# VEER SURENDRA SAI UNIVERSITY OF TECHNOLOGY, BURLA

# DEPARTMENT OF CHEMICAL ENGINEERING

## CHEMICAL ENGG THERMODYNAMICS LAB

## LIST OF EXPERIMENTS

1. To calculate the Coefficient of Performance (COP) of   Air   Conditioning Test Rig

2. To calculate the Coefficient of Performance (COP) of water to water Heat Pump

3.  To find out the dryness fraction of steam by using separating calorimeter

4. To find out the dryness fraction of steam by using Throttling calorimeter

5. To measure the specific latent heat of vaporization using electric method

6. To determine the Vapor-Liquid Equilibrium (VLE) curve for the $ccl_4$ - toluene mixture

# EXPERIMENT NO: 1

**1.    OBJECTIVE:**

To study the vapour compression air conditioning cycle.

**2.    AIM:**

To calculate the Coefficient of Performance (COP) of   Air   Conditioning Test Rig

**3.    INTRODUCTION:**

Air conditioning is the simultaneous control of the temperature, humidity, motion and purity of the atmosphere in a confined space. Air conditioning applies in the heating season as well as in the cooling season. The Air conditioning has wide applications in submarine ships, aircrafts and rockets. Air conditioning is associated with the human comfort and controlling the humidity ratio.

**4.    THEORY:**

Air conditioning may be defined as the process of removing heat from a substance under controlled conditions. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings. This is widely used for cooling of storage chambers in which perishable foods, drinks, and medicines are stored. Figure shows the schematic of the unit with complete description.
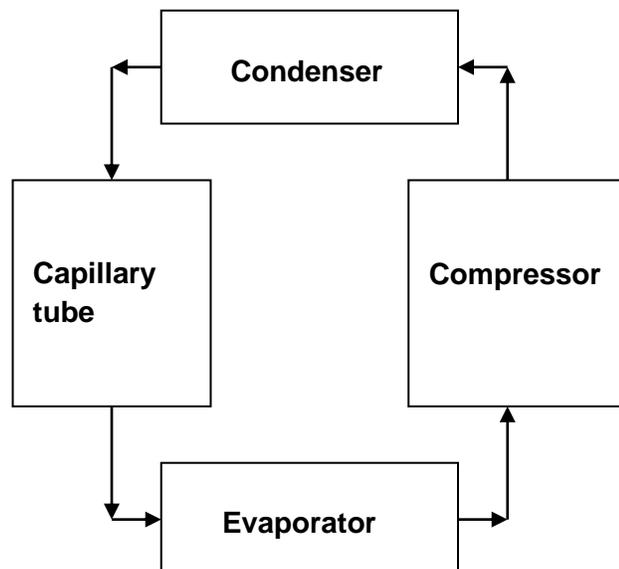
## COMPRESSOR:

The main function of compressor is to raise the pressure and temperature of the refrigerant by the compression of the refrigerant vapour and then pump it into the condenser.

## CONDENSER:

Condense the high pressure vapour refrigerant into the high pressure liquid by condenser fan and passes it into the receiver tank for recirculation

## CAPILLARY TUBE:

Expands the liquid refrigerant at high pressure to the sub cooled liquid refrigerant at low pressure so that a measured quantity of liquid refrigerant is passed into the evaporator.

## EVAPORATOR:

Evaporates the sub cooled liquid refrigerant by absorbing the sensible heat into vapour refrigerant and sends back into the compressor.

## VAPOUR COMPRESSION CYCLE:

The refrigerant starts at some initial state or condition, passes through a series of processes in a definite sequence and returns to the initial condition. This series of processes is called a cycle.
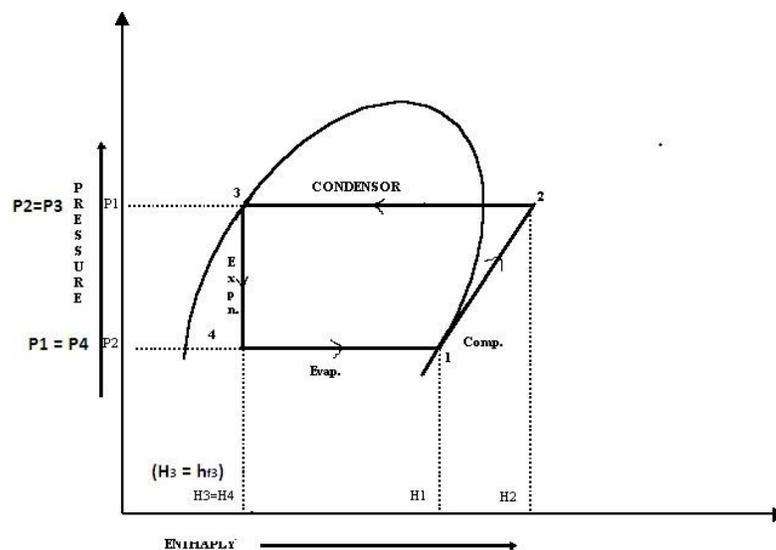


**STANDARD VAPOUR COMPRESSION CYCLE (SVCC):**

The Standard Vapour Compressor Cycle (SVCC) consists of the following processes:

- Reversible adiabatic compression from the saturated vapour to a super heated condition.
- Reversible heat rejection at constant pressure (sub cooling liquid and condensation of the refrigerant)
- Irreversible enthalpy expansion from saturated liquid to a low pressure sub cool liquid.
- Reversible heat addition at constant pressure.

**COEFFICIENT OF PERFORMANCE (C.O.P):**

The coefficient of performance of (C.O.P.) of a refrigerating cycle is defined as the ratio between net refrigeration (output) and compressor work (input).

$$C.O.P = \frac{RE}{CW}$$

$$RE = H_1 - H_4$$

$$CW = H_2 - H_1$$

$$C.O.P = \frac{H_1 - H_4}{H_2 - H_1}$$

**5.    DESCRIPTION:**

The window air-conditioning test rig unit is required to conduct experiments and demonstrate the processes of cooling of atmospheric air. The unit consists of a compressor (1Tone) filled with **R-22 r**efrigerant. Both evaporator and the air cooled condenser are mounted on board with fan. Air is sucked from the room and is supplied to the room after cooling. The system is provided with a digital temperature indicator. The unit will be fitted with all instrumentation facilities so that temperature and pressure can be measured at different points in the air-conditioning system.

