भारत सरकार
Government of India
पृथ्वी विज्ञान मंत्रालय
Ministry of Earth Sciences
भारत मौसम विज्ञान विभाग
India Meteorological Department

सतह वेधशालाओं के प्रेक्षकों के लिए अनुदेश

INSTRUCTION TO OBSERVERS AT THE SURFACE OBSERVATORIES

द्वारा जारी
मौसम विज्ञान के महानिदेशक , नई दिल्ली

ISSUED BY

THE DIRECTOR GENERAL OF METEOROLOGY, NEW DELHI

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प्राक्कथन

डॉ. एस.सी. रॉय द्वारा तैयार की गई यह विभागीय पुस्तिका भारत में द्वितीय और तृतीय श्रेणी की वेधशालाओं में प्रेक्षकों द्वारा उपयोग के लिए अभिप्रेत है । प्रत्येक प्रेक्षक को पहले चार अध्यायों को बहुत ध्यान से पढ़ना चाहिए और उसमें निहित अनुदेशों का दैनिक प्रेक्षण कार्य में सख्ती से पालन किया जाना चाहिए । मौसम विज्ञान विभाग को प्रेक्षक को ऐसे किसी भी अनुदेश की व्याख्या करने में खुशी होगी जो उसे स्पष्ट नहीं है । जब कोई अपने स्टेशन का दौरा करता है तो उसे एक निरीक्षक के साथ पुस्तक में सभी संदिग्ध बिंदुओं पर चर्चा करने का हर अवसर लेना चाहिए ।

यह हैंड बुक और विभागीय क्लाउड एटलस मिलकर पुराने “प्रेक्षकों के लिए अनुदेश” का स्थान लेते हैं जो अब प्रिंट से बाहर है ।

पूना
मई, 1930

सी. डब्ल्यू. बी. नॉर्मैंड
वेधशालाओं के महानिदेशक

दूसरे संस्करण के लिए प्राक्कथन

विभाग के बाहर की मांगों को पूरा करने के लिए इस पुस्तिका के एक नए संस्करण की आवश्यकता है और पाठ के कई हिस्सों को संशोधित करने और अनुदेशों को आम तौर पर अद्यतित करने का अवसर विभागीय रूप से लिया गया है ।

पूना
दिसंबर, 1933

सी. डब्ल्यू. बी. नॉर्मैंड
वेधशालाओं के महानिदेशक

तीसरे संस्करण के लिए प्राक्कथन

इस पुस्तिका का दूसरा संस्करण अब प्रिंट से बाहर है । इस तीसरे संस्करण में पाठ के कुछ अंशों को संशोधित किया गया है और अनुदेशों को अद्यतन किया गया है ।

पूना
सितम्बर, 1941

सी. डब्ल्यू. बी. नॉर्मैंड
वेधशालाओं के महानिदेशक

F O R E W O R D

This departmental hand-book, prepared by Dr. S. C. Roy is intended for use by the Observers at second- and third-class observatories in India. The first four chapters should be very carefully read by each observer and instructions contained therein should be followed strictly in the daily observational work. The Meteorological Department will be glad to explain to the Observer any instructions that are not clear to him. He should also take every opportunity to discuss all doubtful points in the book with an Inspector when one visits his station.

This hand-book and the departmental cloud atlas together replace the old "Instructions to Observers" which is now out of print.

POONA
May, 1930

C. W. B. NORMAND
Director General of Observatories

FOREWARD TO THE SECOND EDITION

A new edition of this hand-book is needed to meet demands from outside the department and the opportunity has been taken departmentally to revise several portions of the text and to bring the Instructions generally up-to-date.

POONA
DECEMBER,1933.

C. W. B. NORMAND
Director General of Observatories

FOREWARD TO THE THIRD EDITION

A second edition of this hand-book is now out of print. In this third edition some portions of the text have been revised and the Instructions brought up-to date.

POONA
SEPTEMBER, 1941.

C. W. B. NORMAND
Director General of Observatories

चौथे संस्करण के लिए प्राक्कथन

1942 में छपी इस हैंडबुक का तीसरा संस्करण अब आउट ऑफ प्रिंट है । वर्तमान संस्करण में जहां आवश्यक हो, पाठ को संशोधित किया गया है और निर्देशों को अद्यतन किया गया है ।

नई दिल्ली
दिसंबर, 1953

एस सी रॉय
वेधशालाओं के महानिदेशक

पांचवे संस्करण के लिए प्राक्कथन

इस पुस्तिका का चौथा संस्करण, जो 1953 में छपा था, अब अप्रचलित है । वर्तमान संस्करण में जहां आवश्यक हो, पाठ को संशोधित किया गया है और अनुदेशों को अद्यतन किया गया है ।

29 जून, 1987
नई दिल्ली

आर. पी. सरकार
वेधशालाओं के महानिदेशक

छठे संस्करण के लिए प्राक्कथन

1930 में भारत के मौसम विभाग द्वारा हैंडबुक 'इंस्ट्रक्शन टू ऑब्जर्वर' का पहला संस्करण लाया गया था । तब से इस प्रकाशन 1933, 1942, 1953 और 1987 में चार बार पुनर्मुद्रित किया गया है । वर्तमान छठा संस्करण पांचवें संस्करण का संशोधित संस्करण है । वर्तमान संकलन में आधुनिक, ऑटोग्राफिक और विशेष उपकरणों पर अतिरिक्त जानकारी शामिल है । स्वचालित मौसम वेधशाला (स्व मौ वे)/ स्वचालित वर्ष मापी / कृषि- स्व मौ वे / विकिरण उपकरणों के रखरखाव और स्थापना प्रक्रियाओं पर अनुदेशों को व्यापक और अद्यतन किया गया है ।

मैं जलवायु डेटा प्रबंधन और सेवाएं और सतह उपकरण (एसआई) डिवीजन की सराहना करता हूँ, जो उन्होंने श्री के एस होसलीकर, प्रमुख, जलवायु अनुसंधान एवं सेवाएं, पुणे के मार्गदर्शन में इस महत्वपूर्ण प्रकाशन को तैयार किया ।

15 जनवरी, 2023
नई दिल्ली

डॉ. एम. महापात्र।
मौसम विज्ञान विभाग के महानिदेशक

FOREWARD TO THE FOURTH EDITION

A third edition of this hand-book, which was printed in 1942, is now out of print. In the present edition the text has been revised where necessary and the instructions brought up-to-date.

NEW DELHI
19th DECEMBER, 1953.

S. C. ROY
Director General of Observatories

FOREWARD TO THE FIFTH EDITION

A fourth edition of this hand-book, which was printed in 1953, is now out ofprint. In the present edition the text has been revised where necessary and the instructions brought up-to-date.

29th JUNE, 1987
NEW DELHI

R. P. SARKAR
Director General of Observatories

FOREWARD TO THE SIXTH EDITION

The First edition of the hand-book 'Instructions to Observer's was brought out by India Meteorological Department in 1930. Since then this publication has been reprinted four times, in 1933, 1942, 1953 and 1987. The present Sixth edition is a revised version of Fifth edition. In the present addition additional information on modern, autographic and Special instruments have been included. Instructions on Maintenance and Installation Procedures of Automated Weather stations (AWS)/Automated Rain Gauge (ARG)/Agro-AWS/Radiation Instruments have been updated comprehensively.

I would like to appreciate the efforts of the Climate Data Management and Services Group and the Surface Instrumentation (SI) Division of the India Meteorological Department for the publication of this Hand-Book under the guidance of Shri. K S Hosalikar, Head, Climate Research & Services, Pune.

15 January 2023
NEW DELHI

DR. M. MOHAPATRA
Director General of Meteorology

आभार-पूर्ति

मुझे प्रेक्षकों को अनुदेश के छठे संस्करण की प्रस्तावना करते हुए बहुत खुशी हो रही है, जिसे नवीनतम उपकरण और इसकी रखरखाव तकनीकों को शामिल करके तैयार किया गया है । यह प्रकाशन विभागीय स्टेशनों के साथ-साथ भारत भर में फैले विभिन्न गैर-विभागीय स्टेशनों पर प्रेक्षकों के लिए एक मार्गदर्शक के रूप में काम करेगा । यह पुस्तक सतह वेधशालाओं में उपयोग किए जाने वाले विभिन्न उपकरणों, उनके प्रदर्शन की स्थिति, प्रेक्षण प्रक्रिया और तकनीकों, रखरखाव, समस्या निवारण तकनीकों के साथ-साथ सतह वेधशालाओं में प्रेक्षकों के कर्तव्यों का संक्षिप्त विवरण प्रदान करती है ।

इस प्रकाशन का समस्त कार्य डॉ. सुदीप कुमार बी एल, वैज्ञानिक - 'सी' के नेतृत्व में डॉ. मनीष रानालकर, वैज्ञानिक 'ई', श्री यू के शेंडे, वैज्ञानिक 'ई' और श्री. अंजीत अंजन, वैज्ञानिक 'ई' के सहयोग से श्री ए डी ताठे, वैज्ञानिक 'एफ' के मार्गदर्शन में अधिकारियों और कर्मचारियों के एक समूह द्वारा किया गया है। श्रीमती गीता हरिकुमार, मौसम विज्ञानी 'बी' द्वारा पुस्तक को तैयार करने और संकलित करने में महत्वपूर्ण योगदान दिया गया था। इसके अलावा, श्री संजय सांगले, मौसम विज्ञानी 'ए', श्री जयेश शाह, मौसम विज्ञानी 'ए', और प्रमोद पारखे, कनिष्ठ अनुवाद अधिकारी द्वारा किए गए योगदान को भी स्वीकार किया जाता है । आशा है कि यह प्रकाशन विभागीय और गैर-विभागीय कर्मियों के लिए उपयोगी साबित होगा जो मौसम संबंधी प्रेक्षणों की रिकॉर्डिंग में लगे हुए हैं ।

पुणे
05 जनवरी, 2023

के एस होसलीकर
प्रमुख, जलवायु अनुसंधान और सेवाएं

ACKNOWLEDGEMENTS

It gives me immense pleasure to introduce the sixth edition of the Instruction to Observers which has been prepared by incorporating the latest instrumentation and its maintenance techniques. This publication will serve as a guide to the observers at the departmental stations as well as various non-departmental stations spread across India. This book provides brief description of various instruments used at surface observatories, their exposure conditions, observation procedure and techniques, maintenance, troubleshooting techniques as well as duties of observers at surface observatories.

The entire work of this publication has been done by a group of officers and staff led by Dr. Sudeep Kumar B L, Scientist C in association with Dr. Manish Ranalkar, Scientist E, Shri U K Shende, Scientist E and Shri. Anjit Anjan, Scientist E, under the guidance of Shri. A D Tathe, Scientist F. Significant contributions were made by Smt. Geeta Harikumar, Meteorologist B towards preparing and compiling the book. Further, contributions made by Shri. Sanjay Sangale Meteorologist A, Shri. Jayesh shah, Meteorologist A and Shri. Pramod Parkhe, Junior Translation Officer are also acknowledged. Hope this publication will be found useful by departmental as well as non-departmental personnel engaged in recording of Meteorological Observations.

Pune
05 January 2023

K S Hosalikar
Head, Climate Research and Services

विषय-सूची

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परिशिष्ट

चित्रों की सूची

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CHAPTER I

INTRODUCTION

1.1 Introduction

In a meteorological observatory, measurement of one or more of several meteorological elements is carried out by an observer. These observations are needed for weather forecasting and also for research and applications in Climatology, Agricultural Meteorology and Hydrometeorology, etc. The usefulness of the observations will depend upon the care and accuracy with which the observations are recorded by the Observer. The routine reporting of weather by our Observer is a part of a World-wide collection of data and is therefore an important and valuable service. Meteorological observations are taken regularly and simultaneously at standard hours of observations all over the World. A point worth remembering by each Observer as he sets out to take an observation is that, thousands of Observers not only in his country but all over the World, are also taking similar observations at the same time and that his observation has to compare in quality with the observations taken by this large international family of Observers.

Surface meteorological observatories of the India Meteorological Department are divided into six classes: -

Sn	Category	Description
1	**CLASS-I**	These are observatories equipped with both eye - reading and self-recording instruments.
2	**CLASS-II**	Most of these observatories are equipped with only eye-reading instruments. Regular observations are taken at least twice daily.
3	**CLASS-III**	These observatories have the same instrumental equipment as Class II observatories, but observations are recorded only once a day.
4	**CLASS-IV, V and VI**	These observatories have a lesser number of instrumental equipment or take non- instrumental observations only.

The details of the different classes of observatories are given in Appendix-I. A large majority of the observatories of this Department belongs to Class-II.

1.2 Instrumental Equipment

The basic instrumental equipment at observatories of the Class-III and higher categories is: -

(i) Digital Barometer/Mercury Barometer *

(ii) Four thermometers – Dry Bulb, Wet bulb, Maximum and Minimum fixed inside the Stevenson Screen.

(iii) Raingauge and Measure Glass.

(iv) Wind instruments – Windvane and Anemometer.

(v) A watch or similar regulated time- keeping device.

1.3 Meteorological Elements.

The following meteorological elements are generally observed at the observatories of the Class-III and higher categories: -

Sl No.	Meteorological element	Observation
1	**Barometric pressure:**	The pressure of the air that is measured with the barometer.
2	**Dry bulb temperature:**	The temperature of the air as measured by the dry bulb thermometer in the Stevenson Screen at the time of observation.
3	**Wet bulb temperature:**	Which gives in conjunction with the dry bulb temperature, the humidity of the air inside the Stevenson Screen and its dew point temperature.
4	**Maximum temperature:**	The highest temperature of the air indicated by the maximum thermometer in the Stevenson Screen since its last setting
5	**Minimum temperature:**	The lowest temperature of the air indicated by the minimum thermometer in the Stevenson Screen since its last setting.
6	**Rainfall:**	Amount of rain fallen between successive observations
7	**Wind:**	Direction and speed of wind given by the Wind vane and the Anemometer respectively
8	**Visibility:**	As judged by the observation of the “visibility land marks”.

9	**Cloud:**	Amount form and direction of the movement of cloud and height of base of low cloud above station level
10	**Weather:**	Character of the weather since the last observation and at the time of observation.
11	**Wave observations:**	For the coastal stations only

* Second Class observatories on the coast are also equipped with a barograph for recording barometric tendency.

1.4 Hours of Observation

(i) At the meteorological observatories, time is expressed according to the 24-hour clock. The 24-hours from mid-night to the next mid-night are numbered consecutively as 00, 01, 02, ….24. The time commonly known as 0530 P.M. is expressed as 1730 hours. The Indian Standard Time (I.S.T.*) should alone be used for observational work.

(ii) The regular hours of observation at most of the Class II observatories are 0830 hours I.S.T. and 1730 hours I.S.T. corresponding to 0300- and 1200-hoursU.T.C respectively. At Class III stations regular observations are taken only at one of these hours daily.

NOTE: - Regular observations are also taken at 0530,1130,1430,2030,2330 and 0230 hours I.S.T. (0000,0600,0900,1500,1800 and 2100 hours U.T.C. respectively) at Class I observatories and some Class II observatories manned by Departmental Observers.

The expressions ‘**morning observations’** and ‘**afternoon observations’** refer to the observations taken at 0830 hrs I.S.T.(0300 U.T.C.) and 1730 hrs. I.S.T. (1200hrsU.T.C.) respectively.

(iii) Extra observations may be requisitioned at any hour by various forecasting centers. The standard of time adopted for reporting these special observations is always the Universal Time of Coordination (U.T.C.) which is5½hours less than the corresponding Indian Standard Time (I.S.T.)

- Indian Standard Time (I.S.T.) is the time corresponding to Longitude 82.5° E and is **5. 30 hours ahead** of the ‘Universal Time of coordinated’ (U.T.C)

1.5 Order of Observations:

The observation of the various meteorological elements for composing a weather report cannot be made at once, but according to a certain sequence. The reading of the barometer is to be made at the exact hour concerned. The instruments at the observatory should be read in the following order commencing from 10 minutes preceding the hour:

(1) Wind instruments (2) Rain gauge (3) Thermometers and (4) Barometer.

Non-instrumental observations (e.g. Clouds, visibility etc.) should be taken in the intervals of 5 minutes between the first and the second readings of the anemometer or if that is not possible before commencing the instrumental observations. It should be ensured that all the elements are observed within the 10 minutes before the prescribed time of observation. All the instruments should, therefore be read as quickly as possible, consistent with accuracy and there should be no delay in moving from one instrument to another.

The procedure to be followed for recording observations and completing the weather observations without delay and dispatching (transmitting) them through Telephone/email/AMSS/Mobile/SMS/internet to different forecasting centres, immediately after observations are taken.

1.6 Observer´s Duties:

The routine duties of the Observer are:

(i) To make **regular** and careful observations **punctually** at the prescribed hours of observations including setting of maximum and minimum thermometer.

(ii) To note the general character of the weather not only at the fixed hours of observations, but throughout the day and to record any unusual or remarkable weather phenomenon, noting its time of commencement, duration and cessation

(iii) To prepare and dispatch (transmit) the **Weather observations through Telephone/email/AMSS/Mobile/SMS/internet** to the different forecasting centers, **immediately** after the observations are taken.

(iv) Send heavy **rainfall warnings through Fax/email/telephone /Mobile/SMS/internet** to the various addresses on the warning list.

(v) To record **extra observations** whenever requisitioned by any forecasting centre and dispatch them by Fax/email/Telephone/Mobile/ SMS as desired.

(vi) To enter immediately after each observation the values of each observed meteorological elements in the Meteorological Register (online/offline/both). Weather remarks with appropriate symbols should also be entered promptly in the Meteorological Register giving the times of commencement and cessation.

(vii) To post hard copy of the Meteorological Registers in weekly batches to the Controlling M.C./ R.C, if required.

(viii) To post, the carbon copies of weather observations each week to the Controlling Meteorological Office **immediately** after the end of the week, if required.

(ix) To prepare **annual returns** of the stock of instruments and forward them to the Controlling Meteorological Office, during the first week of April every year.

(x) To keep instruments **clean and free from dust.**

(xi) To change the charts of the self-recording instruments, if any, regularly.

(xii) To arrange for a competent Deputy Observer to take charge of the observatory work in his absence.

(xiii) To notify to the Controlling Meteorological Office **permanent charges of observer ships** together with the ' Charge List ' of instruments, etc. on prescribed forms.

(xiv) To send voluntary reports to the Controlling Meteorological Office regarding special phenomenon like hailstorms, earthquakes etc. soon after their occurrence, in accordance with the instructions given in Chapter 6.

NOTE: -**The regular Observer should train the Deputy Observer thoroughly. If the Deputy Observer is not efficient the chances are that his mistakes will be counted against the regular observer.**

1.7 General Instructions Regarding Observations:

(i) **Punctuality:** Punctuality is a matter of prime importance in recording meteorological observations. The Observer should take great care to ensure that the clock or the watch by which he is guided keeps correct **Indian Standard Time**.

To avoid delay and irregularity he should be ready near the barometer a few minutes before the prescribed time of observation.

(ii) **Faithful Recording:** Every observation should be recorded faithfully as read. In cases of doubt the observations should be repeated until the Observer is satisfied. If any observation is not taken, the space in the Meteorological Register allotted for it should be left blank. The reason for the omission must, however, be clearly stated. In no case should false figures be inserted subsequently.

(iii) **Immediate Entry of Observations**: Each observation must be entered/written down in the Meteorological Register **immediately after it is taken.** The readings should never be jotted down on the scraps of paper with the intention of copying them in the Pocket Register later on.

(iv) **Check on Entry:** Each observation must be checked after it is noted down in the **Meteorological Register** to make sure that no mistake has been made.

1.8 General Instructions for the care of the Instruments:

(i) The positions of the instruments must never be changed, except under orders from the Controlling Meteorological Office.

(ii) When an instrument is out of order and the Observer is unable to rectify its defect, the Controlling Meteorological Office should be informed immediately.

(iii) Unserviceable instruments should in no case be thrown away by the Observer without the previous approval of the Controlling Meteorological Office.

(iv) The barometer is a very delicate instrument and must be handled with great care. The Observer should under no circumstances try to rectify any defect found in a barometer without previous instructions from the Controlling Meteorological Office. (See section 2.1.2.3)

(v) The bottle attached to the wet bulb thermometer must always be filled with rainwater or distilled water or well water. Under exceptional circumstances when ordinary well water has to be used, it must be boiled, allowed to settle overnight and filtered before use. The muslin and thread should be renewed **<u>once in a fortnight in fine weather, once a week in dusty weather and immediately after every dust storm that occurs.</u>** (See section 2.2.2)

(vi) Wind instruments should be cleaned and oiled <u>at least once a fortnight in dusty weather and once a month in the rainy season.</u>

(vii) Tall grass or shrubs should not be allowed to grow around the rain gauge as these would vitiate its exposure.

CHAPTER 2

INSTRUMENTAL OBSERVATIONS (EXPOSURE, ERECTION AND CARE OF INSTRUMENTS)

2.1 Pressure:

The pressure of the atmosphere at any point is the weight of the air column which stands vertically above unit area with the point at its centre. For meteorological purposes, atmospheric pressure is usually measured by a digital barometer/mercury barometer where the height of the mercury column represents the atmospheric pressure. The C.G.S. unit of pressure is the dyne per square centimeter, but this is inconveniently small. The unit employed for reporting pressure for meteorological purposes, is, therefore, the hecto-Pascal (millibar) which is defined as equal to 1000 dynes/Sq. Cm.(100Pa is one hecto-Pascal and one pascal is equal to one Newton force per unit square meter and One hectopascal is equivalent to one millibar).

The **Fortin barometer** is the most frequent type of barometer used for calibration work. This is a highly accurate instrument that measures with an error rate of between 0.03 percent and 0.001 percent on the whole scale reading depending on the measurement range.

The accuracy requirements, for surface measurements of the atmospheric pressure and tendency, as stated by various technical commissions of the WMO are given in the table below.

	Climatology	Aeronautical meteorology	Synoptic and Marine meteorology
Pressure	± 0.3 hPa	0.5 hPa	± 0.1 hPa
Tendency	-	-	± 0.2 hPa

The barometers used in India Meteorological Department are of 2 types:

- **Digital barometer**- These barometers also contain MEMS (Micro Electro-Mechanical System), is a **chip-based technology where sensors are composed of a suspended mass between a pair of capacitive plates**.
- **Mercury barometer-measures the atmospheric pressure by adjusting the height of mercury inside a tube**.

Almost all the Meteorological stations functioning under India Meteorological Department are equipped with Digital/Mercury Barometers. Mercury barometers are not produced now in IMD laboratory because mercury being a protoplasmic poison it requires extensive safety measures for conducting distillation and filtering of mercury in the Laboratory. Also, critical components required for production of mercury barometer are nowadays not available in the market.

In order to overcome this, it is decided by IMD to procure good quality digital barometers to serve as standard for surface pressure at Meteorological stations. As a first step, IMD installed 200 digital barometers including in-built power backup. This wall mounted Digital Barometer are designed to be compact and hassle free to operate 24/7. They have been installed at various IMD Stations. These barometers are proven international standard with very high degree accuracy and with automatic temperature compensation.

Fig. 1 Digital Barometer

2.1.1 Digital Barometer

These barometers also contain MEMS sensors but have been characterized and calibrated to achieve much a higher accuracy compared to the devices they are intended to calibrate. **The accuracy of these barometers can be as high as 0.008%**.

According to the World Meteorological Organization (WMO), analyzed pressure fields are a fundamental requirement of meteorology. Barometric pressure is a key parameter for weather prediction, and the accuracy of atmospheric pressure data forms the basis of all reliable weather forecasting.

The Digital Barometer PTB330 used by IMD at surface observatory leverages trademarked BAROCAP® sensor technology that combines absolute pressure measurement and exceptional accuracy with low hysteresis and long-term stability. For generating historical models of high- and low-pressure systems, or monitoring developing severe weather for an early warning system, the PTB330 deliver accurate barometric pressure readings under the harshest of conditions.

2.1.1.1 Pressure Data

The PTB330 accurately calculates instant pressure along with WMO pressure trend and tendency code (pressure tendency looking back three hours) for immediate forecasting and long-term modeling. It also stores 12 months of data for review and can be stored in Computer.

2.1.1.2 Redundant measurement

One, two, or three BAROCAP sensors for redundant pressure measurement. With two or three sensors connected, the unit constantly compares readings to ensure stable, reliable pressure readings.

2.1.1.3 Accuracy and long-term stability

BAROCAP single-crystal silicon material and capacitive structure sensor technology in the PTB330 allows it to consistently and reliably operate over a wide temperature range, even for highly demanding professional meteorology needs.

2.1.1.4 Easy Installation and maintenance

It can be wall mounted or connected to a standard DIN rail, and includes an easy-detachment mounting plate.

An IP65-rated housing and UPS power supply of 12 V DC power source for the PTB 330 for outdoor applications. The power supply of UPS is being checked regularly and replace the SMF battery by every two years.

2.1.1.5 Data communication

An RS232 serial output is standard with optional use of a high-speed RS485 serial line. The PTB330 also offers USB connection to a PC either via a terminal program or Windows® software application. Linear voltage and current output for pressure are also available.

2.1.1.6 Intercomparison with travelling standard

These standard barometers are compared with travelling standard every year. Any deviation and offset are to be kept as per record. If deviation is more than WMO recommended and this barometer may be replaced with new one.

2.1.2 Mercury Barometer:

The Kew Pattern Barometer used at the observatories of the India Meteorological Department is illustrated in Fig.2. Its essential parts are (1) a glass tube about 90 cm. long closed at the top and open below (2) a cup or cistern and (3) a brass scale. The glass tube is filled with mercury and its open end is dipped in the mercury in the cistern, which prevents air from entering the tube. Above the mercury column in the tube is an empty space and great care is taken to remove all air from this space as its presence even in very minute quantities, will vitiate the readings of the instrument. The mercury column in the tube is supported by the pressure of the air on the surface of the mercury in the cistern. This forms the basic principle on which a barometer is constructed. As the mercury in the barometer tube rises or falls due to changes in the atmospheric pressure, the mercury level in the cistern changes in the opposite direction. This change of level in the cistern is taken into account in the graduation of the scale itself.

2.1.2.1 Setting and Reading the Barometer: Detailed instructions constituting the standard procedure for reading the barometer are given below. These must be carefully followed in the order in which they are given:

(i) **Read the Attached Thermometer: Every barometer** has a thermometer attached to it. This may be graduated in Absolute, Fahrenheit or Celsius scale. The attached thermometer must be read to nearest tenth of a degree (by mentally dividing one degree into ten equal parts) (Fig. 2) and the reading entered in the appropriate column in the Meteorological Register. Always use the graduation etched on the glass stem of the thermometer. Changes in the temperature caused by the Observer's presence are likely to affect the thin mercury thread in the thermometer more quickly than the larger volume mercury in the barometer. It is therefore, important that the attached thermometer is read first before setting and reading the barometer.

(ii) **TAP the Instrument** gently two or three times with the pads of the fingers, to prevent the mercury from adhering to the size of the glass tube.

(iii) **Illuminate the White Screen** fixed behind the mercury tube, by means of a torch, holding it in the left hand in front and slightly to the left of the barometer. **Never use** a lighted match or other naked light for this purpose as this warms the instrument and leads to inaccurate setting.

(iv) **Setting the Vernier Scale:** There is a milled screw at the side of a barometer for operating a small moveable scale known as the Vernier. There is a sliding piece along with the Vernier at the back of the instrument. Its object is to ensure that the Observer's eye is at the same level as the top of the mercury column to avoid errors due to parallax while reading the observations.

A good plan for setting the Vernier is as follows: -

First place the Vernier high as in Fig. 4 so that a little white space can be seen between the Vernier and the domed mercury surface. Then lower the Vernier very slowly till the lower edge just apparently touches the highest point of the mercury surface. No white space must be visible (from any position of the eye) between the lower edge of the Vernier and the top of the mercury surface. At this position, the Observer's eye, the bottom edge of the Vernier and the sliding piece moving along with the Vernier at the back of the instrument will be in the same straight line. If the Vernier is set correctly the white back-ground will be visible only at the sides as two triangles of equal area. A diagram depicting correct setting of the Vernier scale may be seen at Fig. 4.

Fig. 2 Kew Pattern Barometer

(v) **Read the Scale:** This operation consists of two parts. First, note between two divisions of the fixed hPa (millibar) scale the base of the Vernier (i.e. Zero division marked O) (touching the top of the mercury column) lies and note the lower reading. In Fig. 3(b) this reading is 1002 hPa (millibars). Secondly look upon the Vernier scale for a division which is in line with a division on the fixed main scale. The value of this division on the Vernier scale gives the decimal place. Referring to Fig.3(b) it is seen that the division of the vernier which coincides with a division on the fixed main scale, is 7. Therefore, the two readings together give the barometer reading as 1002.7 hPa. Similarly, the barometer reading for Fig. 3(a) is 984.9 hPa. Enter this reading in the Meteorological Register, under the column “Bar as read”.

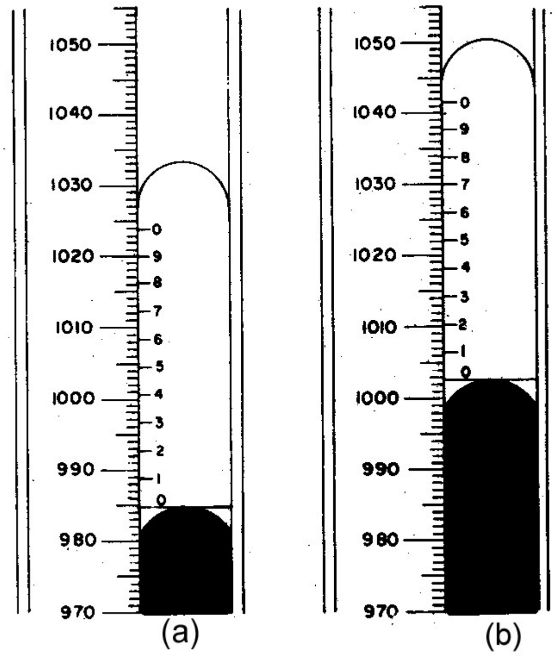

Fig. 3 Reading the Kew Pattern Barometer

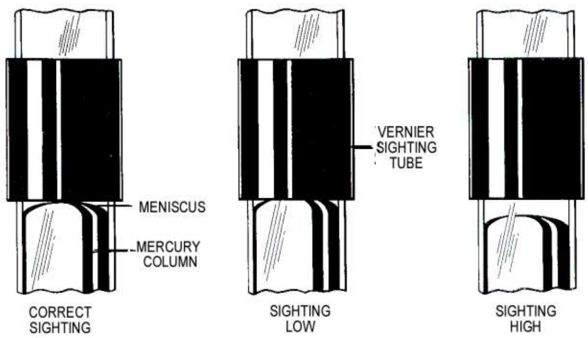

Fig. 4 Correct Adjustment of Vernier

(vi) **Always check the Reading: -** After entering it in the Meteorological Register. Be very careful to avoid errors of 5 or 10 hPa. When no Vernier division is in exact coincidence with a division on the fixed scale, the Vernier division nearest to coincidence should be taken.

2.1.2.2 Correction and Reduction of Barometer Reading –

The pressure values too be recorded in the registers and reported in the weather observation are obtained by applying the following corrections to the barometer reading taken as above.

(i) Corrections for Index error and for reducing the pressure to the standard temperature of 0°C or 285°A and to standard gravity of 980.665 cm/ sec^2. The resultant value denotes the pressure at the station level (reduced to the standard temperature and standard gravity.) at the time of observation and is to be entered in the appropriate column of Meteorological Register. This value is not to be reported in the observation.

(ii) Correction for reducing the station level pressure to the mean sea level for station whose elevation is less than 800 gpm* or to the geo-potential of the nearest standard pressure level (850, 700 or 500 hPa) if the station elevation is 800 gpm or above. This value is to be entered in the Meteorological Register and reported in the Weather observation under "**PPP**"

A set of Tables (Table I and Table II) called “Bar Reduction Tables” are supplied to each observatory to enable the Observer to apply the corrections described above. The use of these Tables is illustrated in the examples that follow. It should be specially noted that temperature read from the Attached Thermometer is to be used in Table I and Dry Bulb Temperature (from the Stevenson Screen) in Table II.

Cautionary Notes:

(1) Avoid wrong reading of the Vernier on the main barometer scale by 1hPa, 5hPa or10hPa. This is possible when observer is in a hurry and there is confusion in the reading of the markings. A comparison of the reading of the previous day will easily help detection of errors in reading of 5 or 10 hPa.

(2) Leave the setting of the Vernier scale of the barometer undisturbed after the observation to facilitate check when called upon by the weather office until the next observation.

(3) Avoid incorrect setting by following guidelines set forth in diagram Fig. 4 and sighting errors as depicted in Fig. 7. The correct eye level will be the position when the front Vernier bottom edge, the bottom edge of the sliding piece at back and the eye are in the same level.

(4) Always use an eyepiece for adjusting and taking readings.

* ′gpm′ stands for “Geo-potential Meter” which is equal to 0.98meter approximately

EXAMPLE I

REDUCTION OF PRESSURE READING TO M.S.L.

Station name – X

	Hb	1473ft. (448.97m)
	Barometer No. Correction for barometer	+0.1 hPa.

	OBSERVED READINGS:	
	Barometer reading, correct to 0.1 hPa	950.7 hPa .
	Attached Thermometer reading, correct to 0.1° (Absolute) (0°C= 273° A)	297.3°A
	Dry Bulb temperature corrected for index error and correct to 0.1°C	21.7°C
	REDUCTION:	
	Barometer as read	950.7 hPa
	Correction for index error	+ 0.1hPa
	Barometer reading corrected for index error.	**950.8 hPa**
	Barometer convention correction (if any) hPa	0.0
	Correction for standard temperature and gravity from { Table I (value corresponding to 960 hPa and 297.5° A)}	-4.3 hPa
	Station Level Pressure (Barometer reading corrected for index error etc.)	946.5 hPa Card Code 14-18 in MR
	Correction for reduction of station level pressure to Mean sea level from Table II {(value corresponding to 946.5 hPa. and 21.7°C by (x) ‘interpolation of pressure, Barometer reading reduced to M.S.L. (PPP)’}	+49.9 hPa. Card Code 14-18 in MR
	Correction for reduction of station level pressure to Mean sea level from Table II {(value corresponding to 946.5 hPa. and 21.7°C by (x) ‘interpolation of pressure, Barometer reading reduced to M.S.L. (PPP)’}	+49.9 hPa.
	Therefore, the final value of pressure for the station X	**996.4 hPa** **Card code 19-23 in MR**

* Hb = Height of barometer Cistern above mean sea level.

Extract from Table I for station X

Pressure (hPa.)

Attached Thermometer	940	960	980	1000	1020
°A	*Subtract*				
297.0	4.1	4.2	4.3	4.4	4.5
297.5	4.2	4.3	4.4	4.4	4.5
298.0	4.3	4.4	4.5	4.5	4.6

Corrections corresponding to 960hPa and 279.5° A= -4.3hPa

Extract from Table II for station X

Attached Thermometer	944	946	948	950	952
°C	*Subtract*				
20.1 – 21.0	49.9	50.0	50.1	50.2	50.3
21.1 – 22.0	49.7	49.8	50.0	50.1	50.2
22.1 – 23.0	49.6	49.7	49.8	49.9	50.0

(x)

(a) Interpolation corresponding 946.0 and 21.7°C = 49.8

(b) Interpolation corresponding 948.0 and 21.7°C = 50.0

(c) Interpolation corresponding 946.5 and 21.7°C$=\frac{a+(b-a)\times 0.5}{2}$

$$=\frac{49.8+(50.0-49.8)\times 0.5}{2}$$

c =49.85 or 49.9 hPa

EXAMPLE II

(REDUCTION OF STATION LEVEL PRESSURE TO THE GEO-POTENTIAL OF THE NEAREST STANDARD PRESSURE LEVEL WHEN THE STATION ELEVATION IS 800 GPM AND ABOVE)

Station – X

	Hb 2942ft. (896.7) gpm	(*Hb-895.0 gpm)
	Barometer No. Correction for index error	+0.1 hPa.

	OBSERVED READINGS	
	Barometer reading, correct to 0.1 hPa	908.6 hPa
	Attached Thermometer reading, correct to 0.1° A (0°C- 273° A)	291.1°A
	D. B. temperature corrected for index error and correct to+ 0.1°C	20.6°C
	REDUCTION:	
	Barometer as read	908.6 hPa
	Correction for index error	+0.1hPa
	Barometer reading corrected for index error	908.7 hPa.
	Barometer convention correction (if any) hPa	0.0
	Correction for standard temperature and gravity from} Table I (value corresponding to 900 hPa and 291.0° A)}	-3.2 hPa
	Station Level Pressure (Barometer reading corrected for index error etc.)	905.5 hPa Card Code 14-18 in MR
	Geopotential of the nearest standard pressure level i.e.850 hPa. from Table II. {The value corresponding to 905.5 hPa. and 20.6°C by interpolation of pressure(x)}	1440.3 gpm. Card code 19-23 in MR

Table I				Extract from Table II for Station – X					
Attached Thermometer	Pressure (hPa)			D.B. temp.	Pressure (hPa)				
	900	920	940		900	902	904	906	908
°A	*Subtract*			°C					
291.0	3.2	3.3	3.3	18.1 – 19.0	1384	1403	1422	1441	1460
291.5	3.3	3.3	3.4	19.1 – 20.0	1386	1405	1424	1443	1462
292.0	3.3	3.4	3.5	20.1 – 21.0	1388	1407	1426	1445	1464

(i) INTERPOLATION

(a) Geopotential corresponding to 940 hPa. and 20.6° = 1426

(b) Geopotential corresponding to 906 hPa. and 20.6° = 1445

(c) Geopotential corresponding to 905 hPa. and 20.6° =

$$= \frac{a+(b-a)\times 1.5}{2} \text{gpm}$$

$$= \frac{142 \quad (1445-142 \ )\times 1.5}{2} \text{gpm}$$

= 1426+14.25 gpm = 1440.25 gpm

= 1440.3 gpm

* Hp – Geopotential of barometer Cistern Level above mean sea level.

2.1.2.3 Care of the Barometer:

(i) Great care must be exercised in handling the barometer. **Care should be taken not to displace it from the vertical.**

(ii) The instrument should be lightly dusted every day with a small soft brush. It should never be rubbed with cloth.

(iii) The chief defects to which mercury barometers are subject to

- the entry of air into the space above the mercury.
- some mechanical defect of the Vernier-head. If the barometer is found defective, the Controlling Meteorological Office should be immediately informed by landline AMSS/email/Telephone/Mobile as desired. **The Observer should in no case try to rectify the defect himself unless specially instructed to do so.**

(iv) A barometer is so placed that there is always enough of natural light available for setting and reading the instrument. The sun should not shine on it directly during any part of time of year. If the instrument is found to be exposed to the direct rays of the sun at any hour of the day or season the Controlling Meteorological Office should be informed.

2.1.2.4 Installation: -

A barometer should be mounted in a room which is not subject to sudden or great changes of temperature or vibration. **A position near a window, against a wall of an unheated and little used room having a north aspect is very suitable.**

A backboard of wood is used for the suspension of a barometer. To facilitate readings, a piece of opal glass or white Perspex is fixed immediately behind that part of the tube where the readings are taken. It is desirable to erect the instrument at such a height that the Observer can read the Vernier comfortably when standing upright. The following instructions should be observed in mounting a barometer: -

(i) Select a suitable place on the wall of a room which satisfies all the necessary conditions of exposure of a barometer.

(ii) Draw a horizontal pencil line on the wall about 1.8 meters above the floor and another line below, the distance between the two lines being equal to the length of the barometer backboard.

(iii) Insert three wall–plugs about 15 cm. apart on each line and fix on to them to wooden planks approximately 90 cm. x 7.5 cm x 2.5cm suitably by means of screws. See that the wooden planks are parallel and horizontal and that the lower one is fixed vertically below the upper one.

(iv) Fix six 2.5cm screws on the upper plank, 15cm apart, leaving 7.5cm space on each side of the plank and mount the backboard of the station barometer on the third screw.

(v) Verify with a plumb line whether the backboard is hanging **vertically**. Then screw it tight to the lower plank.

(vi) Now mount the barometer on the peg attached to the backboard and see that the cistern of the barometer hangs freely inside the ring attached to the backboard.

(vii) Then tighten the screw of the peg and **gently** adjust the three radial screws **R1, R2 & R3** of the ring until they touch the cistern of the barometer and clamp is in a truly vertical position.

(viii) If the mercury sticks to the top of the barometer tube, give fairly sharp taps to the cistern with the pads of your fingers.

If the station has a spare barometer, it can be mounted on another screw of the upper plank. The other three screws are meant for hanging inspection barometer.

2.1.2.5 Shifting of Barometer: -

Barometer must be very carefully handled so as to avoid breakage or admission of air into the tube. **A BAROMETER MUST NEVER BE SHIFTED BY THE OBSERVER UNLESS AUTHORITY AND INSTRUCTIONS FOR DOING SO HAVE PREVIOUSLY BEEN RECEIVED FROM THE CONTROLLING METEOROLOGICAL OFFICE.** Usually an Inspector is sent by the Controlling Meteorological Office to install a new barometer or to shift the barometer to another position. The following instructions should be strictly followed in order in which they have been given the Observer is asked to shift the barometer in extraordinary circumstances.

(1) Unscrew the three radical screws R1, R2, and R3 of the lower ring A (Fig.2).

(2) Remove the locking screw L from the peg from which the barometer is suspended.

