# Practical Manual

# Of

# Introductory Agro-Meteorology & Climate Change

# (13A.266)

**Jharkhand Rai University**

**Ranchi, Jharkhand**

# PREFACE

Agriculture and weather are the essential components of the crop production. Crop production depends upon the prevailing weather conditions at different stages of crop growth. Precise measurements of weather elements are required to understand the proper interpretation in relation to crop growth and development. Recently, the course curricula of undergraduate classes has been reoriented according to IV Dean‘s committee of ICAR. The practical exercises of this manual are according to new syllabi of agrometerology course running in the UG programme.

Nine exercises have been included in the manual. The material has been drawn from various publications with and without seeking permission from authors/publishers. The authors would like to express their gratitude of all of them. The authors would be grateful to receive suggestions from readers for further improvement of this manual. The authors wish to acknowledge the financial assistance received from ICAR for publication of this practical manual.

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# Content

# Unit -1

## Agro-meteorological observatory site selection, installation and exposure of instruments

An observatory is a specially designed station or place where the regular and simultaneous records of the weather data are made by physical measurements using various techniques, sensors, skills, recorders, instruments etc. by standard methods at hours recommended by IMD and WMO. IMD was established during 1875 with its central office at Pune which takes up this responsibility. Country is divided into 35 meteorological sub divisions.

To facilitate the collection of data at one point, five regional centres were established, which are located in five different places, for which the headquarters are mentioned against each as detailed below.

North zone — Delhi

East zone — Calcutta

South zone — Chennai

West zone — Bombay

Central zone — Nagpur

Weather affects agriculture at every stage; therefore, knowledge of crop weather relationship helps in opti-mizing the agricultural operations. Since meteorology and climatology are primarily observational science, adequate care has to be taken for getting most representative and accurate observations of weather parameters for their worthwhile application in weather and climate prediction.

In arid and semi-arid agriculture, the weather aberrations are more as compared to the humid agriculture that adversely affect the agricultural production. The weather variables and their measurement, if taken in time for the weather forecast for short and medium range one can avoid from the great losses in the arid and semi-arid areas. Therefore, urgent and rapid data collection and their dissemination is possible e by well settled agro met observatory in the data measurement and management for weather forecast agencies like India Meteorological Department (IMD), National Centre for Medium Range Weather Forecast (NCMRWF) and State Agricultural Universities for their better use for the farming community.

**Types of general observatories**

On the basis of instrumental facilities, observer type, data observation frequency and mode of data transmission, IMD has divided general observatories into 6 classes:

Class I (Special station): Autographic recording and eye rec ording, all data elements are recorded at least thrice(0530,1130,1430,2030,0230 IST).

Class II (Synoptic station) : Eye reading, almost all data recorded at least twice(0830, 1730 IST).

Class III(Synoptic station) : Eye reading,data are recorded part time once a day(0830 IST).

Class IV(Climatological station) : Eye reading without barom eter all data recorded except pressure once a day.

Class V (Rainfall station) :Eye reading only, rainfall is rec orded daily.

Class VI(Less or Non instrument station) : Less or no instrument, wind direction, cloud, speed visibility etc. are recorded daily.

**Agro meteorological observatories**

Agromet observatories are those stations at which physical elements of climate and biological, agricultural elements, generally of phenological nature or both related to agriculture are observed to explore crop - environment relationship. World Meteorological Organization (WMD) has divided agromet observatories into four categories-Principal, Ordinary, Auxiliary and Specific purpose agromet observatories.

**Types of the observatories**

The observatories are classified on the basis of the number and type of instrum ents available. Essential and optional availability of the instruments in each type observatory are as below:

(a) **Auxiliary ( or class C) observatory:**

Essential instruments

1. Single Stevenson screen with

Dry bulb thermometer

Wet bulb thermometer with one spare set of thermometers

Minimum thermometer Maximum thermometer

Non-recording rainguage and measuring glass (with one spare measuring glass) Optional instruments

1. Wind vane 2. Anemometer 3. Dew gauge

(a) **Ordinary (or class B) observatory:**

Essential instruments

1. Single Stevenson screen with

Dry bulb thermometer

Wet bulb thermometer with one spare set of thermometers

Minimum thermometer Maximum thermometer

Non-recording rainguage and measuring glass (with one spare measuring glass)

Soil thermometers at the depth of 5, 10, 15, 20 and 30 cms along with the stand

Class A pan evaporimeter with fixed point gauge covered with a wire mesh and an ordinary thermometer for measuring water temperature in the evaporimeter

Wind vane

Anemometer and Optional instruments

1. Dew gauge 2. Sunshine recorder 3. Self-recording rain gauge and

4. Double Stevenson screen with thermograph and hygrograph.

**(b) Principal (or class A) observatory:**

1. Instruments of class B observatory
2. Self-recording rain gauge
3. Thermograph and
4. 4. Hygrograph

**Criteria for site selection**

I. The site should contain a flat rectangular plot with 55 meters (180 feet) in north-south direction and 36 meters (120 feet) in east-west direction**( Fig. 1)**,

II. The site must be representative of climate, soils and agricultural (cropping) conditions of the area and should be located at the centre of the farm,

III. The site must be free from water logging and easily accessible throughout the year,

IV. Site selected should be away from hills, buildings, streams and trees to avoid shade, shield or channel affects,

V. It should be away from steep slopes, water bodies and frequent irrigation.

VI. The recommendable distance from the obstacles from the raingauge and other instruments are at least twice and 10 times the height of the obstructions, respectively.

**Fencing**

After the site selection, it should be wire fenced, normally to a height of about 1.5 meter with a gate locking arrangement to protect from theft, animals and rodents which may cause damage to and cables.

**Surface conditions**

The surface of the observatory should be cleaned regularly and be covered with thin grass as barren ground causes increased ground radiation. The grass should be periodic ally trimmed.

**Coordinates of the observatory**

Since data has far wider application, therefore, exact location of the observatory should be known. For t his purpose, coordinates of the site of the observatory, i.e. latitude and longitude to the nearest meter and elevation (height above mean sea level) to the nearest meter should be obtained. The elevation refers to the ground on which raingauge stands, in the absence of which it refers to the ground under thermometer screen.

**Precautions for installation**

1. The instrument should be robust, durable, accura te and simple for operation and should not require calibration graph without any electric al connection.

2. While installing the Stevenson screen which contains the therm ometers, care should be taken that it should open in North direction to prevent direct sun shine during observation.

3. Tall instruments should be on one side of the observatory so that they may not shade small instrument.

**Hours of observation:**

Since Meteorological elements vary with time, it is necessary that they should be recorded at a particular time on every occasion. In India, the main observations are recorded as per the guide lines of I.M.D. at 0830 and 1730 IST.

At Agromet observatories, the observations are recorded at 07:00 and 14:00 hours LMT except evaporation and rainfall which are recorded at 08:30 hours IST. Radiation observations including sunshine are recorded as per LAT (Local Apparent Time). At meteorological observatories the hours are numbered consecutively from mid- night 00 hours to midnight 24 hours, the hours after noon being 13 hours, 14 hours and so on. Time as 2:30 p.m and 2:30 a.m are expressed as 1430 and 0230 hours I.S.T. respectively.

The instruments should be read in the following order: 1. Wind instruments 2. Rain gauge

3. Thermometers 4. Barometer

**Type of observations**

The observations are of two types:

1. Instrumental (for which instruments are used). Most of the observations rec orded in observatory

2. Sensory (for which observer uses his senses and these are prim arily visual). These are current weather including clouds, visibility, thunder storm, lightening, fog etc.