**6. UTILITIES REQUIRED:**

      6.1      Electricity Supply: Single Phase, 220 V AC, 50 Hz, 5-15 Amp. Combined socket with earth connection.

      6.2      Floor Area Required: 1.5 m x 1.25 m

**7. EXPERIMENTAL PROCEDURE:**

      **7.1      STARTING PROCEDURE:**

7.1.1   Connect the computer with USB cable to operate via software.

7.1.2   Switch 'ON' the main power supply.

7.1.3   Switch 'ON' the compressor.

7.1.4   Wait for 2-3 minutes for switch 'ON' the compressor.

7.1.5   After 10 minutes note down the reading of temperature sensor.

7.1.6   Note down the reading of pressure gauges.

7.1.7   Note down the voltage & ampere.

7.1.8   Repeat steps 5 to 8 after every 10 minutes till the temperature of outlet of air     come constant.

      **7.2  CLOSING PROCEDURE:**

      7.2.1 .Switch 'OFF' the compressor.

      7.2.2 .Switch 'OFF' the mains.

**8.  OBSERVATION & CALCULATIONS:**

**8.1     OBSERVATION TABLE:**

| SI.No | $P_1$ (kg/cm$^2$) | $P_2$ (kg/cm$^2$) | $T_1$ (°C) | $T_2$ (°C) | $T_3$ (°C) | $T_4$ (°C) | $T_5$ (°C) | V (Volts) | I (Amp) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

## 8.2     CALCULATIONS:

Mark points 1, 2, 3 using (P1, T1), (P2, T2), (P2, T3) respectively on P-h diagram for (R-22) read H1, H2 and H3 (where H3 = H4).

$$C.O.P = \frac{H_1 - H_4}{H_2 - H_1}$$

## 9.      NOMENCLATURE:

| *Nom.* | *Column Heading* | *Units* | *Type* |
|--------|------------------|---------|--------|
| C.O.P. | Co-efficient of performance for compressor | * | Calculated |
| $P_1$ | Pressure at compressor suction | kg/cm$^2$ | Measured |
| $P_2$ | Pressure at compressor discharge | kg/cm$^2$ | Measured |
| $T_1$ | Temperature at compressor suction | °C | Measured |
| $T_2$ | Temperature at compressor discharge | °C | Measured |
| $T_3$ | Temperature at condenser outlet | °C | Measured |
| $T_4$ | Temperature at evaporator inlet | °C | Measured |
| $T_5$ | Temperature of air at outlet of duct | °C | Measured |
| $H_1$ | Enthalpy of refrigeration effects at compressor inlet | kJ/ kg | Calculated |
| $H_2$ | Enthalpy of compressor work at compressor outlet | kJ/ kg | Calculated |
| $H_3$ | Enthalpy of sub cooling at the outlet of condenser | kJ/ kg | Calculated |
| $H_4$ | Enthalpy of refrigerant inlet of evaporator | kJ/ kg | Calculated |
| I | Ampere meter reading | Amps | Measured |
| V | Voltmeter reading | Volts | Measured |

## 10.    PRECAUTION & MAINTENANCE INSTRUCTIONS:

10.1    Operate the Valves gently.

10.2    Never run the apparatus if power supply is less than 180 volts and above 230 volts.

10.3Duct should be free from dust particles.

## 11.    TROUBLESHOOTING:

If electric panel is not showing the input on the mains light, check the main supply.

## 12.    REFERENCES:

12.1    Dossat, Roy J. (2004). *Principles of Refrigeration*. 4th Ed. ND: Pearson Education Pvt. Ltd. pp 125-126.

12.2    Jordan, Richard C. & Priester, Gayle B. (1966). Refrigeration & Air Conditioning. 2nd Ed. ND: Prientice-Hall of India Pvt. Ltd. pp 444-447,455-466.

12.3    S.C. Arora, S Domkundwar (1995). A Course In Refrigeration And Air Conditioning. 5th Ed. Dhanpat Rai & Sons pp 16.1-16.24.

12.4    Psychometric Chart.

**OBJECTIVE:**

To study mechanical heat pump test rig and to study the vapor compression refrigeration cycle.

**AIM:-**

To calculate the Coefficient of Performance (COP) of water to water Heat Pump.

**INTRODUCTION:**

Refrigeration is the branch of science that deals with the process of reducing and maintaining the temperature of a space of material below the temperature of the surrounding. Heat must be removed from the body being refrigerated and transferred to another whose temperature is below that of the refrigerated body.

**THEORY:**

A water to water heat pump is mechanical equipment which is used to supply the heat to the system, where it is installed, and maintain its temperature more than that of surrounding. Mechanical heat pump absorbs heat from surrounding (atmosphere). Work input to a heat pump is supplied by compressor. With reference to the fig. Heat $Q_2$ is supplied to the room and temperature $T_2$ is maintained above the $T_1$ whereas heat $Q_2$ is absorbed by the surrounding. Hence performance of heat pump is given by

$$C \ O \ P = Q / W$$

Where Q = heat removed from the system.

W = work supplied in compressor.

## VAPOUR COMPRESSION REFRIGERATION CYCLE:





STANDARD VAPOUR COMPRESSION CYCLE (SVCC)
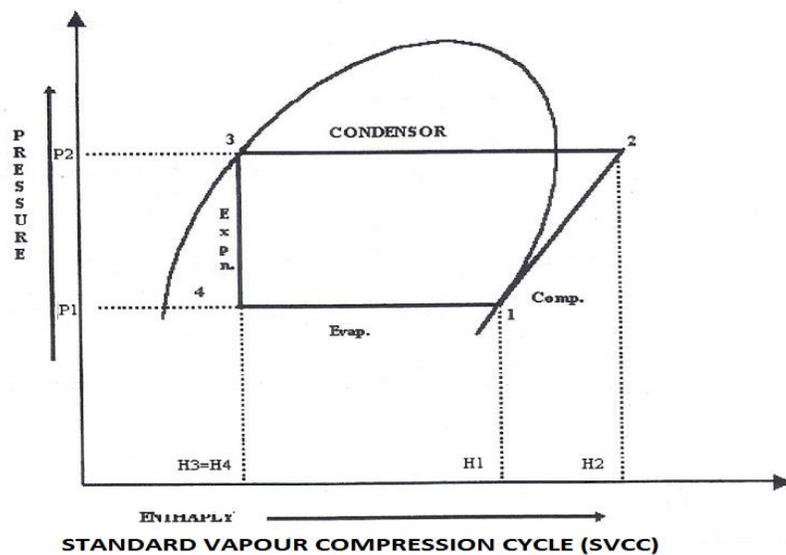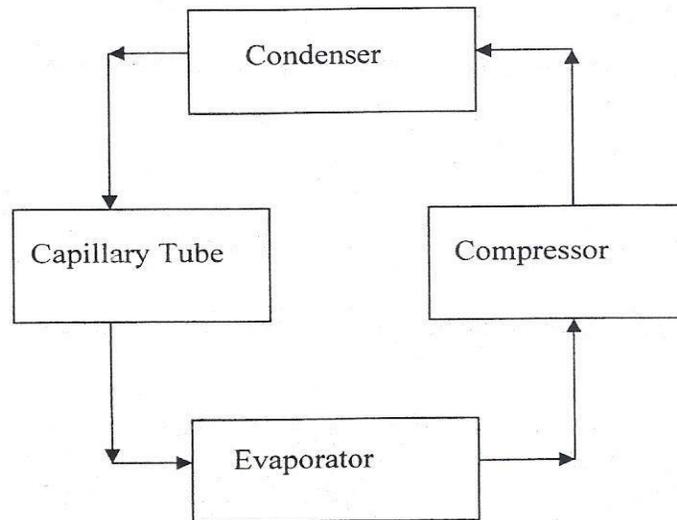
The standard vapor compressor cycle (SVCC) consists of the following processes:

1. 1-2 reversible adiabatic compression from the saturation vapour to a superheated condition (electrical) input.