(3) Hold the barometer firmly in the right hand just below the attached thermometer and lift it clear of the peg and the lower ring with your left hand.

(4) Gradually tilt the barometer holding it in both the hands. The tilting must be very slow and gentle; otherwise the mercury will rise suddenly in the glass tube and may hit its closed end so hard as to smash it. Slow down the tilting more and more as the mercury rises in the tube until a click is heard. It is very important to note whether the barometer makes a ′click’ when it is been inverted because this sharp sound indicates that the vacuum (empty space at the top of the mercury column) is free from air. When the mercury has completely filled the glass tube, invert the barometer completely with the cistern end up-wards. The barometer can now be carried out safely in this inverted position. Keep the barometer carefully in this inverted position in some safe corner, taking care that the instrument does not fall down on account of its lower end slipping away, on the floor.

(5) Remove the backboard from the wall.

(6) Select a suitable place on the wall of a room which satisfies all the necessary conditions of exposure of a barometer. Fix the wooden planks on this wall as was done in the old site by first fixing wall plugs and insert six 2.5 cm. screws in the upper plank as per instructions (ii) to (iv) under Section 2.1.2.4 ′Installation ′. Mount the backboard of the barometer on the third screw. Verify with a plumb line whether the backboard is hanging vertically. Then screw it tight to the lower plank.

(7) Carry the barometer to the new site, in the inverted position (i.e. with the cistern end upwards) as gently and carefully as possible. Jerk should be avoided.

(8) Then holding the barometer firmly in both hands, the right hand being just below the attached thermometer, tilt the barometer very gradually into the vertical upright position again, so that its cistern is at the lower end. Be very careful that the instrument gets no jerks in this operation as otherwise the mercury may rise suddenly in the glass tube and may hit its closed ends so hard as to smash it.

(9) Holding the barometer firmly in hand, mount the barometer back on the peg so that the cistern of barometer is within the ring A and screw in the locking screw L.

(10) Carefully screw in the three radial screws (R1, R2, R3) of the bottom ring until they just touch the barometer when hanging freely and clamp it in this vertical position.

2.2 Temperature:

Temperature of a body is the condition which determines the ability to communicate heat to other bodies or to receive heat from them. Heat energy appeals to the sense of touch and the degree of hotness or coldness of a body is known as its temperature. In a system of two bodies, that which loses heat to the other is said to be at a higher temperature and is the hotter one. Meteorologists are interested in the temperature of the air, of the soil and of water bodies. Temperature is measured by means of a thermometer. A thermometer consists of a glass bulb containing a mercury / spirit connected with a glass tube of very small bore closed at the top. The rise or fall of mercury / spirit in the tube due to expansion / contraction of mercury / spirit is measured by calibrating the tube with standard temperature. Thermometers are graduated in different scales. The scale accepted for use in the India Meteorological Department is the Celsius scale giving temperature in degree Celsius.

2.2.1 Thermometers: - The thermometers to be read are: -

SN	Type of thermometers	Details
1	Dry – Bulb Thermometer	For obtaining temperature of the surrounding air.
2	Wet – Bulb Thermometer	This helps to find out the relative humidity of the surrounding air.
3	Maximum Thermometer	To indicate the highest temperature reached, since the time of its last setting.
4	Minimum Thermometer	To indicate the lowest temperature reached, since the time of its last setting.

All the above thermometers are exposed in a special type of shelter called the Stevenson Screen, which is described in detail Section 2.2.7. The procedure for reading these thermometers is given below:

(i) **Hours of Reading and Setting. -** The dry and wet bulb thermometers are to be read at each observation immediately before taking the barometer reading. The maximum and minimum thermometers are both to be read twice daily i.e., at the time of the routine morning (0830 hrs.) and afternoon (1730 hrs.) observation. As regards setting, both the maximum and minimum thermometers are to be set after the routine morning observation, while the minimum thermometer is to be set after the routine afternoon observations also. It should be noted that at the time of the routine afternoon observations, the maximum thermometer if only to be read without disturbing it in any way from its position in the Stevenson Screen.

(ii) **Order of Reading. -** Having let down the door of the Stevenson Screen**,** first read the dry bulb and wet bulb thermometers as **quickly** as is consistent with accuracy, so that they may not be heated by the presence of your body or your breathing directly on the bulbs. Then read the maximum and the minimum thermometers.

(iii) **What to Observe.** - In the case of the dry bulb, the wet bulb and the maximum thermometers, observe the position of the end of the mercury column (Fig. 5) but in the case of minimum thermometer note the position of the end of the dumb-bell shaped indexed **farthest from** the bulb (Fig. 6).

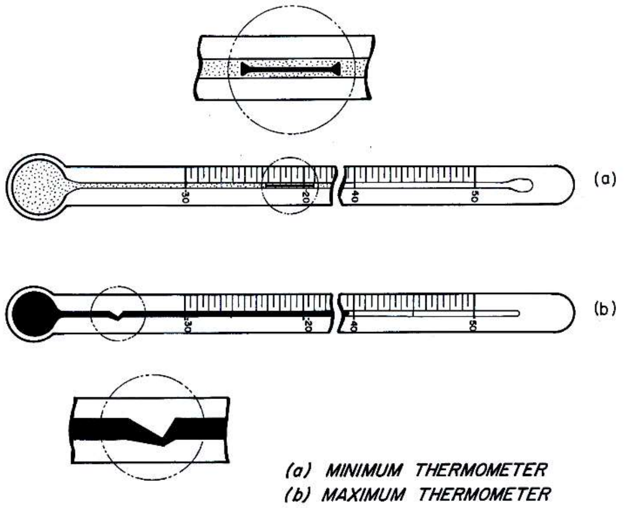

Fig. 5 How to Read Mercury Thermometers

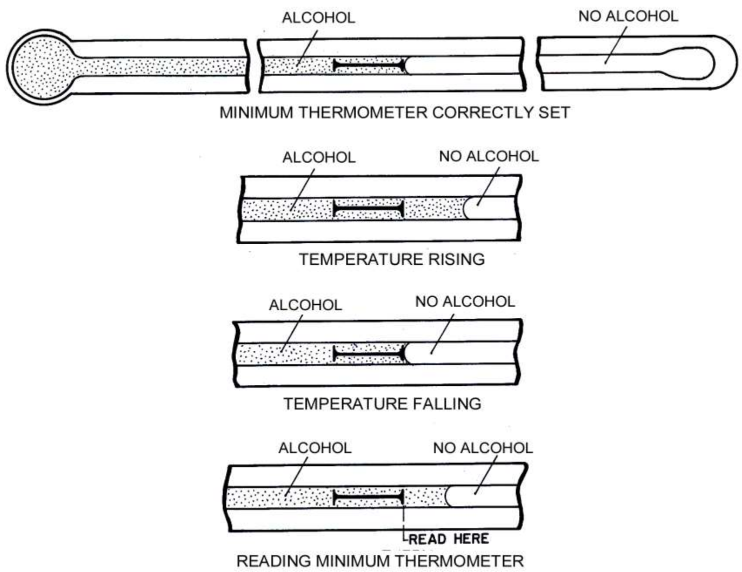

Fig. 6 How to Read Spirit Thermometers

(iv) **Sighting Error: -** While taking a reading make sure that the straight line joining your eye to the end of the mercury column (or index in the case of minimum thermometer is at rightangles to the length of the column. Errors due to wrong sighting may easily amount to as much as 0.5 degree (See Fig. 7).

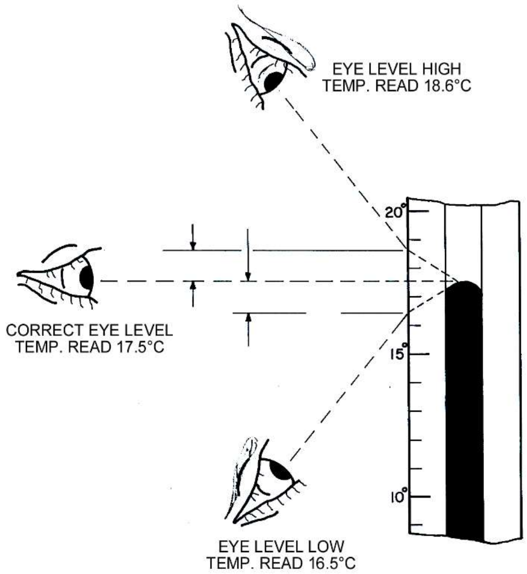

Fig. 7 Sighting Error

(v) **Degree of Accuracy: -** Read all the thermometers to the nearest tenth of a degree (Fig.7). **Always use the graduations etched on the glass stem of the thermometer and not the bold graduations on the porcelain scale on the thermometer mount.**

(vi) **Entry: -** Enter each reading in the appropriate column of the **Meteorological Register immediately** after it is taken.

(vii) **Check: - After** making the entry, **verify if the whole number of degrees has been read correctly.** Mistakes of ten or five whole degrees are thus avoided. The bold graduations on the thermometer mount are of help in this connection.

(viii) **Setting: - As** soon as the readings of the maximum and the minimum thermometers have been noted and checked at the time of routine morning observation, set the thermometers ready for the next observation. Similarly, after noting and checking the reading of the minimum thermometer at the time of the routine afternoon observation, the minimum thermometer alone is set.

Detailed instructions for the settings are given in Sections 2.2.3 and 2.2.4.

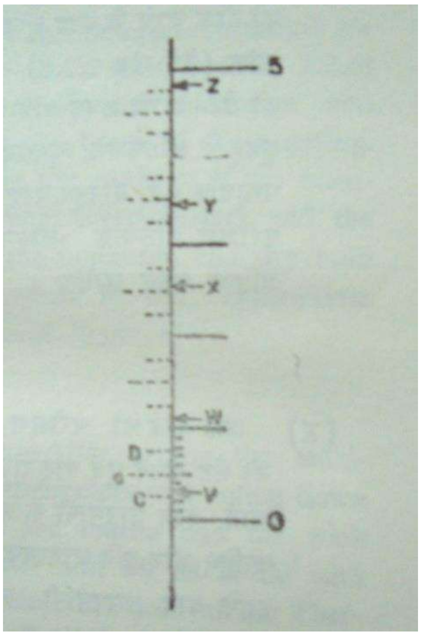

Fig.8 Subdivisions of a Degree

(ix) **Test Readings-** When set, the end of the mercury thread of the maximum thermometer and the end of the index of the minimum thermometer farthest from the bulb should indicate the same temperature as indicated by the dry bulb thermometer corrected for instrumental error. This check (See Section 2.2.6) must be applied daily for both the maximum and minimum thermometers at the times of their setting. After checking, the morning test readings of the maximum, minimum and dry bulb thermometers and the afternoon test readings of the minimum and dry bulb thermometers are to be entered in the appropriate columns of the Meteorological Register.

(x) **Examination of Wet Bulb–-** After setting the maximum and minimum thermometers and noting down the test readings, examine the **muslin** and the wick of wet bulb thermometer and **fill its bottle** water, if necessary. Then close the door of the Stevenson Screen. The muslin and the **wick** may be renewed if found necessary, as per instructions in para (ii) of Section 2.2.2.

NOTE: - When observing by artificial light take care not to heat the thermometer bulb with the lamp.

2.2.2. Mounting of the Wet Bulb Thermometer and its care: - The dry bulb and the wet bulb thermometers are precisely alike and usually having small bulbs which may be round or cylindrical. The bulb of the latter is always kept wet by means of a muslin sheath fed by water from a bottle through a wick.

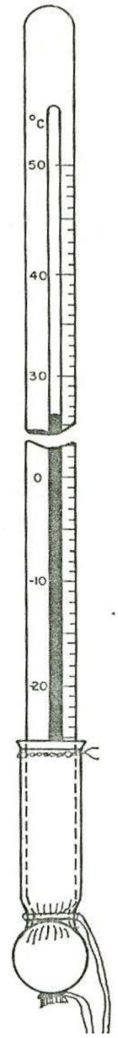

Fig. 9 Mounting of Wet Bulb Thermometers.

(i) **Mounting of the Wet Bulb Thermometer: -**The general arrangement of the Thermometer, wick and the water bottle are shown in Fig. 9. The bulb of the thermometer should be covered with only one single layer of thin and soft **muslin** supplied by the Meteorological Department. The muslin should first be washed in boiling water to remove all the starch. Before wrapping it round the thermometer bulb, it should be washed thoroughly in pure soap and water and rinsed several times in distilled water. Great care should be taken in handling the muslin and the thread to prevent contamination from the hand. Unless the muslin and the thread are completely free from grease, they will not keep moist, if the bulb is round, cut a circular piece of muslin about 3 cm. in diameter and take a suitable bag of it to be tied round the bulb. For a cylindrical bulb, rectangular piece of muslin may be sewn to form a close-fitting jacket around the bulb, next tie the muslin sheath round the neck by a piece of thread. See that that the muslin (only one-fold) is stretched smoothly over the bulb. After fixing the muslin, trim its edges carefully with a pair of scissors so that all the superfluous muslin with its loose ends is cut off, but take care that the muslin extends just a little up the stem above the bulb. For the **wick,** take **four** strands of darning cotton supplied by the Meteorological Department and loop them around the neck of the bulb over the muslin in the form of a noose (See Fig. 9) so that **eight ends** bang down into the bottle of water.

Take care not to fasten the wick too tight round the neck of the bulb, or otherwise the circulation of the water along the strands will be checked at this point. The bottle must have a small neck so that the air inside the screen may not be moistened by evaporation of water in it; alternately it should have a cover with a small hole through which the cotton strands pass.

The bottle must not be placed directly below the wet bulb but a little on one side of it away from the dry bulb; otherwise the thermometer may read too high. The part of the wick exposed to the air should be about 10 to 15 cm in length and must dip into the bottle without forming loops. If the wick is allowed to hang in a loop, water will drip down from the lowest point of the loop and the bottom will soon be emptied. In no circumstances should the stand of the wick cover the bulb, for there should be nothing else touching the bulb but muslin.

(ii) **Care of the Wet Bulb Thermometer. -**The bottle must always be kept free from dirt and filled with clean water. The water supply should be frequently checked and renewed. For this purpose, the Observer should store up rain-water in well corked bottles. If for any reason the stock of rain-water is exhausted and ordinary water has to be used, it must be boiled well and then left for a few days to allow all the impurities to settle down. The use of ordinary water unless distilled or boiled causes a coating of hard crust on the bulb of the thermometer, thus making its readings entirely unreliable. If a white deposit appears on the bulb of the thermometer, it should be removed by rubbing the bulb with vinegar or lemon juice,if the crust is thick, dilute nitric acid should be used.

Both muslin and the wick must always be kept clean and free from dust and grease. Any visible contamination should be considered an absolute indication of the necessity of replacement. They should therefore, be renewed at least **once a fortnight** in fine weather, **once a week** in dusty weather and immediately after a dust-storm.

(iii) **Management of Wet Bulb during Frost**. - The management of the wet bulb thermometer during frost or at times when the wet bulb reading is below 0°C requires considerable care and attention, as the supply of liquid water to the bulb may be cut off due to freezing of the water on the threads of the wick. It is therefore, necessary that when the wet bulb temperature is expected to reach a temperature 0°C and below, the Observer should make it a point to visit the Stevenson Screen at least half an hour before the hour of observation to examine the wet bulb thermometer. If he finds little or no difference between the readings of the dry and wet bulb thermometers, it is probable that the supply of liquid water to the bulb of the wet bulb thermometer has been cut off and there is no water or ice covering it. This is likely to happen particularly in dry windy weather. In such circumstances, the wet bulb thermometer should not be read until a new thin film of ice or supercooled water has been formed on the muslin as described below, and until the reading has fallen below that of the dry bulb thermometer and remained steady there.

The following procedure should be followed: -

Remove the wick and if there is a button of thick ice at the lowest part of the bulb, immerse it in water long enough to melt the ice. Moisten the muslin slightly with the **ice-cold water** by means of a feather or a brush. Excessive amount of water should not be used for moistening the muslin. An unventilated thermometer usually takes from a quarter to three quarters of an hour to reach a steady reading after the muslin is moistened, depending on the ventilation and the actual wet temperature. If more than the minimum amount of water is used it will take quite some time for the thermometer to attain a steady reading. Further a thick layer of ice may form over the bulb, preventing the mercury inside it from responding to the thermal changes in the air and thus introducing serious error in wet bulb readings.

After the muslin is moistened, the temperature may (1) either remain steady at 0°C, till all the water on the muslin has frozen to ice and then fall gradually to the true wet bulb reading; or (2) fall below freezing point but without the formation of ice, the water being super-cooled. In the formal case, the wet bulb will be covered with a thin coating of ice and in the latter by a layer of supercooled water. In either case the Observer should read the dry and wet bulb thermometers only when the readings have reached **steady** values. To determine whether the bulb was covered with ice or supercooled water, the wet bulb must be touched with snow crystal, a pencil or other object, just after the observation is completed. If the temperature rises to 0°C and commences to fall again, it can be assumed that the water on the wet bulb was supercooled at the time of observation; in that case, the dew point should be calculated from the Tables for use when the wet bulb is covered with ′Water′ in the I.M.D. Hygrometric Tables. If, however, the temperature does not go up, it means that the bulb had a coating of ice at the time of observation and the dew point should then be calculated from the Tables for use when the wet bulb is covered with **′Ice′** in the Hygrometric Tables.

NOTE**: -**(i) In warm dry weather water evaporates rapidly from the wick and there is danger of muslin being left dry. On the other hand, in damp cold weather, too much water may collect on the muslin and even drip down from the bulb. Both these defects tend to a high reading of the wet bulb thermometer; they should be avoided by adjusting the length of the wick exposed to air. Therefore, make it a point always to examine the muslin before reading the wet bulb thermometer.

(ii) The reading of the wet bulb thermometer should be taken as accurately as possible, as mistakes of a fraction of a degree in the wet bulb reading when it is below 0°C would introduce a large error in the calculation of the relative humidity values.

2.2.3 How to Set the Maximum Thermometer. -The bore in the stem of the Maximum thermometer is made extremely fine near the neck of the bulb. When the temperature of the air rises, the mercury in the thermometer expands and forces its way into the stem past this constriction; but when the bulb cools, none of the mercury above the constriction can get back into the bulb and the length of the mercury thread remains just the same as it was when the bulb was the warmest. The end of the mercury thread farthest from the bulb thus registers the maximum temperature reached.

To set the thermometer, remove it from its support and grasp the upper end of the wooden mount, keeping the bulb end downwards and taking care not to bring any pressure on the thermometer stem so as to break it. Then stretch out the arm and swing it briskly from the shoulder, beginning the swing **with the right arm raised more than 45 degrees above** the horizontal and ending about 30 degrees beyond the vertically down ward position (see Fig. 10). The swing must be vigorous but smooth.

FIG. 10 Setting of Maximum Thermometer

While swinging the thermometer, stand in a clear space and take care to see that the instrument does not strike anything (including your own person and clothing) and get damaged. It is advisable to hold one´s clothes with the left hand. Repeat the swinging till the thermometer bore on both sides of the constriction is completely filled with mercury. Then replace the instrument on its support in the Stevenson Screen keeping the bulb end about quarter of an inch lower than the other end. Verify if the thermometer reads nearly the same as the dry bulb. The maximum thermometer after setting should register the same temperature within 0.3° to 0.6°C as the dry bulb temperature when the temperature recorded by both the thermometers are corrected from respective index corrections. If not, the instrument must be at rest.

NOTE: - Before reading a maximum thermometer it is advisable to make sure that the end of the mercury thread nearest to the bulb has not run away from the point of constriction through vibration or otherwise; if it has, the thermometer should be tilted very gently, until the end of the detached thread comes in contact with the constriction of the tube.

2.2.4 How to Set the Minimum Thermometer. - The liquid inside the **Minimum Thermometer** is **spirit** in which is immersed a dumb- bell shaped index. When the temperature falls, the spirit drags the index along with it towards the bulb end; but when the temperature rises the spirit expands and runs past the index without disturbing it. Thus, the end of the index **farthest from the bulb** gives the lowest temperature attained by the instrument.

To set the minimum thermometer, remove it from its supports and tilt it slowly, bulb upwards, until the index touches the end of the spirit column (See Fig. 11). Tap the instrument gently if necessary. Now mount it horizontally in the Stevenson Screen and verify that it reads nearly the same as the dry bulb thermometer as in the case of maximum thermometer mentioned earlier. See that the instrument if fixed properly to its support so that the position of the index may not be disturbed by the vibration of the screen in strong winds.

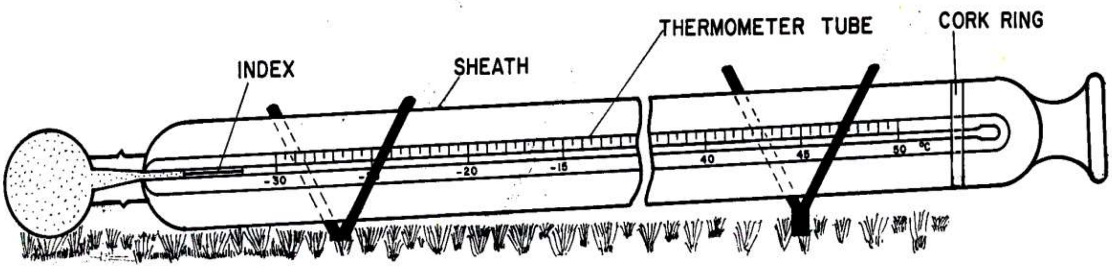

Fig. 11 Minimum Thermometer Correctly Set

NOTE: - Before reading the minimum thermometer **always examine the spirit column and make sure that there are no drops of spirit in the upper end of the tube and no air bubbles in the spirit column or in the bulb.** If the spirit column is broken or drops of spirit are lodged in the upper end of the stem, restore the column at once in accordance with the instructions given in Section 2.2.5. In such cases the remarks ′thermometer out of order′ should be entered in the Meteorological Register.

2.2.5 Defects in Thermometers and How to Remove them: -

(i) **Graduation Marks not Distinct: -** The thermometer graduations often become indistinct by use. To restore the graduation, rub lamp black oil or black lead pencil on the thermometer stem, which should be dry. Remove the superfluous black paint from the stem by gently wiping it with a piece of cloth on paper.

(ii) **Break in the Mercury Thread: -** A mercury thermometer, dry, wet or maximum, is considered defective if the mercury thread is broken anywhere. It is repaired simply by swinging the thermometer briskly at arm's length in the manner shown in Fig. 9, until the mercury thread is continuous.

A maximum thermometer is liable to go out of order and cease to be self-registering. The mercury may recede from its maximum position when the temperature falls below the maximum to a greater or lesser extent. This generally happens when, after use for some time, the constriction near the bulb is not sufficiently fine to prevent the mercury above it falling back into the bulb when the latter cools. The Observer should accordingly test the instrument occasionally by gently warming it by holding it in his palm and noting whether the mercury column retains its position in the tube, when the hand is removed from the bulb. The test should be made with the stem nearly horizontal. In the vertical position, if the column falls back into the bulb, the thermometer may still continue to be used.

If a maximum thermometer shows the above defect or reads about the same as the dry bulb thermometer, especially at the time of the routine morning observation for a few days in succession, it should be replaced by a spare thermometer and in the fact should be reported to the Controlling Meteorological Office for replacement of the defective instrument.

If at the time of the routine morning observations, the maximum thermometer reads less than its reading at the time of the routine afternoon observation on the previous day by 0.5°Cor more, for 3 days in succession it should be replaced by the spare thermometer available and the fact should be reported to the Controlling Meteorological Office for necessary action.

(iii) **Defects in the Minimum Thermometer:**

(a) **Drops of Spirit Lodged at the Top- A** portion of the spirit column may evaporate and condense in drops at the end of the thermometer farthest from the bulb. Unless the Observer regularly inspects the minimum thermometer, a length of spirit column covering 5 to 10 degrees may be lodged in this way at the top of the thermometer. To remove this defect, immerse the bulb and the **whole of the spirit** column of the thermometer, with the bulb end downwards, in a vessel of cold water; if necessary add some powdered ice to the water bath. Allow the sun to shine* on the upper part of the thermometer in which the spirit drops are lodged but not on the water bath which should be screened from the sun's rays. Leave the thermometer immersed in the water bath in this upright position for about an hour to allow all spirit to run down the tube.

If the bulb end of the minimum thermometer is even only very slightly higher than the farther end, it may cause break in the spirit column in the upper part of the tube. If drops of sprit frequently appear in the upper end of the tube, the bulb end of the thermometer should be lowered slightly, say, by 0.3cm. in order to prevent the same.

(b) **Break in the Spirit Column. -**The spirit column of a minimum thermometer is sometimes broken in to several fragments. To rectify this fault, swing the instrument briskly at arm's length in the manner shown in Fig.12 and stop it with a gentle jerk. It will sometimes be necessary to repeat the operation a number of times to unite the detached column entirely. After reuniting the broken columns by swinging, keep the thermometer immersed in cold water for at least an hour, exactly as in (a).

(c) **Index Protruding out of the Spirit.: -** The index is sometimes thrown out of the spirit and may stick in the upper part of the thermometer stem. In this case hold the Instrument vertically in the right hand with the bulb end lowest and gently tap the lower end of the thermometer mount against the palm of the left hand, as shown in Fig.12.

If several gentle taps fail to move the index, increase the force, a little at a time, until the index starts; then allow the index to fall of its own accord within the continuous column of spirit. Give gentle taps if necessary. Generally, this will be all that is necessary to set the index in the right place. Sometimes broken columns of spirit can be united partly or wholly by this process. If, however, repeated tapings do not succeed in displacing the index, turn the thermometer upside down so as to transfer the greater portion of the spirit column to the end farthest from the bulb. Then reverse the instrument and allow the index, to fall to the lower end of the transferred column of spirit. Restore the spirit column by repeated swinging's and finally keep the thermometer immersed in cold water for about an hour.

(d) **Index gone into the Bulb or Stuck in Bend above the Bulb. -** If the bulb and the stem is in the same straight line simply raise the bulb until the thermometer is vertical. Then gently tap the instrument and the index will slide down into the tube.

If the barometer is bent above the bulb, hold it **horizontally** with the bulb **pointing upwards**. Tap the bulb end of the thermometer sharply against the fleshy portion of your palm and then raise it upwards. The index will slide forward into the spirit column. Finally, leave the thermometer immersed in a cold bath as in (a).

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* On a cloudy day the upper part of the stem should be heated by applying a piece of cloth soaked in hot water.

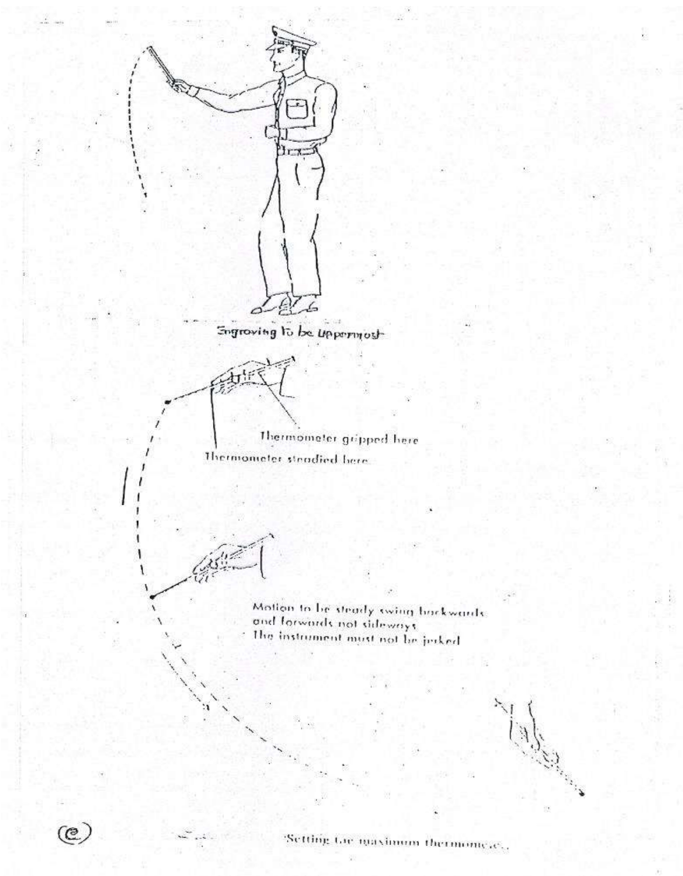


Fig.12 Repairing Minimum Thermometers

(e) **Bubble in the bulb**. - In this case hold the thermometer horizontally so that the bubble is against the entrance of the tube, then warm the bulb by grasping it with your palm until the bubble raises in the tube. Now shake out the bubble by swinging and finally leave the thermometer immersed in cold water.

NOTE: - The minimum thermometer is liable to the above faults during transit. Always examine the thermometer after taking delivery and remove any defects found in the thermometer in accordance with the foregoing instructions before bringing it into use.

2.2.6 Test Reading: -In order to detect any of the above defects, which would result in the instruments not recording correctly, **both the maximum and minimum thermometers should be compared daily with the dry bulb thermometer** at the times of their setting. These comparative readings are known as Test readings and are to be taken as follows: **-**

Immediately on setting the maximum and minimum thermometer after the routine morning observations, read the maximum, the minimum and the dry bulb thermometers quickly, one after the other in the order given. Make sure first, that the mercury column of the maximum thermometer and the spirit column of the minimum thermometer are both continuous, (i.e., there is no break in them), and be sure to record the readings of the index of the minimum thermometer, farthest from the bulb. This will be in flush with end of the spirit column. The time taken to read this thermometer should not exceed a minute or so. The actual readings should be entered without applying the index correction**.** Similarly, on setting the minimum thermometer after the routine afternoon observations, read the minimum and the dry bulb thermometers quickly one after the other, and enter both the actual readings.

The difference between the readings of the maximum and minimum thermometers and the readings of the dry bulb thermometer in the test observation after applying their respective corrections, should not exceed 0.3° and 0.6°C respectively. If the difference exceeds this limit (i.e., 0.3°C for maximum and 0.6°C for minimum) it is probable that the thermometer has become defective. The Observer should then carefully examine the maximum or the minimum thermometer, as the case may be, and remove the defect according to the instructions given above.

2.2.7 Care of the Thermometers: -

(i) The thermometers should be kept clean and the bulbs bright. If water has condensed on any of the thermometers it should be wiped off and several minutes allowed to lapse before the readings are taken.

(ii) Care should be taken to see that the ten-degree divisions marked on the thermometer porcelain mount agree with the corresponding graduations on the stem. After a period of use, the stem of thermometer may become loose and slip relatively to the mount, thus introducing a possibility of error in reading. Under no circumstances should a thermometer after repairs or adjustments, be fitted to amount belonging to another thermometer.

2.2.8 Exposure of Thermometers and Erection of Thermometer:

(i) The essential conditions for the exposure of thermometers, are that air should have free excess to the bulbs of the thermometers and neither the sun should shine nor rainfall on them. It is also important for purposes of comparison that the thermometers are exposed under similar conditions at all stations. These conditions are fulfilled by mounting the thermometers in a screen of the approved pattern called the Stevenson Screen. (Fig. 13).

Fig. 13 Stevenson Screen

(ii) It is a rectangular box with its sides and door double louvered and with a double layered roof with air space in between. The upper roof projects 5cms. beyond the size of the screen and slopes from front to back. Its internal dimensions are, length 56cms, width 31.5cms, and height 41.2cms. The front of the screen is hinged as a door and can be opened downwards. The screen is mounted on four wooden posts.

(iii) **Choice of Site for the Stevenson Screen**. - The site should be on a fairly large and open plot of level ground at least 30 m. in diameter; any site on a steep slope or in a hollow is subject to exceptional meteorological conditions and should therefore be avoided. The Stevenson Screen and the rain gauge should preferably be on the same plot and be enclosed by a rectangular fence 10 m. by 5 m. (See plan Fig. 14). The screen should be as far away as possible from large trees, buildings and **other obstructions to prevailing winds.**

The space set apart for the screen should be maintained, as far as possible in the same state, no shrubs or trees being planted within the area, nor changes made in the cultivation of the ground immediately surrounding the fence, particularly such which require a large amount of additional irrigation.

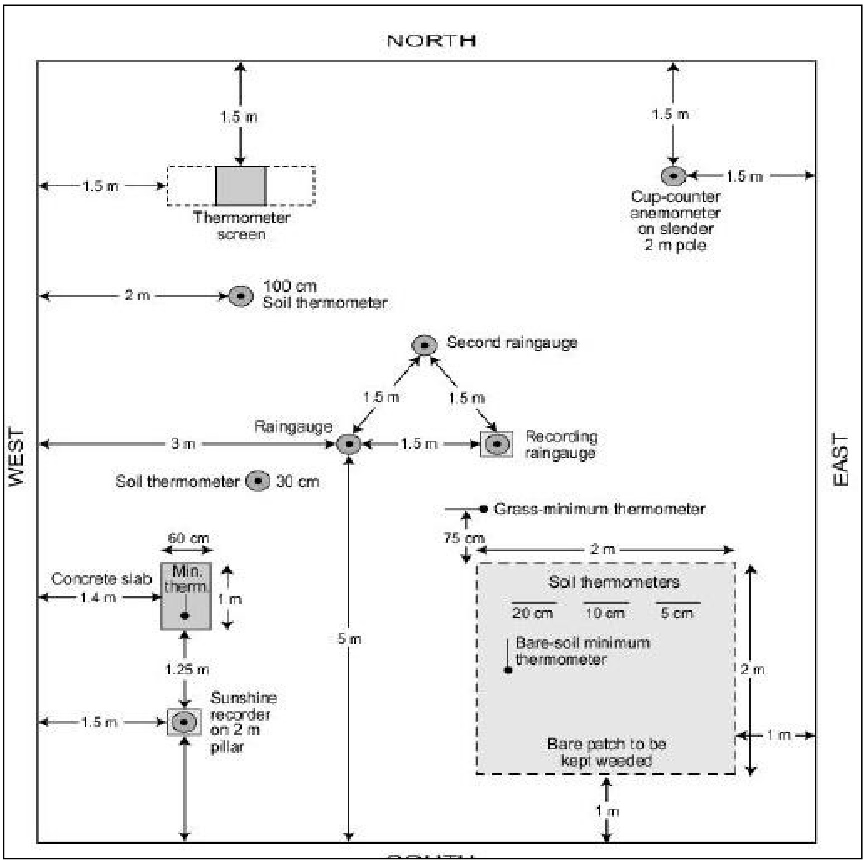


Fig. 14 Plan of Stevenson Screen and Rain gauge in Position and The Standard Barbed Wire Fence.

(iv) **Erection of the Stevenson Screen**. - The Stevenson Screen is to be erected on four stout wooden posts (See Fig. 13). with its **door opening to the north** and at such a height that the **bulbs of the wet and dry bulb thermometer shall be between 1.30 and 1.40 metres above the ground.**

The four ends of the wooden posts should be coated with coal tar and buried vertically in concrete under the surface of the ground so that the tops of the posts are 1.25 m. above the ground level. While erecting the Stevenson Screen, the concrete platform should be sunk 5cm. below the ground level and space above filled with earth to make it flush with the surrounding ground. An open concrete surface beneath the box is liable to result in erroneous readings of the thermometers inside the screen owing to the effect of radiation from such a surface. The distance between the post (marked 1,2,3 and 4) should be such that the corner legs of the screen (also marked 1,2,3 and 4) fit in easily in the sockets at the top of the corresponding posts. The number of a leg of the screen and the corresponding number on the post should face in the same direction.

Before fixing the post permanently by ramming the concrete, make sure that they are **perfectly vertical,** and their tops are **1.25 m. above** the ground and that the door of the Screen mounted on the post **faces north.** Then fix legs of the Screen in the sockets by means of 7.5cm screws.

Cautionary Note:

1. Always use the graduations marked on the stem of the thermometer itself to avoid errors due to improper alignment of the stem and the mount.
2. Ensure that the bulb of the wet bulb thermometer is free from encrustation and that the muslin and the wick are clean.
3. Do not pour water on the wet bulb or the bottle just before the observation finding the bulb dry.
4. Before closing the door of the screen after an observation ensure that the maximum and minimum thermometers are kept on their supports firmly after setting.
5. The Door of the screen should not be closed with a bang so as to jerk the thermometers inside.

2.3 Precipitation:

Precipitation, whether it is rain or snow is expressed as the depth to which it would cover a horizontal projection of the earth´s surface, if there were no loss by evaporation, run-off or infiltration and if any part of the precipitation falling as snow or ice were melted.

(a) Rainfall:

The simplest method of measuring precipitation is by setting up gauges with a horizontal circular aperture of known area, collecting and measuring at regular intervals the precipitation collected in them. It is assumed that the amount of precipitation collected in the gauge is representative of a certain area around the point where the measurement is made. The choice of the instrument and the site itself, the form and exposure of the measuring gauge, the prevention of loss of precipitation by evaporation and the effects of wind and splashing are some of the important points to be considered in the correct measurement of precipitation.

2.3.1 Measurement of Rainfall. -The amount of rainfall at a station is measured by a rain gauge. The standard rain gauge of the India Meteorological Department was the Symon´s pattern rain gauge used with specially graduated measure glasses. In 1969, the India Meteorological Department accepted the recommendations of World Meteorological Organisation for the use of Fibre Glass Reinforced Polyester (FRP) Rain gauge as the standard instruments at all rain gauge stations in the country.

Fig. 15 (i) FRP Rain gauge

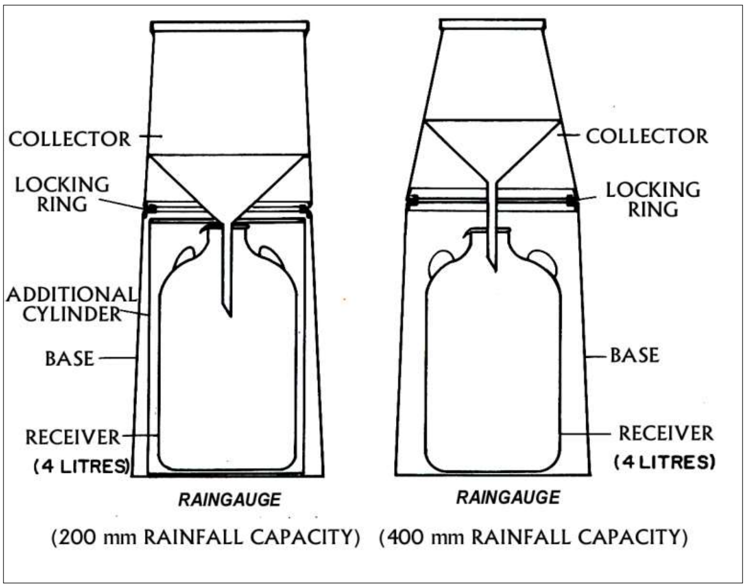


Fig. 15 (ii) Rain gauge 200mm AND 400mm Rainfall

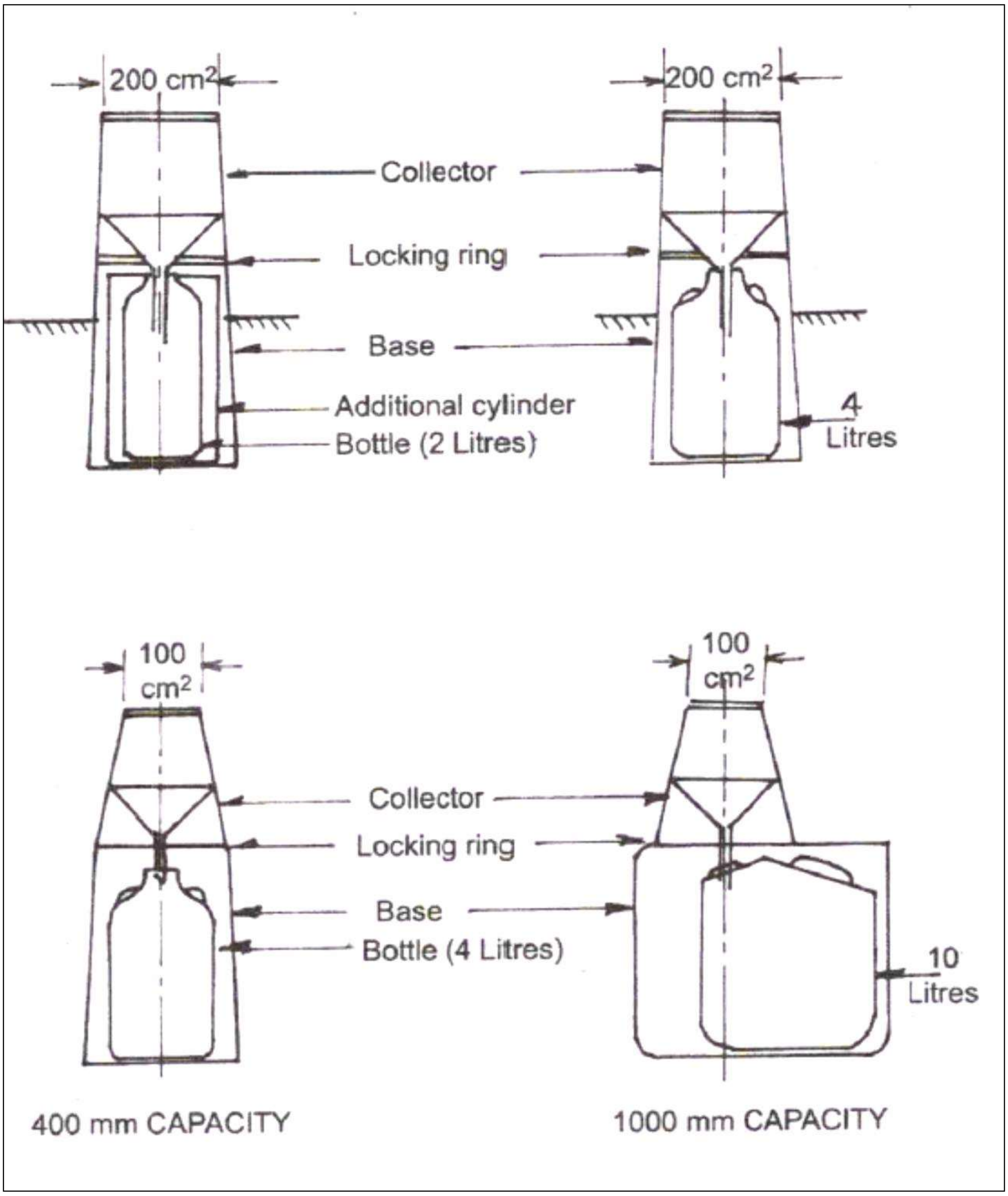


Fig. 15 (iii) Collectors of Different Capacity

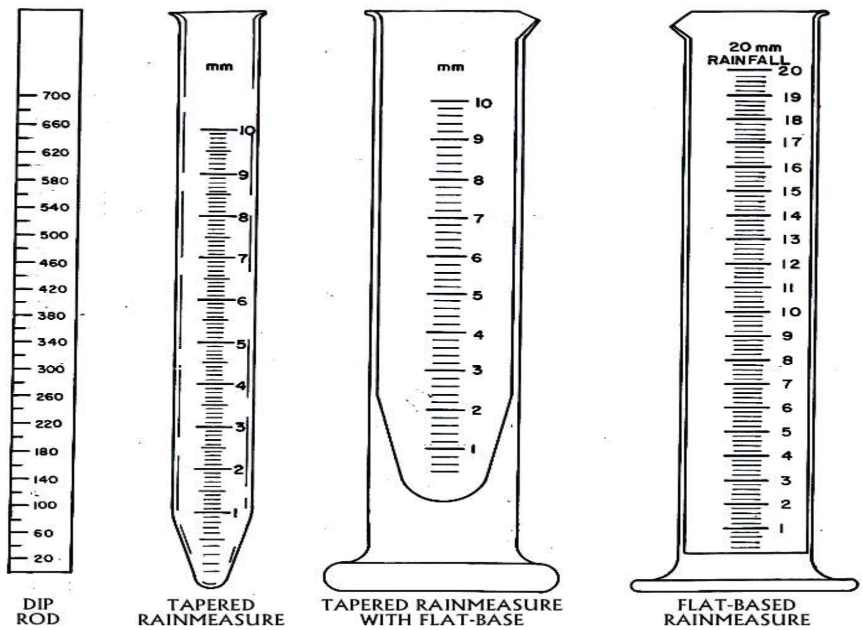


Fig. 15 (a) Measure Glass For 100 sq. cm Rain gauge (20 mm of rain)

The essential parts of a rain gauge are: (1) a collector with a gun metal rim of truly circular shape 100 or 200 sq. cm. area (2) a base (3) a polythene bottle and (4) a measure glass. Both the collector and the base are made of fibre glass reinforced polyester. Fig. 15(a) and 15 (b). The collector has a deep-set funnel and the complete rain gauge has a slight taper with the narrower portion at the top. The collectors have their apertures so designed that the 100 and 200 sq. cm. area ones are interchangeable. The smaller collector has a diameter of 112.9 mm corresponding to 100 sq. cm. and the bigger one is of 159.6 mm diameter corresponding to 200 sq.cm. There are also two types of interchangeable bases, the smaller base being used for all types of receivers except the largest. The rain falling into the funnel collects in the bottle kept inside the base and is measured by means of special measure glass which is appropriate to the area of the aperture and which is graduated in tenths of millimeter. This has usually a capacity of 20 mm of rain.

