis of the nature of heat exchange process, heat exchangers are classified

as a] Direct contact heat exchangers or Open heat exchangers
b] Indirect contact heat exchangers.

a] Direct contact heat exchangers or Open heat exchangers

In direct contact heat exchanger, the heat exchange takes place by direct mixing of hot and cold fluids. This heat transfer is usually accompanied by mass transfer.

Examples: Cooling towers, direct contact feed heaters. **b. Indirect contact heat exchangers**

In this type of heat exchangers, the transfer of heat between two fluids could be carried out by transmission through a wall which separates the two fluids.

It may be classified as

[i] Regenerators

[ii] Recuperators [or] Surface heat exchangers.

EFFICTIVENESS:

$\varepsilon = [1 - \exp(-U\ _A/C_{min}\ \{1 + C_{min}/C_{max}))] / 1 + [C_{min}/C_{max}]$

$C_h = C_{pn} \times m_h = 4.187 \times 400 \times 10^{-4} = 0.167 = C_{max}$

$C_c = C_{pc} \times m_c = 4.187 \times 333.3 \times 10^{-4} = 0.140 = C_{min}$

$= [1 - \exp(-(1.685) \times (0.6123))] / 0.140 \times [1 + 0.663]] / 1 +$
$[0.839]$ Effictiveness $= \varepsilon = 0.52$.

COUNTER FLOW:

LMTD $= [T_{hi} - T\ _{ci}]$ **-** $[T_{ho} - T\ _{co}]$ / in $[T_{hi} - T\ _{ci}/T_{ho} - T$
$_{co}] = [355 - 324] - [330 - 308]$/ in $[355\text{-}324/\ 330\text{-}$
$308] = 26.24$ K.

$Q_h = m_{ch}\ C_{ph}\ [\ T_{hi} - T\ _{ho}]$
$= 0.08 \times 4.187\ [355\text{-}$
$330]\ Q_h = 8.374$ KJ/sec.

$Q_c = M_c\ C_{pc}\ [T_{co} - T\ _{ci}]$
$= 0.053 \times 4.187\ [324 -$
$308]\ Q_c = 3.551$ KJ/sec.

Qact $= 8.374 + 3.551 / 2$
$= 5.962$ KJ/sec.

Overall heat transfer co-efficient

$U = Q_{aet}/A \times$ LMTD

U = Overall heat transfer co-efficient
$[W/m^2K]\ A = \pi DL = 3.14 \times 0.013 \times 1.5$
$= 0.06213.$

$U = 5.962 / 0.06123 \times$
$26.24 = 3.543\ W/m^2K$

EFFICTIVENESS

$\varepsilon = 1 - \exp[-U\ _A/C_{min}\ [1 + C_{min}/C_{max}]] / 1 + [C_{min}/C_{max}]$

$\varepsilon = [1 - \exp[-3.543 \times 0.06123/0.222]\ [1 + 0.663]] /\ 0.663 + 1$

$C_c = M_cC_{pc} = 0.053 \times$
$4.187 = 0.222$ KJ/sec.

$C_h = M_hC_{ph} = 0.68 \times$
$4.187 = 0.333$ KJ/sec.

U = Overall heat transfer co-efficient $[W/m^2K]$

A = Area = M^2

$\varepsilon = 0.62\%$

PARALLEL FLOW SIDE

HOT WATER SIDE			COLD WATER SIDE		
Flow rate [kg/s]	T_{hi} [^{0}C]	T_{ho} [^{0}C]	Flow rate [kg/s]	T_{ci} [^{0}C]	T_{co} [^{0}C]
400ml/10sec.	56	45	400ml/12sec	34	39

COUNTER FLOW SIDE

HOT WATER SIDE			COLD WATER SIDE		
Flow rate [kg/s]	T_{hi} [^{0}C]	T_{ho} [^{0}C]	Flow rate [kg/s]	T_{ci} [^{0}C]	T_{co} [^{0}C]
800ml/10sec.	82	57	800ml/15sec	35	51

CALCULATION:

PARALLEL FLOW:

LMTD = $[T_{hi} - T_{ci}] - [T_{ho} - T_{co}] / \ln [T_{hi} - T_{ci}/T_{ho} - T_{co}]$

T_{ci} = Entry temperature of cold fluid [^{0}C].