2. 2-3 reversible heat rejection at constant pressure (de-superheating and condensation of the refrigeration)

3. Irreversible is capillary tube expansion from saturated liquid to a low-pressure vapour.

4. Reversible heat addition at constant pressure.

**COMPRESSOR**

The main function of compressor is to raise the pressure and temperature of the refrigerant by the compression of the refrigerant vapor and then pump it into the condenser.

**CONDENSER**

Condense the vapour refrigerant into the liquid by condenser fan passes it into the receiver tank for recirculation.

**CAPILLARY TUBE:**

Expands the liquid refrigerant at high pressure to the sub cooled liquid refrigerant at low pressure so that a measured quantity of liquid refrigerant is passed into the evaporator.

**EVAPORATOR:**

Evaporates the sub cooled liquid refrigerant by absorbing the sensible heat into vapour refrigerant and sends back into the compressor.

**OBERVATION TABLE:**

| S No | T (min) | Mass of water (condenser) | Mass of water (evaporator) | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | V | I |
|------|---------|---------------------------|----------------------------|-------|-------|-------|-------|-------|-------|-------|---|---|
| 1 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | |

## CALCULATIONS:

Mark points 1, 2, 3 using $(P_1, T_1),(P_2, T_2),(P_2,T_3)$ respectively on P-h diagram for (R-134a) and read $H_1$, $H_2$ and $H_3$ (where $H_3 = H_4$) to calculate COP.

Data:

Cos $\phi$ = 0.8

$\rho_\omega$ = 1000kg/m3

Cp = 4.186kj/c

$$(C.O.P)_{TH} = \frac{H_1 - H_4}{H_2 - H_1} = ----------$$

CALCULATION FOR COLD WATER:

(In evaporator)

$$m = \frac{V_{we} \times \rho_w}{t \times 1000 \times 60} kg/\sec = ----------$$

$$RE_{Act} = m \times C_p \times (T4_i - T4_f) kJ/\sec = -----$$

$$CW_{Act} = \frac{V \times I \times Cos\phi}{1000} kJ/\sec = -----------$$

$$(C.O.P)_{Act} = \frac{RE_{Act}}{CW_{Act}} \quad --------------------------------$$

$$(C.O.P)_{Rel} = \frac{C.O.P_{Act}}{C.O.P_{Th}} = ------------------$$

CALCULATION FOR HOT WATER:

(In condenser)

$$m = \frac{V_{we} \times \rho_w}{t \times 1000 \times 60} \, kg/\sec = - - - - - - - - - -$$

$$RE_{Act} = m \times C_p \times (T5_i - T5_f) kJ/\sec = - - - - - - - - -$$

$$CW_{Act} = \frac{V \times I \times Cos\phi}{1000} \, kJ/\sec = - - - - - - - - - -$$

$$(C.O.P)_{Act} = \frac{RE_{Act}}{CW_{Act}} \quad \text{-------------------------------}$$

$$(C.O.P)_{Rel} = \frac{C.O.P_{Act}}{C.O.P_{Th}} = - - - - - - - - - - - - - - -$$

## UTILITIES REQURIED:

1. Electricity Supply: Single Phase, 200 VAC, 50Hz, 5-15Amp socket with earth connection.

## EXPERIMENTAL PROCEDURE:

1. Clean the apparatus and make it free from dust.
2. Ensure that all ON/OFF switches given on the panel are at OFF position.
3. Now switch ON the main Power supply.
4. Ensure that all valves are open position.
5. After the gap of 10 or 15 minutes take the reading of pressure gauge, voltmeter, ampere meter and $T_1$, $T_2$, $T_3$, and $T_4$ by digital temperature indicator.

## NOMENCLATURE:

| | | |
|---|---|---|
| $\rho_\omega$ | = | Destiny of water, $kg/m^2$ |
| $\text{Cos } \phi$ | = | Power factor |
| $C_p$ | = | Specific heat of water, $kJ/kg \ ^0C$ |
| $(C.O.P.)_{Rel}$ | = | Relative coefficient of performance. |
| $(C.O.P.)_{Th}$ | = | Theoretical co- efficient of performance. |
| $(C.O.P)_{Act}$ | = | Actual co- efficient of performance. |
| $CW_{Th}$ | = | Theoretical compression work kJ/sec. |
| $CW_{Act}$ | = | Actual compression work kJ/sec |
| $H_1$ | = | Enthalpy of refrigeration effects at compressor inlet, kJ/kg. |
| $H_2$ | = | Enthalpy of compressor work at compressor inlet, kJ/kg. |
| $H_3$ | = | Enthalpy of sub cooling at the outlet of condenser, kJ/kg. |
| $H_4$ | = | Enthalpy of refrigerant inlet of evaporator, kJ/kg. |
| $P_1$ | = | Pressure at compressor suction, $kJ/cm^2$. |
| $P_2$ | = | Pressure at compressor discharge, $kJ/cm^2$ |
| $RE_{Th}$ | = | Theoretical refrigeration effect kJ/sec. |
| $RE_{Act}$ | = | Actual refrigeration effects kJ/sec. |
| $T_1$ | = | Compressor inlet temperature, $^{0C}$ |
| $T_2$ | = | Compressor outlet Condenser inlet temperature, $^{0C}$ |
| $T_3$ | = | Condenser outlet temperature, $^{0C}$ |
| $T_{4i}$ | = | Initial Water temperature of evaporator, $^{0C}$ |
| $T_{4f}$ | = | Final Water temperature of evaporator, $^{0C}$ |
| $T_{5i}$ | = | Final Water temperature of condenser, $^{0C}$ |
| $T_{5f}$ | = | Final Water temperature of evaporator, $^{0C}$ |
| t | = | Time, min |
| I | = | Ammeter reading, Amps. |
| V | = | Voltmeter reading, volts |
| $V_{we}$ | = | Volume of water in evaporator, ltr. |
| $V_{we}$ | = | Volume of water in condenser, ltr |
| m | = | mass of water, kJ/kg. |