## Data recording

Meteorological operations are required for a variety of purposes which can be broadly classified into two categories: I. Forecasting II. Climatological study.

In the country, there is an international understanding to have uniformity in the observatory set up including instruments installation procedure as well as timing. Different weather elements with units and different instruments are shown in Table 3.1.

Different thermometers used for measurement of temperature in an agrometeorological observatory are:

**Maximum thermometer :** Maximum thermometer is a mercury-in-glass thermometer with a constriction in the bore below the lowest graduation. When the temperature falls after reaching the maximum value, mercury does not return to the region below the constriction, provided that the stem of the thermometer is approximately horizontal. The range of maximum thermometer graduation is from -20°C to 55°C.

**Minimum thermometer :** Minimum thermometer is a spirit thermometer, commonly used liquid being absolute ethyl alcohol. Within the liquid there is a very light dumb bell shaped glass index which moves freely within the spirit but not readily eme rge from the liquid due to surface tension. The thermometer is tilted slightly so that bulb end is upward, the glass index slides along the tube until it reaches the meniscus. But when temperature rises, it remains stationary while the liquid moves ahead in the column. The range of minimum thermometer graduation is from -40°C to 50°C.

**Self recording of temperature:**

Continuous air temperature is recorded by bimetallic thermograph that work on the principle of expanding of two different metals in length at different rates with the temperature variation. The outer strip of iron - nickle alloy having negative coefficient of expansion much less than the inner strip of brass and the different expansion is recoded at clock drum by pointer. The bimetallic thermograph is kept in big Stevenson screen.

**Exposure and installation of air thermometers**

To give a representative reading, the thermometers are protected from direct sunlight, sky, earth and surrounding objectives with a adequate ventilation. For this purpose thermometers are kept in Stevenson screen.

**Stevenson screen:** Stevenson screen is a wooden box whose side walls are louvered providing free movement of air with gusts suppressed. Its upper roof is double with space in between preventing solar radiation and consequent heat affecting the inside. These are of two types. Small Stevenson screen and large Stevenson screen. Sm all Stevenson screen has a size of 2' x 2.5' x 3' whereas large has 4' x 2.5' x 3' with 4' large lags mounted on the earth for fixing in concrete material **( Fig. 2)**. Thermometers ( maximum, minimum, dry and wet) are kept in small Stevenson screen whereas se lf recording instruments like thermograph and hair hygrograph are kept in large Stevenson screen for ventilation and protection from outside objects.

## Measurement of soil temperature

For measuring of soil temperature, the mercury -in-glass thermometers are used for the depth of 5, 15 and 30 cm with their stem bent at right angles or other suitable angle with their scale facing upward are the most conve-nient. For greater depth, the soil thermometers are installed in greater depths like 50 cm in iron pipes.

### Grass minimum thermometer

The idea about ground frosts which are very crucial from the point of view of agriculture, is obtained from Grass minimum thermometer. Grass minimum thermometer consists of sheathed alcohol minimum thermometer, simi-lar to the ordinary minimum thermometer and is used to measure temperature at soil surface covered with vegetation. This is also called terrestrial radiation minimum thermometer.

**Table 3.1: Measured ele ments, units in general use and me asuring instrume nts**

| S. No. | Ele ment | Unit | Instrument(s) |
|---|---|---|---|
| 1. | Temperature | Degree Celsius (°C) | Thermometer, hygrograph |
| 2. | Wind speed | kmph, mps, knots | Anem ometer, Anemograph |
| 3. | Wind direction | Degrees clockwise from north on the scale 00-36, where 36 is the wind from the north, 09 from the east and 00 refers calm. | Wind Vane, Anemograph |
| 4. | Relative humidity | Per cent (%) | Dry and wet bulb therm ometers, hygrograph |

| | | | |
|---|---|---|---|
| 5. | Precipitation | millimetres (mm) | Rain guage, dewgauge, snowguage |
| 6. | Evaporation | millimetres (mm) | Evaporimeters |
| 7. | Duration of sunshine hours | hours (h) | Sunshine recorder |
| 8. | Cloud cover | Oktas (1/8 of the celestial dome) | Visual, observed in the observatory |

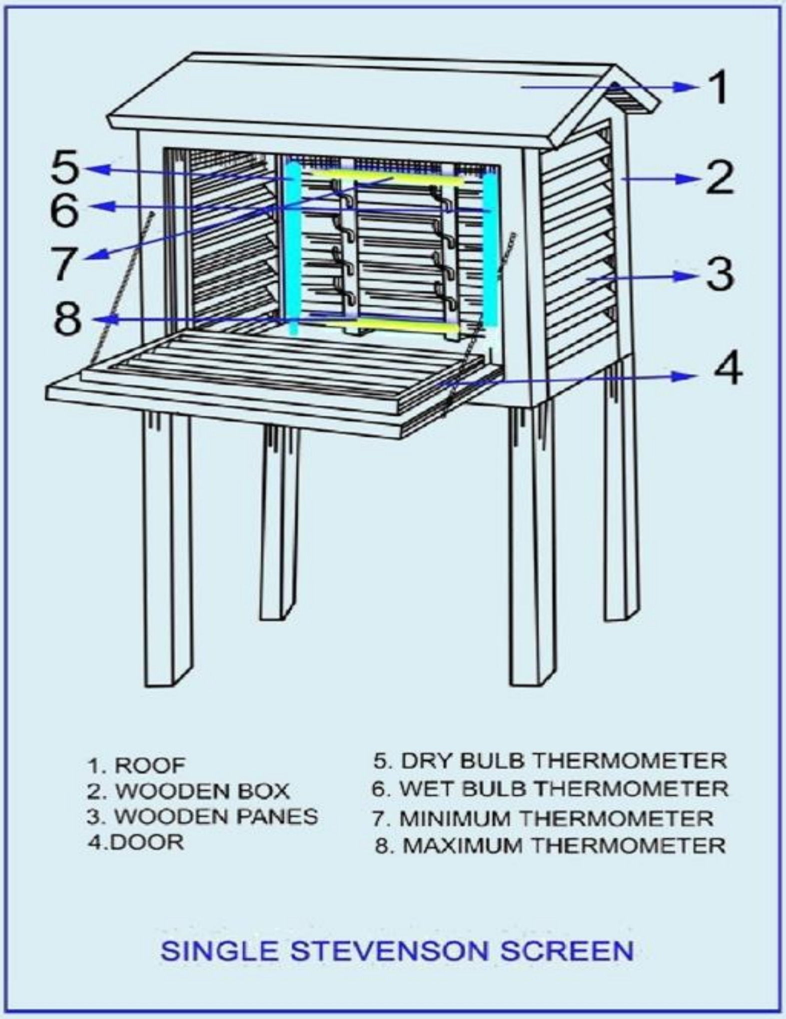



**Fig. 2 Single Stevenson screen**

**Wind instruments:**

The site for wind instruments must be as open as possible and should be away from tall structures. The instruments namely anemometer and wind vane should be placed on wooden posts or masonry pillars so that the height of the centre of the cup in case of anemometer and the arrow head should be 10 feet above the ground level. The pillars should be vertical to the ground surface. In order to maintain natural rotations of wind vane and anemometer, the instruments should be regularly lubricated by oiling.

**Sunshine recorder**

It is placed at elevated place and usually placed at a platform of 5-10 feet from the ground surface. It is kept on a horizontal plane.