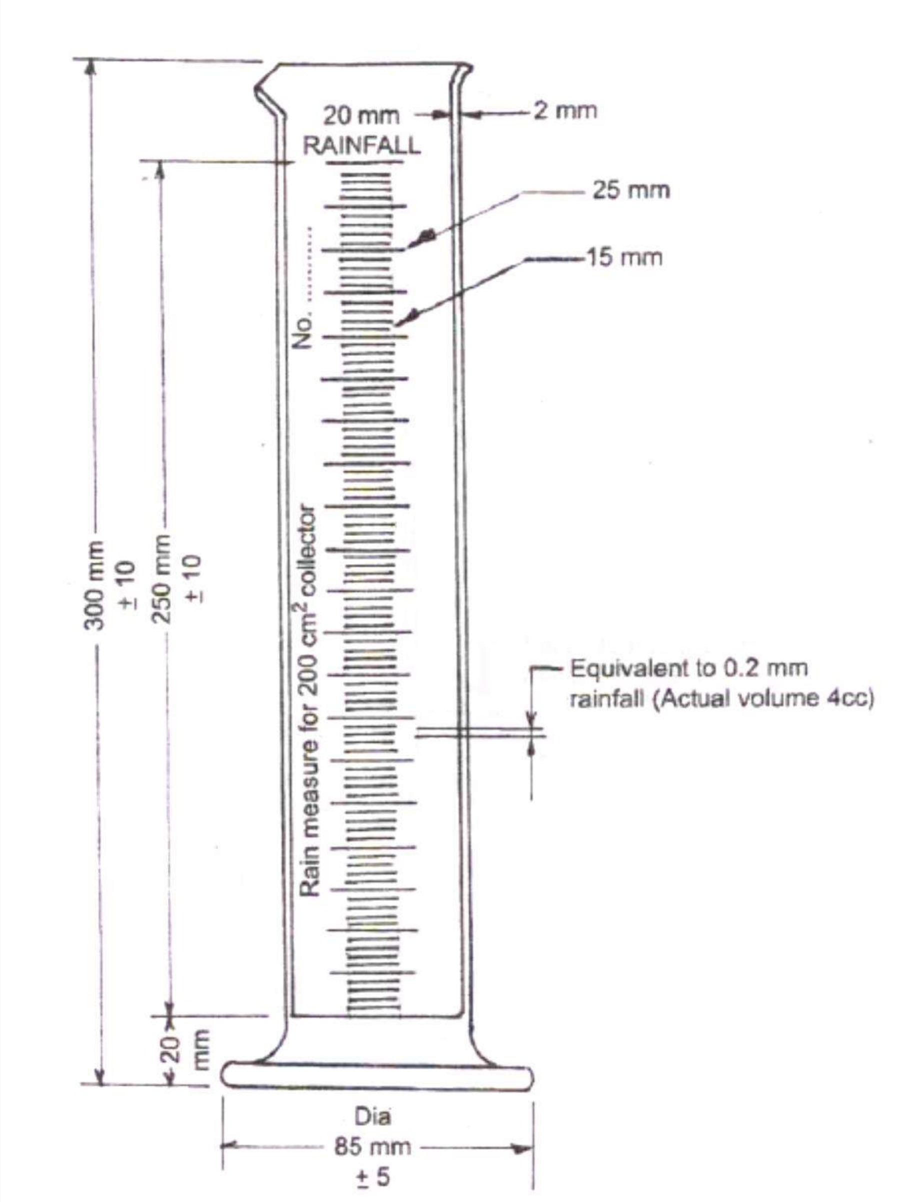


Fig. 15(b) Rain Measure For 200 sq. cm Collector

(i) **How to Measure the Rainfall. -**Remove the funnel of the rain gauge and take out the polythene bottle. Place the measure glass Fig. 15 (a) and (b) in an empty basin and slowly pour the contents of the receiver into the glass taking care to avoid spilling. If, however, any water is spilled into the basin, add it to the water in the measure glass before arriving at the total amount collected. While reading the amount of rain in the measure glass, hold it upright between the thumb and the first finger or place it on a table or other horizontal surface. Bring the eye to the level of the water in the glass and take the reading of the bottom of the meniscus or curved surface of the water. The amount of rain should be read in millimeters and tenths. It is extremely important to note that the correct type of measure glass appropriate to the type of the rain-gauge funnel in use should be used for measuring the amount of rain; otherwise completely wrong results will be obtained.

(ii) **Measurements by Installments. -** If the receiver contains more than 20 mm of rain, measure it in two or more instalments and add the amounts together for instance if the rain water fills 20mm glass to the top mark twice and the reminder measures 9mm at the third filling, the total amount of rainfall is (20+20+9) 49mm. In actual practice the glass need not be filled exactly to the 20mm mark as this can only be done by trials which require time. It is much quicker to fill the glass very near to the top graduation and note the actual reading at each filling. For example, 49 mm of rain may be measured in 3 or 4 instalments as indicated below:

15+14+10+10=49 mm

(iii) **Remeasurement for Check. -** To avoid error the rain water should not be thrown away after the first measurement but should be poured into a vessel and remeasured. **The amount should always be written down in the Meteorological Register and checked by remeasurement before the water is thrown away. ***

(iv) **Overflow of Rainwater. -** During heavy rain inspect the rain gauge at **frequent intervals** and measure out the rainfall or keep it in a bottle (if provided) securely corked for measuring at the time of observation, lest the receiver which can normally hold 400mm of rainwater, should overflow. If however, rainwater **has** overflown into the additional cylinder, this should be taken out carefully and its contents measured and added to the amount of water in the receiver. **If there are a number of occasions when it has over flown the Controlling Meteorological Office has to be informed and a receiver of larger capacity asked for.**

* N.B.: - If your stock of rainwater for the wet bulb is not sufficient, store up more water in well-corked bottles (See Section 2.2.2)

(v) Snow or Hail. -On days of snowfall or hail or when the water collected in the gauge is frozen, remove the bottle with the collector and pour into it a measured amount of warm water (as measured with the measure glass) to melt the ice or snow. After it has completely melted, measure out the total amount of water in the bottle and subtract from it the amount of water added. When the precipitation is in the form of sleet or snow, any snow immediately above the collector should be separated and pressed in to the collector. This snow should be melted as described above and the water equivalent obtained. The amount of water (actual rain or thawed snow) already in the bottle shall also be measured. The sum of these two in mm gives the amount of precipitation when the snowfall is heavy. The readings of the rain gauge will be unreliable in the event of the gauge being entirely buried in snow or the snow being blown away by wind.

If, however, the fall of snow is so great as to bury the gauge completely, or snow appears to have been blown out of the gauge by wind, the depth of fresh undrifted snow must be measured by plunging vertically a rod or stick into the snow at two or three places over any fairly level plot of ground. **Care should be taken to measure only the depth of snow fallen during the interval since the gauge was last read.** The mean of several measurements made in different places should be taken. To convert depth of snow into mm of rainfall 100 mm of snow may be taken as roughly equivalent to 10 mm. of rain.

NOTE: Detailed instructions for measurement of snow are given in Section 2.3.5.

(vi) **Accidental Breakage of the Measure Glass.** —Two measure glasses are supplied to each station, one for use and one to be kept as spare. In case the glass in use is broken, the spare one should be brought into use and a replacement obtained, for the broken one through the Controlling Meteorological Office. If it should so happen that the glass is accidently broken and there is no spare, borrow and ordinary compounder´s measure glass and record the rainfall in milliliters (i.e. cc) until a new glass is received. In such cases, take care to note in the Meteorological Register the word ´Millimeters' against the rainfall entry. Do not, on any account, borrow a rain measuring glass belonging to another rain gauge. If a compounder´s measure glass is not available, store up in separate bottles, the rainwater collected at different hours of observation. Keep the bottles well corked and place a label on each indicating the date and hour of collection of the rain-water. On the receipt of new glass, measure these amounts and enter them in the Meteorological Register as usual.

(vii) **Hours of Measurement and Entry of Rainfall in the Meteorological Register: -**

(1) Examine the rain gauge receiver for rain daily at every hour of observation. Enter the amount of rainfall measured at each observation in the appropriate column of the Meteorological Register. This indicates the amount of rain which actually fell during the period between the last observation (regular or special) and the present observation. The rainfall is to be entered in millimeters and tenths of millimeters. Enter 0.0 for no rain and a 't' (Meaning trace) for rainfall below 0.1 mm.

If during heavy rain it is found necessary to measure out the rain several times between any two observations, take the last measurement at the exact hour of the second observation and enter in the appropriate column the total of all the measurements made during the intervening period.

(2) There is one column of the Meteorological Register that is to be filled in only at the time of routine morning observations. It gives the total amount of rain which fell during the preceding 24 hours (i.e. from 0830 hrs. IST of the previous day till 0830 hrs. IST of the present day) and is obtained by adding all the measurements made during this period.

NOTE: - In case of snow or hail, the solid precipitate should be melted and resulting water measured as rain.

(viii) **Care of the Rain gauge and Rain Measures. -**

1) It should be ensured that the collector of the rain gauge does not get choked with dirt and that the receiving bottle and additional cylinder, if any, are always clean. They should be emptied regularly of sediment or other material that may have fallen into them and cleaned periodically.

2) The outer surface of the visible portion of the rain gauge should also be kept clean by wiping it occasionally with a wet cloth. The rain gauge does not need any painting and this should not be attempted at any time.

3) The collector, receiving bottle (and additional cylinder if provided) and the base should be examined for leaks regularly. If found to be leaking, they should be repaired either locally if possible with the aid of the repair kit or replaced by fresh components.

4) While replacing the collector on the base it should be ensured that the two locking rings have engaged properly. The locking ring fixed to the collector and base are delicate and should not be handled roughly.

5) Care should be taken not to dent or deform the gun metal rim of the collector by rough handling.

6) The rain-gauge should always be kept locked for safety.

7) The grass round the gauge should be kept short. No shrubs or plants should be allowed to grow round the gauge.

8) Both the rain measure glasses should be kept spotlessly clean. They should be handled gently to avoid breakages and stored dry in a safe place when not in use. Always wipe it dry before leaving it in the Stevenson Screen after use. This is very important in freezing weather when there is a risk that the it may become frozen to the wood by any residual water left adhering to the base.

2.3.2 Repair Kit for Minor Repairs to the Raingauges:

Each station shall have a small repair kit to carry out minor repairs. The repair kit consists of two solutions A and B, solution A being the Get coat and solution B the Hardener, a small quantity of chopped strand mat and little bit of surface mat. The kit is useful in patching up external cracks and crevices of the fibre glass material and for attaching any broken pieces like the funnel outlet tube and for covering up any external portions which have chipped off. The use of the repair kit is not recommended for any patch work in the internal surfaces which may spoil its smooth finish and prevent the smooth flow of water.

The repair may be done according to the procedure given below: -

(a) Clean and file, if necessary, the portions where repairs are necessary.

(b) Mix solutions A and B in the proportion of 100: 3 using a spatula or a metal or glass rod. (**Note**: Only small quantities of the mixture shall be prepared at a time as the mixture hardens very quickly. About 50 to 100 gms at a time should be adequate.)

(c) Apply a small quantity of the mixture over and around the required place and allow it to harden. Cut small bits of the chopped strand mat and place them over the spot, using a 1" brush. Apply by dabbing the prepared mixture of the solution A and B over the chopped strand mat, till it is completely wet. Allow this to harden.

(d) For obtaining a finer – finish the surface mat may be used and wetted by dabbing it with the prepared mixture as was done for the chopped strand mat.

(e) Now clean the container, the spatula and the glass or metal rod, used for preparing the mixture of the two solutions. The brush may also be cleaned. These can be cleaned with water, dried and kept aside for use once again when necessary. The bottles containing solutions A and B be should kept tightly closed to avoid hardening and evaporation respectively.

Caution. -Avoid the solutions from getting in contact with the eyes and do not allow the chopped strand mat or surface mat from coming into contact unnecessarily with the body. They cause irritation to the skin.

2.3.3 Exposure of Rain gauge: The amount of precipitation collected in a rain gauge depends to a considerable extent on its exposure and great care must be exercised in selecting a suitable site. The rain guage should be set on a level ground away from trees, buildings and other obstruction and not upon a slope or terrace. The distance between the rain gauge and obstacles should be as far as possible 4 times the height of the obstacle. **In any case, the distance between the rain gauge and the nearest object should not be less than twice the height of the object above the rim of gauge.**

Subject to the above conditions position sheltered from the wind is preferable to an exposed one.

In order that observations at different stations are comparable, the exposure must be as uniform as possible at all stations. The rim of the rain gauge should be exactly horizontal and remain at a height of **30 cm. above the ground level.** This rule must be strictly adhered to in the erection of the instrument. The site of the Stevenson Screen should be so chosen that the rain gauge can be placed on that plot of ground at a distance of 3.6 m. from the screen to its south. See plan of observatory enclosure Fig. 14.

2.3.4 Erection of Rain gauge: The rain gauge should be fixed on a masonry or concrete foundation 60 x 60 x 60 cm sunk into the ground (Fig. 16). The base of the gauge should be embedded in the foundation as shown in the figure, so that the rim of the gauge is exactly 30cm. above the surrounding ground level. This height is necessary to prevent more than a negligible amount of rain splashing into the gauge from the surrounding ground. If the height exceeds 30cm limit, a positive correction to the catch of the rain gauge will be necessary, since the catch decreases owing to wind eddies set up by the gauge itself.

The rim of the gauge should be kept perfectly level. The horizontality should be checked with spirit level laid across the rim.

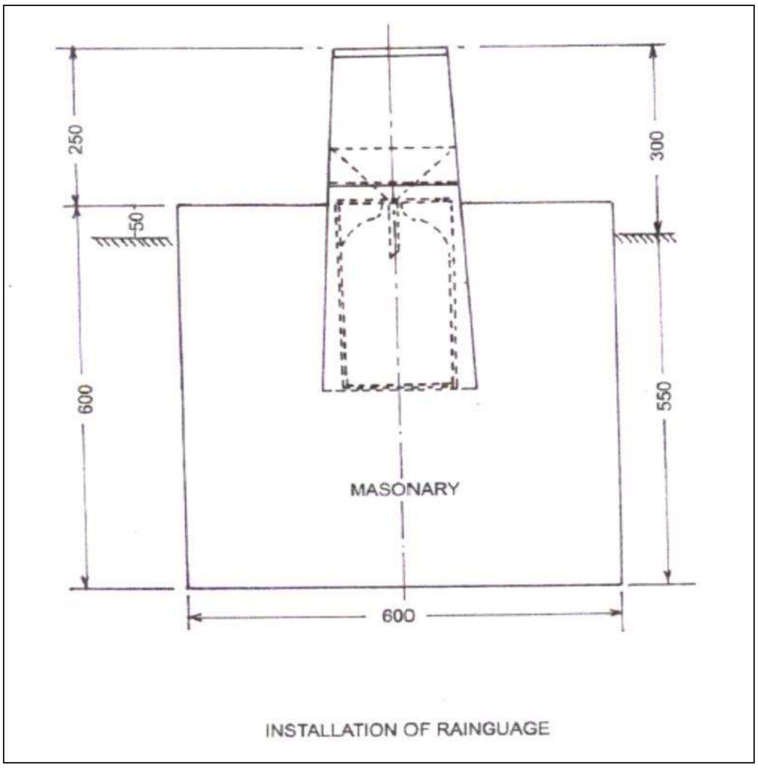


Fig. 16 Installation of Rain gauge

2.3.5 Measurement of Snowfall:

Snowfall is measured either as the depth of snow which has fallen in a stated period, or melted and measured as water. The depth of snow is usually measured in millimeters and its water equivalent in millimeters and tenths obtained by dividing the snow depth by 10, assuming the density of snow as 0.1. This value is however, only a rough approximation and varies very much with the depth and texture of the snow. For accurate measurement of precipitation at stations where snowfall is likely, special snow gauges are used. A snow gauge consists of a cylindrical receiver 203 or 127 mm in diameter, mounted on an iron stand at such a height provided with wind shields. Unshielded gauges are quite unreliable in strong winds because their catch may either be increased by drifting snow or blown off by the wind eddies around the mouth of the gauges. At stations where snow gauges are not available, the snow is measured with the ordinary rain gauges if the snowfall is light. In heavy snowfalls, the depth of snow is measured with snow poles and water equivalent of snow determined; or cut samples of snow taken, melted and measured as water in the ordinary 127 mm measure glass.

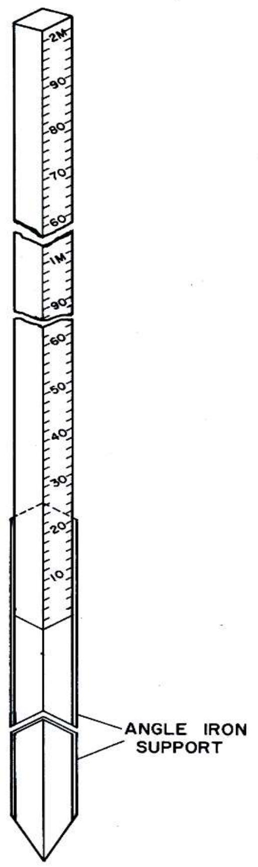


Fig. 16a Snow Pole

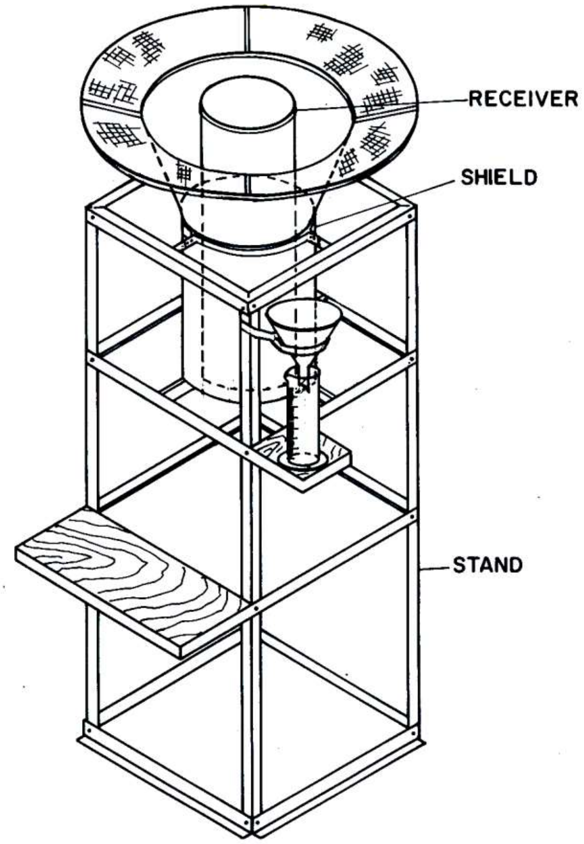


Fig. 16b Snow gauge on a stand

2.3.5.1 Measurement of Snowfall at Observatories Provided with I.M.D. 203 mm or 127 mm Snow gauges.

Detailed instructions for the installation and use of the I.M.D. Snow gauges are given in a separate circular supplied along with the snow gauge. The following general instructions should be followed for the measurement of snowfall.

Remove the receiver from the wind-shield and pour into it a measured amount of very warm water. Since a large excess of water increases the error arising from the decrease in the volume of water with fall of temperature, only sufficient water to melt the snow in the receiver should be added. The warm water when first measured into the measure glass, should be poured slowly so as not to crack the glass. When the snow is completely melted, measure out the total amount of water in the receiver into the empty measure glass. Subtract from it the amount of warm water added. This gives the amount of precipitation in millimeters and should be entered in the Meteorological Register. Whether the precipitation thus recorded consists of snow or rain or both, should be made clear by a suitable entry in the remark's column.

2.3.5.2 Measurement of Snowfall at Observatories which have only a 100 Sq. Cm. Rain gauge.

(1) During light snowfalls the amount of snow collected in the rain gauge should be melted by adding warm water and the quantity of water measured and recorded as described in the previous paragraph.

(2) During heavy falls the readings from the rain gauges will be unreliable because the gauge may be entirely buried in snow, or on the other hand, the snow may have been blown out by wind or eddies generated by winds. During periods of heavy snowfall, the Observer should make one of the following three separate measurements: -

(a) **With the 100 sq. cm. Rain gauge:** When the precipitation is in the form of sleet **or** snow,

(i) Any snow immediately above the funnel should be separated and pressed into the funnel. This snow should be melted as described above and the water equivalent obtained.

(ii) Measure the amount of water (actual rain thawed snow) already in the receiver. The sum of these two in millimeters and tenths will give the amount of precipitation and should be entered in the register.

The usual remarks about the snow or rain or both should be given in the remarks column of the register.

(b) **Depth of fresh undrifted Snow, when the Precipitation has occurred as Snow: -**The depth of snow may be obtained by taking a mean of several vertical measurements in places where there is no drifting of snow, using a graduated ruler or scale. Care should be taken to measure only the depth of snow which has fallen, since the previous hour observation. Special precautions should be taken not to measure any old snow. This can be done by selecting a suitable material (wooden boards or white painted metal sheets about 1-meter square) and placing it on top of the snow surface after taking the earlier observations and measuring the depth down to this material at present. On a sloping surface, measurements should still be made with the measuring rod verticals. Divide the depth of snow thus obtained by ten and enter this amount in millimeters and tenths in the register.

(c) **Cut Sample Method: -**To be used only when there has been no sleet or rain and the snow has not melted: A cut sample of snow is obtained by inverting the body of the rain gauge over the snow where its depth appears to be uniform and about the average amount. To avoid collecting old snow, small wooden or stone floors may be used and the body of the raingauge pressed down into the snow till its edge touches that floor. Slip a thin plate under the body, remove the cylinder of snow thus cut out, melt it by adding a measured quantity of warm water from the measure glass and record the water equivalent as described earlier. This method can be adopted only when all the precipitation has occurred in the solid form.

2.3.5.3 At Observatories, where there is an I.M.D. Snow gauge as well as a Rain gauge: -Precipitation should be measured only in the snow gauge on days of snowfall or when there is both rain and snow.

NOTE: - Special care should be taken to use the proper measure glass for measuring the precipitation. At stations provided with both the 203 mm. snow gauge and 127 mm. rain gauge two different measure glasses will be available for use with each of the instruments. The appropriate measure glass should be used with each instrument.

2.4 WIND

Wind is defined as air in motion and is expressed in terms of direction and speed. Wind direction is regarded as the direction from which it blows and speed as the rate of movement of air in its instantaneous direction.

Wind direction is determined with reference to true North and is expressed to the nearest 10 degrees or to 16 points of the compass (Fig.17). Wind speed is measured in knots (nautical miles per hour) or in kilometers per hour.

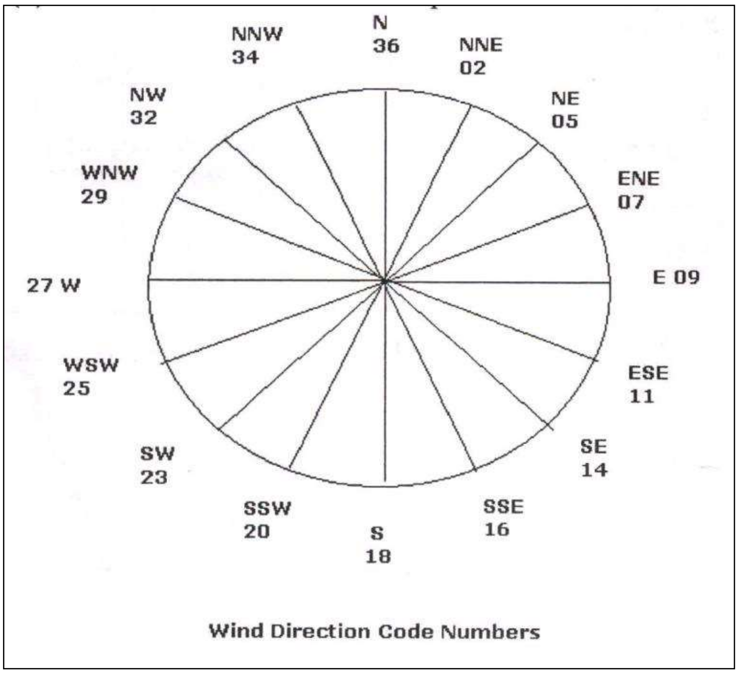


Fig.17 Points of the Compass

2.4.1 Wind Direction. -The wind direction is given by an instrument called the Wind vane (Fig.18). It is a balanced lever which turns freely about its vertical axis. In the most common type, one end of the lever exposes a broad surface to the wind, whilst the other end is narrow and points to the direction from which the wind blows. Under this movable system is fixed a rigid cross, the arms of which are set to the four cardinal directions – North, East, South and West. Some windvanes are provided with eight direction indicators, N, NE, E, etc.

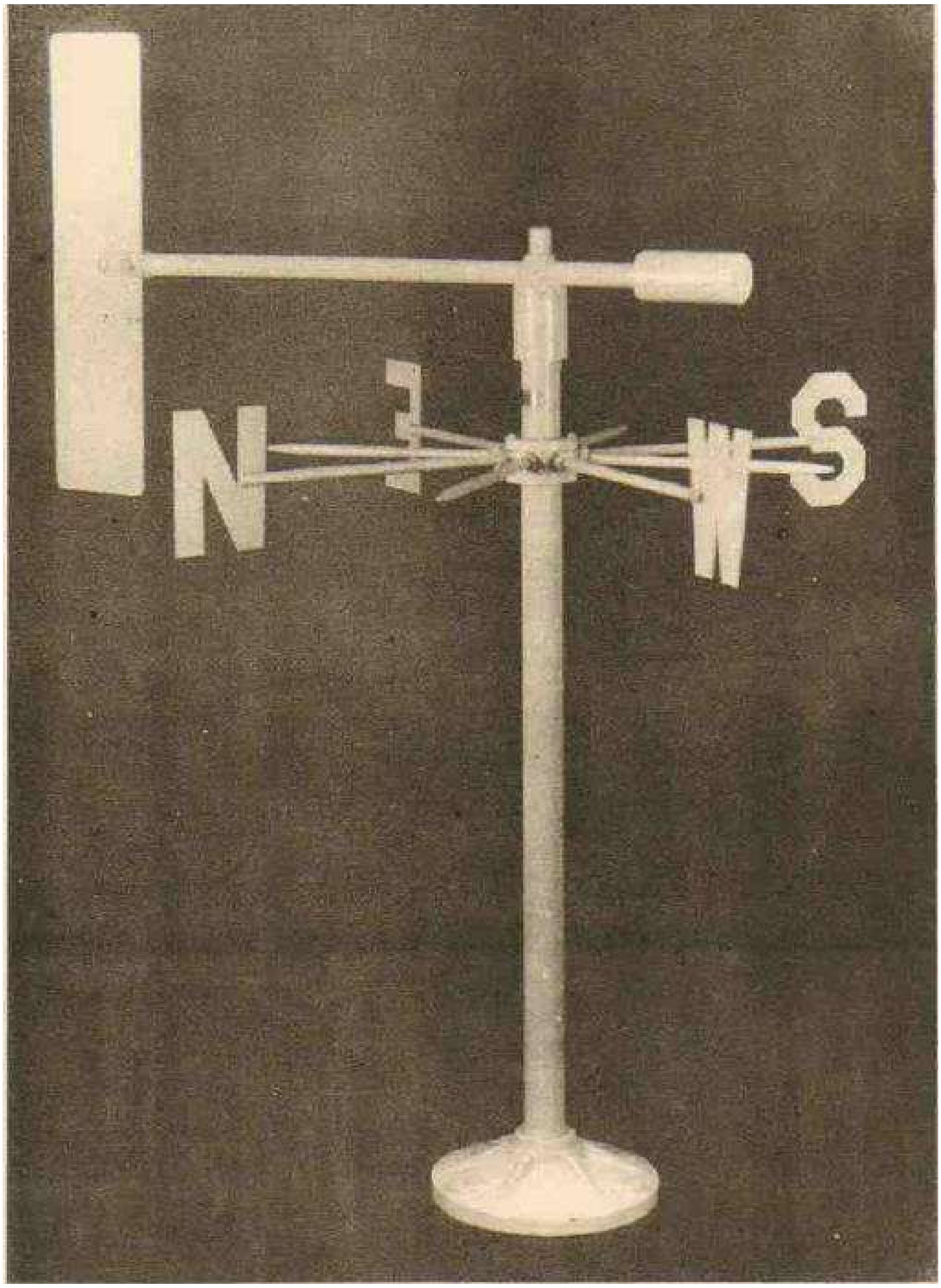


Fig. 18 Windvane MK-II

Direction	Code	Figures	Direction	Code	Figures
North	N	36	South	S	18
North-north-east	NNE	02	South-south-west	SSW	20
North-east	NE	05	South-west	SW	23
East-north-east	ENE	07	West-south-west	WSW	25
East	E	09	West	W	27
East-south-east	ESE	11	West-north-west	WNW	29
South-east	SE	14	North-west	NW	32
South-south-east	SSE	16	North-north-west	NNW	34
			Calm.. .		60

2.4.2 Windvane - Mk II. —The windvane (Fig.18) consists of a horizontal aluminum arm (1) carrying a fin (2) at one end and counter balanced about its axis of rotation by means of cylindrical mild steel balance weight (3) having much smaller surface. The vane consists of a flat plate and exposes a broad surface to the wind whilst the other end is narrow and points to the direction from which the wind is blowing. The rotating arm is supported by an arm support (4) The entire assembly being mounted over a cap (5) housing a ball bearing. The horizontal arm is firmly attached to the bearing housing cap (6) by means of a guide pin (7) so that there is no relative movement between the two. Below the bearing housing cap is the top ball bearing (8) housed within the support tube (9). The spindle (10) is a brass rod freely rotating in the ball bearing (11) at top and another lower ball bearing (12) below, with the top end projecting out through the arm support. It carries at its top extreme a top nut. (13) The spindle is firmly fixed to the bearing housing cap by means of a brass by-retaining screw (14) so that when the horizontal arm moves the spindle also rotates along with it in the ball bearings. The support tube (15) is attached below to a mounting ring (16) which carries the four cardinal direction arms (17) and the four inter cardinal arms. (18) The mounting ring rests on a collar (19) at the top of the main support (20) and can be rotated and fixed on it in any desired direction by means of four set screws (21). At the lower end the main support tube is attached to an aluminum base casting (22) provided with three holes for taking the foundation bolts.

The entire windvane can be installed in the beginning irrespective of its orientation with respect to the true north. The correct orientation of the direction arms with respect to the Geographic North is done by loosening the four set screws (18) on the mounting ring, rotating the ring suitably and refixing it correctly by tightening the screws. It is not necessary to grout the foundation bolts themselves very accurately in order to achieve proper orientation of the instrument.

(a) **Exposure** —The wind vane must be freely exposed and be high enough above buildings and trees so as not to be affected by the eddies created by them. In a very open site >the vane can be installed on a steel or wooden lattice tower or mast 6 meters high and well guyed, within the observatory enclosure. Where the site is obstructed by trees etc., it may be erected on a building or a high mast so that it is higher by at least 3 meters than the highest obstacle in the immediate vicinity. If this requirement would necessitate a very high mast in the observatory enclosure, a separate site for the mast should be selected, such as the roof of a building. When both the anemometer and the windvane are fixed on the same platform they should be at least 2 meters apart.

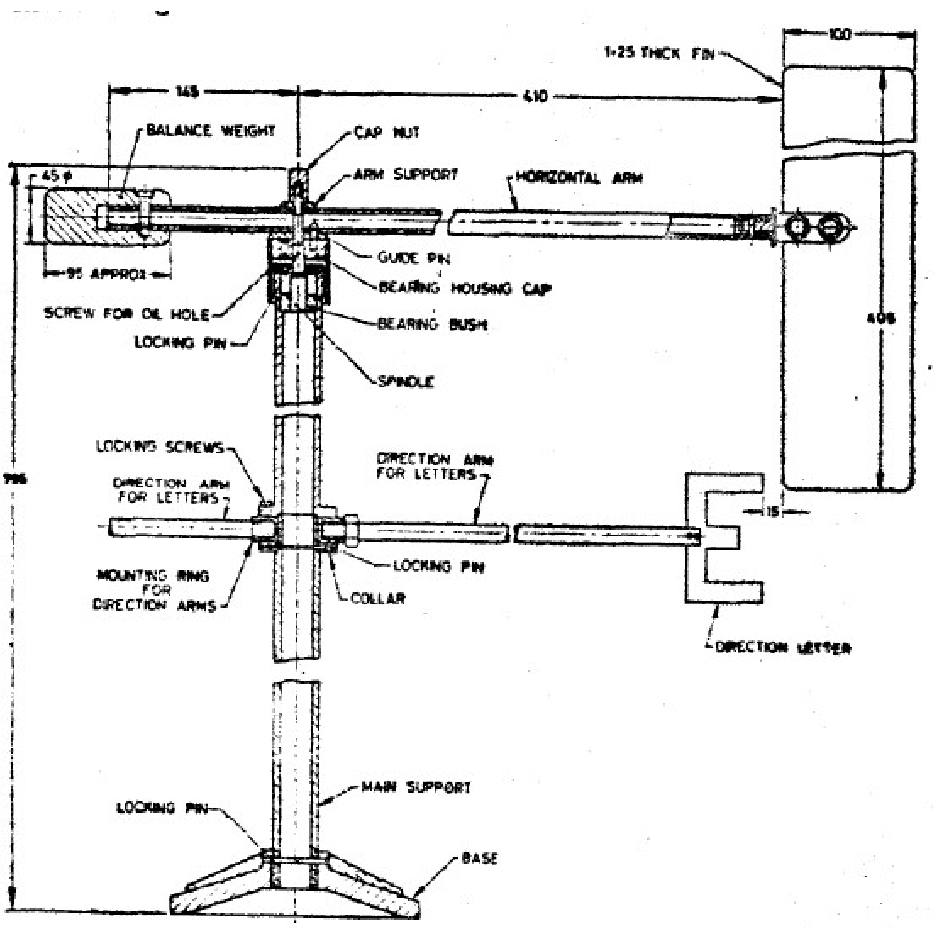


Fig. 19 Windvane Mk II - Details

(b) **Installation** —The wind vane is dismantled for dispatch and has to be assembled before installation. Wipe all the parts clean, check that no part is damaged and then assemble the instrument in the following order: Screw the four lettered and the four unlettered direction arms into the mounting ring (13) beginning with the N direction rod. Screw them as far as possible into the threaded holes of the ring in the correct order, hold the letters in a vertical position and then tighten the check nuts so that they press against the ring. Ensure that all the four letters are vertical after the check nuts are tightened. Take out the horizontal arm and loosen the two retaining screws (20) at the end of the fin boss (21). Introduce the fin in the slot of the fin boss and fix it in position by tightening the screws. Make sure that the fin is quite vertical. The complete arm with fin and balance weight should now be placed over the spindle projecting out at the top after removing the top nut. Replace and tighten the top nut. The wind vane is now fully assembled.

The base of the wind vane should now be fixed to the parapet wall of the roof or to the cross rail of the wind tower at the site selected. For this, three 9.5 mm (3/8 inch) diameter standard bolts should be grouted into the masonry of the parapet wall with cement, using the base of the wind vane itself as the template. Allow the cement to set.

The most important points in the installation of a wind vane are (1) the spindle about which the vane turns must be truly vertical (2) the direction rods indicating the cardinal points must be correctly oriented to true direction North, South, East and West. The setting of the direction indicators may be done by means of a magnetic compass, which gives the magnetic north. In India the magnetic north lies to the east or west of the true north at an angle of the order of 3°. This angle varies from place to place and should be accurately determined from a map showing lines of equal magnetic declination.

To determine the magnetic north, fix a pin vertically very close to the place where the wind vane is to be installed. Standing at a distance of about a meter from the place, approximately to the south of it, at the farther end of the roof or tower, sight the pin through the prismatic compass. Move slightly till the 0° mark on the floating dial of the compass coincides with the pin. Remaining in the same position and still sighting the pin through the compass, ask an Assistant to fix another pin behind or in front of the first pin at a distance of about 30 cm. so that both lie in the same line of sight. Draw a straight line indicating the direction of the magnetic north. To obtain the direction of the true north, read off the declination of the place from the map showing lines of equal magnetic declination and mark the true north to the east or west of the magnetic north as the case may be. Now draw a true north-south line indicating its direction towards the north by an arrow head.

Having determined the true north, place the assembled windvane on the three bolts and tighten with nuts and washers taking care to see that the main support is vertical. Where the windvane is to be installed on the cross rail of the wind tower, a teakwood plank of 250 mm **x** 250 mm square and at least 35 mm thick should first be fixed to the cross rail by means of suitable standard mild steel bolts and nuts. The base of the windvane should then be fixed over the wooden plank by means of three suitable steel bolts and nuts. Now loosen the four screws (18) on the mounting ring for direction arms and rotate the ring till the N rod is practically over the N-S line. Holding two plumb lines against the N and S direction rods, rotate the mounting ring until the tips of the two plumb bobs rest on the N-S line. In this position tighten the four screws on the mounting ring. Test again with the plumb line held against the N and S direction rods to see that the tips of the plumb bobs rest on the N-S line. The instrument is now correctly oriented and ready for use.

(C) Operation. —The Observer should stand as close as possible to the base of the support of the vane, to avoid parallax errors and note carefully the direction in which the counter-weight points i.e. the direction from which the wind is blowing. The windvane should be watched for a few minutes to obtain the mean direction of the wind. Before taking a reading make sure that the windvane moves freely. As ordinary wind vanes often fail to respond to light winds, give a turn to the vane by hand and allow it to take up the direction of the wind. Always verify that the wind direction given by the vane agrees with that estimated.

2.4.3 Maintenance of Windvane :- The instrument is dispatched from Pune suitably lubricated and no lubrication is needed soon after installation. **Every fortnight** lubricates the ball bearings with a few drops of spindle oil. For this, remove the horizontal arm after taking out the top nut. Take out the oil hole screw (22), put a few drops of oil into the hole and replace the screw.