## PRECAUTIONS & MAINTENANCE INSTRUCTIONS:

1. Never run the apparatus if power supply is less than 180 volts and above 230 volts.

## TROUBLESHOOTING:

1. If electric panel is not showing the input on the mains light, check the main supply

PRESURE-ENTHALPY Diagram Refrigerant R-22
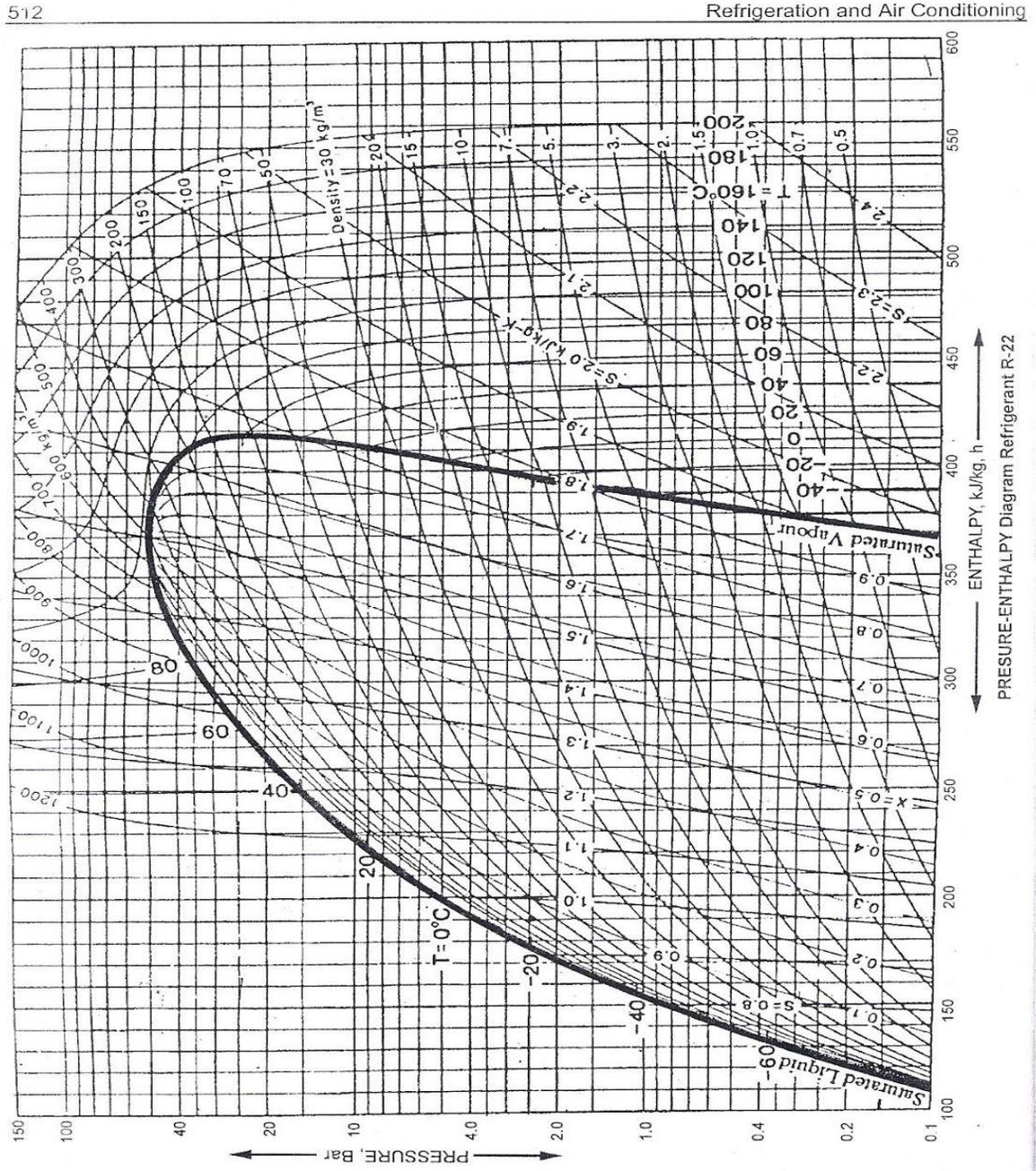
# EXPERIMENT NO:-3&4

**OBJECTIVE:**

To study the combined Separating and Throttling calorimeter and its effects.

**AIM:**

To find out the dryness fraction of steam by using separating calorimeter

**THEORY:**

**DRYNESS FRACTION:**

The term dryness fraction refers to wet steam.  It is defined as ratio of mass of dry steam actually present to the mass of the wet steam, which contains it.

Let in the sample of wet steam:-

$$X = \frac{W_d}{W_d + W}$$

Where

X    =    Dryness fraction of the sample

$W_d$    =    Wt. of dry steam in Kg.

W    =    Wt. of water vapours in suspension

**SEPARATING & THROTTLING (COMBINE) CALORIMETER:**

The steam passing out from a separating calorimeter may still contain some water vapours in it.  In other words it may not be absolutely dry.  Again, in a throttling calorimeter steam after passing through the throttle valve must be superheated or at least dry saturated.  This limits the extent of dryness fraction that can be reliably measured, depends upon the pressure of steam in the main steam pipe.  If a sample of steam, which may be still wet after passing through the throttle valve i.e. it will not be superheated.  Thus under this condition the throttling calorimeter fails to enable us in determining the value of dryness fraction of steam. To overcome these

difficulties we make use of combined separating and throttling calorimeter. First the steam is passed through separating calorimeter where it loses most of its moisture and becomes comparatively drier, it is then passed through the throttling calorimeter where superheating takes place without change of total heat. The temperature and pressure of steam after throttling are measured by using a thermometer and manometer respectively.

Let,

W $\qquad$ = $\qquad$ Weight of suspended moisture collected in the separating calorimeter.
$W_d$ $\qquad$ = $\qquad$ Weight of the steam leaving the separating calorimeter and entering the Throttling calorimeter.

$\quad X_1$ $\qquad$ = $\qquad$ Dryness fraction of steam shown by Separating Calorimeter.

$X_1$ $\qquad$ = $\qquad\dfrac{W_d}{W_d + W}$

It is not the accurate dryness fraction of steam as the separating calorimeter may not have been to remove the whole of the moisture of the sample of steam.

$\qquad W_d + W$ $\qquad$ =Total weight of wet steam entering the separating calorimeter.