**Open pan evaporimeter**

This instrument is installed at a place free from water logging. The pan rests on a wooden plank which is painted white and placed about 5-6 cm above the ground surface. This allows free circulation of air.

**Problem:**

1. Name the different thermometers which are kept in Stevenson screen. Solution:

2. Name the different instruments installed in an agromet observatory. Solution:

3. What precautions are to be followed in handling of instruments while recording weather data?

**Problem: 1. Draw the layout plan of a standard agrometeorological observatory.**

# Unit -1

## Measurement of long and short wave radiation

Solar radiation affects to a large extent the micro-climate thereby, the crop growth and yield. Spectral quality of sunlight intercepted by the crop canopy and light that penetrates through the canopy are other important factors determining the crop growth in the system. The measurements should enable the evaluation of the photosynthetic efficiency of the system and matching of this with alternate designs of canopy structure. Instruments used for the measurement of radiation (Fig.3) for the study of micro-climatic regimes are:

(1) Line quantum sensor ( 2) Net radiometer (3) Spectroradiometer ( 4) Pyranometer

(5) Pyrano - albedometer etc.

Radiometers are named according to the nature and direction of radiation which they absorb and indicate. The commonly used instruments are :

Name of the instrument Radiation me asured

1. Pyranometer or Solarimeter : Direct and diffuse solar radiation
2. Pyrheliometer Direct solar radiation
3. Pyrradiometer Solar and long-wave radiation
4. Pyrgeometer Long-wave radiation
5. Netradiometer Net radiation flux

**Measurements of different components of solar radiation.**

**Material required:** Pyrano-albedo meter, millivolt meter etc.

The visible part of the spectrum is short -wave radiation. The solar radiation is a combination both direct and diffused radiation. So, to measure direct solar radiation, the diffuse radiation has to be subtracted from the total incident radiation. The total incident radiation, diffused radiation and radiation reflected from various surfaces can be measured with the help of a pyrano –albedo meter. When radiation is incident on the sensitive element of the instrument, it produces electric current which is measured in millivolts in the millivolt meter. There is a conversion factor for each instrument. When the reading in millivolt meter is multiplied by conversion factor, the reading comes out in langley per metre per second or watts per metro per met re per second.

Procedure:

1. Connect the pyrano-albedometer properly to the millivoltmeter.

2. Keep the instrum ent ready for taking observations by setting the knob at

_ON‘, in the millivoltmeter.

3. Level the instrument, if needed, using a small spirit level.

4. Total incident radiation, diffuse radiation and reflected part of the radiation shall be recorded simultaneously, as per the instructions given for the instrument, on the selected surfaces.

5. Normally, a bare soil, a dry turf, a wet turf and a crop canopy may give values of real worth comparison.

6. Repeat the proc ess at 15 minute intervals for at least 6 times on the same surfac es and record the observations in the rec ording sheet provided for this exercise.

7. Calculate albedo and direct radiation as per the formulae in point no.9 given below.

8. Observe the trends in albedo and absorbed radiation with variation in time.

**Formulae:** a) Direct radiation = Incoming radiation - Diffuse radiation

b) Albedo = Reflected radiation/Total Incoming radiation x 100

**Graph:** Plot a neat graph for all the measurements recorded above.

**Problems1**: What are different radiation measuring instruments?

**Solution:-**

**Problem 2:** How will you calculate direct radiation and albedo?

**Solution:-**

# Unit -3

# Measurement of maximum and minimum air temperature, its tabulation trend and variation analysis.

## Temperature

Air temperature is the temperature of the air rec orded by the thermom eter exposed in a standard type of screen called Stevenson screen.

Heat and temperature

Temperature is the measure of mean kinetic energy of per molecule of the molecules of an object, while the heat is the measure of total kinetic energy of all the molecules of that object.

Measure ment of air temperature

Temperature of the air is one of the important factor in crop - weather relations. Its measurement helps in understanding the rate and amount of water loss in the process of evaporation from the soil and transpiration from the plant system for a given environment. Temperature is measured using three type of scales namely Fahrenheit, Celsius and Kelvin. The melting point of ice on the t hree scales is 32°, 0° and 273° and boiling point of water is 212°, 100° and 373°, respectively. The relations between three scales are

$K = C + 273$

$C = 5/9(F – 32)$

$F = 9/5 (C +32)$

**Temperature instruments**

**1. Maximum thermometer**: This is a mercury thermometer and records the highest or maximum temperature reached during past 24 hours or since last setting. Maximum temperature generally occurs in the world between 14.00 to 1600 hrs. (Fig. 5).

**2. Minimum thermometer**: This thermometer records the lowest temperature of air reached during last 24 hours or since last setting. Lowest temperature of the day generally occurs just before sunrise or clear day and after sunrise on cloudy day (Fig 5).

**3. Dry bulb thermometer**: This is a mercury thermometer which gives the prevailing temperature of air at 4' 3'‘ to 4' 6'‘ height. It is required to calculate relative humidity and vapors pressure.

**4. Wet bulb thermometer**: This is similar to dry bulb thermometer but the bulb of thermometer acts as a evaporating surface. It is used for calculating dew point, relative humidity and vapour pressure.

5. **Thermograph:** This instrument continuously records air temperature with passage of time (Fig.6). This is not a accurate instrument but its importance lies in its automatic recording of air temperature.

**6. Infra-red thermometer:** This is a sophisticated instrument used for measuring instant temperature. It contains thermocouple and thermistors up to accuracy 0.1 °C and response time less than one second. It is very accurate, rapid, and portable and without any contact, temperature is obtained.

Diurnal temperature variation and its measurement

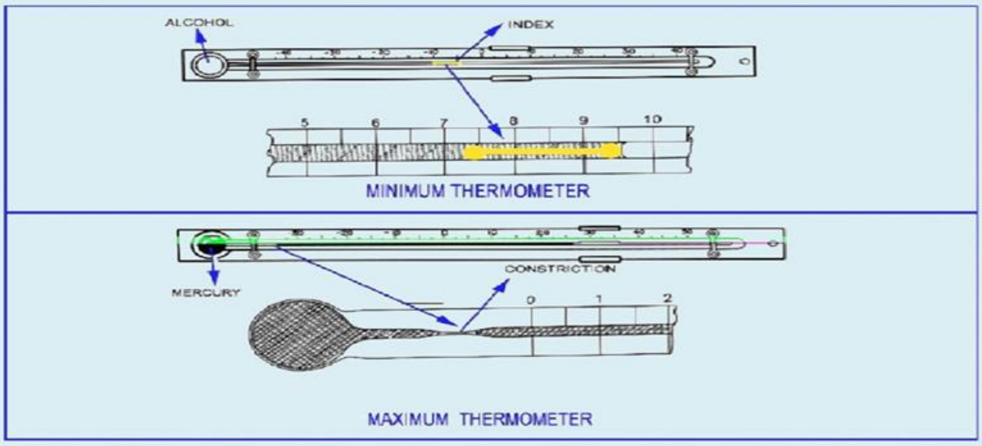
From sunrise until 2 to 4 pm when the energy supplied by in coming solar radiation is greater than that is being lost by earth in the form of long wave radiations, the air temperature rises. From 2 to 4 pm, the loss of that energy from the earth is greater than the energy received from the sun, the air temperature starts falling and reaches its lowest value just before sunrise ( about 4 - 6 am).