T_{co} = Exit temperature of cold fluid [^{0}C].

T_{hi} = Entry temperature of hot fluid [^{0}C].

T_{ho} = Exit temperature of hot fluid [^{0}C].

$= [329 - 307] - [318 - 312] / \ln [(329 - 307) / (318 - 312)]$

$= 12.31$ K.

Mass flow rate of hot water $m_h = 400/10 \times 10^{-6} \times 1000 = 400 \times 10^{-4}$ Kg/s.

Mass flow rate of cold water $m_c = 400 / 12 \times 10^{-6} \times 1000 = 333.3 \times 10^{-4}$ Kg/s.

$Q_h = m_h \times C_{ph} [T_{hi} - T_{ho}]$

$= 400 \times 10^{-4} \times 4.187 \times [329 -$

$318]$ $Q_h = 1.842$ KJ/sec.

$Q_c = m_c \times c_{pc} [T_{co} - T_{ci}]$

$= 333.3 \times 10^{-4} \times 4.187 [312 -$

$307]$ $Q_c = 0.698$ KJ/sec.

$Q_{act} = [Q_h + Q_c] / 2 = [1.842 + 0.698]$

$/ 2$ $Q_{act} = 1.27$ KJ/sec.

Overall heat transfer co-efficient

$A = \pi \times D \times L$

$= \pi \times 0.013 \times 1.5$

$= 0.06123$ m^2.

$U = Q_{act}/A \times LMTD$

$= 1.27 / 0.06123 \times 12.31 = 1.685$ W/m^{2}K

Result:

Thus the heat transfer experiment was conducted in a double pipe parallel flow and counter flow heat exchanger.

PARALLEL FLOW:

LMTD = 12.31 K

Heat Transfer Q = 1.27 KJ/sec. Overall heat transfer co-efficient U = 1.685 W/m^{2}K Effictiveness ε = 0.52 = 52%

COUNTER FLOW

LMTD = 26.24 K

Heat Transfer Q = 5.962 KJ/sec. Overall heat transfer co-efficient U = 3.543 W/m^{2}K Effictiveness ε = 0.62 = 62%

Expt.No: 4 Determination of COP of a Refrigeration System

AIM

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 s uction, 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, 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^{0}C.]

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 ΔT/Δt.
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.

LM

[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.

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

Expt. No: 5 Experiments on Air Conditioning System

AIM

To determine the carnot COP, theoretical COP and capacity of the refrigeration and air conditioning system.

FACILITIES REQUIRED AND PROCEDURE a] Facilities required to do the experiment:

Sl. No.	Facilities required	Quantity
1.	Air-conditioning test rig.	1

b] Introduction:

Air Conditioning for human comfort or industrial process requires certain processes to be carried out on air to vary the psychometric properties of air to requirements. These processes may involve the mixing of air streams, heating of air, cooling of the air, humidifying air, and dehumidifying air and combination of the process. All such processes are studied with the given air-condition test rig.

c] Procedure for doing the experiment:

Step No.	Details of the Step
1.	Switch on the mains.
2.	Switch on the condenser, fan and blower.
3.	Switch on the compressor and allow the unit to stabilize.
4.	Note down the following. a] Pressure P_1, P_2, P_3 and P_4 from the respective pressure gauge. b] Note the corresponding Temperatures T_1, T_2, T_3 and T_4 at the respective state points. c] Monometer readings. d] Note DBT and WBT at the inlet of the duct [before evaporation]. e] Note DBT and WBT at the outlet of the duct [after evaporation].