Now the improved quality steam leaving the separating calorimeter enters the throttling calorimeter, which ultimately leaves superheated. Throttling process occurs when steam is expanded through a small aperture as in case of throat of nozzle. During this process, no work is done, there is no heat supplied, and there is no change in total heat i.e. total heat remains constant.

Let,

P $\qquad$ = $\qquad$ Gauge pressure before throttling.

$X_2$ $\qquad$ = $\qquad$ Dryness fraction of the steam leaving the separating calorimeter and entering

$\qquad$ Throttling calorimeter.

$P_1$ $\qquad$ = $\qquad$ Gauge pressure of a steam generator.

$L_1$ $\qquad$ = $\qquad$ Latent heat of wet steam entering the throttling calorimeter

$P_2$ $\qquad$ = $\qquad$ Absolute Pressure of superheated steam.

$t_1$ = Temperature of superheated steam after throttling

$t_2$ = Saturation temperature at pressure $P_2$

$H_{w1}$ = Sensible heat of water at pressure P,

$H_2$ = Total heat of dry steam at pressure $P_2$

$C_p$ = Specific heat of superheated steam at $P_1$

Total Heat before throttling = $H_{w1} + X_2 L_1$

Total Heat after throttling = $H_{w2} + L_2 + C_p(t_s - t_2)$

If the steam is in a superheated state after throttling.

Since the total heat during throttling remains constant. Total heat of steam entering the throttling calorimeter= Total heat of steam leaving the throttling calorimeter

$$H_{w1} + X_2 L_1 = H_{w2} + L_2 + C_p(t_1 - t_2)$$

$$H_{w1} + X_2 L_1 = H_2 + C_p(t_1 - t_2) \qquad\qquad (H_2 = H_{w2} + L_2)$$

$$X_2 = \frac{[H_2 + C_p(t_1 - t_2)] - H_{w1}}{L_1}$$

Total Dryness Fraction $\quad X = X_1 \times X_2$

## DESCRIPTION:

The set up consists of a separating and throttling calorimeter. A steam generator is provided at the base of the apparatus. A digital temperature controller is provided to control the temperature inside the steam generator. Steam from steam generator is passed from separating calorimeter where most of the water particles get separated from steam and then passed to throttling calorimeter where steam get superheated. After that, superheated steam is passed through heat exchanger to condense the steam. A manometer and a thermometer are connected with throttling calorimeter to measure the pressure and temperature after throttling process.

**Separating Calorimeter**

It consists of two concentric chambers, the inner chamber, and the outer chamber, which communicates with each other through an opening at the top. As the steam discharges through the metal basket, which has a large number of holes, the water particles due to their heavier momentum get separated from the steam and collect in the chamber. The comparatively dry steam in the inner chamber moves up and than down aging through the annular space between the two chambers and enters the Throttling Calorimeter.

**Throttling Calorimeter**

It consists a narrow throat (Venturi). Pressure and temperature are measured by manometer and thermometer. The steam after throttling process passes through the condenser and condensate is collected.

**UTILITIES REQUIRED:**

Water supply continues for heat exchanger.

Space required: 1.0m x 1.0m

Electricity Supply: single Phase, 220 V AC, and 4 KW

Electronic balance: say 1 kg.

Steam table for calculation

**EXPERIMENTAL PROCEDURE:**

1. Close the drain valves of steam generator properly.
2. Fill steam tank ¾ with Clean Water and ensure that no foreign particles are there.
3. Ensure that **ON/OFF** Switch given on the Panel is at **OFF** position.
4. Fill the manometer tube with water (half level).
5. Now supply of the continuous water to the heat exchanger (say 2liters per minute).
6. Put the thermometer in throttling calorimeter.
7. Now switch **ON** the Main Power Supply (220 Volts AC, 15 amp.).
8. Close the ball valve properly provided before the separating calorimeter.
9. Set the temperature of water with the help of digital temperature controller (Let $105^0$c to $120^0$c).

10. Switch **ON** the heaters of steam generator.

11. Fully open the ball valve provided before the separating calorimeter when the pressure of the steam generator rises up to 1 kg / cm$^2$ and firstly closes the drain valve of separating calorimeter.

12. Now slowly open the needle valve provided after the separating calorimeter and maintain the constant pressure in the pressure gauge provided before the throttling calorimeter.

13. A light buzzing sound comes from throttling calorimeter confirms throttling.

14. Allow some time for the steady state if pressure of the pressure gauge fluctuates stables it manually by operating needle valve.

15. Note the pressure difference and temperature after the throttling from the manometer and thermometer//temperature sensor.

16. Collect the suspended moisture from the separating calorimeter and weight it (after 1 or 2 minutes).

17. Also collect, the dry steam condensing after throttling calorimeter and weight it (after 1 or 2 minutes).

18. Now calculate the dryness fraction of steam.

**FORMULAE:**

**Dryness Fraction of Steam Measured By Separating Calorimeter:**

$$X_1 = \frac{W_d}{W_d + W}$$

**Dryness Fraction of Steam Measured By Throttling Calorimeter:**

$$X_2 = \frac{[H_2 + C_p (t_1 - t_2)] - H_{w1}}{L_1}$$

**Actual Dryness Fraction:**

$$X = X_1 \times X_2$$

**Pressure after Throttling:**

$$P_2 = 1.033 + \frac{h}{10000} \quad \text{kg f / cm}^2$$

Absolute Pressure ($P_1$)  =  Gauge Pressure + Atmospheric Pressure.

**Atmospheric pressure** = 1.033 kg f / cm$^2$

**OBESERVATION & CALCULATION:**

**OBESERVATION TABLE:**

| S.No. | Gauge Pressure before throttling (P) Kg / cm$^2$ | Temp. after throttling, ($T_1$) $^0$C | Manometer difference, (h) (mm) | Weight of moisture collected, W (kg) | Weight of dry steam, $W_d$ (kg) |
|---|---|---|---|---|---|
| 1 | 0.25 | 101 | 170 | 20 | 60 |

**CALCULATION TABLE:**

| S.No. | Absolute pressure before throttling, $P_1$ Kg f / cm$^2$ | Absolute pressure after throttling, $P_2$ Kg f / cm$^2$ | Dryness fraction from separating calorimeter, $X_1$ | Dryness fraction from throttling calorimeter, $X_2$ | Actual dryness fraction of steam, X |
|---|---|---|---|---|---|
| 1 | 1.283 | 1.24 | 0.75 | 0.99 | 0.74 |

## NOMENCLATURE:

W      =      Weight of suspended moisture collected in the separating calorimeter.

$W_d$      =      Weight of the steam leaving the separating calorimeter and entering the Throttling calorimeter.

$X_1$      =      Dryness fraction of steam shown by Separating Calorimeter.