Keep the instrument clean. Examine the four set screws (18) once a month and tighten them, if necessary.

Once every six months examine carefully all the parts of the instrument and wash them thoroughly in kerosene oil, clean and lubricate them.

Proceed as follows: Take out the top nut and lift off the horizontal arm with the fin and balance weight. Unscrew the long brass retaining screw (12) and remove the bearing housing cap (5). The top ball bearing will now be visible.

Unscrew the four screws (23) which fix the support tube (9) over the main support. Lift off the support tube. Keeping the support tube vertical, pour kerosene oil into it from top, rotate the spindle and let the oil drain freely out from below. Now invert the support tube and pour kerosene oil into it rotating the spindle to and fro. Repeat the process three or four times until the ball bearings are well cleaned.

When the bearings have become dry, put a few drops of lubricating oil on to the two ball bearings. Twirl the spindle backwards and forwards a number of times so as to get the oil well distributed inside the bearings.

Now reassemble the instrument in the following order: (a) Fix the support tube over the main support (b) Slide the bearing housing cap over the spindle and fix it to the latter by means of the long brass screw (c) Place the horizontal arm assembly (d) Finally, screw the top nut.

If the vane becomes unbalanced or is stiff even after lubrication, it should be returned to the Instruments Division, Pune for repair.

Whenever the defective part is returned, the complete vane assembly with the support tube should be sent after detaching it by unscrewing the four screws (23) which fix it to the main support.

Packing: The windvane with its direction rods and main support is supplied in a special box and should be packed in the same box in which it is received while returning the complete instrument to Pune for replacement and repair. To pack, detach the fin from the fin boss of the horizontal arm and unscrew all the eight direction rods after loosening the check nuts. Fix the fin plate to the base of the box over the flet lining with a small screw. Place the direction rods in their places on the sides of the box and clamp them with the wooden clamps provided. Place the main support with the support tube in position in the centre of the box horizontally and clamp it with the wooden blocks provided. Screw the lid down. The case is now ready for dispatch.

2.4.4 Wind Speed:- The wind speed is measured by an Instrument called the Anemometer. Fig. 20 shows the Cup- Anemometer used in the observatories of the India Meteorological Department.

Fig. 20 Cup Counter Anemometer MK II

(a) Principle:

The instrument consists of three large semi-conical cups with beaded edges fixed at the ends of three rods.

The cups are mounted symmetrically about a vertical axis so that the diametral plane of each cup is vertical. As the force on the concave side of any cup, due to the wind is greater than that on a convex side in a similar position, the cup wheel rotates. For any given anemometer, the dimensions and design are such that the speed at which the cup wheel rotates depends to a good approximation, solely on the wind speed, provided the wind speed is steady and is greater than the minimum required to set the cups in motion; the lower limit is due to the effect of friction on the bearings of the cup wheel. The rate of rotation does not depend on the direction of the wind nor to any appreciable extent, on the density of the air.

The cups are attached to a central spider which is mounted on a spindle carrying a worm. The worm engages with a gear wheel and drives a revolution counter mounted in a waterproof aluminium housing. The gear ratio between the cup and counter spindle is so chosen, in relation to the factor of the anemometer, that the counter indicates directly the run of wind in kilometers and tenths, when the instrument is suitably exposed.

To obtain the run of the wind in kilometers and tenths over a given period, the counter is read at the beginning and end of a period and the difference noted. The mean wind speed during this given period is obtained by dividing the difference in counter readings by the time interval in minutes.

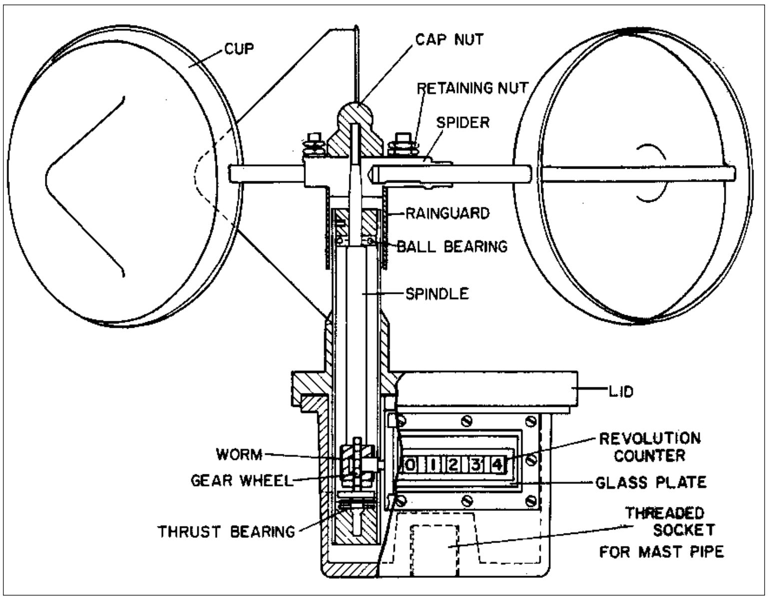


Fig. 21 Cup Counter Anemometer MK-II Details

(b) Description:

The MK II-cup anemometer (Fig. 21) consists of a cup wheel with three semi-conical cups having beaded edges made from thin copper sheet, 127 mm in diameter and mounted symmetrically about a vertical axis so that the diametral plane of each cup is vertical. The cups are attached to a central spider by means of three arms made of brass. The spider is pivoted at its central point to a vertical steel spindle passing through an aluminum tube attached to the lid of the anemometer housing, also made of aluminum. The top of the spindle moves in a small ball bearing while the bottom rests on a thrust bearing. The lower tip of the spindle is enclosed inside a bushing which allows free rotation of the spindle. The rotation of the upright spindle is transferred by means of a worm and gear to a counter having bold figures with a range from 00000 to 99999. The four white figures to the left give the whole number of kilometers and the last figure which is red gives tenths of kilometer. The counter mechanism thus reads up to 9999.9 km before repeating itself. The housing is provided at its base with a threaded socket for mounting the instrument on a 13 mm (1/2 inch) gas pipe. The ball bearing at top is protected from rain and dust by means of a rain guard. The window through which the figures of the counter can be seen is also similarly protected by means of a glass plate with a gasket. The lid of the housing can be lifted off by unscrewing the five screws from below the flange of the housing. A gasket is provided between the housing and the lid to protect the interior of the housing from rain and dust.

(c) Exposure:

The wind velocity near the surface of the earth varies rapidly with height and is also greatly affected by the presence of irregularities in the ground or nearby obstacles such as trees and buildings. For synoptic reports of the surface wind and for general climatological records, it is therefore necessary to define the height and conditions under which the measurement should be made. The standard exposure of wind instruments over level, open terrain is 10 meters above the ground. Open terrain is defined as an area where the distance between the anemometer and any obstruction is at least 10 times the height of the obstruction. The adoption of the standard-exposure is especially important at airports. This ideal-exposure will rarely be obtainable in practice, but great care should be taken to ensure that the site actually chosen is the best possible.

Where a standard exposure is unobtainable, the anemometer should be installed at such a height that its indications are reasonably unaffected by local obstructions, and represent as far as possible what the wind at 10 m would be, if there were no obstructions in the vicinity. This will usually necessitate placing the anemometer at a height exceeding 10 m by an amount depending on the extent, height and distance of the obstructions but it is impracticable to lay down any precise rules for determining this, since local conditions differ so widely. A site on a steep hill or on the edge of a cliff will be unrepresentative of the general wind flow and should not be used. Besides giving incorrect values of the mean wind speed, an obstructed exposure often has excessively high values of gustiness.

In a perfectly open and flat situation, a wooden lattice tower or mast 10 m high affords an excellent exposure, where the situation is obstructed by trees etc. the instrument may be erected on a building or high mast so that it is higher by at least 3 meters than the highest obstacle in the immediate vicinity. If this requirement would necessitate a very high mast in the observatory enclosure, a separate site should be selected, such as the roof of a building. When both the anemometer and windvane are installed side by side, they should be separated by a minimum distance of at least 2 meters.

(d) Installation:

The anemometer is dispatched from Pune in a specially designed case, in which the cup frame assembly is removed from the main body of the instrument. Before installation, the instrument should be examined to see that no part is damaged and then assembled by unscrewing the cap nut of the spindle, fitting the cup when assembly on the spindle and replacing the cap nut.

As local needs and conditions vary greatly, it has not been practical to provide uniform mounting arrangements for the anemometer. The instrument has a socket in its base with 13 mm (1/2 inch) British Standard pipe thread tapped, into which can be screwed a 13 mm. (1/2 inch) standard gas pipe. The anemometer is locked to the gas pipe by a locknut. A short length say 30 cm of appropriately threaded gas pipe should be screwed and locked into this and if necessary, a length of larger diameter piping (38 mm. i.e. 1½ inch or 50 mm. i.e. 2 inch bore) should be attached to the end of the first piece of piping through a reducing socket. The 13 mm (1/2 inch) pipe is not sufficiently rigid to support the anemometer when used in lengths greater than about 30 cm. To install the instrument, the gas pipe should be rigidly embedded in the parapet wall of the roof or any other suitable masonry structure selected or securely fixed to the side of the tower or masonry structure by means of strong iron clips. The length of the gas pipe should be such that the cup wheel of the anemometer is at least 1.2 m. above the supporting wall when the instrument is screwed to the gas pipe.

(e) **Operation:**

Wind Speed at the hour of Observation

Surface wind speed for synoptic purposes is reported in knots. To determine the wind speed at the time of observation, take two successive readings of the anemometer at an interval of 3 minutes. Subtract the first reading from the second one and multiply the difference by 20. This gives the mean wind speed over a period of three minutes in kilometers per hour. To obtain the mean wind speeds in knots multiply this by 0.54. (1 kmph=0.54 knots). Special Conversion Tables are supplied to all observatories.

The detailed procedure is described below. Watch the counter and as soon as the last figure in red moves up and the next one appears exactly in line with the black ones, note down the time and the counter reading. Take a second counter reading exactly three minutes later, subtract the first reading from the second and multiply the result by 20. This gives the mean wind speed during the three minutes of observation.

Example :-

Counter reading at the beginning of the observation	2090.9 km
Counter reading after 3 minutes.	2093 .1 km
Difference in km	2
Wind speed in kmph.	2.2 x20 = 44
Wind speed in knots	44 x 0.54 = 24

After computing the wind speed from the anemometer readings, compare it with the estimation of the wind force based on the observation of the effect of the wind on the surrounding objects in order to detect serious errors if any, in the calculation of the wind speed. The Table of Beaufort Scale given on page 75 should be used for the purpose.

Average Wind Speed during the Day

The average wind speed during the day in kmph is obtained by dividing by 24, the difference in the counter readings in kilometers at 0830 1ST on two successive days and rounding off the quotient to the nearest whole number. The average wind speed in knots is obtained by multiplying before approximation, the wind speed in kmph. by 0.54.

Example

Counter reading at 0830 hours on 20-7-1972	9974.5 Km.
Counter reading at 0830 hours on 21-7-1972	0083.7 Km.
Difference in k i l o m e t e r s	109.2
The average wind speed on 20-7-1972 in km.p.h	109.2/24 = 4.5
Average wind speed on 20-7-1972 in knots (Cod 10 pp 75-76)	4.5 x 0.54 = 24

2.4.5 Care of the Anemometer:

(a) **Maintenance**

The instrument when dispatched from Pune is suitably lubricated and no lubrication is required soon after installation. However, the instrument should be inspected, cleaned and lubricated at intervals of three months according to the following routine:

(i) Place the instrument on a clear bench, remove the cap nut (Fig. 20) and lift the cup wheel with spider off the spindle. If the cup wheel is stuck to the spindle, loosen the cap nut but do not remove it; support the cup wheel in one hand and strike the cap nut smartly with a mallet or the wooden handle of a screw driver.

(ii) Clean the cup wheel thoroughly checking that cup retaining nuts are tight and that the cups are not loose in their arms.

(iii) Clean thoroughly the exterior of the housing and the spindle tube.

(iv) Undo the five screws which hold the lid of the housing and lift the lid and spindle assembly off the housing. Clean the inside of the housing and dry it thoroughly, if damp. Clean the glass cover of the window. Grease the threaded socket at bottom, which goes over the 13 mm pipe.

(v) Put a drop one or two of clock oil in the worm and over the teeth of the gear wheel.

(vi) Similarly, put a drop of spindle oil down the side of the spindle, projecting out at top. The oil will go down the spindle through the top bushing and will lubricate the ball bearing below it.

(vii) Apply a drop of clock oil below the worm and gear where the lower thrust bearing is just visible in the slot of the tube. This will lubricate the lower thrust bearing.

(viii) Now reassemble the anemometer.

Dust and other foreign matter may get into the instrument case and settle on the revolving parts. The bearings and gear also require thorough cleaning, and lubrication once "in a while. The instrument should therefore be carefully inspected and all the bearings thoroughly washed, cleaned and lubricated at intervals of six months (and specially after every dust storm) according to the following routine:

a. Follow the steps (i) to (iv) given above.
b. Remove the three screws that fix the top bushing to the spindle tube and pull of the bushing.
c. Take out the screws that fix the bushing at the lower end of the spindle tube and remove the lower bushing. It will come off with the lower disc of the thrust bearing.
d. Remove the remaining parts of the thrust bearing.
e. The spindle with top ball bearing can now be pulled off its tube from the top.
f. Clean both the top ball bearing and the lower thrust bearing with its discs in clean kerosene oil and remove all traces of grease and dirt.
g. Clean the spindle, worm and gear thoroughly with a soft camel hair brush soaked in kerosene oil and lubricate the worm and gear with a little thin clock oil. The top ball bearing may be lubricated with a drop of spindle oil and the lower thrust bearing with clock oil.
h. Now reassemble the anemometer in the following order: Spindle, lower thrust bearing, lower bushing, top bushing, housing lid, cup wheel assembly and finally cap nut. While reassembling make sure that the meshing of the worm and gear is proper and not too tight or too loose.
i. If either of the bearings shows deterioration or are found to be in bad condition, the whole instrument should be returned to the Instruments Division, Pune for replacement and repair.

(b) Accuracy:

The anemometer is checked against a standard instrument in a wind tunnel or in the open and is expected to have frictional and other errors less than 10%.

The anemometer normally begins to rotate at wind speeds of the order of **1½-2** knots and between 2-5 knots. Its indications depend to a large extent on the bearing friction and the state in which the instrument is maintained. If the friction seems excessive, the anemometer should be tested as follows. Place the anemometer on a horizontal surface indoors at a place free from draughts and rotate the cups for 30 seconds at a rate of 1 revolution per second in the same direction as the wind would turn them. The time taken for the cups to come to rest after being released should exceed 60 seconds.

(c) Packing:

The anemometer is supplied in a special box and should be packed in the same box and in the same manner in which it is received while returning the instrument to Pune for replacement and repair.

To pack the anemometer, remove the cap nut and lift off the cup wheel assembly. After screwing back, the cap nut, place the counter housing with the spindle tube in the box with the glass window at the top. Place the cup frame in position with packing material. Screw down the cover of the box. The instrument is now ready for dispatch.

CODE 10

SURFACE WIND VELOCITY (ff)

TABLE OF SPECIFICATIONS FOR ESTIMATING WIND SPEED OVER LAND OR SEA

Specifications				**Speed of wind at 33 ft. (10m) above ground**	
Beaufort No.	**Descriptive term**	**Land**	**Sea (Provisional)**	**Knots**	**km. per hour**
1	**2**	**3**	**4**	**5**	**6**
0	Calm	Calm; smoke rises vertically	Sea like a mirror	Less than 1 0	Less than 1 0
1	Light Air	Smoke bends from the vertical and drifts slowly with the wind; windvane not affected.	Ripples with the appearance of scales are formed but without foam crests.	1 - 3 2	1 – 5 3
2	Light Breeze	Wind felt on face; leaves rustle, ordinary vane moved by wind.	Small wavelets, still short but more pronounced; crests have a glassy appearance and do not break.	4 - 6 5	6 – 11 9
3	Gentle Breeze	Leaves and small twigs in constant motions; wind extends light flag.	Large wavelets. Crests begin to break foam of glassy appearance; perhaps scattered white horses.	7 - 10 9	12 - 19 16
4	Moderate Breeze	Rises dust and loose paper; small branches moved.	Small waves becoming longer; fairly frequent white horses.	11 - 16 13	20 - 28 24
5	Fresh Breeze	Small trees begin to sway; crested wavelets form on island water.	Moderate waves taking a more pronounced long form; many white horses are formed (Chances of some spray).	17 - 21 18	29 – 38 34
6	Strong Breeze	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty.	Large waves begin to form, the white foam crest are more extensive everywhere (Probably some spray).	22 - 27 24	39 - 49 44
7	Moderate Gale	Whole trees in motion; inconvenience felt when walking against the wind.	Sea heaps up and white foam; breaking waves begin to blow in streaks along the direction of the wind (spindrift begins to be seen).	28 - 33 30	50 - 61 55

8	Fresh Gale	Breaks twigs off trees; generally, impedes progress due to difficulty experienced in walking against wind.	Moderately high waves of greater length; edges of crests break in to the spindrifts; the foam is blown in well-marked streaks along the direction of the wind.	34 - 40 37	62 - 74 68
9	Strong Gale	Slight structural damage occurs (Chimney pots and slates on roof removed)	High waves; dense streaks of foam along the direction of the wind; crests of waves begin to topple, tumble and roll over; spray may affect visibility.	41 - 47 44	75 - 88 82
10	Whole Gale	Trees uprooted and considerable structural damage occurs for instance Kutcha houses blown down (seldom experienced inland).	Very high waves with long overhanging crests. The resulting foam, in great patches is blown in dense white streams along the direction of the wind. On the whole, the surface of the sea takes white appearance. The tumbling of the sea becomes heavy and shock- like. Visibility is affected.	48 - 55 52	89 - 102 96
11	Storm	Widespread damage (Very rarely experienced) .	Exceptionally high waves (small and medium sized ships might for a time be lost behind the waves). The sea is completely covered with long white patches of foam laying along the direction of wind. Everywhere the edges of the wave crests are blown into froth. Visibility affected.	56 - 63 60	103 - 117 110
12	Hurricane	----	The air is filled with foam and spray, Sea completely white with driving spray. Visibility very seriously affected.	64 and over	118 and over

CHAPTER 3

INSTRUCTIONS FOR REPAIRS, REPLACEMENTS AND PACKING

3.1 Local Repairs of Defective Instruments:

3.1.1 Barometer: - The barometer is a very delicate instrument and the Observer should in no case try to rectify its defect himself unless specially instructed to do so (See Section 2.1.2). If the barometer is found in any way defective, the Controlling Meteorological Office should be in informed immediately by Telephone/email/AMSS/Mobile/ SMS.

3.1.2 Thermometers: - If the defect is such that it can be rectified by following the instructions given in Section 2.2.5, this should be done by the Observer using proper care. If the defect cannot be rectified locally, the Controlling Meteorological Office should be informed immediately.

3.1.3 Wind-Vane, Anemometer, Rain-gauge and Watch: - If the defect can be removed by local repairs, the Observer should inform the Controlling Meteorological Office by Telephone/email/AMSS/Mobile/ SMS or letter according to the urgency of the matter, stating briefly the nature of the defect and the estimated cost of repairs. **Previous sanction for the repairs must in all cases be obtained before any expenditure is incurred.** The sanctioning authority will arrange for payment on receipt of relevant vouchers and bill of charges. Petty repairs such as soldering a rain-gauge or replacing the glass of the anemometer may be done locally with the sanction of the Superintendent of the Observatory without obtaining the previous sanction of the Controlling Meteorological Office.

3.2 Replacement of Defective Instruments:

3.2.1 When spare is available: - If a defective instrument cannot be repaired locally and a spare is available, the observer should bring **the spare** one into use and inform the Controlling Meteorological Office by letter about the change, stating the time from which the change is affected and the nature of the defect of the original instrument. He should also request the Controlling Meteorological Office to send another instrument to be kept as spare.

3.2.2 When spare is not available: - If the spare is not available, the Observer should report by Telephone/email/AMSS/Mobile/ SMS.or by letter, according to the urgency of the case to the Controlling Meteorological Office and request for replacement.

3.3 How to pack Thermometers, Measure Glasses and Watches:

Place the instrument in its box with plenty of cotton wool on all sides, so that no portion of the instrument touches any portion of the box, or is likely to do so during transit. Then put the box inside a much larger deal-wood box, placing plenty of cotton wool above, below and on all sides of the inner box, so that the inner and outer boxes do not touch each other anywhere and are not likely to do so during transit. If enough cotton-wool is not available, other suitable packing material, such as waste paper or wood shavings, may be used for the latter purpose.

3.4 Maintenance:

Meteorological instruments at Observatories should be painted periodically at least once in two years. At coastal stations it would be advisable to repaint them more frequently. The old paint should be completely removed by means of emery paper before the new paint is applied.

The specification of the paints to be used are given below

Name of Instrument	Paint	Under Coat	Finishing Coat	Make of paint	Remarks
Cup counter Anemometer	Robbialac synthetic enamel	Two coats red oxide primer	One coat of Wedge-wood blue	Jenson and Nicolson	Moving parts like Cup assembly are not to be painted.
(a) OrdinaryWind-vane	Do	Do	Do	Do	Moving parts like Vane assembly are not to be painted.
(b) Direction letters	Do	Do	Do Duco-red	Imperial Chemical Industries	..
Ordinary Rain-gauge	Do	One coat red oxide primer	One coat of Robbialac black	Jenson and Nicolson	..
Tank for open pan evaporimeter	Jensolac	Red oxide primer	Acid and Alkali resistant white (Chlorinated rubber white)	Do	..
Stevenson Screen	--	One coat of primer (red oxide)	One coat of RobbialacJhimil white	Do	..

CHAPTER 4

AUTOGRAPHIC INSTRUMENTS, ITS FUNCTIONING, OPERATION AND MAINTENANCE

4.1 Aneroid Barograph

An aneroid barograph is a portable instrument for automatic and continuous recording of atmospheric pressure at a particular location. The basic principle of the instrument is similar to that of an aneroid barometer except that the instrument carries a recording pen (instead of the indicating pointer) and a clock driven drum fitted with a recording chart paper with the pen resting over it.

Fig. 22- An Aneroid Barograph – temperature compensated

The movement of the pressure capsule due to changes in pressure is magnified by a system of levers and the recording pen traces a continuous record of the variations in atmospheric pressure on the chart. As the friction between the pen and the chart is quite large (it is much greater than the total friction in bearings of the instrument), the barographs usually have larger size of pressure capsules to be able to drive the pen on the chart. The force to the pen largely depends on the effective cross-section of the aneroid. For a given capsule, the force required to move the recording pen is largely proportional to the effective cross-sectional area of the capsule. A number of these are often used in series to obtain the desired magnification for recording on a chart.

Though the barographs have comparatively less magnification than an aneroid barometer, good quality aneroid barographs have been designed which are able to meet the observational requirements for synoptic purposes. The main design features of such barographs are that they employ pressure capsules which are so compensated for temperature that the reading does not change by more than 1 hPa (mb) for a temperature change of 20°C. The pressure sensor also has very low hysterisis, such that a difference in reading before and after a change of pressure of 50 hPa (mb) does not exceed 1 hPa (mb). The design provides for a scale factor of at least 10 hPa (mb) to 15 hPa (mb) on the chart so that the chart could be read correctly to 0.1 hPa (mb), while the scale error at any point does not exceed 1.5 hPa (mb). The barographs have long period stability (say at least one year). These instruments are thus considered quite suitable for use at synoptic stations.

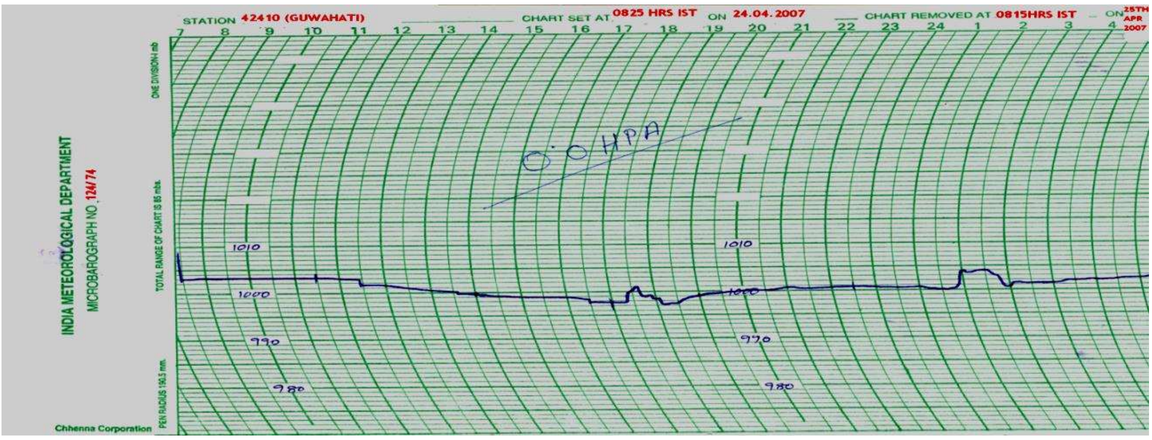


Fig. 23- Recording of pressure on a chart for 24 hours of period

4.1.1 Construction details

An aneroid barograph basically consists of: i) a pressure sensitive capsule or a stack of capsules, ii) a system of levers that magnifies and links the movement of the pressure capsule to a recording pen which rests on a recording drum and iii) a clock mechanism with the recording drum mounted over it. A chart graduated in units of pressure is wound over the drum. Thus, as the clock drives the drum, the pen traces a record of atmospheric pressure over the chart. The whole assembly is mounted on a metal base plate and is enclosed in a glass case.

Several types of pressure sensitive elements have been used in barographs. The aneroid element usually consists of a partly evacuated pressure capsule with a strong steel internal spring that prevents it from collapsing under external atmospheric pressure. Some instruments however, have no internal spring. The corrugated diaphragms forming the capsule, are made of tempered steel and the capsule itself acts as a spring. A stack of such capsules mounted in series on the same vertical axis is used to derive sufficient force to overcome the friction in the mechanical assembly and between the recording pen and the chart. Some barographs, on the other hand, use a length of sealed flexible metal bellows with internal steel helical spring. The bellows are made of silver-plated beryllium copper with deeply corrugated surface.

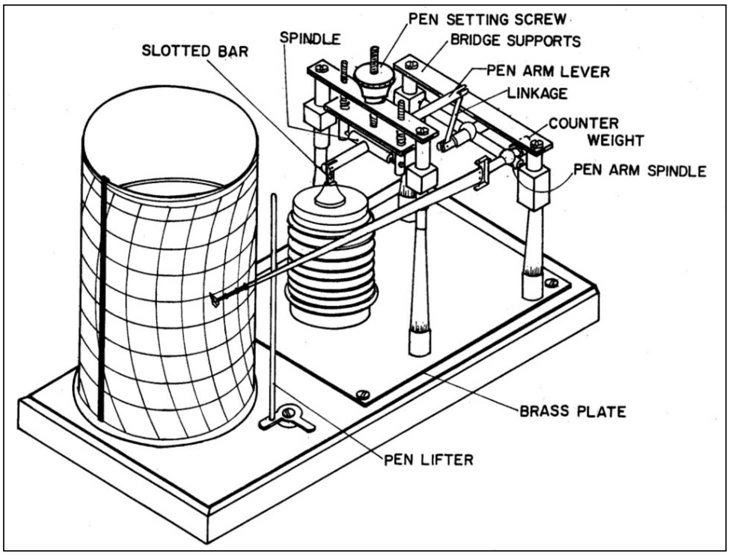


Fig. 24 Aneroid barograph with its lever mechanism

The construction of different types of barographs usually follows a similar pattern. The basic features of the design are that the aneroid element is fixed to the brass base plate and the vertical motion of the top free end of the aneroid is magnified by a system of levers and transmitted to a recording pen. The pen thus traces the pressure variations on a chart wound on a clock drum.

The system of levers, spindles, adjustment screws etc is mounted within a framework of brass vertical pillars and horizontal bridges. The top free end of the aneroid element carries a slotted bar, with a number of tapered holes to fasten the aneroid to one end of the main pen lever arm using a tapered pin. The choice of the appropriate hole on the slotted bar, to which the end of the lever arm may be anchored, is important as it determines the zero position of the pen on the recording chart. This end of the lever arm is thus usually fixed to the hole appropriate to the mean pressure of the station.

At some distance from the aneroid slotted bar, the pen lever arm carries a small horizontal spindle held on two adjustable pivots. The point thus acts as a fulcrum for the lever mechanism. The spindle pivots can be raised or lowered by a knurled head zero setting screw mounted on a brass plate that forms a bridge over two vertical pillar supports. The longer arm of the lever, extending beyond the spindle, is attached to the pen arm spindle through a vertical link. The linking strip is actually screwed to a small arm fixed to the spindle at right angles to its axis, so that the movement of the recording pen is further magnified. The position of the linking strip on the small arm can be adjusted with the help of the screw to obtain the desired magnification. The pen arm spindle is held on bearings in two vertical pillars and carries the recording pen with its usual gate suspension so that the pen rests on the chart.

Thus, the main lever arm with its fulcrum at the horizontal spindle supported on the bridge, has its smaller length attached to the aneroid slotted bar, while its longer length is joined to the pen arm spindle. The small movements of the aneroid are hence greatly magnified and transmitted to the recording pen. Further, while the position of the lever arm on the slotted bar (the hole to which it is fixed with the pin) enables larger displacement of the pen for proper zero setting, finer adjustments are done by raising or lowering the fulcrum with the help of the zero-setting screw. The scale value of the instrument, however, is varied by adjusting the position of the vertical linking strip along the small arm on the pen arm spindle. Fig.24gives some constructional details of an aneroid barograph with its lever mechanism assembly.

The fixing of the recording pen to the pen arm, adjustment of the pen arm length and position, the method of mounting the clock driven recording drum and chart etc are all similar to any other self-recording instrument e.g. as in the case of a thermograph. The drum could have a daily or weekly movement. Usually a reversible double-sided gear inside the drum enables to choose one-day or seven-day recording. A pen lifter arm enables the pen to be lifted off the chart whenever required and a time marking device fitted to the base makes a time mark on the chart when pushed in from outside the housing.

It is usually not practicable to obtain a linear scale over the whole recording range but by proper adjustment of the pen arm and spindle, a satisfactory adjustment for the range of pressure to be recorded at the station can be achieved.

The whole instrument is enclosed in a metal cover with glass windows.

4.1.2 Range of barographs

Three different ranges of barographs are commonly in use:

i) <u>Small pattern (or small scale) barographs having:</u>

Total range of instrument	about 100 hPa (mb);
Chart range	100 hPa (mb);
Scale value	10 hPa (mb) corresponds to 7.5 mm on the chart.

ii) Open scale barographs having:

Total range of instrument	about 100 hPa (mb)
Chart range	85 hPa (mb)
Scale value	10 hPa (mb) corresponds to 19 mm on the chart

iii) Microbarographs having:

Total range of instrument	about 90 hPa (mb)
Chart range	30 hPa (mb)
Scale value	10 hPa (mb) corresponds to 37.5 mm on the chart.

Of these, the open scale barographs are commonly used at most of the meteorological observatories, while microbarographs are used at main synoptic stations where greater accuracy is required. The small-scale instrument is used at these stations only in the absence of anything better, as the scale value is too small to read the barogram with sufficient accuracy for synoptic purposes. The small-scale type is generally used at some climatological or coastal stations having limited accuracy requirements. For sea level stations, the pressure range covered is say from 950 to 1050 hPa (mb).

4.1.3 Operation, setting and adjustment of barographs for routine recording of atmospheric pressure

The general procedure for operation, setting and adjustment of barographs for satisfactory pressure recordings viz. adjustment of setting screw, length of pen arm, scale value, fixing the chart on the drum, pen pressure and pen inking, time- marking etc. are all generally similar to those described in section 4.2.2 for operation of a bimetal thermograph. Some relevant details are discussed below:

4.1.4 Setting the barograph

The most critical adjustment in a barograph is the setting of the instrument to agree with the station pressure as obtained from the mercury barometer. The mercury barometer is read and after applying the index correction and reducing the value to standard temperature and gravity, the true station level pressure corrects to 0.1 hPa (mb) is obtained. With the help of the fine adjustment knurled screw, the barograph pen is then set to this value slowly so that the aneroid element along with its system of levers is able to follow the change in case of any lag. While doing so the instrument is gently tapped on the drum near the pen, to ensure that the pen is not sticking on the chart due to friction.

The instrument is so set that the mean station pressure is at about the centre of the chart. If, however, at any time the pen is observed to be very near the top or bottom of the chart and is likely to go beyond the chart limit, the zero of the instrument/scale values are re-set either by adjusting the position of the tapered pin on the slotted bar or the length of the arm to the pen-arm spindle.

As very low values of pressure are beyond the normal working range of the aneroid, some change in scale value may be observed at high level stations. This can be determined by long period comparisons with a mercury barometer and necessary corrections are carried out to the readings. If the error is large and systematic the scale value may be altered.

4.1.5 Daily routine operation and care of barographs

The general every day routine of operations and maintenance as described for a bimetal thermograph in considerable detail (section 4.2.3) is also equally applicable for aneroid barographs.

The barograph readings need to be regularly checked and compared with those obtained from the mercury barometer and corrective measures taken as and when necessary. The instrument is lightly tapped to overcome the effect of friction between the pen and the chart before a pressure reading is taken from the chart at any instant for barometric comparison.

Often a common type of chart is used at all the stations. The pressure values are thus usually not printed on the chart. It is thus necessary to enter the pressure range of the chart for the station before it is wrapped on the clock drum. For example, for a sea level station using an open scale barograph with a range from 960 to 1045 hPa (mb), the values are written at every 10 hPa (mb) on the chart for ease of reading the record.

4.1.6 Evaluation of the record and determination of barometric tendency

Occasionally it is necessary to evaluate the atmospheric pressure from the barograph and to determine barometric tendency. The barograph gives a continuous record of atmospheric pressure and is thus able to show the nature and amount of pressure changes that occurred since the chart was put to record. Information on the characteristics of pressure changes viz., rising or falling or changing in some other manner during the preceding three hours from the time of observation is known as ‘barometric characteristic' and the total amount of barometric change during the period is termed as ‘barometric tendency'.

The determination of pressure from a recorded barograph chart at any particular time requires in the first instance, to ascertain the clock error at that time from the time marks on the chart. The pressure is then read from the chart at the required time allowing for the clock error. The observed pressure reading is thereafter corrected for any error in scale value and/or for error in the pen setting to obtain the true pressure correct to 0.1 hPa (mb).

The amount of barometric tendency is obtained by subtracting from the corrected pressure at the time of observation ‘a', the corrected value at three hours preceding the time of observation ‘b', i.e. (a-b). The tendency is considered as positive if ‘a' is less than ‘b'.

When a barograph is used to obtain absolute pressure values, the record is better checked with a mercury barometer reading at least once in 24 hours.

4.1.7 Sources of error in pressure measurements with a barograph

A well-designed barograph is a sensitive instrument and when well-maintained provides good records of pressure fluctuations. The instrument is however, subject to errors due to effect of temperature, hysteresis and drift (creep). Hysteresis errors can be reduced by waiting a sufficient length of time before taking a reading. Full temperature compensation of the instrument is generally done at 1000 hPa (mb) (achieved by leaving some air or other gas in the capsule). Thus, at other pressures the compensation is not complete and the instrument may give some error. At high level stations the error may be more.

In addition, the friction in the bearings and between the pen and the chart and friction between the ends of the spring inside the aneroid element (whenever the capsule has an internal spring) give rise to errors in the instrument.

4.1.8 Accuracy of barographs

Even a well-designed barograph generally meeting the requirements as given above, is susceptible to errors and its accuracy is of a much lower order than that of a mercury barometer. Thus, while the instrument cannot be much depended on for the measurement of absolute values of pressure, it is extremely useful for measuring pressure changes over a few hours and indicating relative variations in pressure.

When a barograph is correctly set at a particular ambient temperature, the overall accuracy of a good sensitive instrument is about ± 0.2 hPa (mb), provided the change in air temperature is not very large. The order of error could be about 0.5 hPa (mb) for a change of temperature by ± 15°C from the temperature at which the instrument is correctly set.

4.1.9 Location and exposure of barographs

The general criteria for location and exposure of barographs are same as for an aneroid barometer. The location is to be free from sudden changes in temperature and vibrations and not exposed to dust/dirt. The barograph is not to be exposed to direct sunshine or to sources of heat at any time. Generally, a shelf at a convenient height near the barometer provides a good location for the instrument.

4.1.10 Installation of barographs

The most satisfactory arrangement is that the instrument is installed with its base horizontal, on a shelf or a wall bracket inside a room (preferably the barometer room) at a height of about one metre from the ground. The exact location is so chosen that the direct sunshine does not fall on the instrument at any time of the day throughout the year and the instrument is away from any artificial source of heat. A sponge-rubber cushion can be conveniently used for mounting the barograph to reduce the effect of vibrations, ensuring however, that the base is maintained horizontal.

4.2 Bimetallic thermograph

A bimetallic thermograph is one of the most widely used instrument for continuous and automatic recording of atmospheric temperature. The thermograph makes use of the physical property of a bimetallic element which shows characteristic changes with change in temperature. When a bimetallic strip or a helix, is held at one end while its other end is left free, and is exposed to the atmosphere, it exhibits changes in its curvature proportionate to the variations in atmospheric temperature and thus gives a measure of air temperature. These are mechanically magnified and the movement is used to operate a recording pen which traces a record of variations in atmospheric temperature.

The sensitive element of the thermograph is a bimetallic strip formed using strips of two metals having widely different coefficient of expansion. The metals most commonly used are invar and brass or invar and steel. The coefficient of expansion of invar, for example, is negligible in comparison with that of brass. The two strips are welded together on their flat surfaces and rolled to form a thin compound strip of bimetal.

It can be shown theoretically, that for a bimetal strip clamped at one end, the displacement at the free end ds, for a change in temperature dt (sensitivity ds/dt) is

$\propto$ the square of total length of the strip;

$\propto$ the difference in coefficient of expansion of the two metals; and

$\propto$ 1 / thickness of strip i.e. inversely proportional to the thickness of the strip.

It can also be shown that the displacement is greatest for a straight bimetallic strip, while the stiffness increases as the cube of the bimetal thickness.

Further, as the time constant (lag coefficient) will be approximately proportional to the mass of the metal, it will vary directly with the thickness of the strip. The strip thickness, however, increases its stiffness (which varies as cube of the thickness). Thus, while a thinner strip may provide a faster response, a thicker strip with adequate stiffness, is able to provide larger force needed to overcome friction in the mechanism and pressure of the pen on the chart and thus helps to obtain better record. A judicious compromise thus has to be made between the various characteristic parameters to obtain a satisfactory design of the bimetal sensing element for the thermograph.

4.2.1 Construction details

The temperature sensitive element most commonly used in a bimetal thermograph, is in the form of a left-handed helical coil of several turns with the metal having higher coefficient of expansion on the outside. Some instruments also use an element bent in the form of an arc of a circle. When the temperature changes, the helix coils or uncoils (or curvature of the strip arc increases or decreases), due to differential expansion of the two metals. With the metal having higher coefficient of expansion on the outside of the helix, a rise in temperature causes the helix to unwind.

The thermograph has a single piece main instrument base with a vertical section, cast in metal (brass/gun metal/aluminium), which serves as a support for the whole instrument. Two metal brackets are screwed a short distance apart, on to the vertical section of the main base. While a recording clock drum is fixed on the base platform, the bimetal helix, the lever mechanism, a setting arm and the recording pen-arm assembly are supported on the two brackets. The lever mechanism basically comprises of a horizontal spindle, which also carries a small brass pillar with a hole at right angles to its axis, so that the pillar is free to move along the spindle and can be screwed to it at any position. The spindle is fixed between the two brackets such that its one end is held on a pivot screw passing through one bracket and the other end projects out of the opposite bracket through a metal bush bearing. The spindle is thus able to revolve freely between the two supports. Further, the setting arm is so fixed to one of the brackets against a spring-loaded screw that its free end can be finely adjusted/turned, as required, about the horizontal spindle with the help of the screw.

Proper and careful mounting of the helix between the support pillars, helps to obtain satisfactory recordings of the temperature variations. The helix is positioned between the two metal brackets with the horizontal spindle passing through its centre. While one end of the helix is rigidly screwed to the setting arm, its other free end is screwed to the small brass pillar on the horizontal spindle, taking care that the central axis of the helix coincides with the horizontal spindle. This will ensure unrestrained, free movement of the helix (coiling and uncoiling of the helix) and the spindle with variations of temperature. The pen-arm is carried by a gate-suspension rigidly attached to the projecting end of the spindle by a screw.

The gate suspension is an arrangement that helps to adjust the pen pressure on the chart to the required minimum. The pen arm moves freely about the gate axis while the gate itself can be rotated on the spindle. As the pen arm is not perpendicular to the pen-arm spindle, right adjustment for proper pen pressure on the chart for the full range of temperature to be recorded, is rather critical. The pen pressure needs to be adjusted to a minimum for smooth record on the chart for the entire range of temperature recording without the pen tending to fall away from the chart. The best arrangement is when the suspension is so held that the pen just rests on the chart near the upper limit of temperature to be recorded. At other positions, either the pen will fall away from the chart when the pen moves up with the rise in temperature, or it will exert more pressure on the chart when it moves down with fall in temperature.