**Maximum air temperature:**

The maximum temperature attained by air during the day is measured by a thermometer called maximum thermometer. It is a mercury-in-glass thermometer with a constriction in the bore below the lowest graduation. It allows the mercury to be forced through with rising temperature but prevent it being drawn back with falling temperatures, provided the thermometer is kept at an angle of 10° from the horizontal with the bulb downwards. It allows the mercury in one way as the constriction acts as a valve. The observer resets the thermometer after reading by holding it firmly in hand by the remote end from the bulb and swinging it briskly downwards. The range of maximum thermometer graduation is from -20°C to 55°C.

## Minimum thermometer:

The minimum temperature attained by air during the day is measured by using a thermometer called minimum thermometer**.** Minimum thermometer is a alcohol thermometer. Alcohol is sensitive for lower temperature than mercury. Within the liquid, there is a very light dumb bell shaped glass index which moves freely within the spirit but not readily emerge from the liquid due to surface tension. The thermometer is tilted slightly so that bulb end is upward, the glass index slides along the tube until it reaches the meniscus. But when temperature rises, it remains stationary while the liquid moves ahead in the column. The range of minimum thermometer graduation is from -40°C to 50°C.



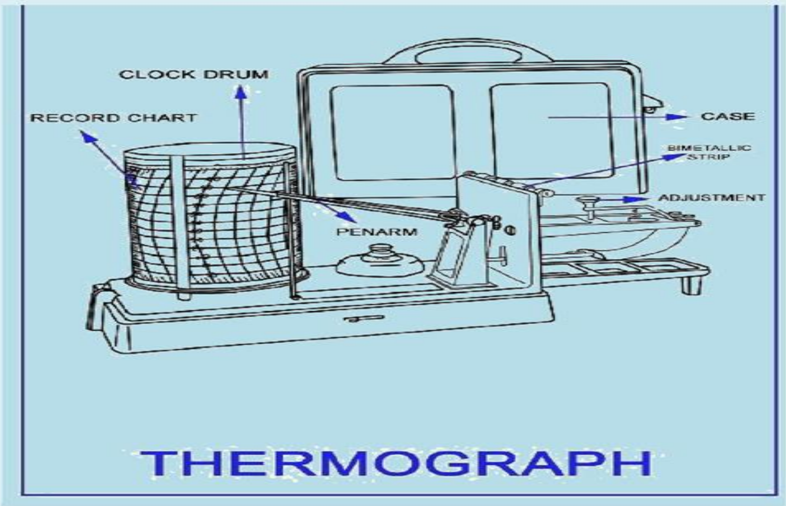

**Maximum and minimum thermometers**

## Recording and setting of air temperature thermometers Procedure:

1. Open the door of Stevenson screen
2. Note the reading of maximum and minimum thermometers in sequence to the accuracy of 0.1°C and verify for the correctness of the observation
3. While taking reading of maximum thermometer, watch carefully first the mercury column and shining line and record the point.
4. If scale is not clearly visible then any black material can be rubbed on the scale and then wipe so that black material fills the marking on the scale. This will enable easy reading of the scale.
5. To avoid error due to parallax for which your eye and the mercury level should be exactly in one line.

While recording the minimum thermometer, the set reading of the earlier day is first seen in the pocket register and then the end of the glass index farthest from the bulb is read.

1. The reading of the maximum thermometer should be at least as high as or higher than any of the dry bulb temperature readings taken since the previous setting.
2. The reading of the minimum thermometer should be as low as or lower than any dry bulb reading taken at or since the previous setting.



**Setting of maximum thermometer:**

1. After morning reading, it should be set.
2. For setting, grip firmly the thermometer and swing vigorously up and down in a semicircle.
3. Take care that it does not slip out of hand.
4. No jerks should be given.
5. After setting, the reading should be equal to that of dry bulb therm ometer.

**Setting of minimum thermometer:**

1. After afternoon reading, it should be set.
2. For setting thermometer should be gently tilted keeping bulb with the meniscus.
3. The end of the index farthest from the bulb then indicates the minimum temperature of the air a t that moment.
4. Care should be taken to avoid the thermometers to protect from the direct sun light.
5. When replacing the thermometer in the screen, incline the instrument slightly by about 2° with the bulb end upper most.
6. Place the other end in the support firm.
7. Then gently lower the bulb making sure that the index does not slide backwards the bulb.

**Self-recording of temperature**

Continuous air temperature is recorded by bimetallic thermograph that works on the principle of expanding of two different metals in length at different rates with the temperature variation. The outer strip of iron - nickel alloy having negative coefficient of expansion much less than the inner strip of brass and the different expansion is recoded at clock drum by pointer. The bimetallic thermograph is kept in big Stevenson screen.

**Stevenson screen:** To give a representative reading, the thermometers are protected from direct sunlight, sky, earth and surrounding objectives with a adequate ventilation. For this purpose thermometers are kept in Stevenson screen. The objective of the screen is to shield the thermometers from radiation from the sun , ground and neighbouring objects and from losing heat by radiation at night. The screen also protects the thermometer from precipitation while at the same time allowing free circulation of air.

**Observations: Record temperature from different thermometers.**

| Date | Time | Temperature | | | T es t r eadi ng at the Time of setting | | |
|---|---|---|---|---|---|---|---|
| | | Dry bulb ( °C) | Maxi- mum ( °C) | Mini- mum ( °C) | Dry bulb ( °C) | Maxi- mum ( °C) | Mini- mu m ( °C) |

# Unit -4

## Measurement of soil temperature and computation of soil heat flux

The surface of the earth gets heated up during the day and gets cooled during the night causing diurnal changes in the top layers of the soil. The crops have their root systems in these layers and extract plant nutrients and water from these layers of the soil, since the heat regimes of these layers are governed by the soil temperatures. Germination of crops are also affected by soil temperature. Therefore, soil temperature becomes extremely important. The movement of moisture in vapour form is mostly governed by temperature gradient in soil. The condensation of water vapour in the air in the form of dew or frost also occurs due to the excessive cooling of the earth surface due to emission of long wave radiation by it.

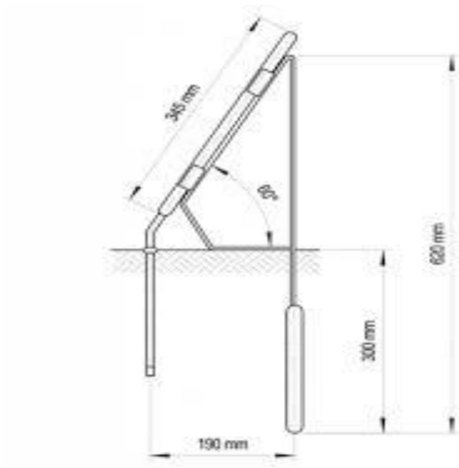
The soil temperature is measured by soil thermometers (Fig. 7). These are mercury –in – glass thermometers of the enclosed scale type. There is a bend of 120° angle just above the bulb, the rest of stem being straight, so that when the soil thermometer is installed at a particular depth of the soil, the bulb rests horizontally. The inclination of the stem at 120° also facilitates the reading of the scale. These thermometers have graduation for every degree Celsius and the graduation starts from the distance of 6.5 cm, 17. 5 cm and 35 cm from the bulb for the 5, 15 and 30 cm depth soil thermometers respectively. Iron stands with sloping sides at 60° to the ground surface are provided to support the thermometers at the right inclination. In the observatory, soil thermometers are installed at a sight which is sufficiently away from obstructions and is free from water logging during the rainy season. Precaution should be taken to remove the soil layer by layer and later replace the same in order, during the installation of the soil thermometers. The soil temperature should be read daily at 0700 hrs and 1400 hrs LMT correct to 0.1°C in the order of 5,15 and 30 cm depths.