$X_2$      =      Dryness fraction of the steam leaving the separating calorimeter and entering Throttling calorimeter.

$P_1$      =      Absolute Pressure of wet Steam entering the throttling calorimeter.

$L_1$      =      Latent heat of wet steam entering the throttling calorimeter at P. (from steam table)

$P_2$      =      Absolute Pressure of steam after throttling

$L_2$      =      Latent heat of steam at pressure $P_2$

$t_1$      =      Temperature of superheated steam after throttling

$t_2$      =      Saturation temperature at pressure $P_2$ (from steam table)

$H_{w1}$      =      Sensible heat of water at pressure P, (from steam table)

$H_2$      =      Total heat of dry steam at pressure $P_2$. (From steam table)

$C_p$      =      Specific heat of superheated steam at $P_1$ (From steam table)

h      =      Manometric pressure difference in mm of water/mercury.

**PRECAUTIONS & MAINTENANCE INSTRUCTIONS:**

1. Manometer should be filled with water/mercury up to half.
2. Thermometer/temp sensor pocket should be ¼ filled with oil (SAE 40) before inserting the thermometer.
3. Cold Water to inlet of Heat Exchanger must be supplied.
4. Do not set the temperature of Digital Temperature Controller above $130^0$ c.
5. Always keep the apparatus free from dust.

**TROUBLESHOOTING:**

1. If the temperature is not increasing after switch on the heater check the continuity of heater.
2. If the DTC displays '1' on the screen it means the computer socket is not connected so connect that.

**REFERENCES:**

1. Single O.P., **"Engineering Thermodynamics"**, 1st ed, 1990, McMillan India Ltd., ND.
2. Sarao, Malhotra & Gambhir, **"Thermal –I"**, 3rd ed, 1996, Satya Prakashan, ND.
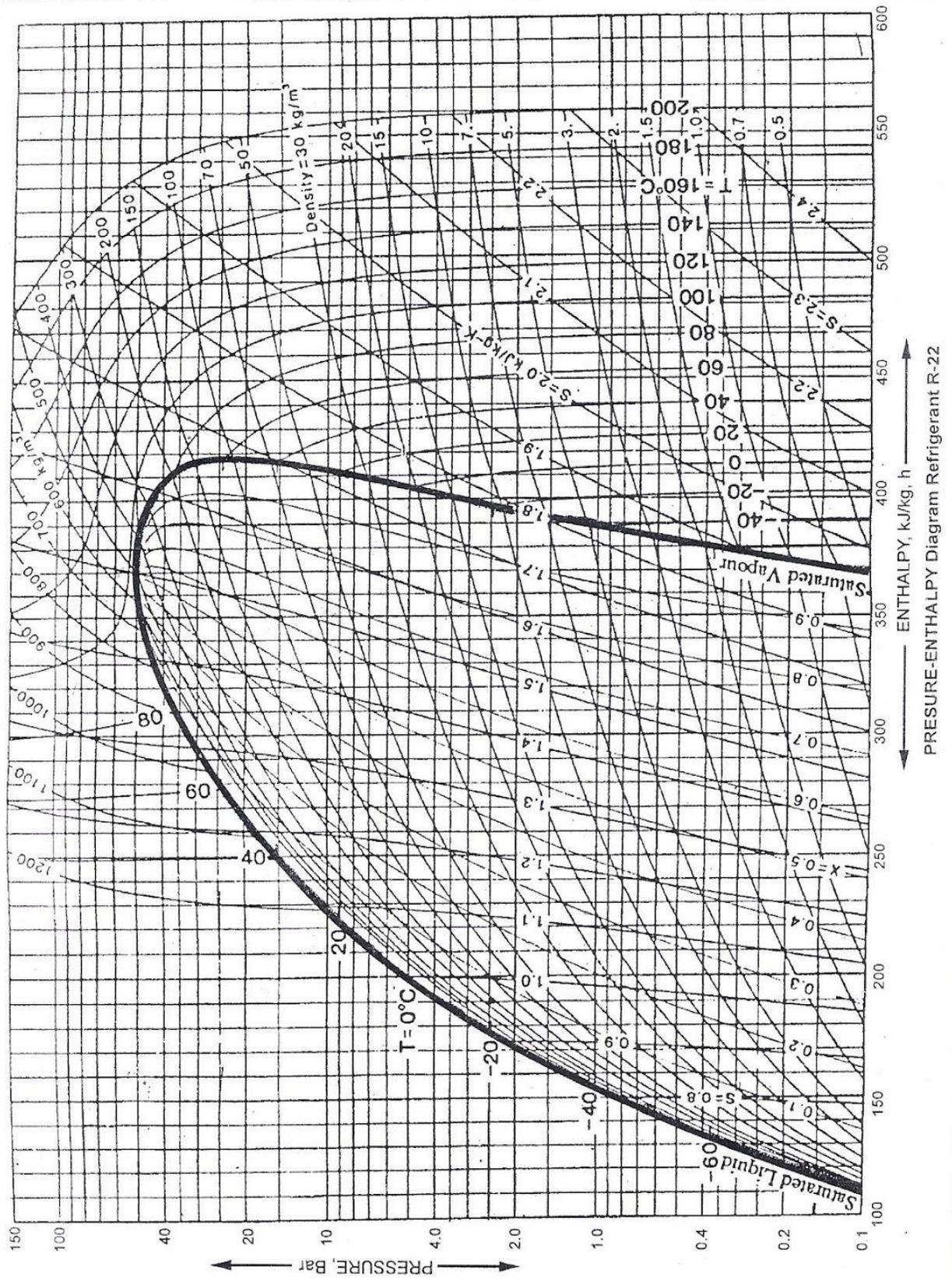
PRESURE-ENTHALPY Diagram Refrigerant R-22

**OBJECTIVE:-**

To enable the student to measure the specific latent heat of vaporization of water by an electric method

**AIM:-**

To measure the specific latent heat of vaporization of water by an electric method

**APPARATUS REQUIRED:-**

Container to hold water

Water to measure its specific latent heat of fusion

Electric heater

Stop watch

Balance

**THEORY:-**

The specific latent heat of vaporization is the amount of heat that is needed change 1 kg of the substance in the liquid state into the gaseous state at the boiling point. When an electric heater is immersed in water, the electrical energy flowing in heater will be totally converted into heat energy. The electrical energy is given by $E=pt$ where p is the heater power in watts and t is the time in seconds E is electrical energy in joules. The heat gained by water is given by $H=mc$ $(T_1-T_2)$, where heat energy is in joules is water mass in kg and c is the specific heat in J/kg°c and $T_1$ and $T_2$ are initial and final temperatures.