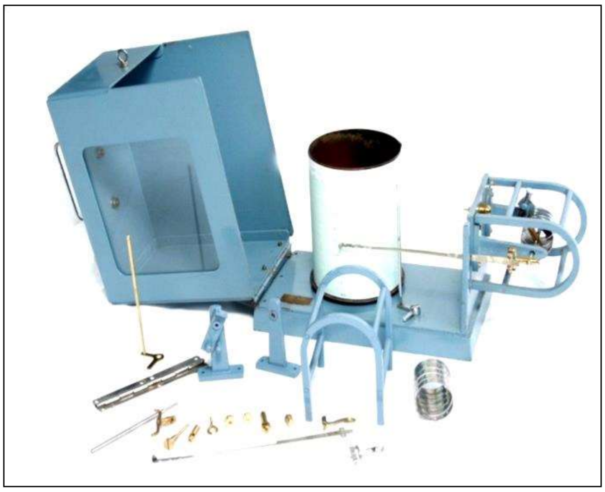


Fig-25 (a) - THERMOGRAPH ASSEMBLY

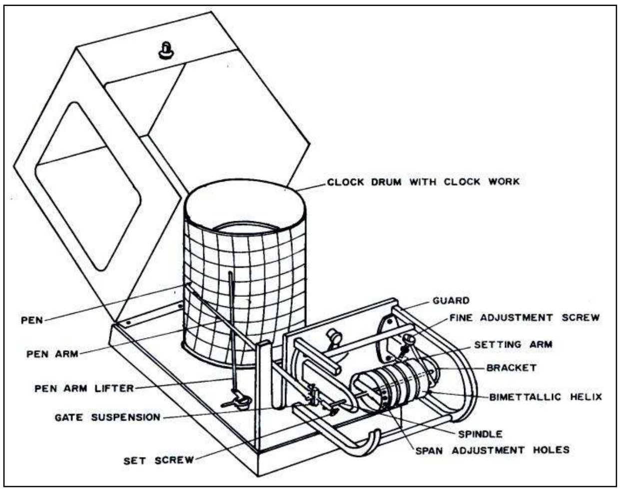


Fig-25 (b) - CONSTRUCTION DETAILS

A pen arm lifter enables the pen to be lifted from the chart whenever required for any adjustment of the pen/chart/drum etc. A time marker device is often provided on the base, which can be lightly pressed from outside the case to make a time mark on the chart.

A clock driven drum that carries the recording chart wrapped around it is mounted vertically on the main base of the instrument. As the drum rotates and the temperature varies, the free end of the helix joined to the spindle rotates around its axis, causing in turn the spindle and consequently the pen-arm to rotate. A trace of temperature record is thus obtained on the chart. The angular motion of the spindle is proportional to the total effective length of the coil. The drum may have a daily or weekly movement so that it is possible to obtain temperature record of a day or a whole week, when the chart is to be changed. In case of daily movement, the drum rotates once in about 25.5 hours, while in weekly clocks, it is once in about 7⅓ days on one full winding. The overlap is necessary to allow some margin of time for changing the chart. In weekly charts, as the record for a whole week is to be accommodated, the recordings are much compressed than what are obtained on daily charts. A metal guard protects the sensitive element against accidental damage, without obstructing the free flow of air. The whole instrument is enclosed in a glass case hinged to the main base.

Two types of clock-drum are commonly in use - a ‘fixed clock type’ or a ‘fixed spindle’ type, either of which can easily be converted to daily or weekly movements by change of gears provided.

Bimetal thermographs commonly use specially designed recording pen which is basically a triangular bucket which can hold enough ink. It has a pointed split tip which is the writing edge. The pen is attached to a short holder which can slide over the end of the pen arm. The two clamps on the pen are used to hold the pen firmly on the pen arm and to adjust the position of the pen on the arm to obtain correct pen arm length. The pen can usually hold sufficient ink for a week's record. A typical pen mounted on a pen-arm, held on a gate suspension is shown in Fig.26.

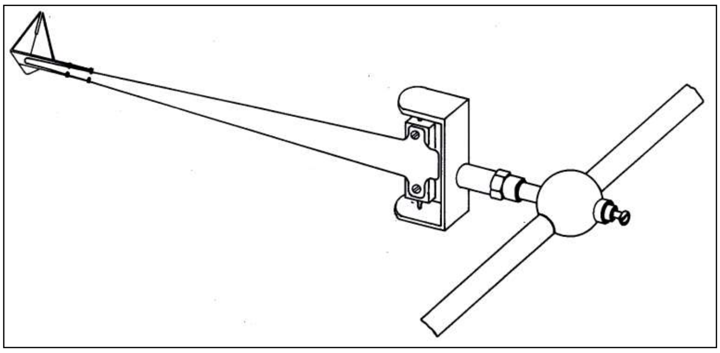


Fig.26 Gate suspension assembly with triangular pen

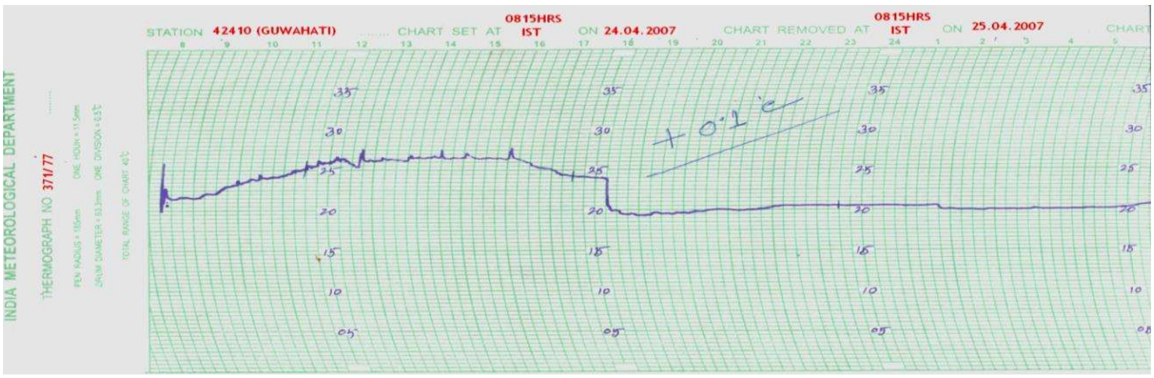


Fig. 27 Recording of temperature on chart for 24 hours of period. Resolution is 0.5^{0}CScaling on the chart during different seasons

A well-designed instrument has a small lag coefficient, the time constant being about 30 seconds in a wind speed of 5 ms^{-1}. It is thus smaller than that of mercury thermometers used in meteorological measurements.

The advantage of the instrument lies in its robustness and simplicity, characteristics so important for any instrument for field use. It can be made to record all temperatures of meteorological interest.

4.2.2 Setting and adjustment of thermograph for routine recording of air temperature

The whole thermograph assembly carries a number of fine adjustment and setting screws, which enable various adjustments required to be carried out simply and easily to obtain satisfactory records.

i) 'Setting screw' adjustment

When a thermograph shows a persistent difference in temperature readings compared to that obtained from a dry-bulb thermometer, the instrument needs to be adjusted for correct recordings. If the error is small (not more than 3°C), it can be corrected by just slightly rotating the position of the whole helix about its axis, which shifts the position of the pen on the chart. This is done with the help of the fine adjustment screw provided with the setting arm. The setting screw is turned slowly till the pen attains the desired position. The instrument is then tapped gently and rechecked carefully to ensure that the position of the pen point does not change. It is then allowed to attain equilibrium with its surroundings for about half an hour or so, before any further readjustment is considered necessary. The setting screw also helps to adjust the zero setting of the instrument, whenever required.

ii) Pen arm adjustment

Sometimes, however, the difference in the thermograph and thermometer readings may be much larger - say more than 3 °C - or the thermograph pen may record very near to the top or bottom of the chart. This may happen at times due to seasonal variation of temperature. In such conditions, the position of the pen-arm itself, relative to the spindle, is better adjusted. This is done by loosening the fine screw fixing the gate suspension rigidly to the spindle and shifting the position of the pen-arm on the spindle until the temperature indicated by the pen on the chart is the same as that of the thermometer. However, if the pen has been recording very near the top or bottom of the chart, it is brought towards the middle of the chart. The gate suspension is tightened again to the spindle. The thermograph is then left undisturbed for half an hour or so to stabilize and attain steady conditions before the readings are rechecked. Any further minor adjustment if required is then carried out by means of the 'setting' screw.

iii) Adjustment for length of pen- arm

The effective length of pen-arm is important for the instrument to record the correct temperature values as per chart graduations. This is achieved by adjusting the pen position while fixing the pen on the free end of the pen-arm to obtain the desired pen-arm length. The pen-arm is also gently moved with a finger over the drum to check if it traces an arc parallel to the hour lines on the chart, which are approximately arcs of circles with radii equal to the length of pen-arm.

iv) Scale value (or magnification) adjustment

At times, it is observed that even when the thermograph is in good working order and free from friction etc., the recording trace is either much compressed, wherein the amplitude of temperature variations recorded is small. This is indicated by the fact that the high temperature recorded on the chart is seen to be too low as per the chart graduations and the low temperature is recorded too high on the chart. Alternatively, the record may be too expanded, in which case the trace amplitude is large so that high temperature is seen recorded too high and low temperature is recorded too low with respect to the graduations on the chart. The instrument is then said to have appreciable 'scale value' error. This is more clearly seen by plotting the dry bulb temperature readings obtained at main synoptic hours of observation against the observed readings of thermograph at those hours read from the chart.

Resetting of the pen is not of much help in such a situation. Since the angular rotation of the spindle due to the motion of the helix is proportional to the total effective length of the bimetal coil, it is necessary here to increase (for too contracted scale) or decrease (for too expanded scale), the effective length of the bimetal helix. Several alternative positions/holes are thus provided at the free end of the helix for attaching it to the small pillar fixed on the spindle, so that the effective length of the helix in use can be altered to obtain the desired magnification (or scale value) of the instrument. The point of attachment of the end of the helix to the pillar, connecting it to the spindle is thus suitably altered with the help of the screw that fixes the helix to the pillar. The movement of the point of attachment of the helix to the pillar by one hole, alters the scale value approximately by about five percent. This adjustment is thus also possible only within certain limits.

It is rather difficult to carry out this adjustment at a field station in the absence of a suitable calibration bath. It is thus better left to be done at the Instrument Test Laboratory of the Meteorological Service or the instrument maker, where the effect of adjustment could be tested and seen easily and quickly in a proper calibration bath. It also requires careful handling of the helix to avoid any mechanical damage.

At a field station, in the absence of any scale value corrections made, it is better to obtain a correction graph for different points of the scale by taking say every three hourly comparative readings between the thermometer and thermograph and obtaining the corrections applicable at different points. These may be plotted drawing a smooth curve passing as far as possible through all the points. The temperature values picked up from the thermograph trace are then suitably corrected by applying the corrections obtained from this graph.

4.2.3 Method of operation

The daily routine operations in case of a thermograph are simple. These include, chart changing, inking the pen and making time marks and other essential entries on the chart to facilitate data evaluation.

i) Changing the chart

The chart is changed daily between 0800 and 0900 hours. For this purpose, the drum is removed from the base (in case of a fixed spindle type drum). Before doing so, the exact time is noted and the pen is lifted from the chart using the pen lifter, taking care that the pen position/ lever mechanism etc. are not disturbed in the process. The chart is then removed from the drum and a new one is fitted. To obtain good reliable records, the chart is wrapped around the clock drum carefully so that it fits tightly all-around the drum with the lower edge of the chart touching the flange at the base of the drum. It is essential to ensure that the lines corresponding to the temperature values as indicated along the length of the chart coincide on the overlapping portion of the chart and the end of the chart overlaps the beginning of the chart and not vice-versa. The clock is wound and if necessary, the regulator is adjusted if the clock has been running fast or slow. The recording range of the instrument is then noted on the new chart.

The drum is then put back in position and the pen tip is just allowed to touch the chart and the drum adjusted for correct time by turning it anti-clockwise when viewed from above, so as to avoid backlash. This is not necessary in 'fixed clock' type drums. Here the pen is made to rest on the chart using the pen lifter and the record observed for some time to make sure that the pen has started writing properly.

After the used chart is removed from the instrument, necessary entries regarding dates, time of beginning and ending of record, time marks, name of station etc. are to be made in the spaces provided for these on the chart.

ii) Inking the pen

If the previous record is satisfactory it is better not to attempt any cleaning etc. of the pen. Simply adding ink is sufficient. Alternatively, the pen is cleaned first and inked thereafter.

iii) Making time marks

It is essential to make time marks on the recorder chart at a few main synoptic hours by pressing lightly the time marker if provided or by carefully depressing the pen arm slightly with the finger or by tapping the pen arm gently near the gate assembly. These time marks facilitate applying proper corrections to the temperature recordings obtained from the chart.

4.3 Hair Hygrograph

The hair hygrograph directly provides a continuous record of relative humidity of the atmosphere. The instrument uses multiple strands of specially treated human hair, held together to form into a bundle about 200 to 300 mm long that serves as the sensing element. The variations in atmospheric humidity give rise to corresponding changes in the length of the hairs, which is magnified by a system of levers finally coupled to a recording pen arm. The pen thus records the variations in relative humidity on a graduated chart wound on a clock-drum. The hair hygrograph is perhaps the only instrument that gives directly a record of relative humidity (both with reference to saturation over water or over ice i.e. even at temperatures below 0°C). Being comparatively simple to operate as a recording instrument and capable of giving long periods of trouble-free service with small cares taken, the instrument is widely used in meteorological networks. Several variations of the instrument design have been developed using i) a bundle of hairs; ii) a dual bundle of hairs or iii) multiple strands of hairs held parallel and side by side. The bunch of hairs may be mounted vertically or horizontally and the hair element to pen arm linkages are arranged to provide a linear or a non-linear record of R.H. on the chart. One of these types that provides linear trace of R.H. on the chart and is widely used at meteorological stations is described here in greater detail.

The hygrograph essentially consists of a hair bundle about 200 to 230 mm long which is firmly held at either end by two adjustable vise type jaws fixed on a brass mounting plate. The hair strands are looped near their centre into an adjustable hook attached to a lever and spindle system, also fixed on the mounting plate so that the bundle of hair is always held in moderate tension. A small beryllium copper spring provided at one of the jaws holding the hair, helps to adjust the tension of the hair element whenever required. The position of the hook on the lever is also adjustable along the length of the lever arm. A pair of brackets fixed to the instrument base, on the rear side of hair mounting plate, holds the pen-arm spindle that carries the pen-arm with its gate suspension. The linkage between the hair element and the recording pen-arm, however, is somewhat unusual and is not a simple lever system. Fig.28 (a) & (b) shows a typical hair hygrograph.

As the changes in length of hair element with changes in humidity are non-linear (nearly logarithmic) in nature, two specially designed opposed quadrants are used as linkages between the system of levers connecting the hair element to the recording pen. One quadrant, with a small counter weight placed at its upper end is attached to the hook-arm spindle while the other is clamped to the pen arm spindle and the two quadrants are held together in contact by a small spring attached between the farther ends of the two quadrants. Thus, the non-linearity in the elongation of hair element with changes in R.H. is transformed into a linear movement of the recording pen. The clock-drum and the brackets holding the pen-arm assembly are mounted on the main instrument base, while hair assembly with its jaws, lever and spindle mounted on a separate plate is fixed to the side of the instrument base. Fig.28 (c) shows some construction details of the instrument.

As the humidity changes, the hairs expand or contract, thus moving the hook upwards or downwards. The displacement of the hook due to variations in the length of the hair element are magnified by the system of levers, thus obtaining a magnified and linear record of R.H over the whole range from 0 to 100% R.H. The standard 25.1/2 hours clock-drum (that makes one complete revolution in 25.1/2 hours) is generally used and chart graduations are usually for 1 or 2 % R.H. (so that the R.H. can be read nearest to 1% R.H.).

While the whole instrument is provided with a hinged cover having a glass window, the hair assembly is covered with a protective perforated brass guard that allows for sufficient exposure of the hair element to the ambient air while protecting the element from damage.

The instrument is generally installed within a large Stevenson Screen. Since the response of the hair element to changes in R.H. depends very much on it being maintained free from manmade or natural contamination, care is taken in locating the screen. It is preferably installed at a place where the surrounding atmosphere is free from any kind of pollution, like smoke, dust, oil fumes/vapours or other industrial exhausts which seriously affect its hygroscopic response and thus are liable to adversely affect the performance of the instrument before long.

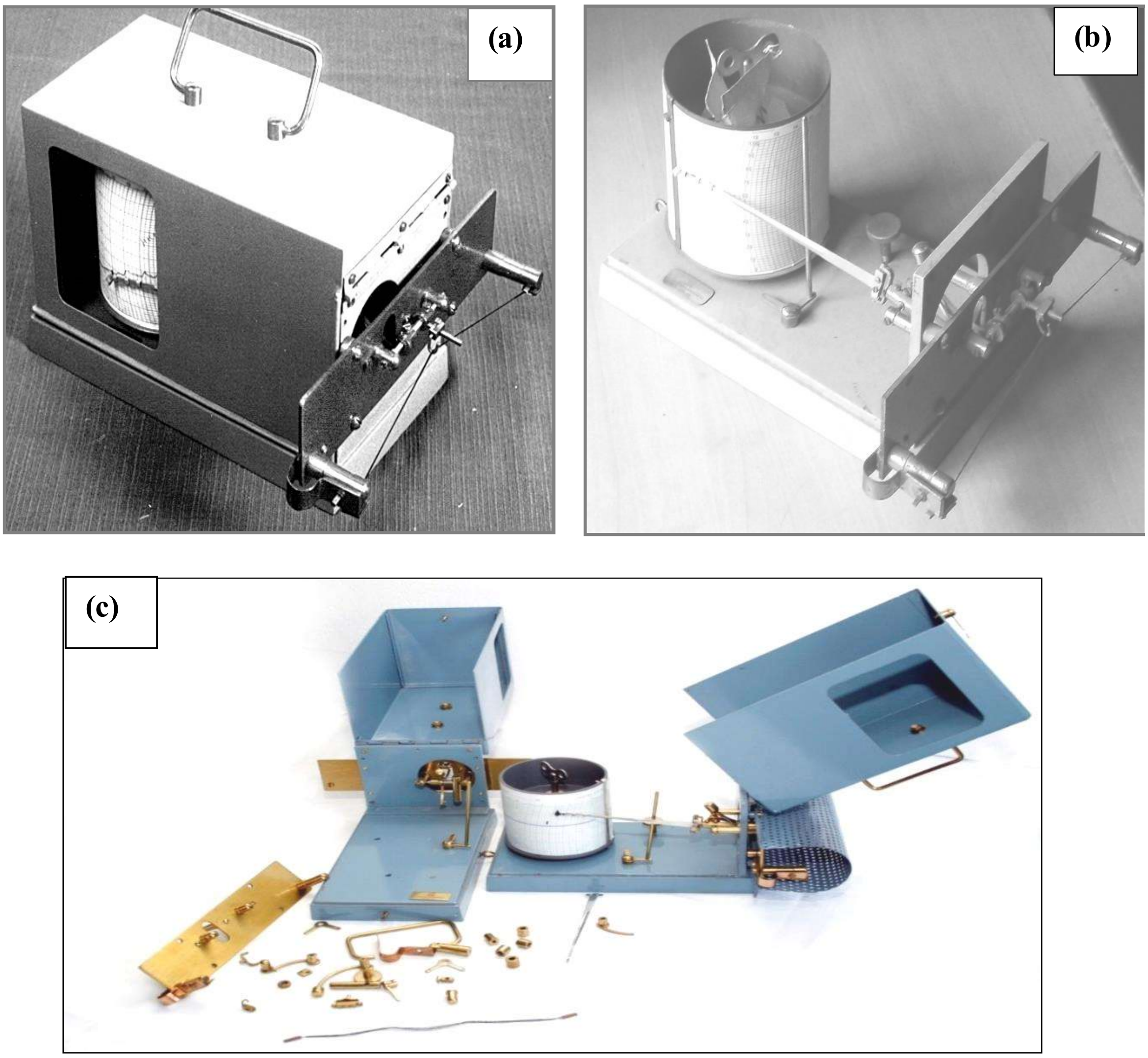


Fig.28 (a) Hygrograph with protective guard removed (b) Instrument with cover case removed (c) Complete assembly of Hair hygrograph.

4.3.1 Operation of hair hygrograph

The routine operation of the instrument involving replacement of chart, inking the pen, making time marks etc., are similar to those carried out with a bimetal thermograph and are described in detail in section 4.2. Making time marks on the chart, however, requires greater care to ensure that the hairs are not over-strained in the process, as this may give rise to a shift in the 'zero' of the instrument/trace. Thus, to record the time mark on the chart, the pen arm is very lightly depressed by a finger only in the direction which would decrease the tension on the hair element i.e. in the direction of decreasing R.H. - the tension on the hairs being minimum, when the humidity is minimum.

For making an observation from the recorder, the instrument is gently tapped with a finger every time, before a reading is taken, to ensure that the pen is free from friction and is at its natural position which would indicate the true reading.

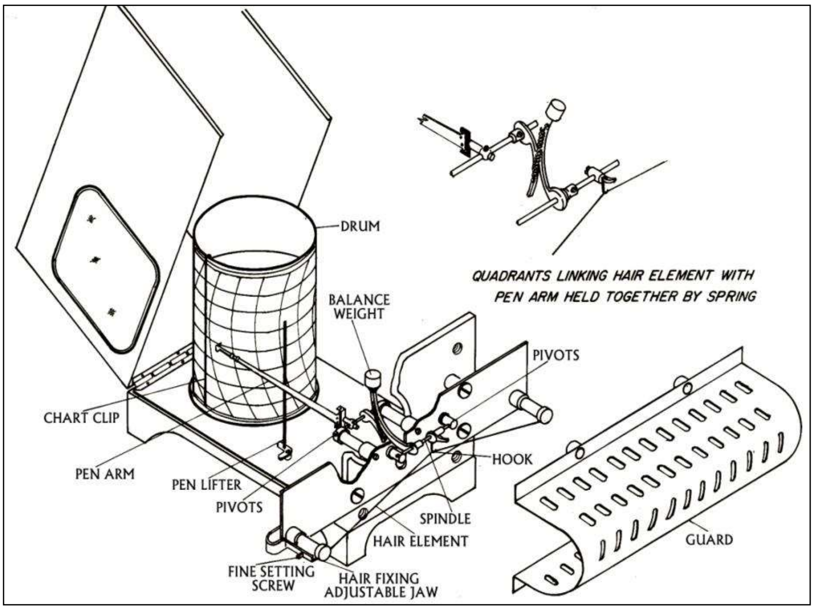


Fig. 29: Hair hygrograph – construction details

4.3.2 Routine setting and adjustment of hygrograph

Like a bimetal thermograph, the hygrograph, with its system of levers, spindle and quadrants etc. linking the sensing element to the recording pen, is also provided with various adjustment and setting devices which help to obtain optimum performance of the instrument and satisfactory records of correct R.H. values. A simple and quick periodic check - weekly, if not twice a week - at the time of changing the chart, on the reliability of the record being obtained, goes a long way in obtaining accurate R.H. values from the record. A comparison between the readings given by a hygrograph and a psychrometer at any instant of time for instance, would be ideal. This is, however, liable to give large differences between the two values - may be even more than 5-6% R.H. at times - as the response of the hair element to changes in humidity is rather slow. Two spot checks, one at 100% R.H. value and another at a lower humidity within a room, when the room temperature is fairly steady, are thus easily carried out. The 100% R.H. check is done by wetting the hair element thoroughly with distilled water using a camel hair brush and draining/wiping off excess water with the brush. When the hairs have attained equilibrium, the instrument would indicate 95-96 % R.H. (and not 100% R.H.) as apparently some excess water retained on the hair increases its weight which causes slight sagging of the hair, thus moving the pen to record less i.e. 95-96% instead of 100% R.H. The check at lower humidity is carried out within a room against the reading given by an Assmann/whirling psychrometer when the room temperature is fairly steady. The checks are better repeated after some time interval and the mean of departure from true readings is taken to determine the correct difference between the readings given by the hygrograph and 100% R.H. and hygrograph and psychrometer in the room. The instrument is then suitably adjusted to correct the departures from the true readings noticed.

4.3.3 Adjustment for full mechanical range of the pen on the chart

The pen has to be free to traverse the full range of the chart from the bottom of the chart to beyond 100% R.H. mark without undue stretching of the hair element. If the pen does not reach the 100% R.H. mark on the chart, perhaps the two quadrants have reached their end position. The pen arm is made loose and then moved up by slightly rotating its position on its spindle and then refixed with the help of the screw fixing it on the spindle. In the other extreme end of the quadrants, the small counter weight at the top of the hook-arm quadrant, may touch the housing, so that the pen does not reach the bottom of the chart. The hook-lever arm is then loosened and the hook-lever rotated slightly on its spindle to obtain the movement of the pen up to the bottom of the chart. The full range of pen movement is normally achieved when:

i) the point of contact of the two quadrants is nearly in the middle of their traverse when the pen reads 50% R.H. on the chart, and

ii) the hook-lever arm at the same time is slightly inclined from the vertical towards the housing.

4.3.4 Adjustment for zero shift/zero error

i) zero shift of 5 to 6 % in R.H. record

If the error in the recorded values at the two check points is small (about 5-6%) and systematic in nature i.e. in the same direction, it could be due to a shift in the zero position indicated by the instrument which often takes place for some reason the instrument being exposed to very low humidity for a long time, accidental over stretching of the hair element, gradual change in dimension due to hair having been under tension for long time etc. This is easily corrected by adjusting the tension on the beryllium-copper (Be-Cu) spring with the setting screw provided for the purpose of bringing the pen to the required reading on the chart. For the 100% R.H. check, the pen is brought to 95% R.H. mark on the chart, in case it shows any departure from it.

ii) zero shift of more than 10% in R.H. record

If, however, the errors observed at the two check points are more than 10% and still systematic in nature i.e. in the same direction, the tension on the hair element requires larger adjustment which cannot be accomplished with the help of the Be-Cu spring. The end piece of the hair element, held by the jaw-clamp is then drawn out or pushed in, by loosening the jaw clamp (with the help of the screw) till the pen is brought approximately to the correct position and the jaw clamp is tightened. Finer adjustment, if any required thereafter, is made by adjusting the Be-Cu spring tension to obtain correct position of the pen on the chart.

4.3.5 Adjustment for magnification / scale value

Sometimes the hygrograph may indicate consistently lower values when the humidities are high and comparatively higher values when the humidities or low or vice versa. This happens when the total span of movement of the recording pen is much less/or more than that indicated on the chart (i.e. for a true humidity value of say 40% - as obtained from a psychrometer the pen indication is 45% (or 35%) on the chart, while for say 80% true R.H., it is recording only 75% (or 85%) on the chart}. The magnification/ scale value of the instrument then needs to be suitably adjusted so that the pen span coincides with the scale graduated on the chart and the R.H. values as recorded on the chart correspond to the true R.H values obtained with a psychrometer.

The magnification can be adjusted by:

i) Raising or lowering the position of the hook (holding the hair element) along the length of the lever arm

Raising the position of the hook towards the spindle increases the magnification while lowering its position along the lever arm away from the spindle decreases the magnification. The change in magnification is very nearly proportionate to the displacement in the position of the hook on the lever arm. The hook is easily loosened and the hair element which is already carefully adjusted and clamped is better carefully taken out from the hook to avoid possible damage to it while adjusting the hook position on the lever arm. The element is then replaced and the hook tightened afterwards.

ii) Lowering or raising the pen arm position on its spindle

This varies the position of the pen-arm relative to the pen-arm quadrant. In effect, it moves the point of contact of the two quadrants corresponding to any humidity value recorded earlier, resulting in increase or decrease respectively, in the magnification for practically the whole range. The method is, however, preferably used in situation, when for example, for low humidity values in particular, the instrument indicates higher (or lower) reading than the true value and the error becomes larger, the lower the humidity.

Making various settings and adjustments to obtain optimum performance of the instrument and reliable records of R.H. values on the chart, however, requires much skill and patience, as this is essentially carried out only by trial and error. Every time, a setting is changed the instrument is allowed to attain its natural position and a record for 8-12 hours (preferably 24 hours) is obtained to evaluate its performance, before further adjustments are made to improve upon the recorded readings.

4.3.6 Sources of error and accuracy in measurements with hair hygrographs

While the relative humidity can be read on the chart nearest to 1%, the overall accuracy of the hair hygrograph in steady atmospheric conditions can be taken as correct to within ± 5%. If, however, the atmospheric humidity changes rapidly, the errors tend to become larger, though the instrument is quite sensitive to changes in humidity.

Thus, as the hair hygrograph gives direct record of R.H., is simple to operate and when properly maintained, it is capable of providing fairly reliable information on atmospheric humidity and its variations with time, it is widely used at meteorological stations except perhaps in regions, which experience extreme temperatures and low humidities. However, the inherent lag of the hair element, the deteriorating effect of atmospheric contamination on its performance, the friction in the mechanical linkages from the hair element to the recording pen and its movement on the chart, the likely zero shift and changes in the characteristics of the hair in course of time due to being subjected to constant tension etc. - all together - are liable to cause large errors in R.H. readings, sometimes as much as 15%. The hair hygrograph is thus not regarded as a very precise instrument which can be used as a standard for making humidity measurements.

4.3.7 Maintenance and care of hair hygrograph

Once properly adjusted, the performance of the instrument essentially depends on the satisfactory maintenance of the hair element and keeping the movement of the system of levers/spindles/cams, free from friction. The hairs are carefully cleaned/washed with distilled water using a camel hair brush, the frequency of cleansing depending upon the local atmospheric conditions. In a more polluted/dustier environment, where the instrument is exposed to industrial exhausts/salt spray at coastal stations etc, the cleaning is done weekly or even more often. The friction in the mechanical movement of the recording system is mainly contributed by the contact surfaces between the two opposite quadrants. Their surfaces are thus maintained and kept clean to obtain smooth traverse of the quadrants. The two surfaces are occasionally polished using a blotting paper rubbed with graphite or lead pencil. This helps to make movement of the quadrants smooth and free from friction. A touch of thin, light clock oil at the spindle pivots/bearings, is also applied at times, if the spindle movement is noticed to be not quite free and smooth.

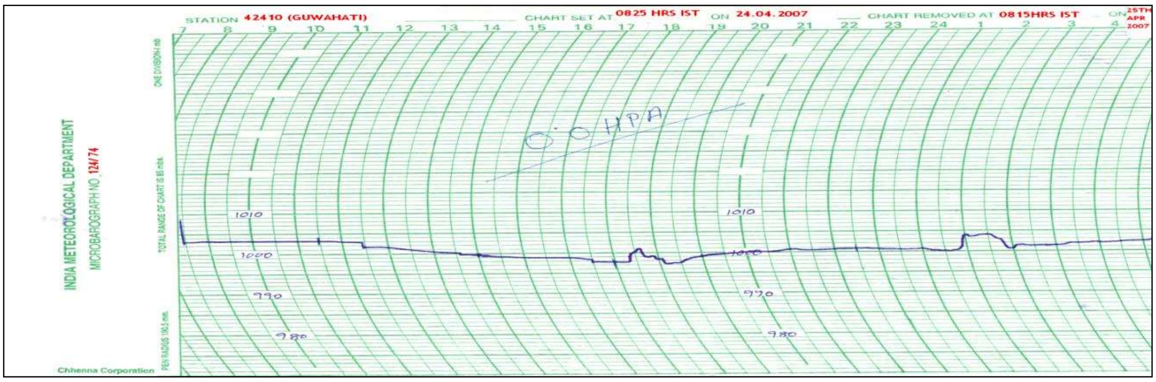


Fig. 30 RECORDING OF RELATIVE HUMIDITY ON A CHART FOR 24 HOURS OF PERIOD

4.4 Self Recording Rain Gauge (SRRG):

Fig.31 Self recording rain gauge assembly

4.4.1 Calibration and testing

To obtain the full range of 10 mm on the scale of chart 325 cc of water is poured from measuring glass.

Particulars	Raingauge for 10 mm Rainfall(mm)	Raingauge for 25 mm Rainfall(mm)
Minimum thickness (base and collector)	3 mm	3 mm
Overall height	675±3 mm	675±3 mm
Internal diameter of gun metal rim	203 - 203.4 mm	128.5 -128.6 mm
Depth of funnel from upper edge of rim (minimum)	175 mm	175 mm
Internal diameter of funnel outlet pipe	10 mm	10 mm
Height to which float has to rise from zero for discharge	60.0 mm	60.0 mm
Diameter of clock drum	93.3 mm	93.3 mm

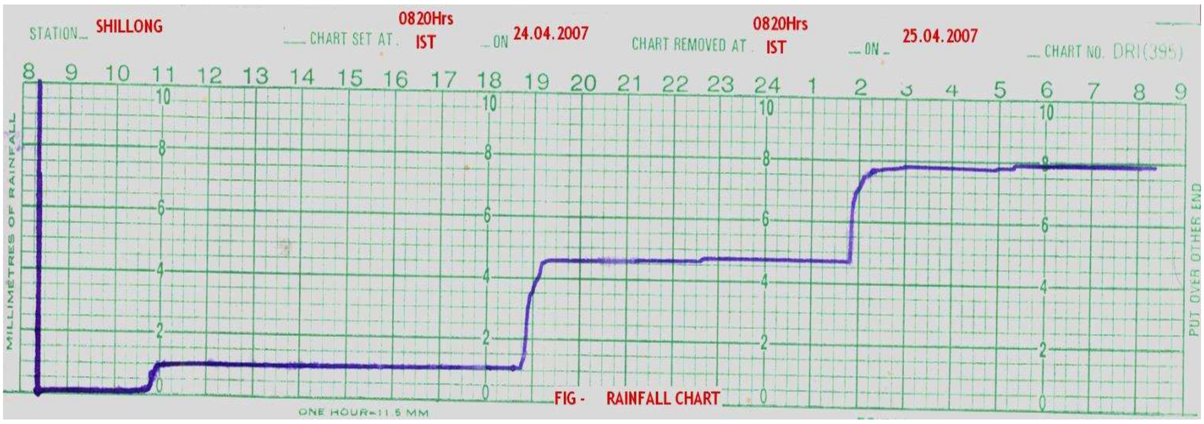


Fig. 32 Recording of rainfall on chart for 24 hours period

4.4.2 Natural Siphon Recording Rain gauge

Basically, the recording rain gauge, like an ordinary rain gauge, is also in two sections:

i) The upper section which comprises of a collector having an aperture diameter of 203 mm and having a deep-set funnel similar to an ordinary rain gauge. It also acts as a cover for the recording mechanism assembly.

ii) A lower section - the base unit, with a sturdy flat top on which the recording device is mounted with three screws, which also help to level the recording unit. The upper section has a glass window and sits on the base unit such that the recording device can be viewed from outside. The cover can be padlocked to the base. It can be easily lifted off the base to provide easy access to the recording device. Fig. 33 shows the rain gauge with collector removed from its base.

Essentially, it is the ingenious recording mechanism of the siphon type recording rain gauge that enables the instrument to automatically make a faithful record of the rainfall over long periods, on a chart paper. The rain water entering the rain gauge collector is led via the funnel into a float chamber, through an entrance tube having wire gauze filter. The chamber has a hollow light float having a vertical rod at its top and a flat strip at its bottom. The rod protrudes through a threaded collar fitted in the centre of the top lid of the float chamber. The collar also serves as a guide to the float rod. The float rod and the float strip move vertically in guides provided at the top and bottom of the chamber. The flat strip also prevents the float from turning around. A recording pen is fitted to the float rod. As the water level in the float rises, the float too rises vertically, and the pen attached to its stem records a trace on a chart wound on a clock-driven drum, thus providing a graphic record of rainfall against time.

Fig. 33 Natural siphon recording rain gauge with collector removed from its base

In order to obtain a record of say 24-hours of rainfall, it may thus be necessary either to have a very large float chamber with a suitable float of appropriate dimensions or alternatively to have some arrangement that would automatically empty the float chamber when it is full, to be able to receive more water as the rain continues

This is achieved by employing a siphoning arrangement, so that as the pen reaches the top of the chart when the float chamber gets filled, siphoning occurs automatically, emptying the chamber quickly, bringing the float to the bottom of the chamber and pen to the zero line at the base of the chart. Fig. 34 shows the rainfall recording mechanism.

The siphoning action is achieved in an ingenious way. The float chamber, having a hollow light float with a vertical rod attached to its top, is joined at its side with a shorter cylindrical siphon-chamber with a V-shaped opening between the two chambers, such that the water from the float chamber is led to the side chamber through this opening. The joint is made water tight. The siphon arrangement has a long discharge tube with a sharp top edge, running up through the bottom of the cylindrical siphon chamber and is placed coaxially within the chamber. The chamber is directly connected with the main float chamber through the V-shaped hole. A polished glass disc cap is used to cover the top of the siphon chamber, while the top of the discharge tube comes up very close to the bottom of the glass disc - almost touching it. The annular space between the glass disc and top of the discharge pipe is very small (of the order of 2 mm - almost of capillary dimensions). Thus, the large total area of the annular aperture is confined into very small vertical distance which enables rapid siphoning without 'dribbling'. When the water level in the outer tube rises to the top of the inner tube, capillary action pushes all the air out through the capillary tube, so that the siphoning starts instantly with full flow, without any tendency for the water to 'dribble' initially. The speed of siphoning is maximum when the area of the annular ring is equal to the area of the top of the discharge tube. Thus if 'd' is the diameter of the discharge tube and 'h' the height of the annular space between glass disc and top of the discharge tube, then the speed of siphoning is maximum when:

$$\pi\, d\, h = \frac{\pi\, d^2}{4}$$

$$\text{or} \quad h = \frac{d}{4}$$

Similarly, siphoning stops also abruptly when the water column is broken as air gets into the capillary at the top of the tube after the water level has reached a fixed depth in the float chamber, as determined by the V-shaped opening between the side chamber and float chamber. The sharp V-shaped-hole joining the two chambers ensures that the siphoning always ends instantly and at the same level of water in the float chamber and that the amount of water siphoned every time is exactly the same. The whole siphoning action is thus natural and automatic; instant and sharp, without the water tending to 'dribble' either at the beginning or at the end of siphoning. When properly adjusted it does not take more than 10 to 15 seconds for complete siphon action.

The instrument thus provides a graphic record of rainfall against time with the pen tracing from zero line of the chart and reaching up to the top of the chart when the float chamber gets filled and siphoning takes place bringing the pen back to zero line. As the rain continues, the pen rises again. However, after the rain stops, the pen stops rising and starts to trace a horizontal line. Since the float chamber empties itself automatically when it gets filled, the instrument can record unlimited rainfall.

The instrument uses a standard clock drum while the chart is usually graduated to have a range of 10 mm of rainfall before siphoning occurs. Once properly adjusted for correct siphoning and recording, the instrument provides long periods of trouble free and sufficiently accurate recordings of rainfall, as the natural siphon action does not require any moving parts except the float. This type of instrument is thus widely used all over the world.

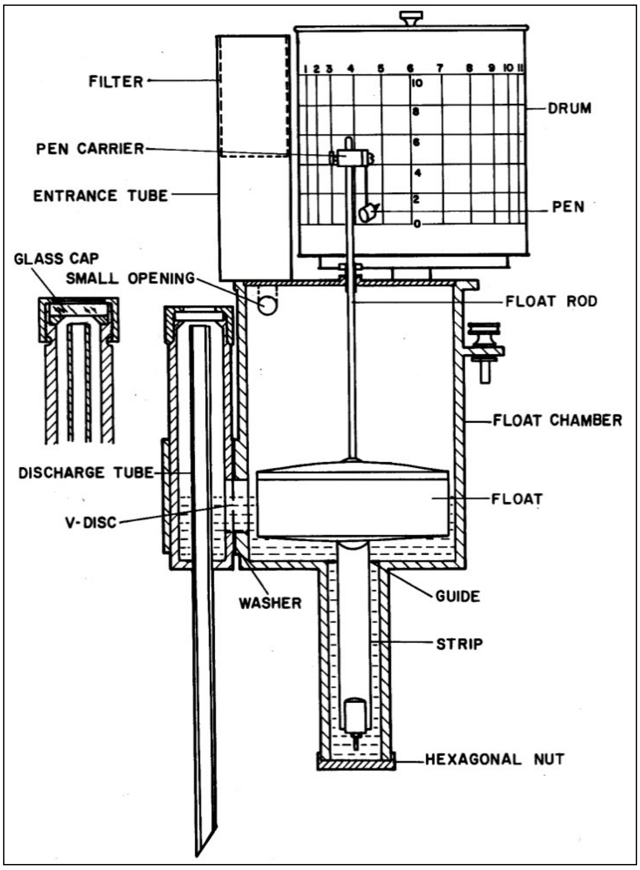


Fig.34 Rainfall recording mechanism

4.4.2.1 Adjustments

Some adjustments may be necessary to ensure that i) the pen reaches the 10 mm indicating horizontal line on the top of the chart when an amount of water equivalent to 10 mm of rainfall is poured slowly into the receiver tube leading to the float chamber, and ii) after all the water is drained out, the pen rests on the zero line of the chart. This is easily achieved by moving the pen carrier on the float rod and/or adjusting (raising) the threaded float rod guide collar on the top lid of the float chamber, if the collar is noticed to restrict the movement of the float upwards.