**Procedure**

1. Install the thermometers with the help of iron stands as discussed above.

2. Read correct to 0.1°C soil temperatures at 0700 hrs and 1400 hrs LMT in the order of 5,15 and 30 cm depths.

## Observation:




Soil Thermometer

Problem 1: What is importance of measuring soil temperature? Draw a sketch of soil thermometer.

Solution:

# Unit -5

# Determination of dew point temperature

Dew point temperature is the temperature at which air would become saturated if cooled at constant pressure without addition or removal of water vapour. Thus, the actual vapour pressure is equal to the saturated vapour pressure at the dew point temperature. The closer the dew point temperature to air temperature, the nearer is the air to be saturated condition. The temperature beyond which air can no longer hold moisture. It means the air becomes fully saturated or dew point of a given mass of air is the temperature at which saturation occurs when the air is cooled at constant pressure without addition or removal of water vapour. It is determined by the amount of water vapour in the air and is entirely independent of free air temperature. It is thus a state of saturation when the air is holding maximum amount of water vapour pressure possible at the existing temperature and pressure.

If the air is cooled below the vapour becomes liquid, it is called condensation. Higher the dew point, higher the moisture content of the air at given temperature. Thus, dew point of humid air will be higher than that of dry air. From the dry bulb and wet bulb temperature readings, the dew point temperature and RH can be obtained by reference to Hygrometric tables. If the height of the place of observation is less than 1500 feet, 1000 mb Hygrometric tables are to be used. Dew point temperature and RH corresponding to specified value of dry and wet bulb temperatures are given in the abo ve mentioned Hygrometric tables at interval of 0.2 °C. While using the tables, interpolation to the nearest 0.1 C has to be done. The following example would illustrate the procedure:
Dry bulb temperature = 34.5 °C, Wet bulb temperature = 29.7 °C

**The values from tables are as below:**

| | | Wet bulb | |
|---|---|---|---|
| | | 29.6 °C | 29.8 °C |
| **Dry bulb** | 34.4 °C | 27.9 | 28.2 |
| | 34.6 °C | 27.8 | 28.1 |

**Interpolating for dry bulb temperature, we get**

| | | Wet bulb | |
|---|---|---|---|
| | | 29.6 °C | 29.8 °C |
| **Dry bulb** | 34.5 °C | 27.9 | 28.1 |

So final interpolated value of dew point temperature is 28 °C for the wet bulb temperature of 29.7 °C . Dew point can also be calculated by the formula:

T =T1 – G (T1 – T2)
Where, T = dew point temperature, T1 = Dry bulb temperature, T2 = wet bulb temperature and G = Glashier factor(Its value depends upon room temperature, given in Table 9.1)
*Example:* If the dry and wet bulb thermometers show the reading of 20°C and 15°C respectively, then find out the dew point temperature and relative humidity.
Solution:

T =T1 – G (T1 – T2)
T1 = 20, T2 = 15, G in table at 20°C = 1.79 T = 20 – 1.79(20 -15)
= 20 – 8.95 = 11.05°C

Saturated vapour pressure from Raino table (Table 9.2) at dew point temperature(11.05°C) is 9.87 mm and at room temperature( 20°C) is 17.51 mm
RH = f/F x100 or 9.87/17.51 x 100 = 56.3%

## Glacier factor for dry bulb temperature

| Dry bulb temp °C | Glacier factor | Dry bulb temp °C | Glacier factor |
|---|---|---|---|
| 4 | 7.82 | 21 | 1.77 |
| 5 | 7.28 | 22 | 1.75 |
| 6 | 6.62 | 23 | 1.73 |
| 7 | 5.77 | 24 | 1.72 |
| 8 | 4.92 | 25 | 1.70 |
| 9 | 4.04 | 26 | 1.69 |
| 10 | 2.06 | 27 | 1.68 |
| 11 | 2.02 | 28 | 1.67 |
| 12 | 1.99 | 29 | 1.66 |
| 13 | 1.94 | 30 | 1.65 |
| 14 | 1.92 | 31 | 1.64 |
| 15 | 1.90 | 32 | 1.63 |
| 16 | 1.87 | 33 | 1.62 |
| 17 | 1.85 | 34 | 1.61 |

**Problem 1**: If the dry and wet bulb thermometers show the reading of 23°C and 18 °C, respectively, find out the dew point temperature and relative humidity.

**Solution:**

# Unit -6

## Determination of vapor pressure and calculation of relative humidity

The important measures of humidity are vapor pressure, relative humidity and dew point temperature. The pressure of air is the total weight of all the gases including water vapors in small proportions. Since water vapor also contributes to this air pressure, the partial pressure due to water vapor alone is called vapors pressure. It is expressed in mill bars or millimeters of Hg. Water evaporate into water vapor. As more and more water is evapo-rated, amount of water vapor increases in the air. However, at any particular temperature, there is a maximum capacity for water vapor that air can hold. The pressure exerted by water vapour under such a saturated condition is called saturated water vapor pressure. SVP increases with increasing temperature. The pressure exerted by water vapor actually present in air is called the actual vapour pressure(AVP) of air. The ratio of actual water vapor pressure and saturation vapor pressure under fixed condition of temperature is called relative humidity.
Measurement of Relative humidity

Water in its different forms is very important for all activities of the life. Growth and sustenance of life heavily depends on it. The relative humidity is a measure of water vapor in the air. The instruments used for measuring the water vapor or relative humidity content of the atmosphere are called hygrometers. The two main type of the instruments used for measuring the relative humidity of the air near the earth‘s surface are
(a) Combination of dry and wet bulb thermometers (also called psychrometer) and (b) Hair hygrometers

Dry bulb thermometer: This is an ordinary mercury-in-glass thermometer graduated from -35 °C to 55 °C. This has a capillary stem of which one end is a bulb containing mercur y and other end is sealed after removing air from the same. The stem is graduated for reading the value of temperature. Mercury level in the stem changes with the changes in air temperature denoting the air temperature. Wet bulb thermometer: This is an ordinary mercury -in-glass thermometer graduated from -35 °C to 55 °C as like dry bulb thermometer whose bulb is wrapped by a piece of muslin cloth just sufficient to cover the bulb and is looped by cotton thread (Cruex thread) that remains the bulb in wet conditions so it is called wet bulb thermometer. When water evaporates from the wet surface, the latent heat requirement is drawn from the bulb of the thermometer and so the mercury column comes down indicating a reduction of temperature. Cooling causes the temperature difference in dry and wet bulb thermometers that is used to calculate relative humidity by using relative humidity tables. Once the temperature of the dry and wet bulb thermometers are obtained, hygrometric tables are used to determine the dew point temperature and relative humidity. The table appropriate for ventilation (wind speed around the thermometer bulb) should be used. When the wet bulb temperature is below the freezing point, alternate tables should be used depending on whether the wet bulb is covered with ice or coated with super-cooled water. Calculations:
Td and Tw are the dry bulb and wet bulb temperatures respectively, in degree Celsius, then the actual vapor pressure

(AVP) in the air is given by:

AVP =e = EW – ½(Td-Tw)

Where, Ew = saturation vapour pressure in mm of Hg (at wet bulb temperature Tw)

EW can be obtained from hygrometric tables against Tw. Td = dry bulb temperature
Tw = wet bulb temperature

(Td – Tw) = wet bulb depression Then RH (%) is given by
RH (%) = e/E x 100

Where, E is the saturation vapor pressure at the dry bulb temperature Td (from hygrometric tables), e is actual vapor pressure‘
e, E and Tw are in mm Hg and can be converted into mill bars or pascals VPD = SVP – AVP
Example: Let, Td = 27.4°C and Tw = 23. 0°C SVP at Tw = 21.1 mm of Hg( from table)
E = SVP at Td =27.4 mm Hg ( from table) Then, AVP (mm of Hg) = e =Ew – ½(Td –Tw)
21.1-1/2 (27.4 – 23.0)

= 21.1 – ½ x 4.4

= 21.1 – 2.2 =18.9 mm of Hg VPD = E –e
= 27.4 – 18.9

= 8.5 mm of Hg RH= e/E x 100
= 18.9/27.4 x 100 = 68.9 %.