Assuming there is no loss of heat to the surroundings, we can say that heat gained by water is equal to electrical energy, i.e.$pt=mL_v$.

Hence    $L_v=pt/m$

**DIAGRAM:-**
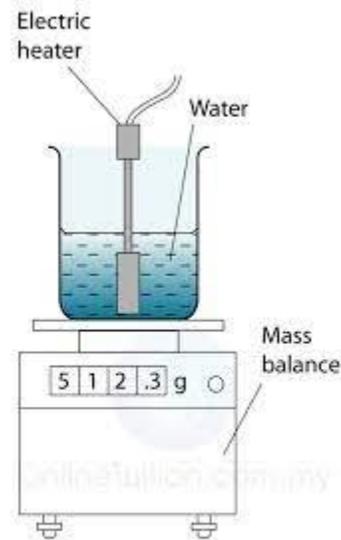


**METHOD-1:-**

1. Prepare all he needed tools and equipment.   .

2. Assemble the experiment as shown

3. Place a quality of water in the container

4 .Measure the mass of the water and container and record it as M.

5. Place the electric heater in water placed in container.

6. Switch on the heater.

7. Turn on the stop was when the water is boiling.

8. After several minutes, switch off the heater and stop watch and record the mass of water as "M"

9. Record the time of the watch as "t"

10.Find the mass of the evaporated water and record it as "m".

11. Evaluate the latent heat of vaporization from Lv=pt/m

12. Repeat steps 7-11 and record three readings in the table.
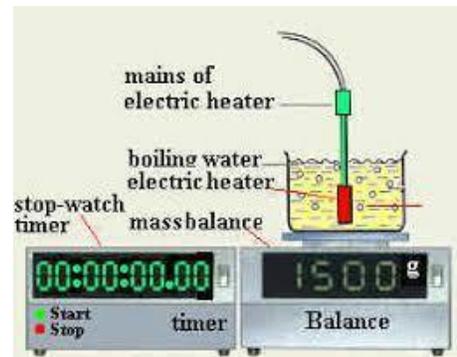
13. Calculate the avg. of the three values obtained.

Heater power's (p) = ------- watts

Mass of water ($M_1$) = ----------kg

**TABLE-1**

| SL NO | STOP WATCH TIME(t) | MASSOF CONTAINER+LIQUID($M_2$) | MASS OF EVAPORATED WATER $M=M_1+M_2$ | CALCULATED $Lv=pt/m$ |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

**METHOD:-2**

1. Prepare all he needed tools and equipment.          .

2. Assemble the experiment as shown

3. Place a quality of water in the container

4 .Measure the mass of the water and container and record it as M.

5. Place the electric heater in water placed in container.

6. Switch on the heater.

7. Turn on the stop was when the water is boiling.

8. After each 5minutes, record the mass of water and container as "$M_2$".

9. Record the time of the watch as "t"

10.Find the mass of the evaporated water and record it as "m".

11.Repeat step8-10 for five times.

12 Plot mass of evaporated vs time.

13  Evaluate the slop from the graph.

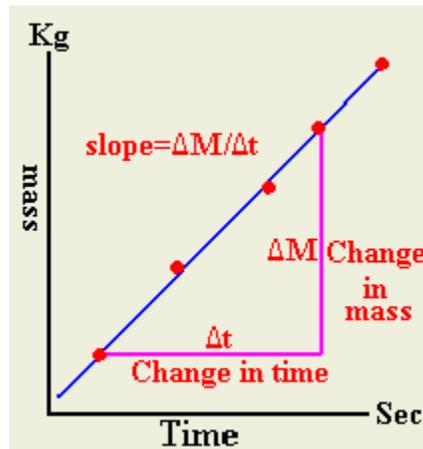14  Calculate the heat of vaporization from $m=(p/Lv)t$ where slope=$p/Lv$.
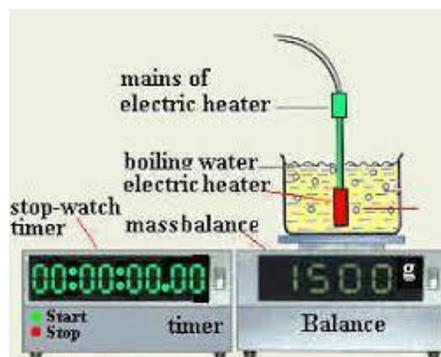
Heater power's (p) = ------- watts

Mass of water and container ($M_1$) = ----------kg

**TABLE-2**

| SL NO | STOP WATCH TIME(t) | MASSOF CONTAINER+LIQUID($M_2$) | MASS OF EVAPORATED WATER $M=M_1-M_2$ |
|---|---|---|---|
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

<div align="center">**EXPERIMENT:6**</div>

**OBJECTIVE:**

To study VLE curve for CCl4-toluene mixture

**AIM OF THE EXPERIMENT:-**

To determine the Vapor-Liquid Equilibrium (VLE) curve for the $ccl_4$ - toluene mixture

**APPARATUS REQUIRED:**

VLE still, Refractrometer and test tubes

**CHEMICALS REQUIRED:**

Carbon tetrachloride, Toluene

**THEORY:**

The design of distillation and other contacting equipment requires reliable VLE data. Although relatively few ideal solutions are known whose equilibrium relations can be calculated from vapor pressure - temperature data of the pure components, by far the larger numbers of systems of industrial importance are non-ideal; and attempt to predict the equilibrium compositions of such mixtures from theoretical considerations alone have not proved successful. It has been the practice to determine such data experimentally under various conditions.

Vapor liquid diagram shows relationship between the composition of the vapor and that of liquid in equilibrium with the vapor for a binary mixture at constant pressure or constant temperature. If liquid and vapor behave ideally, such curves are calculated as follows:

From Raoult's law:

$P_1 = P_1 X_1$

$P_2 = P_2 X_2$

Where $p_1$ and $p_2$ are partial pressures of components 1 and 2 in the mixture,

$P$ = total pressure

$P_1$ and $P_2$ are vapor pressure of pure components at the same temperature as mixture.

From Dalton's law of partial pressures:

$P_1 = P y_1$

$P_2 = P y_2$

$y_1$ and $y_2$ are the mole fractions of components in vapor

From these equations we have:

$$x_1 = \frac{P - P_2}{P_1 - P_2}$$

$$y_1 = \frac{P_1 x_2}{P}$$

Theoretical VLE curve can thus be calculated by choosing various boiling points of the mixture and calculate x and y as shown above. Carbon tetrachloride - toluene system closely follows ideal behavior.

**PROCEDURE**:

The vapor - liquid equilibrium still containing about 15O ml to 200 of known mixture (with low composition of high boiling component) is heated gently. The toluene – $CCL_4$ mixture being distilled over and the vapor being re-cycled for at least 45 to 60 minutes before any samples are taken, to allow equilibrium between liquid and gaseous phases to be attained (temperature of vapor, t, and remains constant).