4.4.2.2 Method of observation

While the total amount of rainfall that has fallen since the record was started and the time of onset and cessation of rain can easily be read from the chart, the intensity of rainfall at any instant or average rate of rainfall during a period of time can also be easily calculated. Example: it can be seen from Fig. 35(a) that

i) The slope of the trace PP' at a point 'A' will give the intensity of rain at that instant viz. :

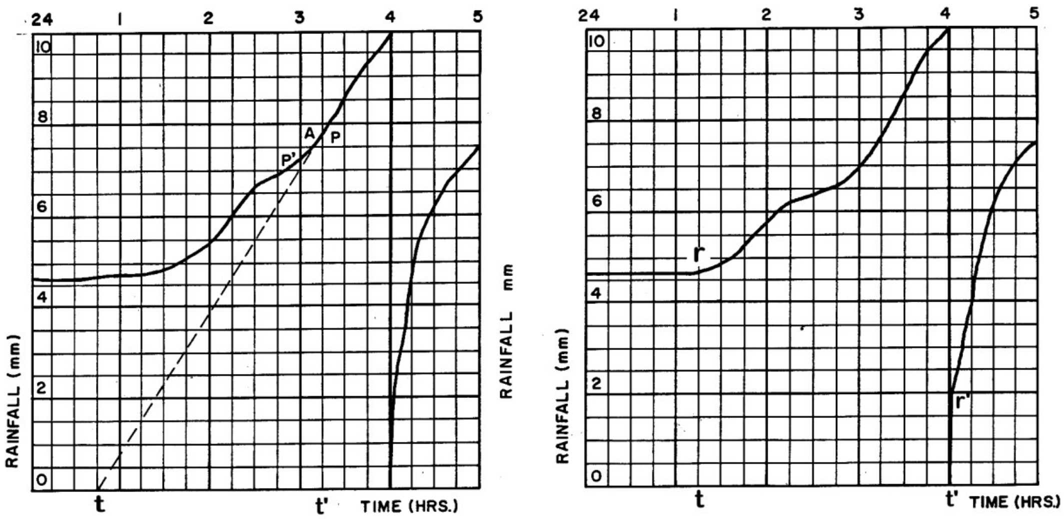
intensity at instant t' = At' / (t'-t) i.e. 8 / 2.5 = 3.2 mm per hour

where At' is in mm and (t'-t) is given in hours.

And

ii) If r is the rainfall in mm up to t hours and r' up to t' hours, the average rate of rainfall during the time interval (t'-t) [Fig 35(b)] is given by :

(r' - r) / (t' - t) i.e. (10- 4.7) / 2.75 = 1.9 mm per hour.



(a)Intensity of rainfall at instant 't'   (b) Average rate of rainfall during interval t'-t

Fig. 35 Computation of intensity of rainfall from the chart

4.4.2.3 Maintenance and care

Apart from the usual care taken to see whether the receiver funnel and the wire gauze filter in the entrance tube are maintained clean and do not get choked by dust/leaves etc., it is important that the inside of the glass cap of the siphon chamber is also clean, as this ensures proper siphoning. If required, the glass has to be cleaned with a soft dry cloth. Regular checks also need to be made for siphoning duration and for correct pen settings for 10 mm and '0' trace lines on the chart indicating satisfactory beginning and end of siphoning action respectively.

A watch on the general performance of the float is also advisable. If the float develops minor leak, some water will get into it and thus the pen will fall below the zero line after the siphoning action. Also siphoning will then occur after more than 10 mm of rain has fallen. If, however, the float develops heavy leak, the instrument will not work. In both cases the float would need replacement.

There is always some amount of water left in the float chamber, even when the siphoning is completed, and the pen is resting on the zero line of the chart. The float chamber is thus liable to be damaged, if the instrument is exposed to snow or frosty weather. In such a situation, either the instrument is provided with some kind of electrical heating device or is removed indoors.

Care also is to be taken to periodically check the flared end of the siphon tube for any clogging by dirt and soil, particularly so at sites where soil is loose and gets easily disturbed by wind and insects.

4.4.2.4 Sources of error

The instrument is liable to some errors in rainfall recording, inherent in the design of the instrument itself. These are mainly:

i) the rain falling into the receiver, when the siphoning action is taking place, goes unrecorded. There is thus always some loss of record of rain, though received in the recorder and the error is proportional to the rate of rainfall and siphoning duration; and

ii) during the period of heavy rain, the series of traces get crowded together, making them indistinguishable, which may result in serious error in computing the total rainfall.

4.4.3 Tipping bucket rain gauge

The tilting or tipping bucket rain gauge is an event-type sensor. A light metal container or bucket is divided into two compartments and is balanced in unstable equilibrium about a horizontal axis. In its normal position the bucket rests against one of two steps, which prevents it from tipping over completely. Rain water is conducted from a collector into the uppermost compartment and after a predetermined amount has entered the compartment, the bucket becomes unstable and tips over to its alternate rest position. The bucket compartments are so shaped that the water is emptied from the lower one. Meanwhile subsequent rain falls into the newly positioned upper compartment. The movement of the bucket as it tips over can be used to operate a relay contact to produce a record consisting of discontinuous steps; the distance between each step on the record represent the time taken for a specified small amount of rain to fall. At each tipping motion a permanent magnet actuates a reed-relay which switches on electrical circuits, producing an electric impulse. These pulses can be used for recording the rainfall data on a recorder.

Fig.36 Tipping bucket assembly

Specifications

Collector area: 324 sq.cm.

Rim diameter: 203.2 mm ±0.2 mm

Rim material: Gun metal/brass/aluminium alloy

Sensing: Reed switch

Resolution: 0.5 mm or 1 mm for rainfall intensity upto 100mm/hr

Accuracy: ±3%

Level: Bull’s eye spirit level fitted on mechanism

The mounting bolts (M8 X 130) with six nuts and six washers with proper surface treatment should be supplied with the rain gauge. All openings of the rain gauge should be covered with stainless steel net to protect against any insects entering inside. Calibration is carried out by flow of known quantity of water through burette.

4.5 Dines Pressure Tube Anemograph (DPT Anemograph)

The Dines pressure tube (DPT) anemograph {Dines, 5.2} provides continuous recording of the instantaneous values of both the wind speed and direction simultaneously on a single chart. While the wind direction is recorded by means of an aero foil wind vane directly coupled to a specially designed mechanical recorder, the wind speed is measured by a pitot-tube device and is recorded by a sensitive float type water-manometer recorder. The rapid response of the instrument enables faithful recording of wind fluctuations, giving a detailed structure of the wind. Thus, from the record, the average velocity of wind during any given time, the frequency of gusts, the maximum and minimum speeds of individual gusts and their duration can be easily determined.

Apart from its rapid response and accuracy of measurement, the DPT anemograph is capable of recording very high cyclonic winds of the order of 250 kmph or more. Another great advantage with the instrument is that it does not require any electrical power for its operation. Thus, when the electrical power is a casualty, as it often happens during a cyclonic storm, and other wind measuring instruments/equipment stop functioning due to power failure and the information on wind speeds—particularly the maximum wind speed encountered during the stormis of vital importance, the DPT anemograph provides an invaluable tool to fully and correctly measure and record the disastrous winds. As such, a large number of these anemographs are in use in India and in several other countries. The instrument is thus described in greater detail.

4.5.1 Principle of measurement of wind speed

The pressure tube (PT) anemograph makes use of the dynamic pressure of the wind to measure and record wind speeds. It is based on the principle of pitot-static tube used for the measurement of wind speed at a point. It has been known that the wind blowing into the mouth of a tube causes an excess of pressure in the tube, depending on the wind speed, while the wind blowing past, across the mouth of the tube causes suction, thus reducing the pressure inside the tube, the reduction of pressure being dependent on the wind speed. Either of these effects can be used to measure the wind speed, using a sensitive manometer. Both these effects can also be suitably combined to obtain magnified effect for better indication/recording of the wind speed.

According to Bernoulli's theorem for fluid motion, the total hydrostatic pressure at any point in a fluid (or air in this case) in streamline motion is related to the fluid velocity at that point. The total pressure `p', also known as `total head' or `total head pressure' at such a point in an airflow, is made up of two parts:

(i) a static pressure of the air stream at the point p_s
(which is the barometric pressure)

and

(ii) a velocity pressure or pressure due to the velocity of wind at the point $(\frac{1}{2})\ \rho\ v^2$

where v = velocity of air stream and ρ = the density of air

Therefore, $p = p_s + (1/2)\ \rho\ v^2$

(In an experiment, the total head pressure in a wind flow can be easily measured by inserting a tube into the air stream with the open end directly facing into the wind and the other end connected to a manometer).

The velocity of air `v', can thus be obtained by measuring the difference that exists between the total head pressure ‘p’ and the static pressure ‘p_s of the air stream at that point.

If two tubes (one with a bigger diameter than the other) are held together concentrically, with the top end of the outer tube joined to the inner tube and several rows of holes (suction holes) are drilled around its wall at some distance from the top joint, they form the pitot-static-tube. The anemograph essentially employs a suitably modified pitot-head for the measurement of wind speed. A T-shaped tube forms part of the horizontal arm of a wind vane, having its one end open and the other end closed. Its vertical support section, which is in communication with the open end, is placed into a pitot-tube inlet pipe. Thus, when the double walled pitot-tube is held vertically, so that the open end of the horizontal arm faces into the wind, the air pressure within the inner tube (of the pitot-tube) is equal to the total head, which increases with the wind speed. This gives rise to the ‘pressure effect’ and the tube acts as a `pressure' tube thus deriving the name `pressure tube' anemograph.

The excess of pressure in the horizontal tube is thus $(\frac{1}{2})\rho v^2$, where ρ = density of air and v = speed of air motion.

On the other hand, as the pitot-tube is held at right angles to the wind flow, the wind blowing across the holes in the outer tube, also sucks out air in the process from the space between the two tubes. This results in a reduction in pressure in the annular space between the tubes, giving rise to a suction effect. The tube thus acts as a ‘suction tube’. The decrease in pressure, however, depends upon the dimensions of the holes, their shape and angle to the vertical axis of the tube.

The variations in the difference in pressure between the pressure and suction tubes thus gives a measure of the variations in wind speed. The two effects are, however, added to obtain larger variations for better measurement and recording by connecting the two tubes to the opposite arms of a sensitive water manometer.

It may be noted that as both the `excess' pressure and the `suction' pressure generated depend on the wind speed, either of these effects can be used to measure the wind speed. In that case however, apart from the small magnitude of the individual effect, the other end of the manometer will remain open to the room. Thus, if the room pressure fluctuates due to the `pumping effect', caused say by strong gusty winds, and does not remain steady at the true atmospheric pressure, the measurements are liable to be in error. As such, the combined effect of the two pressures is better used for recording the wind speed. This not only helps to magnify the resultant effect but also avoids the errors caused due to the other end of the manometer being open to the room as it is independent of any possible difference in the atmospheric pressures between the outside of the building and inside, where the recorder is installed.

The usual U-type manometers are not considered suitable for the purpose as the pressures to be measured are very small. A wind speed of about 30 kmph gives a pressure of only about 7mm of water, which is less than 1 hPa. The use of sensitive water manometers capable of reading correct to 0.05 mm of water or better, needed for ordinary wind speeds normally encountered, is thus essential for the purpose.

Though the difference in pressure between the `pressure' and `suction' tubes is proportional to the square of the wind speed, an ingenious float- type sensitive water manometer, designed by W.H. Dines, translates the movement of its float to be directly proportional to the wind speed so as to obtain a linear scale for the wind speeds measured. This is then recorded on a chart wound on a clock-drum.

The pressure tube anemograph consists of three main parts:

i) Head and Vane,

ii) Mast, which supports the head and vane and the pressure and suction pipes as well as carries the direction transmitting tube, and

iii) Speed and Direction recorder usually placed vertically below the head and vane assembly.

4.5.2 Head and vane

In the DPT anemograph, the horizontal pressure tube is built into the wind vane so that it always faces the wind, while the suction tube forms part of the vertical pipe section that supports the wind vane. The head and vane assembly essentially consist of two parts:

Fig. 37 DPTA Assembly

a) The horizontal rotating part:

It is a specially designed wind vane with a large fin of aero foil section at one end of a horizontal tubular arm while the other end of the arm has an open inlet, which serves as the pressure tube. It also has a small vertical tubular arm in the middle to support the vane and is open to the horizontal tube. It thus forms part of the pressure tube and slips over the vertical pipe of the main `head'. A rain guard is provided around the tube to prevent any rain water going into the pressure tube. The vane keeps the horizontal pressure inlet always facing into the wind.

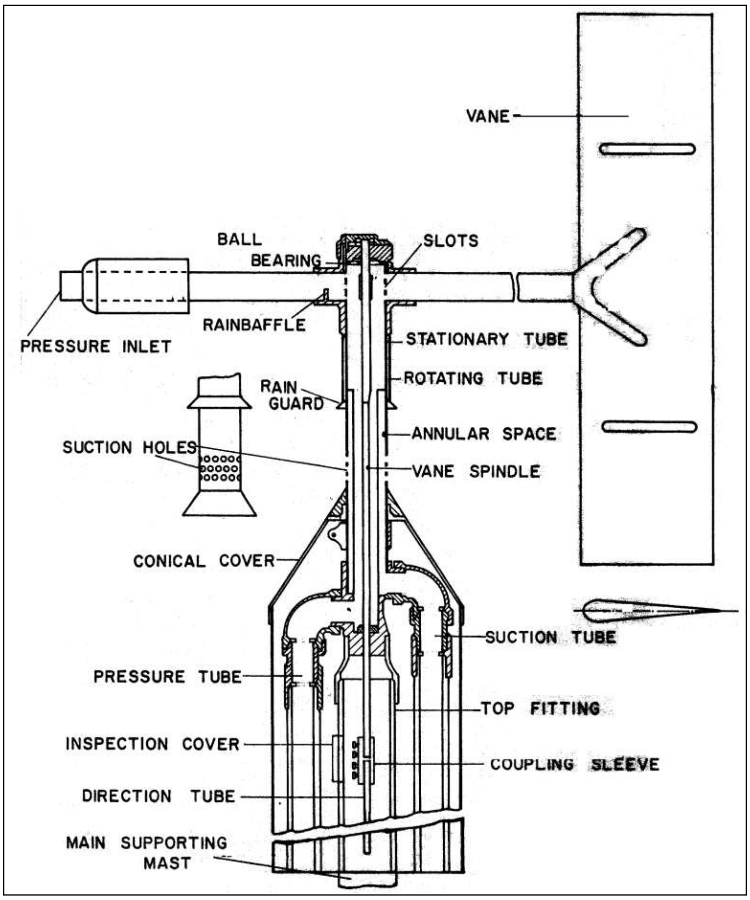


Fig. 38: Head and vane of Dines Pressure Tube Anemograph

b) The vertical fixed part:

The `head' which supports the vane consists of a vertical stationary tube with two concentric sections: i) the inner section which is always in communication with the pressure inlet (built into the vane) through vertical slots at the top of the main central tube and forms the `pressure tube' and ii) the outer section which has a number of holes--the suction holes--all around at its lower end. Since the suction effect is very much dependent on the orientation of the tube, a number of holes are drilled all around the tube at its lower end in several rows. The outer section forms an annular space around the inner tube, which thus becomes what is known as the `suction tube'. The suction and pressure tube outlets terminate in elbows (which are connected to the recorder by means of additional tubes). The main central tube of the head carries at its top a ball race (special bearing). The vane rests on the bearing, which thus carries the whole weight of the vane and also forms the support for the direction spindle. The whole unit is called the `head'.

The vane rotates on the ball bearing. The vertical tubular vane arm which rotates with the wind and the stationary main vertical supporting tube have an excellent smooth fit to provide satisfactory air seal between the vane and its support. The pressure and suction outlets, being not symmetrical to the mast, are liable to vitiate the suction effect with the change in wind direction. The outlets are thus enclosed within a symmetrical cylindrical cover with a conical top, which presents a symmetrical obstruction to the wind and thus helps to produce a uniform suction effect irrespective of wind direction. The whole assembly is supported on a pipe mast.

The direction spindle attached to the vane passes down the central pressure tube through an airtight seal. It is further extended by joining to a length of direction tube, which passes down through the mast and is connected to the direction recorder.

4.5.3 The mast

A suitable mast of appropriate height comprising of a single steel pipe or made up of a set of iron pipes of varying diameters, carries the head and vane assembly at its top. It provides support to the pressure and suction tubes leading from the head to the recorder while the direction spindle passes down through the mast to the recorder.

4.5.4 Wind speed recorder

The wind speed recorder is a specially designed float type water manometer. It consists of a cylindrical tank about half filled with distilled water, a specially designed bell- shaped hollow float and a recording system mounted on the top of the tank. The float is in two parts, the inner part is open at the bottom while the outer part is completely closed. It has sufficient buoyancy to float in the cylindrical water tank.

The hollow float, open at the bottom, rests with its mouth downwards, partly immersed in the tank, with some amount of air trapped in the space inside the float above the water surface. The pressure tube from the vane is lead into this part of the float through a vertical pipe passing up the centre of the tank. While the upper end of the pipe projects above the water surface into the space inside the float, its lower end is connected to the pressure tube through a stop cock `P'. The suction tube is connected through another stop cock `S' to the air space above the float and the water surface in the upper part of the tank.

As the wind blows into the pressure inlet of the wind vane and past the suction holes in the outer tube, an increase in pressure is carried through the `pressure' tube to the inside of the float, generating a 'pressure effect'. A simultaneous decrease in pressure in the `suction' tube sucks out the air from the space above the float at the same time to reduce the pressure there, giving rise to a `suction effect'. Changes in wind speed thus cause changes in the air pressures inside the float and in the tank outside the float. The float is thus differentially operated to rise with the increase of wind speed and to fall as the wind speed decreases. With a decrease in wind speed, the float falls under its own weight.

The float however, has an ingenuous design wherein the outer surface of the float at the water level is cylindrical but the inner surface is uniquely shaped. When the opposite sides of this specially shaped float are subjected to the ‘pressure’ and ‘suction’ effects, the movements of the float with variations in the differential pressure are made directly proportional to the wind speed. Thus, though the pressure difference is proportional to the square of the wind speed, a linear scale of wind speed recording is obtained.

The two stop cocks provided on the pressure and suction lead tubes are such that when they are closed to the vane, they are open to the room so that the inside and outside of the float are open to the room. The difference in pressure between the inside and outside of the float is thus reduced to zero. This enables proper zero setting of the speed recorder.

A drainage plug is provided near the stop cock in the pressure tube entrance to the water tank. This helps to drain off any water that may enter the pressure tube inlet at the wind vane due to rain blowing into it. Also, if the float is moved up and down by hand to carry out some checks, the water level in the tank sometimes may rise above the level of the centre pipe and some water may thus enter the inlet pressure tube. If much water accumulates in the inlet tube, the records obtained will not be correct. This could be detected from the decrease in gustiness in the records.

A roller fitted at one end at the top of the float runs freely in a vertical guide fixed on a side within the tank. It guides the up and down movement of the float. This also prevents the float from rotating about its axis. A water level gauge fixed to the outside of the tank indicates the water level in the tank (outside the float) and also enables to make adjustment of the water level - adding or removing water through its top to keep the level constant.

A vertical rod attached to the float passes through a friction free gland at the top of the tank and carries a recording pen, which moves up and down with the float. The rod also carries a small cup at its top to place some lead shots in it to adjust the zero setting on the chart. The pen traces the wind speed records on a chart wrapped over a slowly rotating clock drum.

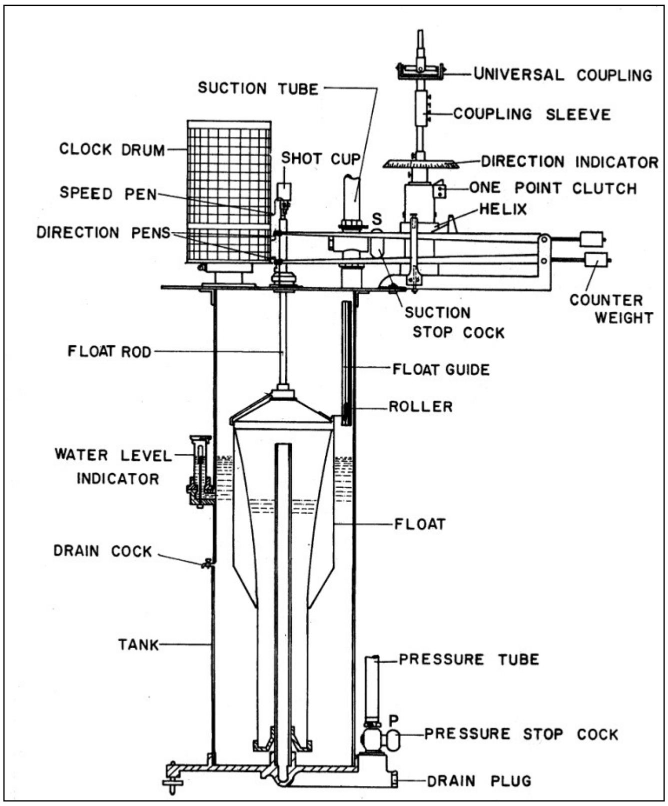


Fig.39- D.P.T. Anemograph wind speed and direction recorder

4.5.5 Wind direction recorder

The direction record is obtained using an ingenuous twin pen direction recorder located below the mast installation and aligned with the head and vane. The recorder has a vertical brass cylinder on which is cut a double helix. The helices are formed as steps on the surface of the cylinder and engage the two recording pen arms. The twin pen arrangement is used to ensure that no record is missed when the brass cylinder may make a complete revolution. One pen or the other, thus always maintains the trace on the chart. The pen arms move in the vertical plane and their motion is guided by the upper and lower cams/steps formed in the helix. The vane is coupled to the helix by the direction tube using a universal coupling to take up slight misalignment. The one-point clutch enables easy coupling between the direction tube and the helix.

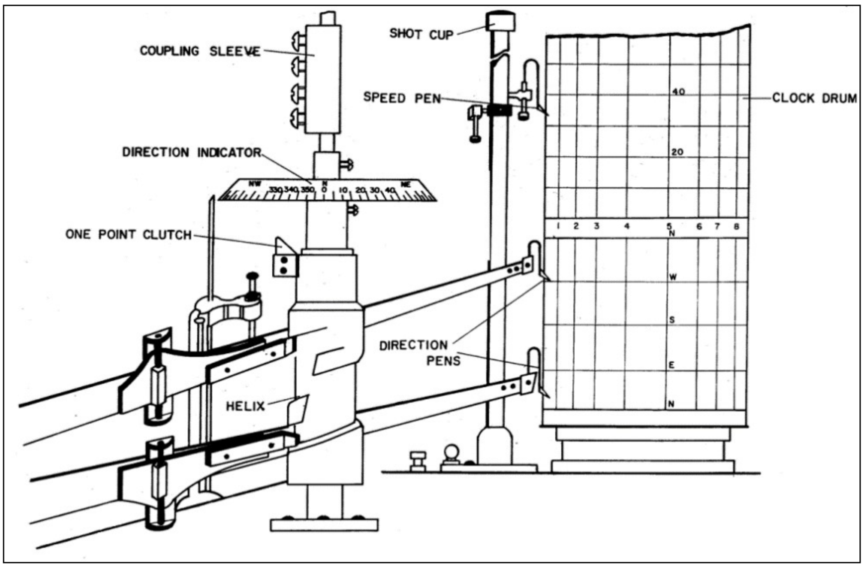


Fig. 40 D.P.T. Anemograph direction and speed recorder mechanism

As the vane rotates the twin direction pens are operated by the helix and the rotary movements of the vane are transmitted to the recording pens as linear displacements in the vertical plane. The pen arms have spring-loaded knife edges, which keep them always engaged with the upper and lower cams/steps of the helix so that the motion of both the pen arms is guided and controlled by the helix cams. The two arms are pivoted and so balanced by counter weights that the upper pen always presses against the upper cam and thus tends to move up. The lower pen on the other hand, presses against the lower cam and thus always tends to fall. When the instrument is properly adjusted, only one pen operates at a time.

The lower pen arm is slightly under-balanced and when disengaged, falls to its stop so that the pen coincides with the lower North line. The upper pen arm however, is slightly over- balanced and when disengaged, rises so that the pen stops on the upper North line on the chart. If the lower pen reaches the upper line or vice-versa, it gets momentarily disengaged and is returned by the counter weight to its own line. At any time, therefore, one of the pens rests idly on its own line - on the top or the bottom North line, while the other pen operates. At no time will both pens operate simultaneously. Thus, if the wind oscillates about the North point i.e. NW or NE, the records will be obtained at the top or the bottom of the chart depending upon which pen is functioning.

A circular scale is fixed about the direction tube near the one-point clutch to provide additional indication of the wind direction.

The direction record is made on the same chart Fig.42 as the speed record with the velocity pen recording on the upper portion of the chart and the direction traces are obtained on the lower portion. The direction graduations on the chart cover 360° and the chart consists of a simple vertical scale in degrees from North through West, South, East and to North, with North at both the top and bottom ends of the chart.

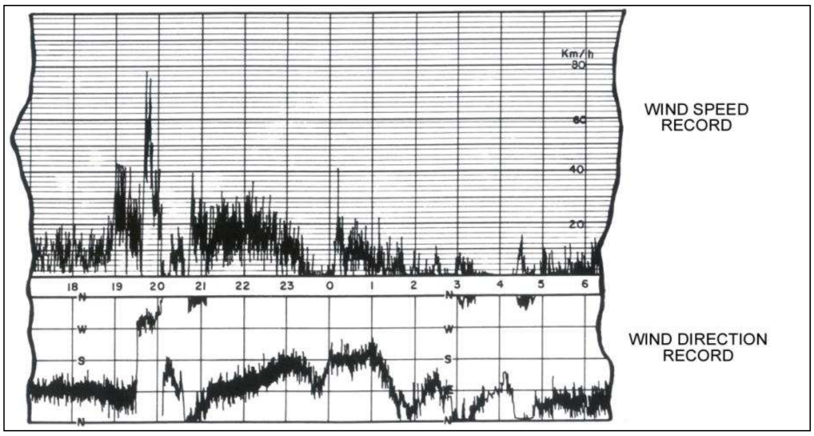


Fig. 41: Typical record – D.P.T. Anemograph

4.5.6 Clock and drum

The recorder is fitted with a daily clock which carries a drum on which is wound the recording chart with both the speed and direction indications printed on it. The clock differs from the other standard types of clocks in its method of fixing the drum, which enables the drum to be slightly raised or lowered to adjust the chart to the direction recorder pens. The clock is wound by moving the handle at its base to and fro.

4.5.7 Remote electrical wind recording with DPT anemograph.

Wind speed and direction as measured by a Dines pressure tube instrument can also be recorded electrically at a remote location. Self-synchronous motors and repeaters have been used for the purpose. A selsyn transmitter is coupled to the vertical rod of the float using a chain and pulley arrangement with a counterweight at the free end of the chain. The linear movement of float rod is thus converted into a rotary movement of the pulley mounted on the selsyn transmitter shaft. A similar arrangement at the repeater shaft drives the speed recorder pen to obtain a linear trace on the chart. The wind vane shaft is also coupled to the direction recorder pen similarly using another selsyn transmitter repeater arrangement. The wind recorder placed at a remote location carries the two repeaters, which operate the two recording pens, thus tracing both the wind speed and direction records on a single chart.

4.5.8 Installation of the anemograph

The instrument consisting of the head and vane is installed on a suitable steel mast or on a tower, either on an open ground or on the roof of a building depending on the availability of a suitable site. The speed and direction recording unit is located directly below the head and vane unit, either inside a shelter if the instrument is located on an open ground or in the corner of a room, if the instrument is on the roof top of a building. In case of roof top installation, the roof is to be broken to make two holes in the roof about 50 cm apart, each of about 10-12 cm diameter, for the direction transmitting tube and pressure and suction pipes to pass through the roof to the recorder unit placed below.

The mast is all assembled first on the ground complete with climbing steps, collars, guy-ropes and strainers etc. including `top-fitting' with the `head' unit screwed to it. The pressure and suction pipes joined to the respective outlets at the head and extended down, are clamped along the mast. The mast is then raised using a pulley and tackle device and the guy wires are straightened till the mast is held tightly in the exact vertical position. The direction shaft is usually assembled from the recorder end to the head to be able to cut the exact length to the recorder coupling. The rotating vane unit and the conical wind shield are then carried up the mast and fixed in position. The vane is simply slipped over the top vertical section of the pressure tube and sits firmly on the two steel pins projecting above the ball bearing.

The speed and direction recorder unit are now carefully set up with the recorder water tank levelled and suitably fixed on the ground to prevent its displacement by any accident which may disturb its alignment and orientation. The float is placed inside the tank with its mouth downwards over the central tube, the float roller engaging the guide and the tank is filled with distilled water to the correct level shown by the level indicator when the float sits at the bottom of the tank. The direction recorder is fixed on the top plate of the tank and the direction disc spindle carefully aligned with the direction shaft from the head so that the coupling sleeve smoothly slides over it. The coupling is to be screwed later after the final adjustment of the wind vane to the true known direction is carried out. The pressure and suction tubes from the head are then connected to the tank with pressure tube to the stop cock at the bottom of the tank and suction tube to the stop- cock above the cover plate of the tank.

The clock and drum and the pens with holders are finally fixed in position to complete the installation.

4.5.9 Setting and adjustments for proper recording

With careful settings and adjustments, the instrument is capable of accurately and faithfully recording the wind speed and directions. Some of the vital adjustments that seriously affect the performance of the instrument are described below:

a) **Direction recorder**

i) Orientation of the vane

To ensure that the wind directions recorded on the chart are true, correct orientation of the vane with respect to the true North (or to an object whose bearing is known) is essential. This can be easily carried out from the ground and is best done on a calm day. The vane is kept steady, aligned to the true North (or any distant object with known bearing) by holding it with a string. The coupling sleeve joining the direction rod to the helix is loosened and the helix turned appropriately till the direction disc and one of the directions recording pens indicate correct and identical direction both on the pointer and on the chart respectively. The sleeve is then tightened and the string is removed.

ii) Engagement of pen arms to the helix

Proper engagement of the pen arms to the helix ensures smooth and continuous records of wind direction. The pen arm knife edges engage with the helix to a depth of about 3 to 4 mm of the contact, just enough to guide the arms smoothly without drag or friction. This ensures that no records are missed, particularly at points where the knife edges slide out of engagement with their helices when the vane (or helix) veers around North. If the depth of contact of the knife edges with the helix is much more than the minimum required, it may give rise to friction in pen movement. On the other hand, if the contact is not sufficient for the pen arms to engage properly, there may be loss of record.

The counter balancing weights to the pen arm lever are so adjusted that both the pens, when disengaged from the helix, have a positive light movement upwards or downwards to their respective North lines. The pen arms also do not rise/fall too rapidly to bounce against their stops.

iii) Alignment and range of pen arms

It is essential that the two direction recording pens as also the speed recording pen are so set that they are all aligned in the same vertical plane when viewed from above, so that they indicate the same time on the chart. Further, when the pens are stationary (as during calm winds), the two direction pens must rest on the upper/lower North line on the chart and the speed pen on the zero line of the speed recording chart. The two direction recording pens, one of which rests while the other one traces the direction records, thus always come to rest on their respective North lines when the helix rotates fully in either direction.

If the direction pens do not come to rest on their respective North lines when they are stationary, the clock drum with the chart may be raised or lowered to achieve their correct adjustment. The speed pen also then needs to be readjusted without disturbing the clock drum any further, by closing the stop cocks to the head and adding or removing the lead shots from the cup to bring the pen to the zero line.

b) Speed recorder

i) Water level in the tank

The water level in the tank is to be maintained to the correct height as indicated on the level gauge. Additional amount of distilled water, if required, is added by removing the top cap of the gauge, while any excess water is drained off by the small stop-cock provided below the gauge on the tank.

ii) Zero-position of the float and smooth movement of float rod

The zero position of the float is indicated when the fiducial mark on the float rod is in level with the top of the guide collar. This is ensured with the help of lead shots in the shot cup. For this purpose, the float is raised by about 10 mm and allowed to fall. When the float weight is correctly adjusted, it will just slowly sink and become steady when the fiducial mark on the rod is in level with the top of the collar.

It is also essential that the float rod, which carries the speed recording pen, moves freely up and down through the guide collar without friction. If the movement is not free, the tank needs to be leveled till the float rod is exactly centered in the hole. If required, the guide collar and the shot cup may be removed from the float rod for the purpose and then refixed in position after the adjustment is done.

iii) Air leaks in the pressure and suction tubes / chambers

Some minor leaks always exist, both in the pressure side along the sleeve where the vane slips over the top fixed portion of the head and in the suction side-around the float rod passing through the guide collar. In a properly maintained instrument, these leaks are within permissible limits for accurate wind speed recording. Larger leaks in the system are however, liable to give erroneous readings. Pressure and suction lines and the air chambers are thus to be kept free from major air leaks.

The leak is usually indicated by the rate of fall of the float. When it is raised manually to the level of 30 kmph as indicated on the chart and then allowed to fall on its own, the time for its fall to the zero line on the chart has to be more than 50 seconds for satisfactory performance. If it is found to be less than this, it is necessary to locate the leak and reduce it.

4.5.10 Method of operation of the DPTA recorder

Once the instrument is working satisfactorily, the routine operation of the instrument, like making time marks, changing the chart etc. is similar to that of any other ink recording instrument.

The method of marking time on the chart is, however, somewhat different from other instruments. As the three recording pens are all in vertical alignment and show the same time on the chart, the time mark is made showing the position of the speed pen at zero line at the exact time. For this purpose, the stop cocks are closed to the head so that the speed pen falls to the zero-line drawing a vertical trace and the exact time to the nearest minute is marked on the chart. If, however, the wind is calm so that the float is already on the zero line, the float is manually raised slightly and allowed to fall drawing a vertical line to mark the exact time.

A time mark is also made similarly on the new chart and the record started ensuring that the drum is rotated anti-clockwise when seen from above to bring the record to correct time setting to avoid any backlash.

4.5.11 Maintenance and care

Once properly adjusted the instrument requires little day-to-day care or maintenance. Like other ink recording instruments, however, it is essential that the instrument is maintained dust free and has clean pens for smooth and fine recording traces on the chart.

Following checks carried out periodically (say once in six months or a year), would ensure long time, trouble free performance of the instrument.

i. **Water level in the recorder tank**

   Water in the tank may be lost by evaporation or some rain water may find its way through the air pipes to the tank. Correct water level thus needs to be maintained for accurate recording.

ii. **Water in the pressure pipe near the drain plug**

   Some water may get collected in the drainage line through the pressure inlet in the head. The drain plug is removed to drain the water.

iii. **Smooth movement of helix and pen arm levers**

   The smooth and free movement of the helix and pen arm levers may be adversely affected in course of time due to dust and moisture. The helix surfaces may be cleaned with a lightly oiled cloth and a drop of oil applied at the top of the helix and to the pivots to restore their free movements. If this does not help, the complete helix assembly would need to be removed and the bearing, spindle and the sleeve cleaned, lightly oiled and reassembled. Use of excess oil is to be avoided as it attracts dirt.

Iv **Smooth movement of float rod**

The float rod and the guide collar are to be maintained clean and dry. Oiling the float rod is not advisable as this collects more dirt. Instead, the rod is simply rubbed, cleaned and polished using a blotting paper.

v. **Orientation of the vane**

Errors may develop in the orientation of the vane due to slipping of direction rod couplings. Vane orientation thus needs to be checked when in doubt and corrected.

vi. **Identification of air leaks in pressure and suction systems**

If the air leak is found to be more than permissible as indicated in section 4.5.9 above, it is necessary to locate the same and reduce it. This requires closing the pressure inlet into the vane/suction holes near the top of the mast, to check and identify the leaks in the pressure/suction lines and remove/reduce them. This is better done by the inspecting personnel/staff from the regional/national instrument centres.

vii. **General check of head and vane, recorder float and chamber**

A yearly check on the general condition of the 'head and vane', the ball race bearing carrying the vane, the recorder float and chamber, the pen arm assembly and the pressure and suction pipes is considered necessary. Any apparent deterioration in their condition and timely remedial actions taken to correct them, would go a long way to ensure good records and enhance the life of the instrument.

4.5.12 Accuracy of measurement

In steady wind, a properly calibrated and well-maintained instrument is capable of giving an accuracy of better than 1 kmph at all speeds above 2-3 kmph.

4.5.13 Sources of error

i) Calibration error

An important source of error is primarily the error in calibration of the instrument, since for lower speeds, an error of 1 mm of water level may be equivalent to a speed change of as much as 2 kmph.

ii) Error due to changes in air density

Since the wind speed as given by the instrument depends on the value of air density ρ, a correction would need to be applied in case the mean air density is significantly different from the standard density assumed for calibration e.g. for measurements at high altitude stations (standard density of air, ρ is taken as 1226 g mm^{-3}).

Such corrections are, however, small and need to be applied only where high accuracy data are required.

iii) Error due to unsteady wind

Since the air in the pressure and suction tubes takes some time to flow in and out, in case of fluctuating winds, the fluctuations recorded may be out of phase with the actuals and the amplitude of fluctuations recorded is much reduced. Thus,

(a) the recorded gustiness is always somewhat smaller than the true value. Also as the float is liable to move up more easily than down, the mean wind speed is likely to be somewhat higher in gusty winds.

(b) means of very short periods are not very reliable.

4.6 High wind speed recorder (HWSR)

Surface Instruments division, Pune has designed and developed indigenously high wind speed recording/monitoring (HWSR) system. The system is based on state-of-the-art technology with a special attention to the power consumption, more protection to lightening, moisture and accuracy. Features like on line transmission and display through website for cyclone management authority is now available and proven its worthiness during very severe cyclonic storm Hudhud. The main components such as sensors and data logger which need very less power requirement hence a 42 AH battery is utilized which can continuously operate the system for a minimum of 25 days without mains power. A solar panel of 12V/30W charges the battery and uninterrupted operation of the system is ensured. The system utilizes IMD make sensors, which is a potentiometric wind vane for the measurement of wind direction and three cup optical anemometer for wind speed. The complete mechanical assembly is made robust using high quality material and manufactured in IMD, Pune workshop by specially trained skilled industrial staff.

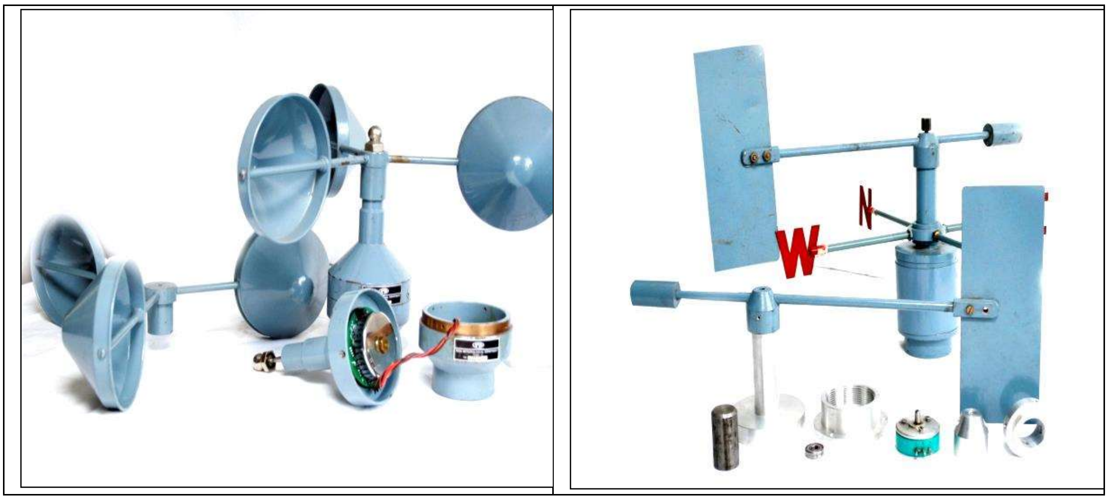


Fig. 42 Wind speed optical sensor (Two Layers PCB) Potentiometric wind vane assembly

4.6.1 Principle

The optical anemometer works on the principle of chopping the IR beam, whose rate of chopping is proportional to the RPM and in turn winds speed. The output is frequency as a function of wind speed. It produces digital as well as analog outputs with respect to the wind speed in knots. Hence suitable scaling has been provided in the data logger. The basic operating element is an opto-coupler which is having a transmitter and a receiver with a toothed wheel connected to the shaft of the cup anemometer. The receiver is a photo detector which receives infrared light from the transmitter through the gaps between the teeth of the wheel and generates pulses proportional to the true wind speed. These pulses are counted by an inbuilt counter in the 16bit microprocessor. The counter resets every 250 milli seconds and 4 samples per second can be measured. A piecewise linearity is derived between the wind speed in knots and number of pulses from the anemometer during the course of calibration in wind tunnel. The required range of measurement is fixed as 0-130 knots.

4.6.2 Wind speed

The potentiometer in the wind vane is a servo-micro torque potentiometer and has a maximum resistance of 10 kilo-ohms over an end gap of about 4 degrees. The Potentiometer is coupled to the wind vane shaft so as to give a resistance output increasing linearly with the increasing of wind direction. Thus 0 KΩ corresponding to the north, 2.5 KΩ for east, 5 KΩ for south, 7.5 KΩ for west and the variation of 0-360 degree corresponds to 0 to 10 kilo ohms.

4.6.3 Quartz clock used in Autographic instruments

Quartz sounds exotic—with a "q" and a "z," it's a great word to play in Scrabble but it's actually one of the most common minerals on Earth. It's made from a chemical compound called silicon dioxide (silicon is also the stuff from which computer chips are made), and you can find it in sand and most types of rock. If you squeeze a quartz crystal, it generates a tiny electric voltage. The opposite is also true: if you apply a voltage to a piece of quartz, it vibrates at a precise frequency (it shakes an exact number of times).