**With Stevenson's Screen wet and dry bulb thermometers**

For deriving the vapor pressure in the India Meteorological Departm ent the formula is as follows: For temperatures of Wet Bulb above 0° C
X = f‘- 0.480 (T-T‘) X p 610 - T‘
Where X = pressure of vapor present in the air (AVP)
f‘ saturation vapour pressure at temperature T‘ °C of the wet bulb.
T Temperature of the Dry bulb in °C.
T Temperature of the Wet bulb in°C.
p Pressure of the air.
% Relative Humidity U = x/f X 1 00
Where x = Pressure of vapor present in the air (AVP).
f = Saturation vapor pressure at temperature T — C of the Dry bulb. u = Humidity in percentage.
By using Saturation Vapor Pressure in mn of Hg table, we can substitute the relevant values and find the vapor pressure present in the air (Actual Vapor pressure) and percentage humidity.
Example: Given T = 20
°C T = 30 °C
p = 713 mm of Hg. (for Hyderabad, Altitude of 545 m AMSL) Note from svp table
Saturation vapor pressure at wet bulb temperature (f) = 17. 54 Saturation vapour pressure at Dry bulb temperature (f) = 31.83
Actual Vapor Pressure ‗x‘ =17.54 ((-0.480 (30-20)) x (713))/610-20
= 17.54 - 5.8
= 11.74 mm
Dew point temperature (T d) = 13.7 °C (By definition, look for temperature corresponding to AVP value in SVP table) Relative Humidity % = 11.74/131.83 = 36.9 %

Vapour Pressure Deficit = SVP (at T) - AVP
= 31.83 - 11.74
= 20.09 mm

**Hair hygrograph**

It record the continuous changes in relative humidity on graph paper during the hours of the day. When a hygrometer is transformed into a self-recording device it is called as a hygrograph. This is used to record the relative humidity of the air continuously.

Table9.2: Saturation vapor pressure over water in mm of Hg. for temperatures 0 to 50 ° C

| Tem. _°C_ | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 4.58 | 4.61 | 4.65 | 4.68 | 4.72 | 4.75 | 4.79 | 4. 82 | 4.86 | 4.89 |
| 1 | 4.93 | 4.96 | 5.00 | 5.03 | 5.07 | 5.11 | 5.14 | 5. 18 | 5.22 | 5.25 |
| 2 | 5.29 | 5.33 | 5.37 | 5.41 | 5.45 | 5.49 | 5.52 | 5. 56 | 5.60 | 5.64 |
| 3 | 5.68 | 5.73 | 5.77 | 5.81 | 5.85 | 5. 89 | 5.93 | 5. 97 | 6.02 | 6.06 |
| 4 | 6.10 | 6.14 | 6.19 | 6.23 | 6.27 | 6.32 | 6.36 | 6. 41 | 6.45 | 6.50 |
| 5 | 6.54 | 6.59 | 6.64 | 6.88 | 6.73 | 6. 78 | 6.82 | 6. 87 | 6.92 | 6.97 |
| 6 | 7.01 | 7.06 | 7.11 | 7.16 | 7.21 | 7.26 | 7.31 | 7. 36 | 7.41 | 7.46 |
| 7 | 7.51 | 7.57 | 7.62 | 7.67 | 7.72 | 7.78 | 7.83 | 7. 88 | 7.94 | 7.99 |
| 8 | 8.05 | 8.10 | 8 .16 | 8.21 | 8.27 | 8.32 | 8.38 | 8. 44 | 8.49 | 8.55 |
| 9 | 8.61 | 8.67 | 8.73 | 8.79 | 8.85 | 8. 91 | 8.97 | 9. 03 | 9.09 | 9.15 |
| 10 | 9.21 | 9.27 | 9.33 | 9.40 | 9.46 | 9. 52 | 9.59 | 9. 65 | 9.71 | 9.78 |
| 11 | 9.84 | 9.91 | 9.98 | 10.04 | 10.11 | 10.18 | 10.24 | 10.31 | 10.38 | 10.45 |
| 12 | 10.52 | 10.59 | 10.66 | 10.73 | 10.80 | 10.87 | 10.94 | 11.01 | 11.09 | 11.16 |
| 13 | 11.23 | 11.31 | 11.38 | 11.45 | 11.53 | 11.61 | 11.68 | 11.76 | 11.83 | 11.91 |
| 14 | 11.99 | 12.07 | 12.14 | 12.22 | 12.30 | 12.38 | 12.46 | 12.55 | 12.63 | 12.71 |
| 15 | 12.79 | 12.87 | 12.96 | 13.04 | 13.12 | 13.21 | 13.29 | 13.38 | 13.46 | 13.55 |
| 16 | 13.64 | 13.72 | 13.81 | 13.90 | 13.99 | 14.08 | 14.17 | 14.26 | 14.35 | 14.44 |
| 17 | 14.53 | 14.62 | 14.72 | 14.81 | 14.91 | 15.00 | 15.10 | 15.19 | 15.29 | 15.38 |
| 18 | 15.48 | 15.58 | 15.68 | 15.78 | 15.87 | 15.97 | 16.08 | 16.18 | 16.28 | 16.38 |
| 19 | 16.48 | 16.58 | 16.69 | 16.79 | 16.90 | 17.00 | 17.11 | 17.22 | 17.32 | 17.43 |
| 20 | 17.54 | 17.65 | 17.76 | 17.87 | 17.98 | 18.09 | 18.20 | 18.31 | 18.42 | 18.54 |
| 21 | 18.66 | 18.77 | 18.88 | 19.00 | 19.12 | 19.24 | 19.35 | 19.47 | 19.59 | 19.71 |
| 22 | 19.83 | 19.95 | 20.07 | 20.20 | 20.32 | 20.44 | 20.57 | 20.70 | 20.82 | 20.95 |
| 23 | 21.07 | 21.20 | 21.33 | 21.46 | 21.59 | 21.72 | 21.85 | 21.98 | 22.12 | 22.25 |
| 24 | 22.38 | 22.52 | 22.65 | 22.79 | 22.92 | 23.06 | 23.20 | 23.34 | 23.48 | 23.62 |
| 25 | 23.76 | 23.90 | 24.05 | 24.19 | 24.33 | 24.48 | 24.63 | 24.77 | 24.92 | 25.07 |
| 26 | 25.22 | 25.37 | 25.52 | 25.67 | 25.82 | 25.97 | 26.13 | 26.28 | 26.44 | 26.59 |
| 27 | 26.76 | 26.90 | 27.06 | 27.22 | 27.38 | 27.54 | 27.70 | 27.87 | 28.03 | 28.19 |
| 28 | 28.36 | 28.52 | 28.69 | 28.86 | 29.03 | 29.19 | 29.30 | 29.54 | 29.71 | 29.88 |
| 29 | 30.05 | 30.23 | 30.40 | 30.58 | 30.75 | 30.93 | 31.11 | 31.29 | 31.47 | 31.65 |
| 30 | 31.83 | 32.02 | 32.20 | 32.38 | 32.57 | 32.76 | 32.95 | 33.13 | 33.32 | 33.51 |
| 31 | 33.71 | 33.90 | 34.09 | 34.29 | 34.48 | 34.68 | 34.88 | 35.07 | 35.27 | 35.47 |
| 32 | 35.67 | 35.88 | 36.08 | 36.28 | 36.49 | 36.69 | 36.90 | 37.11 | 37.32 | 37.53 |
| 33 | 37.74 | 37.95 | 38.17 | 38.38 | 38.60 | 38.81 | 39.03 | 39.25 | 39.47 | 39.69 |
| 34 | 39.91 | 40.13 | 30.36 | 40.58 | 40.81 | 41.04 | 41.26 | 41.49 | 41.72 | 41.95 |
| 35 | 42.19 | 42.42 | 42.66 | 42.90 | 43.14 | 43.38 | 43.62 | 43.86 | 44.10 | 44.34 |
| 36 | 44.58 | 44.83 | 45.07 | 45.32 | 45.57 | 45.81 | 46.06 | 46.32 | 46.57 | 46.82 |
| 37 | 47.08 | 47.34 | 47.59 | 47.85 | 48.11 | 48. 38 | 48.64 | 48.91 | 49.17 | 49.44 |
| 38 | 49.71 | 49.97 | 50.24 | 50.52 | 50.79 | 51.07 | 51.35 | 51.62 | 51.90 | 52.18 |
| 39 | 52.46 | 52.74 | 53.02 | 53.31 | 53.59 | 53.88 | 54.17 | 54.46 | 54.75 | 55.04 |
| 40 | 55.34 | 55.63 | 55.93 | 56.23 | 56.53 | 56.83 | 57.14 | 57.44 | 57.74 | 58.05 |
| 41 | 58.36 | 58.67 | 58.98 | 59.29 | 59.60 | 59.92 | 60.24 | 60.56 | 60.88 | 61.20 |
| 42 | 61.52 | 61.85 | 62.17 | 62.50 | 62.82 | 63.15 | 63.49 | 63.82 | 64.15 | 64.49 |
| 43 | 64.82 | 65.16 | 65.50 | 65.84 | 66.19 | 66.53 | 66.88 | 67.23 | 67.58 | 67.93 |
| 44 | 68.28 | 68.63 | 68.99 | 69.35 | 69.71 | 70-08 | 70.44 | 70.80 | 71.17 | 71.53 |
| 45 | 71.90 | 72.27 | 72.65 | 73.02 | 73.39 | 73.76 | 74.14 | 74.52 | 74.90 | 75.29 |
| 46 | 75.67 | 76.06 | 76.45 | 76.84 | 77.23 | 77.63 | 78.02 | 78.42 | 78.82 | 79.22 |
| 47 | 79.62 | 80.03 | 80.43 | 80.84 | 81.25 | 81.66 | 82.07 | 82.48 | 82.90 | 83.32 |
| 48 | 83.74 | 84.16 | 84.59 | 85.01 | 85.44 | 85.87 | 86.30 | 86.74 | 87.17 | 87.61 |
| 49 | 88.05 | 88.49 | 88.93 | 89.38 | 89.83 | 90.27 | 90.72 | 91.17 | 91.62 | 92.08 |
| 50 | 92.50 | 93.0 | 93.4 | 93.9 | 94.4 | 94. 8 | 95.3 | 95. 8 | 96.3 | 96.7 |