The liquid and vapor are then sampled at noted temperature (t) and analyzed for molar composition of more volatile component in vapor (y) and liquid (x) .The heating is stopped and the feed liquid replaced by another feed mixture (increasing gradually the amount of high boiling liquid), the liquid and vapor once more allowed to come to equilibrium (indicated by constant temperature) and collecting the samples of liquid from the still and the condensate. The still liquid being hot, should be collected in an ice cooled test tube to avoid any change in composition due to vaporization. The above procedure should be repeated for at least six feed compositions.

The samples are viewed under a high precision refractometer, and their composition determined from the pre determined calibration chart for $CCl_4$ - toluene mixture, which converts refractive index to mole fractions. This way t-x-y and x-y diagrams can be plotted.

The calibration curve ($n_D$ vs. mole fraction of more volatile component, x) should be generated at a specific temperature (say $25^0C$) by taking different mixtures of $CCl_4$ - toluene of known molar composition and recording the refractive index of the mixture. The samples collected should also be evaluated at the same temperature.
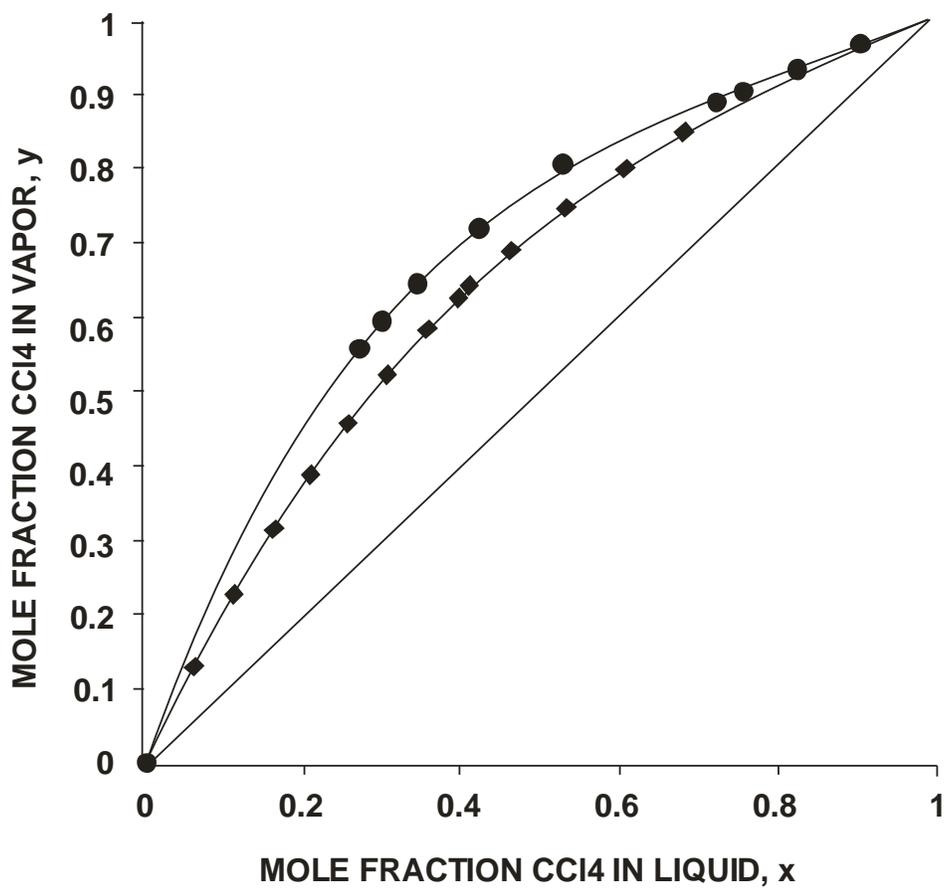
## CALIBRATION CURVE FOR CCl$_4$-TOLUENE AT 16°C



$y = -27.757x + 41.529$

$R^2 = 0.9916$
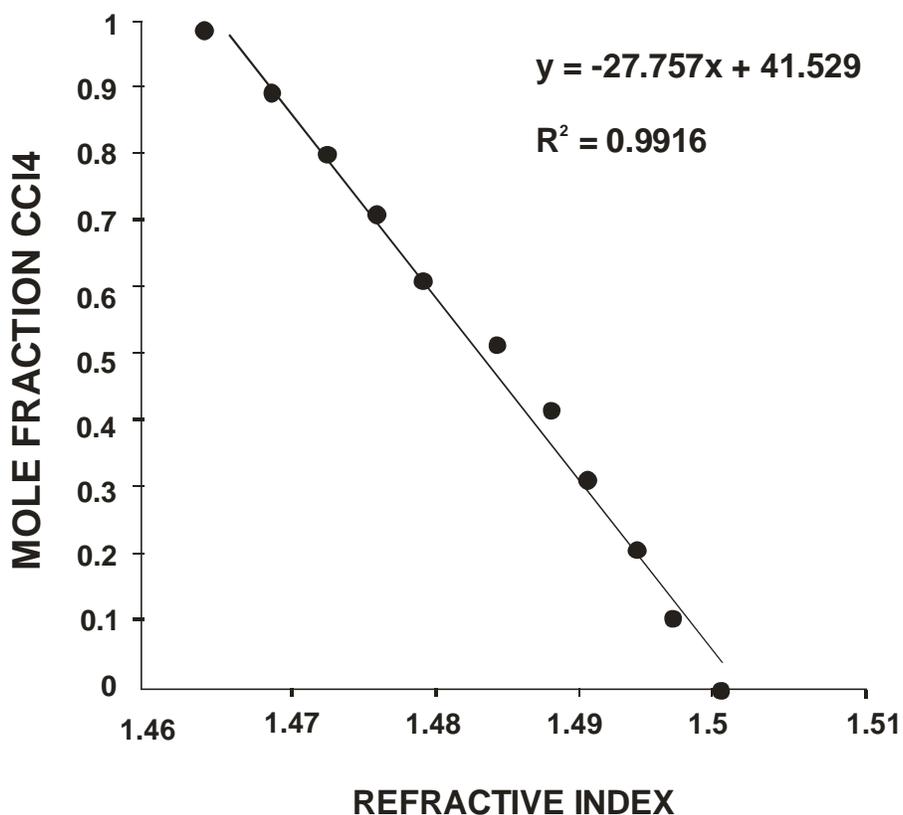
**AVAILABLE LITERATURE DATA**

- **PRESENT DATA**

**VLE DIAGRAM FOR CCI4-TOLUENE SYSTEM AT 760 mm Hg**