Inside a quartz clock or watch, the battery sends electricity to the quartz crystal through an electronic circuit. The quartz crystal oscillates (vibrates back and forth) at a precise frequency: exactly 32768 times each second. The circuit counts the number of vibrations and uses them to generate regular electric pulses, one per second. These pulses can either power an LCD display (showing the time numerically) or they can drive a small electric motor (a tiny stepping motor, in fact), turning gear wheels that spin the clock's second, minute, and hour hands.

A quartz clock contains the following components:

a) Battery.
b) Electric stepping motor.
c) Microchip.
d) Circuit connects microchip to other components.
e) Quartz crystal oscillator.
f) Crown screw for setting time.
g) Gears turn hour, minute, and second hands at different speeds.
h) Tiny central shaft holds hands in place.

(Note: Battery is the main component for this quartz clock, it should be replaced as per guidelines . Quartz clock, 1.5 volts batteries are required after every 15 days or as per necessity.

CHAPTER 5

SPECIAL INSTRUMENTS AND OBSERVATIONS

5.1 Assmann Psychrometer :

5.1.1 General:- If the air is not saturated with moisture, the wet bulb thermometer will always read less than the dry bulb thermometer. This is due to evaporation of water from the muslin round the wet bulb and consequent cooling. The wet bulb temperature depends not only on the amount of water vapour in the air surrounding it but also on the speed with which the air is passing over it. For ordinary thermometers, the formula for calculating the relative humidity from the dry and wet bulb readings is correct only for wind speed between 4 and 10 metres per second (i.e. between 8 & 20 knots.). This condition is not always obtained in a Stevenson Screen. Moreover, readings of a dry bulb thermometer in the screen are not always unaffected by radiation and do not then indicate the true temperature of the air. These drawbacks are overcome in the Assmann Psychrometer (Fig. 44(a)) which is a portable instrument designed to give more accurate readings of the wet and dry bulb temperatures of the air. In this instrument air is drawn past the dry and wet bulbs by means of a clock-work exhaust motor. Each bulb is protected from external radiation by two highly polished coaxial tubes so that the instrument can be held even in strong sunshine without risk of solar radiation affecting the readings.

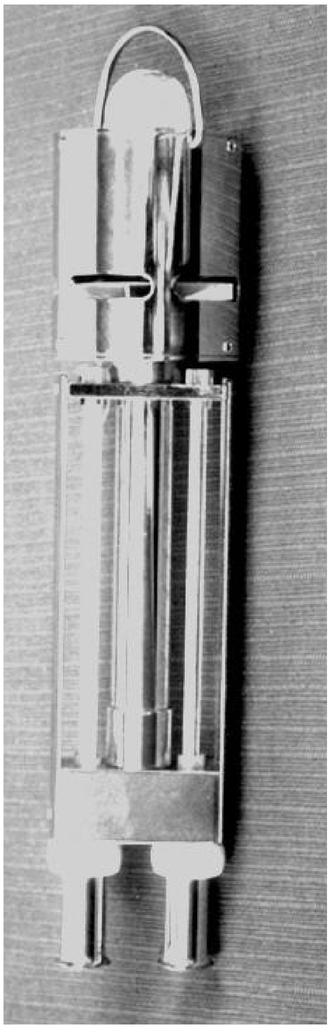


Fig. 43(a) Assmann Psychrometer

Detail description of the instrument and instructions for its use are given below: -

5.1.2 Description: - The Assmann psychrometer (**Fig.43(a)**) consist of two sensitive mercury-in-glass thermometers A, A1 mounted side by side in a nickel-plated, polished frame D. The thermometers have a range of -10ºC to + 60º C and can be read correct to 0.1ºC. The bulb of one of the thermometers is covered with thin muslin which is moistened with distilled water before use. The thermometers are suspended in the frame with their bulbs surrounded by two thin coaxial metal tubes B and B1 which are nickel plated and highly polished; they are thermally insulated from the rest of the frame by tufnol retaining pieces E and E1 and protect the bulbs from the effects of exposure to solar radiation. The tubes can be removed from the frame by unscrewing the tufnol pieces. Ventilation of the bulbs is affected by the fan F, driven by the clock-work motor encasedin the housing H, air being drawn past the bulbs and up the hollow central column C. The clock-work motor runs for about 7-8 minutes on one winding and provides adequate ventilation of the bulbs for about 5 minutes. The frame complete with thermometers can be unscrewed from the motor housing when it is required to replace a thermometer. A suspension ring "R" provides the top of the housing enables the instrument to be hung with the thermometers vertical either from a metal support fitting, provided with the instrument as an accessory, or from one's hand. The instrument is supplied with muslin for the wet bulb, a container for distilled water, the metal support fitting and an injector for moistening the wet bulb.

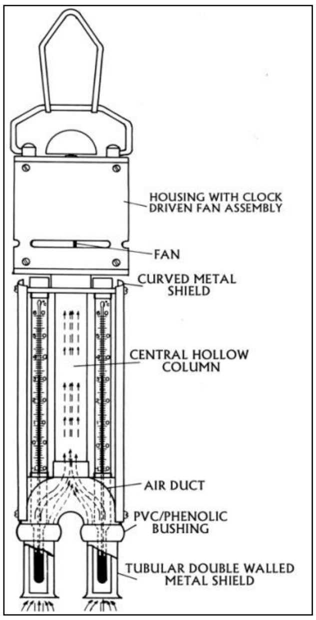


Fig. 43(b) Construction details

5.1.3 Exposure: - Observations should be made in an open place with the instrument either suspended from a clamp or bracket attached to a thin post, with the ducts about 1.2 m. from the ground, or held by one hand at arm's length, with the inlets slightly inclined into the wind.

For comparison with temperatures indicated by thermometers in the Stevenson Screen it should be hung inside the screen by means of a hook or held in the hand out-side, as described above.

5.1.4 Operation:

i. Moisten the wet bulb. To do this, the injector is filled with distilled water and the bulb is pressed until water rises to the top of the glass tube. The tube is then pushed up the right-hand inlet of the psychrometer until the muslin surrounding the wet bulb is fully immersed in water and the injector is then withdrawn. **The wet bulb should never be moistened by using the injector as a squirt.** do not spill any water in and around the metal tubes. Shake the instrument **gently** to throw out excess water, if any, round the wet bulb.

ii. Wind the clock-work motor; do not over wind it.

iii. Wait for about two minutes until the wet bulb reading has become steady. If during observation, the wet bulb temperature shows a sudden rise, it is very likely that the muslin has become dry. The muslin should then be moistened again and the reading repeated.

iv. Read the Wet Bulb.

v. Read the Dry Bulb.

5.1.5 Precautions:

i. Only distilled or rain water should be used for moistening the wet bulb.

ii. The thermometers should be read correct to 0.1 ºC and the index corrections of the thermometers applied before the humidity calculations are made.

iii. **Special humidity tables should be used** to obtain the relative humidity, dew point and vapour pressure of the air. These are different from the tables used to determine relative humidity etc., from dry and wet bulb reading of Thermometers kept inside a Stevenson Screen.

iv. Keep the muslin clean and change it as frequently as required. The thermometers can be withdrawn by unscrewing the clock-work dome which holds them in position in the frame of instrument. Any visible contamination should be considered an absolute indication of the necessity of replacement. Only one layer of muslin should be used, and the bag should be fit snugly for wet bulb. Long tubes of wicking are sometimes supplied for wet bulb. When these are used, it is only necessary to cut off the proper length and tie it above and below the bulb, this wicking is not as satisfactory as the flat piece of muslin if it does not fit as snugly to the bulb as desired.

v. The muslin should be washed thoroughly in pure soap and water and rinsed several times in distilled water before fixing it round the wet bulb. Care should be taken in handling the muslin or wick to prevent contamination from the hand.

5.2 Whirling Psychrometer:

5.2.1 Description: - In the whirling or sling psychrometer, the aspiration is provided by whirling or rotating the thermometers, which are mounted side by side on suitable wooden frame for that purpose (Fig. 44). To obtain the desirable air speed of about five meters per second past the thermometer bulbs, about four revolutions per second are sufficient for a 30 cm long psychrometer.

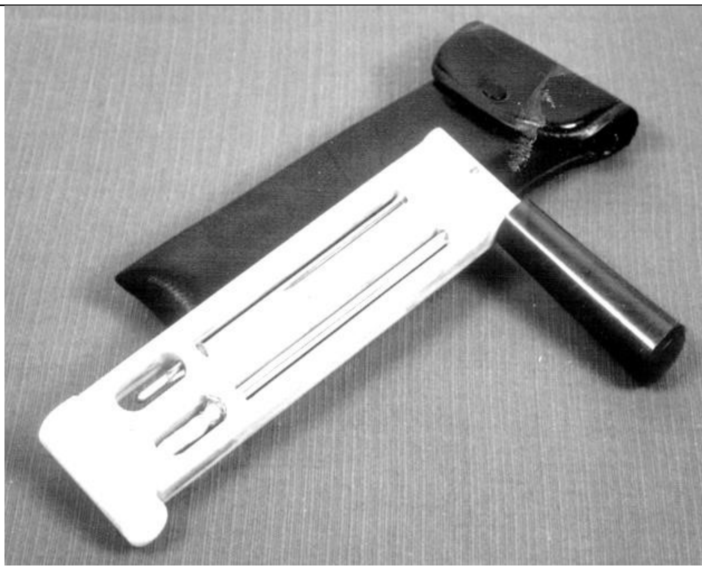


Fig. 44 Whirling psychrometer with leather case

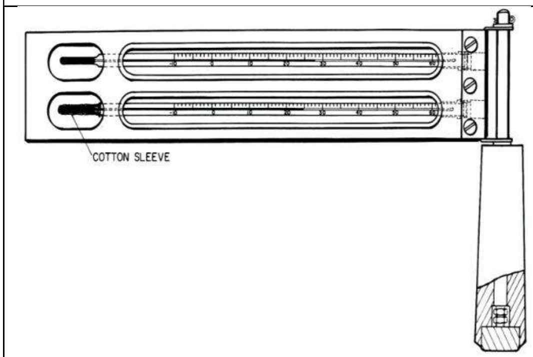


Fig. 44 (a) Whirling psychrometer (straight handle)

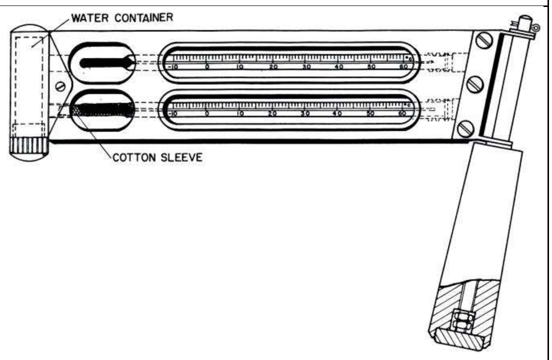


Fig 44 (b) Whirling psychrometer (inclined handle) with water container

5.2.2 Operation:

i. Moisten the wet bulb, using the minimum amount of water to wet the wick completely and without spilling any water on the frame.

ii. Whirl the instrument, standing with the back to the Sun to avoid direct sunlight falling on the instrument, or in a place sheltered from direct solar radiation.

iii. Read the wet bulb thermometer after about 15 seconds of whirling and take care to hold the instrument in the shade of the body, but not so close as to allow body heat to affect the reading. Note this reading but do not record it.

iv. Continue whirling and read after about 10 seconds. If the reading is still dropping rapidly, continue reading at intervals of ten seconds. When succeeding readings become separated by only one degree or less, they should be made at intervals not longer than 5 seconds.

v. Finally, when continued ventilation causes no further lowering of indicated temperature from the wet bulb thermometer, note and record the lowest reading correct to 0.1 ºC.

vi. Read the dry bulb thermometer at the same time.

5.2.3 Precautions:

i. Since the bulbs are not protected against radiation, the psychrometer should always be used only in the shade, sheltered from direct Sun.

ii. Special humidity tables should be used to obtain relative humidity, dew point or vapour pressure of the air by means of the whirling psychrometer. These are different from the tables used for determining humidity from the readings in a Stevenson Screen.

iii. Thermometers may easily be broken as a result of lack of proper care in the operation and storage of whirling psychrometer.

iv. Only distilled or rain water should be used for moistening the wet bulb.

v. The wick or muslin should be replaced as often as necessary to maintain a covering that is free from dust and other foreign matter. The muslin or wick should be thoroughly washed in pure soap and water and rinsed several times in distilled water before it is used. Care should be taken in handling the muslin to prevent contamination from the hand.

5.3 Grass Minimum Thermometer:

5.3.1 Description: -The grass minimum or terrestrial radiation thermometer is used mainly to obtain information about 'ground frost' at night. It is a sheathed minimum thermometer in which the graduations of the stem are protected by an outer glass jacket. The bulb is link-shaped and provides a larger surface for exposure than a spherical bulb.

5.3.2 Exposure: The instrument is exposed in the Stevenson Screen enclosure on a plot covered with short grass 2.5 to 5.0 cm. high. It is kept on two Y- shaped wooden supports fixed in the ground to a depth of 12 cm. with the bulb just touching the tips of the blades of grass. Care should be taken to see that the bulb does not touch the wooden supports. When the ground is snow- covered, the thermometer should be supported immediately above snow without actually touching it. The proximity of walls, trees, branches, etc. should be avoided and it should be noted that the use of any protecting cage for the thermometer would vitiate the readings.

5.3.3 Precautions: -In order to avoid condensation of sprit in the thermometer, it is advisable not to leave the grass minimum thermometer exposed in the open during day time. It should be kept in the screen in a vertical position, bulb downwards. It is convenient to fix in the floor near a back corner of the screen a small pill box, in which the bulb of the thermometer can rest, the stem being supported in the corner of the screen.

5.3.4 Reading and Setting: -The instrument should be read at the hour of routine morning observation, viz., 0830 hours I.S.T. After the reading is taken, the thermometer should be kept in the screen, bulb downwards, until the evening, when it should be reset (like the ordinary minimum thermometer) and placed out on the wooden supports.

5.4 Evaporimeter:

Water is continuously lost from the earth's surface by evaporation. The rate of evaporation depends on many factors such as the nature of soil and vegetation, the temperature and humidity of the air, wind speed etc. For practical purposes however, it can be expressed as the volume of liquid water evaporated from unit area in unit time. Over a given area this is proportional to the depth of liquid water lost in unit time. Accordingly, evaporation is generally measured, as millimeters of water lost per day. The instrument used for measuring evaporation is called 'Evaporimeter'. The most common evaporimeter in use at India Meteorological Department's station is the Class-A Pan Evaporimeter (also called U.S.A. pattern open pan evaporimeter).

Fig. 45 Class A Open Pan evaporimeter

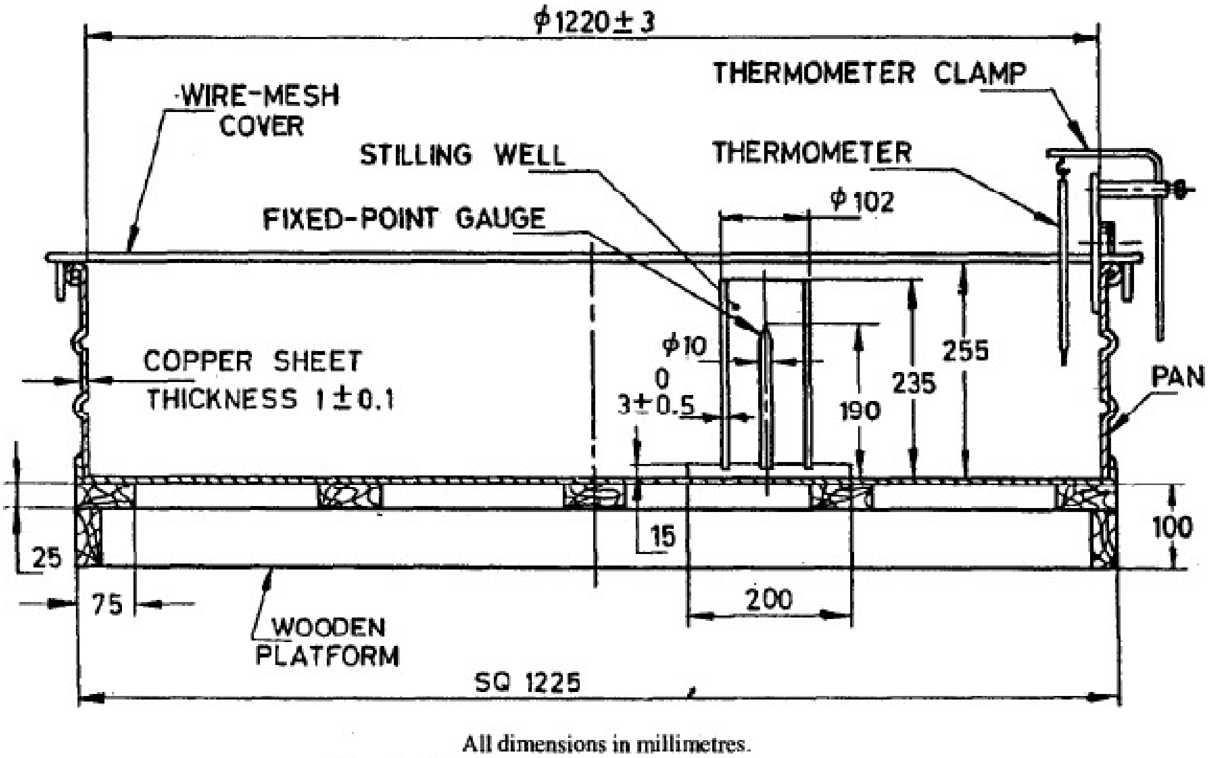


Fig. 46 Pan Evaporimeter set-up – construction details

5.4.1 Class A Pan Evaporimeter: -This evaporimeter consists of a large circular pan with a stilling well to provide an undisturbed water surface around the point of a Fixed-Point gauge (**Fig. 45)** by breaking any ripple caused by wind that may be present in the main part of the pan. The pan rests over a white painted wooden stand which ensures that the bottom of the pan is above the level of surface water in rainy weather.

The pan is covered with wire-netting of standard mesh to avoid loss of water by extraneous agencies such as birds and animals. A thermometer to measure the surface temperature of the water is fixed with a brass clamp to the side of the pan so that the bulb just dips in the water. The amount of water lost by evaporation from the pan during any given interval of time is measured by adding known quantities of water to the pan from a graduated cylinder (**Fig 47**) till the water level touches the reference point. The amount of water added equals the amount of water lost by evaporation from the pan and this divided by the time interval gives the rate of evaporation. Rain falling into the pan is accounted for by assuming that the catch of a nearby rain gauge represents the added depth of water due to the rain.

Evaporation from the pan can also be obtained with the aid of a moving point hook-gauge (**Fig.48**).

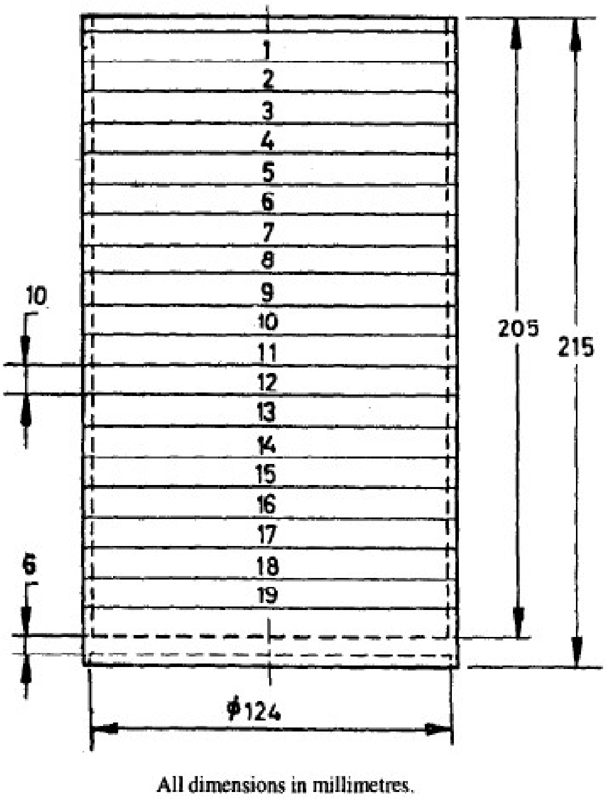


Fig. 47 Measuring cylinder

Fig. 48 Hook Gauge

Exposure: -The pan should be exposed in a relatively sheltered position in order to prevent out splashing caused by high winds. It is generally installed in the Observatory enclosure by the side of the rain gauge, so that the exposures of the two instruments are identical and the amount of precipitation caught by the pan is represented by the amount caught by the rain guage.

Place the wooden stand on hard soil so that it does not get tilted even after heavy rains. No cement or brick platform should be used for stand, since this will affect the evaporation loss from the pan. The ground should be filled sufficiently to level the stand and to keep the bottom of the pan above the level of surface water in rainy weather. Keep the pan on the support and make sure the bottom of the pan is in level. The rim of the pan should be exactly 36.5 cm above ground level.

Place the stilling well in the pan above 30 cm from the north edge of the pan so that the gauge can be conveniently observed. Check the level of the top rim of the stilling well with a spirit level. Add water to the pan till the level reaches the tip of the reference point. Place the wire mesh cover over the pan and make sure it fits tightly over the rim all round. Clamp the thermometer stand to the side of the pan and fix the thermometer to the clamp so that the bulb is just dipping in water. The instrument is now ready for use.

Operation: - Readings should be taken twice daily at 0830 & 1730 IST.

The Observation is made as follows. At the prescribed time read the thermometer, then add water to the pan using the measuring cylinder, (as explained below) until the tip of the fixed point coincides with the surface of the water in the well. The measuring cylinder is so graduated that the graduations run from top to the bottom. Fill the cylinder so that the water comes to the Zero line on the top of the scale. Add water carefully from the cylinder to the pan till the water rises to the tip of the gauge. Usually more than one filling of the cylinder will be necessary to bring the water level to the standard height. Reflection of the sky in the water will assist in determining when the point first touches the surface. As the water approaches the tip of the point, pour slowly to prevent overfilling as some time is required for water to flow from the pan into the stilling well. Read the level of the water remaining in the cylinder. Suppose two full cylinders of water & 11 cm.ie, 51 cm of water from the cylinder have been added to the pan. Since the radius of the bucket is ten times that of the pan, the reading divided by the 100 viz.,5.1mm is the amount of water lost by evaporation from the pan, if no precipitation has occurred since the previous hour of observation.

If precipitation has occurred during the interval between the two observations & exceed s the water lost by evaporation, water has to be removed from the pan, instead of being added. The wire mesh cover has to be removed before taking water out of pan. Water added to the pan is marked positive (+) and water removed from the pan as negative (-) Record the amount of the water added or removed to the nearest cm. if the amount of water removed is 58 cm & the precipitation (since last observation) is 6.7 mm The water lost by evaporation is given by 6.7- 5.8 = 0.9 mm Detailed example are given below:

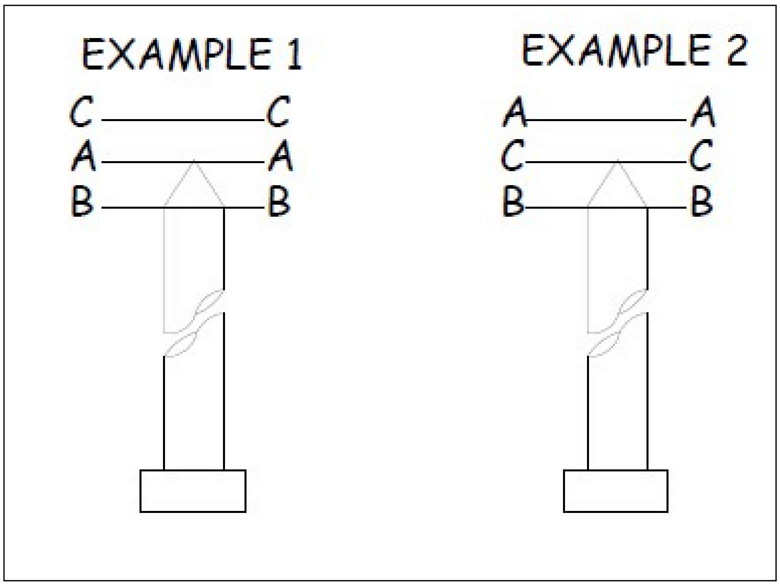


Fig. 49 Moving point of Hook-Gauge

Example I: - AA in Fig.-49indicates the level of the water in the pan when it is set, say at 1730 hours IST. and CC the level the next morning at 0830 hours IST. If the amount of water removed from the pan to bring the level to AA is 58 cm., the difference in level CA is 5.8 mm if there had been no rainfall, the water level would have been at BB. To obtain the level BB, one has only to imagine level CC to be lowered by the depth of precipitation. If 6.7 mm. is the amount of rainfall during the interval CB=6.7 mm, the evaporation is then given by AB=6.7-5.7=0.9 mm.

Example II: -If there is only light rain the water level may not rise above AA the setting level, as in the previous case, but may be say at CC below AA, but above BB, the level of water, if no rain had fallen into the pan. If 37 cm. of water has been added to the pan (AC=3.7 mm.) and rainfall is 1.2 mm. then actual evaporation since 1730 hours is 3.7 mm. +1.2 mm.=4.9 mm.

When due to heavy rain the level of water in the tank has risen to such a height that it is less than 12 mm. from its rim, no evaporation readings will be recorded.

In case the pan evaporimeter is equipped with a moving point hook-gauge, proceed as follows:

Place the hook-gauge (Fig.48) on the stilling well and turn the head of the gauge, so that the tip of the hook-gauge goes below the water surface. Then reverse the motion of the head so that the point of the hook just touches and slightly deforms the water surface from below (but without actually piercing through the surface). Note the readings of the vertical scale and the head.

If the water freezes, all ice should be broken away from the sides of the pan and the water level brought back to the fixed point while the ice is floating. Provided this is carried out, the fact that some of the water is frozen does not affect the level. If the ice is too thick for this to be done, the measurement should be held over till the subsequently observation hour and the evaporation over the extended period determined.

Precautions:

Inspect the pan carefully for leaks at least once a month, since any leaks will render the measurement valueless. Report the finding of any leaks in the observation form for the month. Separate Report should also be sent to the Controlling Meteorological office, about the date on which the leak was discovered and the date on which it was repaired.

Clean the pan as frequently as necessary, about once fortnight or more often, to keep it free from sediments, scum and oil films. The cleaning should be done just after a routine observation so that no observations are lost as far as possible. An oil film will materially reduce the rate of evaporation. A small amount of copper sulphate may be added to the water to discourage the growth of algae.

Clean the stilling well occasionally and remove any sediment in it. Clean the centre point rod with soft cloth and water. The three side holes must be free from dirt or any sediment.

Check that the measuring cylinder is kept clean and the graduations are clear. Check it for leaks frequently.

When heavy rains threaten to overflow the pan, remove enough water to lower the level to about 100 mm below the rim. The quantity of water removed must be carefully measured and noted. This should be done immediately after an observation. Keep water level in the tank always between 2.5 to 5.0 cm below the rim, by adding or removing water if necessary. Whenever water is added or removed, record the reading before and after a brief interval of, say, 5 minutes, and enter these in appropriate columns.

Once every year, the pan should be painted after scraping the surface carefully and the inner surface tinned if necessary. Chlorinated white rubber paint with appropriate thinner should be used.

Check periodically (especially after heavy rains) and ensure that the wooden platform and the bottom of the tank are perfectly horizontal.

While recording the temperature of the water, ensure that the bulb of the thermometer is kept below the level of water.

5.5 Soil Thermometers:

The surface of the earth plays an important part in meteorology, by absorbing solar radiation and warning the air as well as the soil layers adjacent to it. About 40 per cent of the incoming solar radiation is absorbed by earth's surface. The heat absorbed from the sun, is however, accumulated in the upper few centimeters of the earth's surface owing to its very low conducting power. As a result of this, the diurnal variation of temperature is maximum at the surface of the earth and decreases rapidly downwards becoming almost negligible at a depth of 30 cms. This, however, is not true of the annual or seasonal variation, which does not decrease so rapidly with depth. Consequently, for studying the thermal structure of the soil, two types of thermometers are used, one for shallow depths up to 30 cms to study diurnal variation and the other for greater depth for the study of annual changes.

5.5.1 Soil Thermometers for Shallow Depths:

Description:

The shallow-depth soil thermometer is illustrated in Fig.50. It is mercury – in-glass thermometer with a bend of 120 degrees in the stem just above the bulb B. The thermometer has a range from -5°C to +70°C and can be read to an accuracy of 0.1°C. It is provided with a triangular iron stand DEFG bent at 60 degrees so that the thermometer when mounted, makes an inclination of 120° with the ground. The sloping side of the stand has two clips to hold stem of the thermometer, while its lower end is so shaped that it can be easily inserted into the soil.

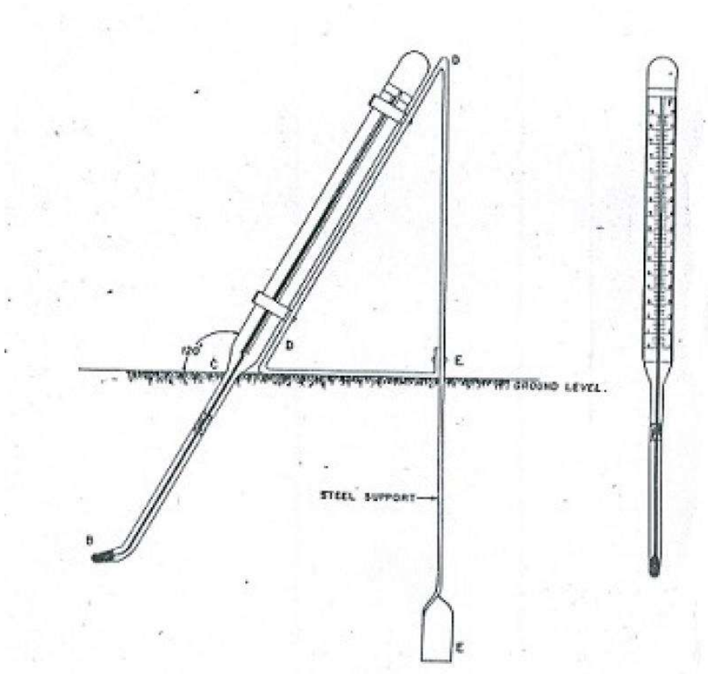


Fig. 50 120 Deg bent soil thermometer

Exposure and Installation:

A small plot of land measuring 2.5 meters by 1.5 meters is enclosed by wire stretched between four short wooden posts 30 cms high fixed at the four corners. This is done to protect the thermometers against any accidental damage. No permanent fencing should be put up as it will vitiate the temperature readings.

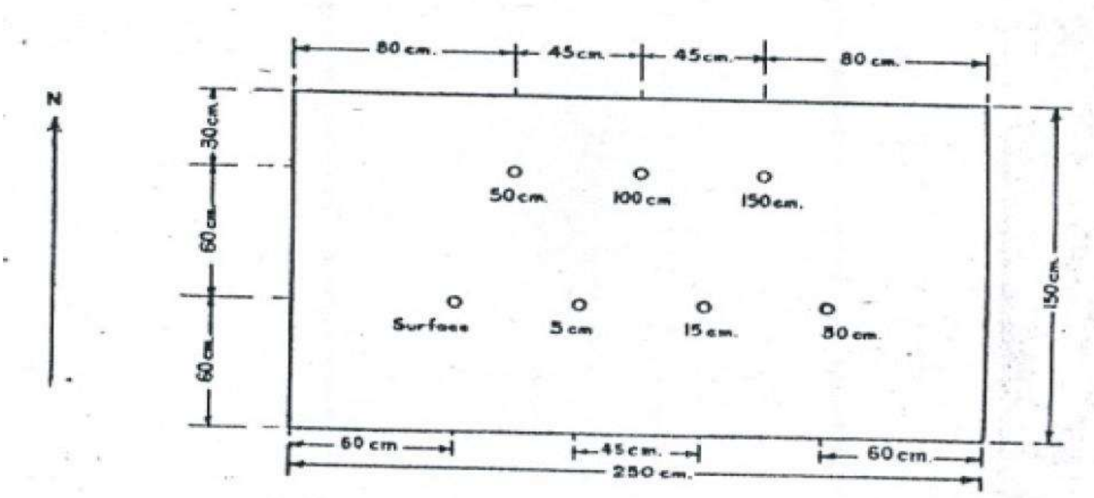


Fig. 51 Installation of soil thermometers

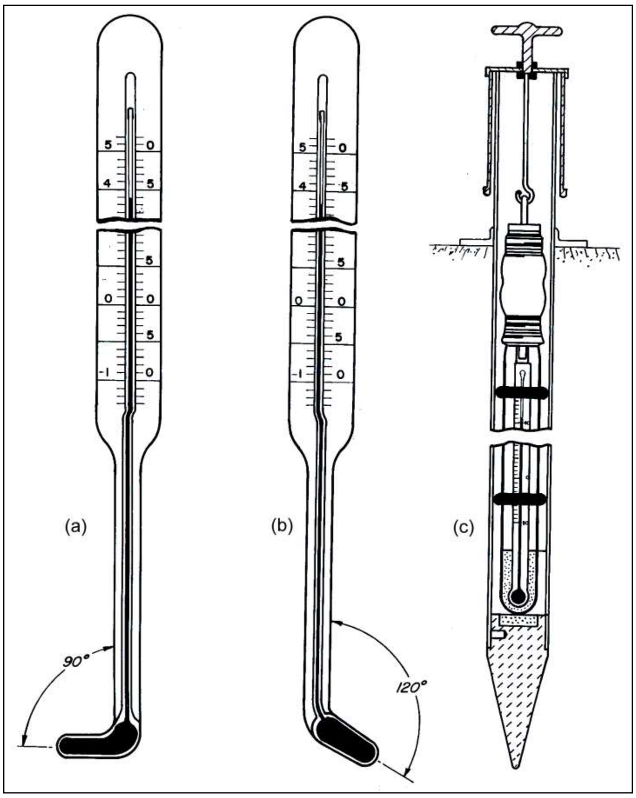
Four thermometers to measure the soil temperature on the surface and at depths of 5, 15 and 30 cms are installed in this plot along a line running East-West at a distance of 60cms from the southern side, as shown in Fig.51. Their stands DEFG of the four thermometers should be fixed into the ground 45 cms apart so that the side DF of each stand is just level with the ground and the arm DE is inclined towards North. While fixing the stands, care should be taken to see that the soil is disturbed as little as possible.

5.5.2 Soil Thermometers for Depth Exceeding 30 cm.

Description:

Fig 51(a) &(b) shows the Symon's pattern earth thermometer used for measuring soil temperature at depths exceeding 30cms. It is mercury-in-glass thermometer enclosed in a snout glass tube with its bulb embedded in a layer of paraffin wax which extends to a distance of 38 mms, above the base of the tube. The whole thing is suspended in a steel tube with a cone fitted to the lower end, so that it can be driven into the ground with as little disturbance of the soil as possible. Tubes of varying lengths are used for measuring temperature at different depths (Reading are generally taken at depths of 50, 100 and 150 cms)

A rubber disc is cemented into a recess in the top of the steel cone and a circular steel flange is fixed to the outside of the tube, in such a position that the distance between the base of the flange and the top of the rubber disc is 51, 101 or 151cms depending upon whether the thermometer is used to measure the temperature at depth of 50,100 or 150 cms respectively. The thermometer is suspended by means of a combination of brass rod chain and metallic cap fitted on to the top of the outer tube.



(a) 90° bent stem soil thermometer	(b) 120° bent stem soil thermometer	(c) deep soil (1m) thermometer

Fig. 51(a) Soil thermometers including deep soil thermometer

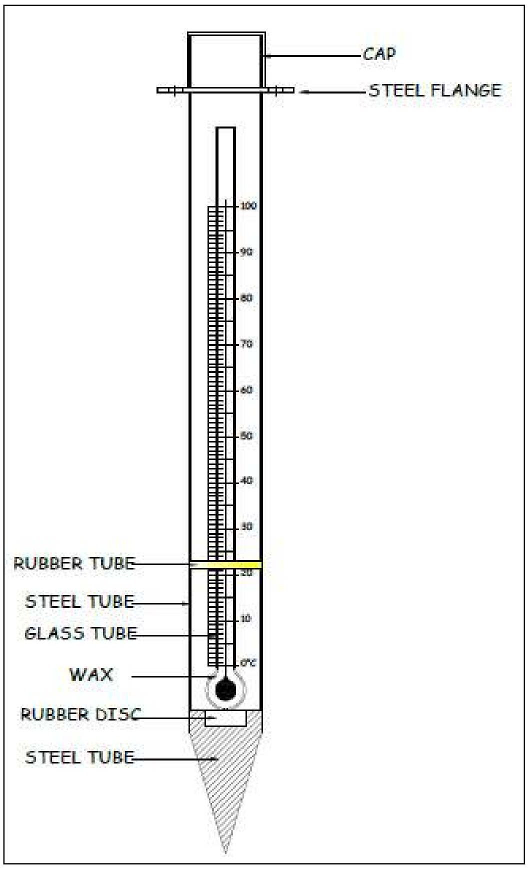


Fig. 51(b) Soil thermometer for depths exceeding 30 cms.

Exposure and Installation:

The three thermometers at measuring temperature at depths of 50,100 and 150 cms are exposed by the side of the shallow-depth thermometers about 60 cms to the North (See Fig.51(a) &(b)). The metal tubes in which the thermometers are to be suspended, are to be driven into the ground until the flange on the outside of each tube is level with the ground. A hole should first be made in the ground to facilitate insertion of the tube. If necessary a hammer or wooden mallet may be used to drive the tube to the required depth. A block of wood should, however, be placed over top of the tube to take blows of the hammer or mallet and care should be taken to see that the tube is vertical. Now suspend the thermometer from the brass rod and chain, within the steel tube. Having done this, the top of the soil should be adjusted so as to be flush with the undisturbed surface of the plot.

Operation:

The thermometers at depths of 5,15 and 30 cms are to be read four times a day at 0700 hrs L.M.T. (Local Mean Time), 0830 hrs I.S.T., 1400 hrs L.M.T. and 1730 hrs I.S.T. They should be read, as they are, without removing them from their stands or disturbing them in any other way.

The other thermometers at 50, 100 and 150 cms depths are to be read only once a day at 0830 hrs I.S.T. For reading the thermometer, remove the metal cap, draw out the thermometer raising it to the same level as your eye and read quickly to the nearest 0.1°C. While taking reading, care should be taken to screen the thermometer from direct sunshine.

Precautions:

If it is found that there is a tendency for rain water to collect and stand over the plot, a channel 15 cms wide and 5 to 8 cms deep should be dug all-round the plot and connected to some main drainage channel, so that the water in the plotwill drain out as it collects. The plot should be kept free from weeds and grass. They should be removed by hand as soon as they appear.

Some types of soil develop cracks in dry weather and it may sometimes happen that the vertical section of the thermometer is situated in a crack. Such a situation must be prevented by light raking of the surface soil when the warm dry weather is approaching instead of keeping the surface smooth and hard.

Any water collecting in the tube of the deep earth thermometers during the time the cap is off should be immediately removed with a sponge or other absorbent material tied to the end of a stick. Water must not be allowed to collect in the tube at any time. If found, the cause should be investigated, and action taken to prevent its recurrences.

CHAPTER 6

VOLUNTARY OBSERVATIONS

In addition to the regular observations taken daily at fixed hours, the Observer is also required to report about special phenomena like lightning strikes, hailstorms and earthquakes, as and when they occur in accordance with the instructions given below:

6.1 Lightning Strikes:

All accidents caused by lightning strikes resulting in loss of life or damage to buildings and other structures should be reported to the Controlling Meteorological Office at the end of every month. If there has been no such accident during a month a 'Nil' report should be sent. The report is to be sent in the form prescribed by the Controlling Meteorological Office.

6.2 Hailstorms:

Occasionally a station may get showers of hailstones (small pieces of ice) in association with a thunderstorm. It is then called a 'hailstorm'. Any such phenomenon must be carefully observed and immediately reported to the Controlling Meteorological Office in the form prescribed for this purpose.

6.3 Earthquakes:

Information about earthquakes is utilized for planning the location and designing of buildings and other structures like dams, reservoirs, bridges etc. It is, therefore important that whenever an earthquake shock is felt, even though it may be slight, the Observer should invariably send a report about it in the prescribed form and in accordance with the instructions received from his Controlling Meteorological Office.

If some new phenomenon is observed during an earthquake which is not provided for in the prescribed form, the Observer should nevertheless make a detailed report about it at the bottom of the form or by attaching a separate sheet of paper if necessary.

A plain language message giving the intensity (slight, moderate, great, very great, or destructive etc.) and the time (I.S.T.) at which the shock was felt, should be added at the end of the routine weather telegram immediately following the occurrence of the earthquake. If this cannot be done on the same day the date of the earthquake should also be given as in the following sample message: -

'Moderate earthquake felt 2130 hours I.S.T. yesterday.'

If an earthquake is not felt by the Observer but by others in his locality, he should collect as much correct information as he can and incorporate it in his report mentioning the source of his information. Similarly, although no damage may have been caused to the Observers' building but damage has been reported elsewhere in the neighborhood due to an earthquake, the Observer should collect relevant particulars about the damage and include them in his report, mentioning the sources from where the details were obtained.

Sometimes separate earthquake shocks may occur at short intervals. The Observer should keep a careful watch for such occurrences and make every attempt to give separate reports for each shock.