## Procedure:-

1. A band of human hair is fixed on the levers and any slight increase in the volume is transmitted to the pen arm.
2. The pen arm is self-inked and works on levers

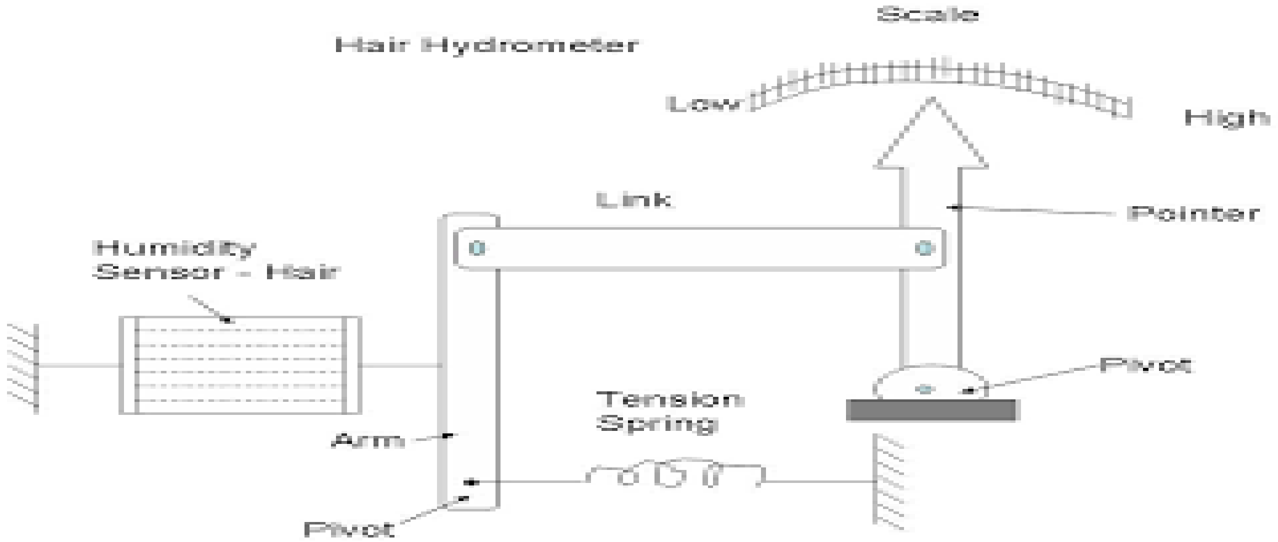



Fig. 8: Hair hygrograph

1. A change in the length of hair is proportional to the log change of relative humidity
2. A calibrated chart is wrapped around a rotating drum. This completes one rotation In 24 hours, and works on clock mechanism.
3. The X-axis repres ents time and Y-axis, the relative humidity.
4. The chart has to be replaced everyday.
5. The dust on the hair should be cleaned and washed regularly. The hair should not be touched with hand.
6. This instrument should be expos ed in double Stevenson screen. The screen should be located in a place where the air is not polluted with smoke, dust, oil and amrnonia releasing industries in the immediate surroundings.

Problem: If, Td= 20 °C and Tw = 16 °C, then calculate actual vapour pressure,VPD and relative humidity.

Solution:

# Unit -7

## Measurement of atmospheric pressure and analysis of atmospheric conditions.

The weight exerted by a column of air on unit surface of the earth is known as atmospheric pressure. This can be
measured by an instrument called barom eter (Fig. 9). There are two types of barom eters, viz.,
1. Mercury
barometers     2. Aneroid barometers
Of these two, the most accurate instrum ent is the mercurial barometer. This is used as standard for calibrating the others. The following instruments are used to measure the atmospheric pressure.

**1. Mercurial barometers:**

There are two types of merc urial barometers. A) Fortin‘s barom eter B) Kew pattern barometer

**Fortin’s barometer:**

**Principle**: Balancing of column of air against a column of mercury in a sealed glass tube. The height of the mercury column is proportional to the pressure.