FORMULA:

DBT = Dry Bulb Temperature
[T_d] WBT = Wet Bulb
Temperature [T_w]

[1] $h_a = \rho_w h_w / \rho_a$

ρ_w = Density of water [1000
kg/m^3]. h_w = Manometer
reading.
ρ_a = Density of air [1.123 kg/m^3].

[2] V_a = Velocity
of air V_a =
$\sqrt{2} \times g \times h_a$

g = acceleration due to gravity 9.81m/s^2.

[2] Velocity of air [V_a]

$V_a = \sqrt{2} \text{ x } g \text{ x } h_a$

$= \sqrt{2} \text{ x } 9.81 \text{ x}$

$3.117 \; V_a = 7.82$

m/s.

[3] Mass of air [m_a] = $\rho_a \text{ x } A \text{ x } V_a$

$= 1.123 \text{ x } 0.0212 \text{ x } 7.82$

$m_a = 0.186$ kg/sec.

[4] Refrigeration effect = $m_a [h_2 - h_1]$.

$= 0.186 [90-76]$

$= 2.604$ KJ/sec. [or] KW.

[5] Capacity = Refrigeration effect / 3.5

= 2.604 / 3.5 [1 tonne of refrigeration = 210 KJ/min. = 3.5 KW]

= 0.744 tonne of refrigeration.

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

T_L = Lower temperature to be maintained in the evaporator.

$P_1 = 55$ PSI $= 55 \text{ x } 0.07 + 1.013 = 4.863$ bar.

$P_4 = 67.5$ PSI $= 67.5 \text{ x } 0.07 + 1.013 = 5.738$ bar.

$P_{min} = [P_1 + P_4] / 2$

$= [4.863 + 5.738] / 2$

$= 5.3$ bar.

From Table R – 22 $T_L = 2^0C = 275$ K

T_H = Higher temperature to be maintained in the condenser.

$P_2 = 285$ PSI $= 285 \text{ x } 0.07 + 1.013 = 20.963$ bar.

P3 = 270 PSI $= 270 \text{ x } 0.07 + 1.013 = 19.913$ bar.

$P_{max} = [P_2 + P_3] / 2 = [20.963 + 19.913] / 2 = 20.438$ bar.

From Table Freon – 22, $T_H = 52^0C = 325$ K.

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

$= 275 / [325 - 275]$

$= 5.5$

Carnot COP = 5.5.

[7] Theoretical COP

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

[Where h_1, h_2, h_3 are enthalpies of refrigerant taken from p-h chart.] $P_1 = 4.863$ bar; $T_1 = 1.112^0C$; $h_1 = 260$ KJ/kg.

P_2 = 5.738 bar; T_2 = 48.88^{0}C; h_2 = 300 KJ/kg. P_3 = 19.913 bar; T_3 = 48.88^{0}C; h_3 = 100 KJ/kg. Theoretical COP = [260 – 100] / [300 – 260] Theoretical COP = 4.

[3] Mass of air $m_a = \rho_a$ x A x V_a

ρ_a = Density of air [kg/m^3] V_a = Velocity of air [m/s] A = H x L

[4] Refrigeration effect = m_a [h_2 – h_1].

h_2 = Enthalpy of ambient air [KJ/kg.] h_1 = Enthalpy of condition air [KJ/kg.]

[5] Capacity = Refrigeration effect /3.5

[6] Carnot COP = T_L / [T_H - T_L]

T_L = Lower temperature to be maintained in the evaporator in absolute unit [^{0}K].

T_H = Higher temperature to be maintained in the condenser in absolute unit [^{0}K].

[7] Theoretical COP = [h_1–h_3] / [h_2–h_1]

h_1 corresponding to P_1 and T_1.

h_2 corresponding to P_2 and T_2.

h_3 corresponding to P_3 and T_3.

[Enthalpy is to be found out from the P-h diagram of R-22]

Result:

Thus the experiment on the air condition system was conducted and result were tabulated.

Carnot COP	Theoretical COP	Capacity TR
5.5	4	0.744