The Fortin‘s barometer is a familiar sight at most of the micro-meteorological laboratories and is an accurate one. It consists of a glass tube of uniform cross section and length, which is closed at one end. It is about one metre in length, filled with mercury and then inverted with it‘s lower end open into a movable cistern of mercury. The cistern vessel contains mercury with a flexible leather bag and screw at it‘s bottom. There are two scales on two sides of the tube, one in centimetres and the other in inches. For accurate readings vernier calipers is also attached.

The mercury column in the tube is supported by the pressure of the air on the surface of the mercury in the cistern. Procedure

1. To take the pressure reading, the height of mercury column is measured on main scale and then Vernier scale is read.
2. To read the Fortin‘s barometer:
   (a) Read the attached thermometer to the nearest degree before the time specified (or barometer observation.
   b) Gently tap the cistern and tube of the instrument 2 to 3 times with the fingers.
   c) Raise the surface of the mercury in the cistern by screwing up the plunger at the base until the tip of the ivory point just touches its image in the clear mercury surface.
   d) Set the lower edge of the Vernier tangent to the top of meniscus.
   e) Read the scale and the Vernier.
   f) Check the reading by making a fresh setting.

**Barograph:**

The sensitive element in this device is an aneroid capsule which consists of a closed circular vacuum box or boxes placed one above the other (Fig. 10). The box is made of an alloy of silver plated beryllium copper. As the atmospheric pressure rises or falls the walls of the box collapse or distant proportional to the impressed pressure changes. The motion is communicated to a lever system connected to a rotating drum on which recording is made. This is an instrument used to record the atmospheric pressure continuously.

**Units of measurements:**

1. Height of mercury column is measured in inches, centimeters or millimeters. 2. The S.I. unit for pressure is Pascal and this is equal to a force of one newton per sq. m. One atmospheric pressure = 29-92 inches or 76 cm or 760 mm of Hg

= 1013.250 mill bar

= 101.325 kilopascal (kPa) 14.7 lbs / inch2

= 1.014 X 106 dynes / cm2

**Problem 1: Draw the neat sketch of Fortin's barometer**

# Unit -8
# Measurement of wind direction and speed

Wind is the air in horizontal motion caused due to differences in atmospheric pressure. Wind has to be specified by its direction and speed. The movement of wind is almost horizontal and the vertical component is very small. The air in horizontal motion near the surface of the earth is called surface wind. Since it relates motion, it is associated with direction and speed. The influence of the underlying terrain condition sharply diminishes with height and observations indicate that wind at a height of 10 m above the ground is fairly representative of general surface wind for meteorological purposes. However, for agrometeorological purpose, the obs ervations are made at a height of 10 feet which is a representative height of crop canopy.

**Wind Instruments:**

**Anemoscope**: This records the direction of the wind continuously.

**Aero vane:** This measures the velocity and direction of the wind simultaneously.

**Wind vane:** This is used in observatories to find the wind direction.

**Anemometer**: It measures speed of the wind.

**Wind vane**

The common instrument to determine wind direction is wind vane (Fig. 12). This instrument indicates the direction from which the wind blows. It is a balanced lever which turns freely about a vertical axis. One end of the lever exposes a broad surface to the wind, while the other end is narrow and points to the direction from which the wind blows. Wind direction is the direction from which the wind is approaching the observer. It is expressed in degrees, measured clockwise from geographical north. The codes and 16 point wind direction is expressed in Table 12.1.

Wind direction known by wind vane is of the shape of a penchant with an arrow head installed on a metal frame free to rotate in the horizontal plane with the direction of the arrow pointing towards the wind direction of the wind. Below the indicator, a frame indicating 4 (north, east, south and west) or 8 or 16 points of the compass is fixed to the frame to facilitate the estimation of the direction.

**Reading of wind vane at the time of observation**

The direction is read by noting the direction to which the arrow head points. Wind vane is read by standing exactly in the line of the arrow of the instrument. Since we record 16 points of the directions and distance between two directions is less, so care is required. The nearest possible is recorded for alphabetical recording and the nearest 10 degree is recorded for wind direction in degrees. It may be noted that we report the windward side i.e. from where the wind is coming. Leeward side i.e. where the win d is going is never reported. In case wind is static, wind may be calm and in that case direction reported is 00.

For example if the arrow head is pointing towards the middle of the region between North(N) and North-west(NW), the direction should be North- North-west

**Measure ment of wind speed**

Wind speed is measured by Robinson Cup counter anemometer which has a mech anical arrangement for converting the rotational motion into linear motion in kmph which is converted into average wind speed in kmph by dividing 24 during last 24 hour (Fig.11). This instrument consists of four hemispherical cups fixed at the end of metal arms from a central point. The cup wheel is pivoted at the centre to a vertical spindle passing through a brass tube attached to the anemometer box. The cup is set in motion due to the pressure differences occurring between the two faces of the cup. The vertical cup is connected to a mechanical counter through a gear system from which the number of rotations made by the cups in a chosen interval of time can be counted. The counter is directly calibrated in kilometers.

To determine wind speed at the time of observation, the two successive readings of the anemometer should be taken at an interval of 3 minutes. The difference between the two readings when multiplied by 20 will give the wind speed in kilometer per hour, if the anemometer is calibrated in kil ometers. For example: If the first anemometer is 4005.6 and the second reading is 4006.8, the wind speed will be 20 x ( 4006.8-4005.6) = 20 x 1.2 = 24 kmph.

**Calculation of mean daily speed**

The mean daily wind speed is calculated at the one hour of observation viz.,7 hrs local mean time at the agromet observatory. The anemometer reading of 7 hrs LMT reading of the previous day is subtracted from 7 hrs. LMT reading of the current day wind speed in kmph can be obtained. Thus, mean daily wind speed on a particular date corresponds to the 24 hour period ending at 0700 hrs LMT of that date.

Exam ple: Anemometer reading at I hour of 20.7.2011 ——— 6754.9 Anem ometer reading at I hour of 19.7.2011 ——— 6475.4

Difference ___

279.5 Mean daily wind speed on 20.7.2011 is given by 279.5/24 = 11.64 kmph

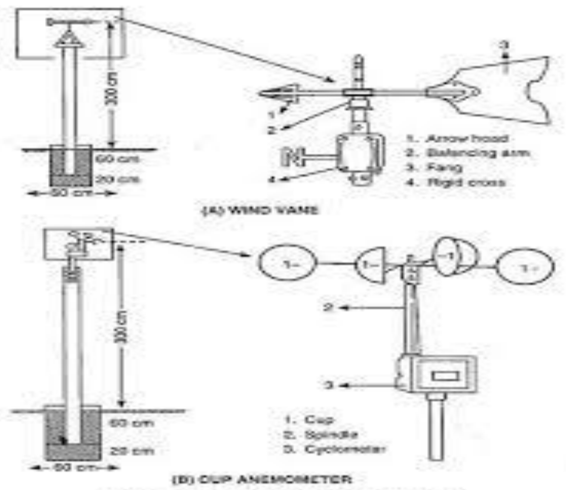



Fig. 2.9. Wind vane and cup anemometer.

**Problem1:**

Calculate the wind speed at the time of the observation on 4.6.2011 and the mean daily wind speed on 5.6.2011 with the following data from cup anemometer:
Date Time Readi ng

4.6.2011 0710 hrs IST* 3345.9

0713 hrs IST. 3346.4

1.6.2011 071 0 hr s. I S T. 3 57 5.5
*At the station concerned, 0710 hrs IST is equivalent to 0700 hrs LMT

**1. Draw levelled diagram of Robinson's cup anemometer?**