6.4 Reporting of Locust Sightings:

Locust is a grass-hopper like insect. Swarms of locusts invade India periodically. Three species of locusts are found in India. Of them, the desert locust is the most destructive to crops. The desert locust affected about 65 countries from Morocco in the west to India in the east. Locust is thus an international pest. Rajasthan and adjoining areas are the most affected parts in India. The desert locust is found in two phases-(i) isolated or scattered and (ii) swarm.

Weather has an intimate relation with every phase of locust. The movements of locusts depend on the prevailing meteorological conditions. The I.M.D, is working in close collaboration with the Directorate of Plant Protection in locust control activities. In order to render effective meteorological support to anti-locust measures, the full time and part time observatories in Rajasthan, Gujarat, Punjab, Haryana, West Uttar Pradesh, Madhya Pradesh and Vidarbha are specially requested to be on the look-out for the appearance of locusts and report locust sightings telegraphically to Agrimet Division, Pune and to the Plant Protection Adviser and Director, Locust Control, Faridabad.

CHAPTER 7

NON-INSTRUMENTAL OBSERVATIONS

Observations of clouds, visibility and weather (and wave observations at coastal stations) come under this category.

7.1 Clouds:

No meteorological observation is so interesting as that of the growth and dissipation of clouds in the sky. A cloud observation consists of (1) identifying the form of cloud (2) estimating its amount (3) estimating the height of its base above the station level and (4) determining the direction of its movement.

7.1.1 Cloud Forms: Clouds are continuously in a process of formation or dissipation and appear therefore in an infinite variety of forms. There are, however, some characteristic forms frequently observed all over the world; and these form the basis for the classification of clouds into 10 main groups called genera. They are (1) Cirrus (2) Cirrostratus (3) Cirrocumulus (4) Altocumulus (5) Altostratus (6) Nimbostratus (7) Stratocumulus (8) Stratus (9) Cumulus (10) Cumulonimbus.

Observations have shown that in the tropical latitudes, clouds are generally encountered over a range of heights varying from the ground to 18 km. Based on this, the ten genera described above have been grouped into four families enumerated in the Table below:

Family	Genera	Heights at which commonly found
High clouds	Cirrus Cirrostratus Cirrocumulus	6 to 18 kms
Middle or Medium clouds	Altocumulus Altostratus Nimbostratus	2 to 8 kms
Low clouds	Stratocumulus Stratus	Ground to 2 kms
Clouds with vertical development	Cumulus Cumulonimbus	Same as low clouds but Cumulonimbus may extend even upto 18 kms.

Detailed descriptions of the various cloud forms with their photographs to facilitate easy identification, are given in the Cloud Atlas supplied to all observatories. This should be studied carefully by every Observer.

7.1.2 Cloud Amount: -The International Unit for reporting cloud amount is 'okta' or $1/8^{th}$ of the sky. When the sky is completely cloudless, the cloud amount is 0 and when it is completely overcast, without any openings or gaps, the amount is recorded as 8. Special care should be taken to avoid over estimation especially when cloud amounts are small.

In estimating the partial amounts of the different cloud forms present at the time of observations, the Observer should estimate how may oktas of the sky would be covered by each form if it alone were present, disregarding the other forms below or above it. Thus, if detached fragments of Stratocumulus (about 3 oktas) are observed beneath a continuous sheet of Altostratus, the cloud amounts should be reported as:

Altostratus	8
Stratocumulus	3

even though the Altostratus is partially obscured by Stratocumulus below it. It will be seen from this, that the estimation of the total amount of sky covered with clouds of all forms is as independent observation and may not necessarily be equal to the sum of the separate amounts of clouds at different levels. The former may be considered less and can never exceed 8 while the sum of the separate amounts at different levels may do so.

7.1.3 Cloud Height: -By cloud height we mean the vertical distance of the base of cloud from the ground level. If the cloud base is diffuse and irregular as in the case of ragged low clouds of bad weather, the height of the lowest patch of such clouds should be reported. Cloud height can be measured with the help of balloons or by cloud search-light at night. At stations where these facilities are not provided, cloud height can only be estimated. In hilly or mountainous areas this may be done fairly accurately by comparing the level of the cloud base with the heights of well-marked topographical features but in level country the Observer should use his judgment taking into consideration the form and general appearance of the cloud.

7.1.3.1 Measurement of Cloud Height by Balloons: - At departmental observatories taking Pilot Balloon ascents for measuring upper winds, the height of base of *low cloud* is sometimes measured by means of balloons (called 'ceiling balloons') which are filled with hydrogen an d released with a known rate of ascent. The time of travel between release of the balloon and its disappearance into the cloud is measured by means of a stop watch. If the rate at which the balloon is ascending is 'n' metres per minute and it takes 't' minutes to enter the cloud, the height of the cloud base is 'nt' metres above ground. It should, however, be kept in mind that the height of cloud obtained by this method is at least an estimation though comparatively more reliable than eye estimation.

This is because the balloon does not go up vertically into the clouds layer but takes a slant course on account of the drift of wind within the sub cloud layer.

Releasing of ceiling balloon as often as practicable will give the Observer an opportunity to check his estimation and is likely to improve his ability to estimate cloud height correctly. The method has its own limitations but as a guide line, the following may be kept in view: -

a) As far as possible the balloon should be released at such a time when it is most likely to enter the lowest cloud layer.

b) The Observer should be able to determine by some practice when the balloon enters cloud specially when thin shreds of Stratus are present.

c) Ceiling balloon should not be released during rain or drizzle as the constant rate of ascent may not hold good under such circumstances.

7.1.3.2 Measurement of Cloud Height by Searchlight: -In this method the angle of elevation 'E' of the patch of light formed on the base of the cloud by a vertically directed searchlight beam is measured by means of an alidade from a point at a distance 's' from the searchlight. The height 'h' of the cloud base is then given by the formula h=S tan E (Fig.53). It may be necessary for the Observer to wait for some time till the lowest patch of the cloud is illuminated by the searchlight. This method is used at a few departmental observatories mostly situated at aerodromes.

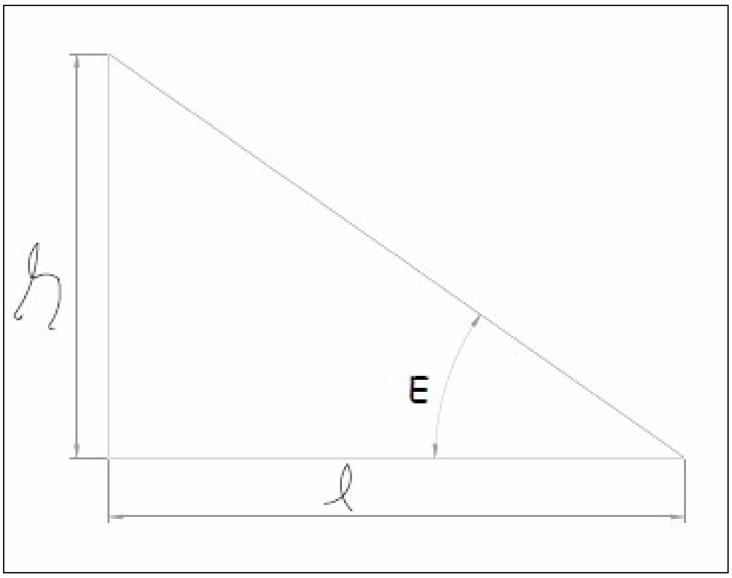


Fig.52 Measurement of cloud height by search light

7.1.3.3 Direction of Movement of Cloud: -A few departmental observatories have been provided with an instrument called 'Nephoscope' for measuring the direction of movement of cloud. Instructions for its use are supplied along with the instrument. At other observatories, the direction of movement of cloud is visually estimated nearest to the eight points of the compass (i.e. N, NE, E, SE, S, SW, W and NW) from which the predominant low cloud and the predominant medium or high cloud are coming. This is done best by observing the movement of the cloud against a fixed point like a pole erected in an open space, corner of a building or stars at night time.

To determine the direction of the movement of cloud, the Observer should select an identifiable part of a cloud like a small gap or well-marked feature and keep it in line with a fixed reference point like the top of a pole or the corner of a building. After a few minutes when the cloud patch has moved, the Observer should move his eye to bring the patch against the reference point. The direction in which the eye has to be moved is the direction from which the cloud is moving. It may be mentioned that estimate of direction of movement of cloud by this method should not be relied upon when the clouds are at low angles. The Observer should, however, be able to report the direction in such cases with sufficient practice and experience.

Particular Care should be taken to avoid the following:

1. Wrong identification of clouds. -Since cloud observations are taken every day, there is a danger of repeating only particular types of clouds from day to day as a habit. It is to be realized that the sky can never be exactly the same on any two occasions. It is constantly changing. Every observation should therefore, be considered as an entirely new effort to locate cloud types and amounts. Identification of individual cloud types can become easier if the Cloud Atlas is consulted. There are however, some misinterpretations which could be avoided if proper care is taken. For example,

i. Stratocumulus clouds could be mistaken for Altocumulus clouds and Cirrostratus for Altostratus. In the former if the formation and growth of cloud has been followed from casual observations of the sky from a few hours prior to the observation time it will be easy to identify the correct type. In the latter case, clear instructions for differentiating one cloud from the other namely Altostratus from Cirrostratus have been given. If these are followed no confusion need arise.

ii. Mistaking an overhead Cumulonimbus for Stratus:

When the zenith of sky is covered to a major extent with Cumulonimbus clouds and it is raining at the station there is a tendency to report it wrongly as Stratus. This wrong interpretation arises from the fact that the top of the cloud decks cannot be seen and the bottom gives an illusion of Stratus formation. This can be avoided if the sky has been observed for a few hours before the time of observation and the growth of the cloud watched.

2. **Incorrect reporting of cloud amounts**: - While estimating the cloud amount for a particular type of cloud, imagine that this type is the only one present in the sky and leave the other types of clouds out of consideration. Moreover, if the sky can be mentally divided into 4 or 8 parts it will help correct estimation. A common mistake is to exaggerate the amount when the clouds are overhead and to underestimate it when the clouds are in the horizon. This is due to optional illusion and allowance has to be made for this factor when estimations of cloud amount are made for this factor when estimations of cloud amount are made.

3. **Reporting of high clouds when the sky is overcast with low clouds**: -It is clear that when the sky is overcast with low clouds, high clouds cannot be observed. It is wrong to report high clouds under such circumstances even if it, cloud be guessed from the development and trend of clouding, that they exist.

4. **Wrong reporting of height of base of clouds**: There is often a tendency to associate a particular type of cloud with a certain height. This may not be always correct. Observations of the movement of clouds would give a fairly clear idea of their height as very low clouds would appear moving faster than those above them.

7.2 Visibility:

For meteorological purposes visibility is defined as the farthest horizontal distance at which a person with normal vision can see an object under normal day light condition (such as a tree or a building) distinctly enough to *recognize* it. Visibility during night may be defined as the longest distance upto which lights of moderate intensity can be identified as such. The criteria used for day light visibility cannot, therefore, be used for night measurements. It is often possible to see that there is 'something' without being able to distinguish what it is, in such cases the object is not visible according to the above definition. The first step in estimating visibility is to choose some prominent objects (called visibility landmarks) situated at standard distances as laid down in the visibility code (see table below) or as near to them as possible, preferably within 10 per cent margin. An ideal visibility landmark should be an object intrinsically dark in colour and so placed that it can be viewed against the horizon sky or other light background. Minarets, towers, factory chimneys and like objects can serve as good landmarks for shorter distances, while for longer distances larger objects like hills and large buildings would be better, as they can be easily seen without straining the eye.

Next, a list of visibility landmarks showing their respective distances and directions from the place of observation and the corresponding code figures for the reporting of visibility should be prepared and kept at a place where it can be made readily available for constant reference. It may, however, not always be possible to fix visibility landmarks corresponding to all the code figures with the result that certain amount of visual interpolation or extrapolation may be necessary depending upon the location of each observatory with respect to its surrounding. Visibility observation then consists in seeing which the farthest object, that is visible is and the nearest object that is not visible. The distance of the latter (and the corresponding code figure) give the range of visibility at the time of observation, as shown in the Table below: -

7.2.1 Visibility Code for Daylight Observations

Landmark	Distance from place of observation	Direction	Observation as to which landmark is visible and which is not	Code figure to be reported for visibility
A	50 meters	( )	A not visible	90
B	200 meters	( )	A visible but B not visible	91
C	500 meters	( )	B visible but C not visible	92
D	1000 meters	( )	C visible but D not visible	93
E	2000 meter (1-¼ miles)	( )	D visible but E not visible	94
F	4000 meters (2-½ miles)	( )	E visible but F not visible	95
G	10000 meters (6-¼ miles)	( )	F visible but G not visible	96
H	20000 meters (12-½ miles)	( )	G visible but H not visible	97
I	50000 meters (31 miles)	( )	H visible but I not visible	98
J	Objects visible at 50000 meters or more	( )	I or further objects visible	99

7.2.2 Determination of Visibility at night: - Visibility at night may be determined in the same manner as during day time provided some suitable lights to serve as landmark can be found at distances corresponding to different code figures specified in Table below: -

Visibility Code for Night Observations

Landmark	Distance from place of observation	Direction	Observation as to which landmark is visible and which is not	Code figure to be reported for visibility
A-100 WATTS LAMP				
A	100 meters	( )	A not visible	90
B	330 meters	( )	A visible but B not visible	91
C	740 meters	( )	B visible but C not visible	92
D	1340 meters	( )	C visible but D not visible	93
E	2300 meter	( )	D visible but E not visible	94
F	4000 meters	( )	E visible but F not visible	95
G	7500 meters	( )	F visible but G not visible	96
H	12000 meters	( )	G visible but H not visible	97

NOTE: At greater distances 100 watts lamp is not suitable.

In practice it is seldom possible to find suitable landmark satisfying the above conditions, in the night. All that can be done is to select as many of the existing lights (street lamps, tower lights, aerodrome boundary lights etc.) round about the observatory as are visible to the Observer from the wind tower or the platform on which the wind instruments are erected.

At many observatories it will not perhaps be possible to get landmark lights for code figures above 95. In such cases, the Observer should try to estimate the visibility by noting the brightness of the light corresponding to the last code figure, and making use of his personal knowledge of any fixed lights in his locality, whose distances are known to him for higher code figures. Apart from the use of lights, a careful Observer can make a fairly good assessment of visibility from a general inspection of the clearness of the atmosphere and his surroundings. For example, even on a fairly dark n night one may spot a distant tower, a range of hills or a long road indicating that in daylight an object a that distance would be clearly visible.

7.2.3 Visibility in different directions: - When visibility is different in different directions, the lowest figure should be reported in the weather telegram but in the registers visibilities in the different directions should be entered as under: -

95 E

96 NW

98

This means that the visibility is represented by code figure 95 towards East, 96 towards North-West and 98 in other directions. As 95 is the lowest code figure, this will be reported in the coded message.

Note: - In the case of passing showers or other passing phenomena not occurring at the place of observation but within sight of it, the visibility observations (whether during day or night) should be made, as far as possible, when the passing showers or other phenomena are not between the Observer and the visibility landmark temporarily obscuring the latter from his vision.

7.3 Weather:

Observations of 'Weather' are recorded under the headings 'Present Weather' and "Past Weather' and the phenomena observed are those specified in the codes for ww and W/WI in the Weather Code. In addition to reporting them in the coded message, the Observer is required to keep a detailed record of weather in the registers maintained by him, giving the times of commencement and cessation of each phenomenon. Explanations of some important phenomena are given in Section7.3.3. Top facilitate their entry in the registers each phenomenon is represented by a symbol. A list of these Symbols is given in Table 7.3.

7.3.1 Present Weather (ww): - The observation of Present Weather is actually noting the state of the sky, and the phenomena occurring at the station or within sight of the station at the time of observation or during the hour immediately preceding it.

'At the time of observation' means during the period occupied in taking and recording the observation for a given hour, namely ten minutes ending at the scheduled hour of observation.

7.3.2 Past Weather (W and W1): -The period covered by 'Past Weather' is different hours of observation and is governed by special rules which are given in the Weather Code.

7.3.3 Some Important Weather Phenomena:

1. **Unusual Gustiness: -** The motion of air is never perfectly uniform but is subject to incessant changes in direction and speed. These changes are called turbulence or 'gustiness' of wind. When the gustiness is of such magnitude that the difference between the velocity in gusts and lulls is much greater than

usually experienced at the station for winds from that direction, it is called 'unusual gustiness'.

2. **Squall:** - A sudden increase of wind speed by at least three stages on the Beaufort scale the speed reaching B.F.6 or more and lasting for at least one minute. *Example:* -Wind speed suddenly increases from 16Km/hr. (B.F.3) to 40 Km/hr. (B.F.6) and remains at 40 Km/hr. for at least one minute.
3. **Gust:** - A sudden brief increase in wind speed of more transient nature than a squall, followed quickly by a lull or slackening of the wind. The increase in the case of a gust is not as large or as much prolonged as in the case of a squall.
4. **Line Squall: -**A violent squall, associated with the passing of a long line or arch of dark cloud and accompanied by thunder and lightning, rain or hail and a sudden cooling with a *shift in wind direction*. A line squall although of short duration may blow off trees and houses.
5. **Gale: -**Wind of **B.F**. 8 or more, blowing continuously and doing damage to trees, houses etc.
6. **Dust or Sand-Storm: -** A dust or sand-storm occurs when owing to the action of a strong continuous wind or a squall, sand or dust is raised in the atmosphere in sufficient quantity to reduce the horizontal visibility to less than 1000 meters. Classification of a dust or sand storm as 'slight'' moderate' or 'Severe' may be done on the basis of wind speed and visibility according to the specifications given below:

   Slight Dust-Storm: -Wind speed 20 to 49 Km/hr and Visibility less than 1000 meters.

   Moderate Dust-Storm: - Wind speed 39 to 74 Km/hr and Visibility less than 500 meters.

   Severe Dust-Storm: - Wind speed 75 Km/hr or more and Visibility less than 200 meters.

7. **Dust Raising Winds: -**Winds of unusual gustiness raising dust or sand in the atmosphere. These should be carefully distinguished from dust-storm which is a more violent phenomenon and usually associated with Cb clouds.
8. **Dust Whirls or Sand Whirls: -**Narrow columns of whirling dust or sand going up in a spiral form.
9. **Drizzle:** - Liquid precipitation in the form of very fine droplets, so small that their individual impact on water surface is imperceptible.
10. **Rain:** - Liquid precipitation of water of appreciable size, thereby differing from drizzle.

11. **Shower:** - Liquid precipitation of water of big size usually marked with sudden onset. The falling drops are more widely scattered than in rain. Showers generally fall from convective clouds (Cumulus or Cumulonimbus)

12. **Thunderstorm:** - Thunderstorm is reported as soon as thunder is first heard whether or not lightning is seen or precipitation is occurring. Thunderstorm is classed 'slight', 'moderate' or 'heavy' according to the following specifications:

Light Thunderstorm: - Light peals of thunder, lightning at fairly long intervals.

Moderate Thunderstorm: - Loud peals of thunder and frequent flashes of lightning.

Heavy Thunderstorm: - Almost continuous thunder and lightning.

13. **Snow: -** Precipitation of crystal of white ice, generally in flakes of light feathery structure.

Sleet: - Rain and snow falling together, or snow melting as it falls.

Drifting Snow: -Snow blown off the ground into the air after it has already fallen.

14. **Hail**: - Precipitation of small balls or pieces of ice. Hail generally falls during thunderstorms.

15. **Fog or Ice Fog**: - Extremely small water droplets or ice crystals suspended in the atmosphere, reducing horizontal visibility to code figure 93 or less. When fog or ice fog occurs, the wind is usually calm or very light and the relative humidity is at least 75 per cent. It is termed as: -

Very Thick Fog: - If the horizontal visibility corresponds to code Fig.90.

Thick Fog: - If the horizontal visibility corresponds to code Fig.91

Moderate Fog: - If the horizontal visibility corresponds to code Fig.92

Slight Fog: - If the horizontal visibility corresponds to code Fig.93.

16. **Mist: -**If horizontal visibility corresponds to code Figure 94 or 95 and relative humidity is at least 75 per cent the phenomenon is reported as Mist.

17. **Dust Haze:** - Extremely fine particles of dust or sand suspended in the atmosphere, reducing horizontal visibility to code Figure 94 to 96, Relative humidity is less than 75 per cent.

18. **Dust Fog: -**Suspension in the air of small dust particles reducing horizontal visibility to code Figure 93 or less. Relative humidity should be less than 75 per cent.

19. Moisture condensed from atmosphere on exposed surfaces**.** It is a common phenomenon of night or early morning with calm air and clear sky.

20. **Frost: -**Crystalline ice deposit, formed in the same manner as dew, when the temperature is below freezing point.

21. **Solar Halo: -**A ring of light round the sun caused by a thin veil of Cirrus cloud. It is often white but sometimes red near the sun, then orange then yellow. In most cases the ring has a radius of 22° surrounding the sun.

22. **Solar Corona: - A** ring of light round the sun, much smaller than a halo. Its inner edge is brownish red while the sky between the ring and the sun has a distinct bluish white colour. The radius of the ring varies from 5° to 8°.

23. **Lunar Halo: -**A circle around the moon similar to the Solar Halo.

24. **Lunar Corona**: - A ring around the moon similar to the Solar Corona.

25. **Fine Weather**: - Sky cloudless or with isolated Cirrus floating in the blue sky and showing signs of dissolving, or with a small amount of pure stratiform cloud at a fixed level, but with no clouds having vertical development.

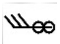
26. **Fair Weather**: - Thin Cirrus covering a considerable part of the sky but not increasing or forming a continuous layer or sky with 'Fair Weather Cumulus' or Altocumulus with characteristic change in the course of the day.

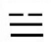
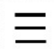
Note: - 'Fair Weather Cumulus' appears in patches in the afternoon and instead of developing further into Cumulonimbus, disappears in the evening.

7.3.4 Symbols for weather Phenomena: -Symbols of a few important phenomena of common occurrence, are given in Table 7.3, below.

TABLE 7.3

Symbols for recording Weather Phenomena in the Meteorological Register

Symbol	Explanation
	Squall
	Line Squall
	Gale
	Dust-Storm
	Dust Raising Winds
	Dust Whirl or Sand Whirl
	Light or moderate Thunderstorm but no Precipitation

	Heavy Thunderstorm without Precipitation
	Thunderstorm (light or moderate) with Rain
	Thunderstorm (light or moderate) with Snow
	Thunderstorm (light or moderate) with Dust Storm
	Light Intermittent Drizzle
	Light Intermittent Rain
	Light Intermittent Snow
	Fog or Ice Fog, sky discernible
	Fog or Ice Fog, sky not discernible
	Mist
	Dust Haze
	Solar Halo
	Solar Corona
	Lunar Halo
	Lunar Corona
	Rainbow

7.4 Wave Observations:

Waves are produced by the action of wind over sea surface. Observations of waves are of practical importance in detecting the approach of a storm and locating the approximate position of its center, when other observations are lacking. Hence Observers at coastal stations are required to record and report observations of waves, in addition to other elements like pressure, temperature etc.

7.4.1 Definition of a Simple Wave: -A Simple wave is defined by the following characteristics: -

(i) **Speed (Cw)**: - Speed at which individual waves travel. It is usually expressed in knots.

(ii) **Length (Lw)**:-Horizontal distance between successive crests or successive troughs – usually expressed in meters.

(iii) **Direction (ddw): -** Direction from which the waves are coming, measured in 16 points of the compass.

(iv) **Period (Pw): -** Time interval required for the passage of successive crests (or successive troughs) past a given point usually expressed in seconds.

(v) **Height (H): -** Vertical distance between the top of a crest and the bottom of a trough, expressed in meters. Fig.54 illustrates what has been stated above,

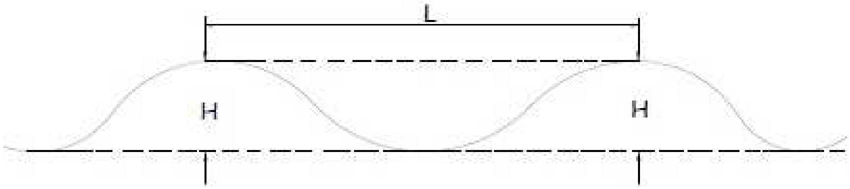


Fig. 53 – Profile of a simple wave

7.4.2 What Constitutes a Wave Observation: - Wave observation consists in measurement or estimation of three characteristics out of the five listed in 7.4.1 namely direction, period and height.

Direction: - The direction from which the waves are coming can be obtained by sighting along with wave crests (i.e. bringing the line of sight parallel to the crests) and then turning through 90 degrees, so as to face the approaching waves. The direction towards which the Observer is then facing, will be the direction of the waves.

Period: - For measuring this element all that is required is a stop watch, though even an ordinary watch with a second hand can serve the purpose. A simple method consists in timing the movements of a floating object. A stop watch is started when the object appears at the crest of the wave. As the crest passes on the object disappears in to the trough, then reappears on the next crest. The time at which the object appears at the top of each crest is noted. The average period is then worked out by dividing the total time taken by the number of waves given by the number of times the object reappeared on a crest.

It is also possible to obtain accurate wave periods by timing the breakers (Waves that break on the beach). As the period of a wave does not change when the wave is approaching the coast, the period of the breakers would be the same as that of the waves in the deep water beyond.

Height: -For accurate observation of this element it is desirable to have a fixed vertical graduated line against which the movement of the water surface can be measured. If a convenient pier exists, a pile at its seaward end, suitably painted with alternate black and white bands will be most suitable. Alternatively, a spar may be mounted vertically and well stayed (in low water). This can be used for observations when the tide is up sufficiently to bring it beyond the breaker zone.

If the arrangements mentioned above are not possible, the height of the waves may be estimated by one of the following methods: -

i. The Observer, by stationing himself, at a convenient and suitable distance from a anchored ship, can observe the approaching waves that strike the bow or stern part of the ship, and with reference to the painted marks on the ship can make fairly accurate estimate of the height.

ii. Wave heights may also be estimated by observing the maximum and minimum water surface level against a steep coast, as for example, when waves strike against a hill jutting into the sea or a rocky coral reef in the sea.

iii. The up and down movement of a floating buoy may also be useful for estimating wave heights. The nearest buoy is chosen for observation so that the vertical height through which the buoy is carried up and down by the waves can be observed and estimated.

7.4.3 Selection of the Observation Spot: -The waves should be observed at a spot where they are not deformed either by the water being very shallow or by the phenomena of reflection, refraction or diffraction. This means that the spot chosen for observations should be well outside the breaker zone, not on a shoal or in an area where there is steep bottom gradient, nor in the immediate vicinity of a jetty or steep rock which could reflect waves back to the observation point. The observation spot should be fully exposed to the sea i.e. not sheltered by head lands or shoal.

CHAPTER 8

MAINTENANCE OF METEOROLOGICAL REGISTER

8.1 Meteorological Register: -

All observations are to be entered in the online MMR or Meteorological Register [Met-T-186 (R)], in accordance with the instructions contained in the pamphlet 'Instructions for making entries in the Meteorological Register' supplied to surface observatories. The instructions should be read and followed carefully. Observatories entering the observations in the online MMR should keep a printout of the same with them.

Observations recorded at Class V observatories are to be entered in the 'Monthly Weather Diary for use at 5^{th} Class observatories (OBS-198)' in accordance with the instructions printed thereon.

Evaporation and soil temperature readings are to be entered in separate registers specially supplied to the stations where these observations are regularly taken.

Punctuality is of the greatest importance in Meteorological Observations and must be striven for at any cost. If, however, an observation is taken earlier or later than the fixed hour the actual time when the observation was taken is to be indicated against **TIME**.

8.2 Preparation of Coded Weather Messages:

Complete instructions for preparing coded weather messages from the observations recorded in the Meteorological Register, are given in the pamphlet on Weather Codes, supplied to all observatories. The Observer must prepare and dispatch all weather observations immediately after he/she has finished taking the complete set of observations. The weather messages should be sent via Telephone, Mobile, SMS, email/internet/VPN to one or more of the forecasting offices of the India Meteorological Department or to other addresses as instructed by the Controlling Meteorological Office. A hard copy of each observation should be kept by the Observer and forwarded to the Controlling Meteorological Office at the end of every week or as directed.

It is of utmost importance that weather messages are prepared immediately after the observations have been recorded and sent off to the Controlling Met Offices and IMD Pune (through online MMR) without delay, on all days including Sundays.

As it is essential that the weather information should reach the Forecasting Offices in time, the Observer should carefully follow the under mentioned procedure for recording observations and preparing weather messages.

The Observer should start the observations about ten minutes before the hour fixed for each set of observations.

1) He should start with the wind instruments, first the windvane and then the anemometer.

2) In the three minutes interval between the first and second anemometer readings, he should record all the non-instrumental observations, viz., clouds, visibility etc.

3) He should then record rainfall (and evaporation readings where evaporimeters are provided) and next read the thermometers, after which he should calculate the dew point temperature with the help of the Hygrometric Tables.

4) Next, he should fill in all the observations taken (i.e. all observations other than pressure) in the weather observation form after which he should proceed to the barometer room and be ready there about a minute before the specified hour of observation for reading the barometer.

5) He should then read the barometer, exactly at the scheduled time of observation.

6) Within about three minutes after reading the barometer, he should complete the reduction of the barometer reading and enter PPP in the Weather Register, after which he should hand over the observations without delay via SMS/Telephone/Mobile/email/internet/VPN to the Controlling Met. Office.

CHAPTER 9

MAINTENANCE OF AWS / ARG / AAWS / ASG / HWSR AND INSTALLATION PROCEDURES

9.1 Introduction

Automatic Weather Stations (AWS), Automatic Rain Gauge Stations (ARG), Agro meteorological Automatic Weather Stations (AAWS), Automatic Snow Guage Stations (ASG) and High Wind Speed Recorder (HWSR)are installed all over India to augment the surface observational network. Conventional meteorological observatories exist in around 560 locations and many districts are still meteorologically unrepresented. In an effort towards automation and to obtain meteorological data from such remote locations, many AWS were commissioned during the years 2006-07. More number of AWS and ARGs are installed during the year 2010-2012.

As per modernization programme, 725 AWS and 1375 ARGs will be available to provide valuable meteorological data for effective operational weather forecasting. Around 2000 AWS and 4000 ARGs are planned for the country for adequate meteorological representation. AAWS were installed for the first time in India in 127 Agrometeorological Field Units, in the Agroclimatic zones of India with sensors for measurement of agriculture-related meteorological parameters in addition to the basic ones. As per modernization plan under DAMU, 660 Agro AWS will be installed at 530 KVKs and 130 AMFUs. 200 Agro AWS have been installed during 2021-2022. There is also requirement of mesoscale AWS in URBAN cities, AWS for schools, ASG in Himalayan region and NE India and HWSR in the coastal stations.

9.2 Technology of AWS:

AWS are unmanned and satellite-based /mobile telemetry based with electronic sensor instrumentation for measurement of meteorological parameters. AWS transmit to INSAT-3D satellite using two different transmission techniques known as Pseudo-Random Burst Sequence (PRBS) and Time Division Multiple Access (TDMA) technique. An AWS has sensors for measurement of air temperature, rainfall, relative humidity, wind speed, wind direction, atmospheric pressure and rainfall. Apart from these basic sensors, Agro AWS(AAWS) have sensors for measurement of leaf temperature, leaf wetness, soil moisture and soil temperature and global radiation. An ARG generally has sensor for rainfall only but in select locations sensors for air temperature and relative humidity are also interfaced, as per the requirements like in the case of a mesoscale network of rain gauge stations available in urban metro cities.

The AWS / AAWS / ARGs/ASG/HWSR sample data frequency is 1 MINUTE /15 MINUTES /EVERY HOUR and transmit it to the satellite /GPRS which is retransmitted to the Earth Station Server, located at Pune where it is processed and made available to the weather forecaster for use. Accurate and reliable data can be ensured from AWS/ARGs which are effectively maintained periodically, at least once in three months and more frequently in rainy and cyclonic situations.

The AWS data, in near real time are available in the web site http://www.imdaws.com.

9.2.1 Satellite based TDMA ERS

A TDMA type data receiving Earth Station has been established at IMD Pune for reception of AWS and ARG station data. The received raw data is decoded in real time and engineering values of meteorological parameters are retrieved and archived. The Earth station is capable of receiving downlink transmissions in entire 300 MHz band (4500 to 4800 MHz) from DRTs onboard INSAT series of satellites. The Earth Station demodulator/DSP receiver and AWS data processing equipment can simultaneously receive, process and disseminate the data from eight carrier frequencies. Thus, data from about 7200 stations can be received at the earth station. The AWS data transmitted through any INSAT satellite is received at the Earth Station. The received signal is down converted and fed to burst demodulator. The demodulated data stream is then fed to data processing system. The processing software received raw data in real time through satellite link. The data is stored in raw files for further processing. The received raw data is then decoded into engineering values and is archived in a database. The processed data can be viewed in tabular and graphical format. The data can also be exported in text, MS Excel formats. The data is then converted into WMO synop code and is then made available through GTS for weather forecasting

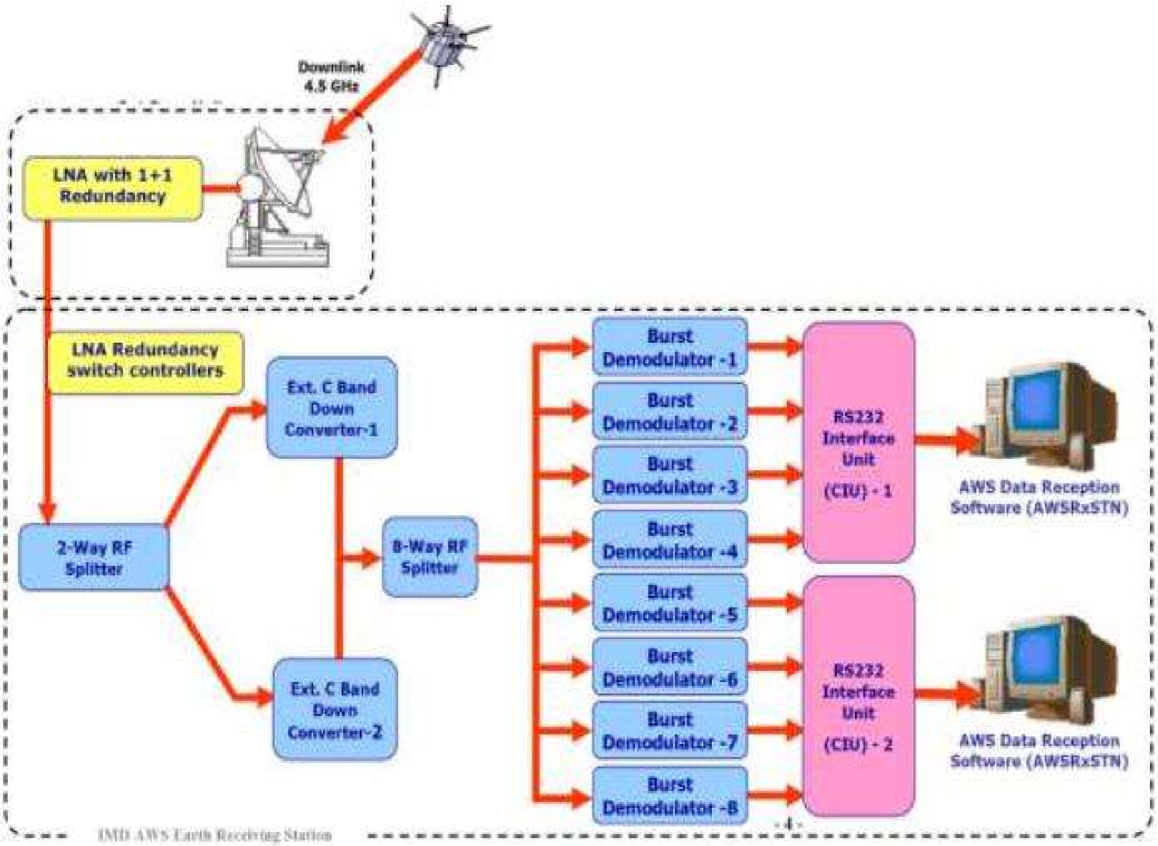


Fig.54 IMD AWS Earth Receiving System

9.2.2 GPRS based SERVER

A GPRS based data receiving Server has been established at IMD Pune for reception of AWS and ARG station data. All GPRS based AWS and ARG data are being received in IMD Pune through FTP. At an interval of 15 minutes, AWS and ARG will take observation automatically and sent to IMD server through GPRS communication. During adverse weather conditions, the AWS and ARG data observation reception from field sites may be made to 1-minute interval.

Fig.55 GPRS based server at IMD Pune

9.3 Installation of AWS / ARG/ASG/ AAWS/ HWSR

The installations of AWS are initially done in locations which have co-located conventional surface observatories. The process of validation of the data is done by comparing the values of meteorological parameters measured by electronic sensors and conventional instruments like mercury thermometers, wind vane, anemometer, barometer, rain gauge etc. After validation is done for all the seasons, the data from AWS installed in remote locations with the same type of electronic sensors can be considered to be representative of the site. In addition, the values are cross-checked and validated by hand-held digital standards carried to the sites by the touring officials.

9.4 Site specifications

An AWS is generally installed ideally in an area of dimensions 15 m x 12 m, with proper meteorological exposure conditions. In places where such an extent of land is not available, an area of 10 m x 10 m is also sufficient. An ideal AWS site is shown in Fig.57.

Fig.56 An ideal AWS site

The temperature and humidity sensor is mounted at 1.5 to 2m height and wind sensor at 10 m height as per the standards prescribed by World Meteorological Organisation (WMO). Rain gauge is installed at least at a distance of 3 m from the centre of the mast where the datalogger enclosure is mounted. Sensor for measurement of atmospheric pressure is mounted within the enclosure where the other equipments like solar charge controller, transmitter, battery etc. are kept. The AWS works on a battery supported by a solar panel for power requirements. The solar panel is mounted in the southern direction at a height of about 3-4 m from ground level with an inclination angle which is the total value arrived at by adding the numerical value of the latitude of the place to 10 to 15 degrees. This is to ensure that solar panel is oriented towards the sun all through the year in that particular location so that at least six to seven hours of sunlight fall on the solar panel at any point of time in a year.

An ARG requires a site of dimensions 5 m x 7 m. An AAWS, has a nearby crop canopy and is located in a site of dimensions 15 m x 15 m. Guidelines for selection of AWS sites and the schematic diagram showing the locations for mounting of the sensors are provided in **Section 9.8**.

9.5 Concept of RIMC / SIMC / IMUs

Automation in the methods of taking meteorological observations means that more and more manpower needs to be empowered and their technical skills have to be upgraded. The upkeep and maintenance of the instruments requires involvement of trained manpower for ensuring trouble-free operations all through the year in order to obtain accurate and reliable observational data.

The vast network of AWS/ARGs/AAWS/ASG/HWSR some of which are in remote and distant locations has state-of-art meteorological instruments. Since proper and timely maintenance of the equipment requires adequate lab facilities and trained manpower at the level of the sub-offices of IMD, the concept of establishment of a 3-tier maintenance system was proposed by HQ, New Delhi at each of the six Regional Meteorological Centres of IMD.

Under this proposal, a Regional Instruments Maintenance Centre (RIMC) is established at Regional Meteorological Centre (RMC), Chennai. State Instruments Maintenance Centres (SIMCs) are established at Meteorological Centres in every state and Instruments Maintenance Unit (IMUs) are to be located at specific departmental meteorological offices, airport meteorological offices or Doppler Weather Radars (DWRs) offices of IMD. Wherever AWS / ARG/AAWS are co-located in IMD observatories, special attention and due care has to be ensured of the equipments by the respective officer-in-charges in maintenance and upkeep of the systems.

The officers at the level of IMUs in IMD observatories will have around 4 to 5 districts in their station’s vicinity under their control. Maintenance and upkeep of the AWS/ARG/AAWS/ASG/HWSR located in those districts will be coordinated by the IMUs. Sites have to be visited frequently, at least once in two months and periodic clearance of bushes, solar panel and changing the battery, cleaning the rain gauge and defective sensors will be the responsibility of the IMUs. Cleaning the rain gauge has to be done more frequently during monsoon and adverse weather conditions to ensure that the rainfall reported by the rain gauge is correct. SIMCs will also function as IMU for the nearby districts. RIMC will also work as SIMC and will undertake the maintenance of the AWS/ARGs in its State / vicinity while handling the additional responsibility of overall coordination in catering to the various requirements SIMCs and IMUs.

9.6 Maintenance of AWS / ARG / AAWS/ASG/HWSR

The functionality of AWS/ ARG/AAWS/ASG/HWSR is based on power supply through 42 / 65 AH SMF batteries, powered by solar panels. No AC power supply is used. Though AWS / ARG/AAWS/ASG/HWSR are considered unmanned to provide data round the clock uninterruptedly, all such electronic equipment will work better with good maintenance strategy. Hence the success of receiving accurate and reliable data from such unmanned stations lies in effective maintenance. It is highly recommended that a log book be maintained to keep track of the maintenance schedule and the types of problems encountered, how it was sorted out etc. so that it can serve as a valuable guidance to all field maintenance personnel.

General instructions

i. It is always preferred to carry spare sensors, laptop, memory card, cables, cable ties, insulation tapes, required tool kit, multimeter, rust remover etc., and handheld digital standards for meteorological equipment while undertaking preventive maintenance tours to AWS / ARG / AAWS /ASG/HWSR sites.

ii. The grass and bushes have to be cleared at least once in three months and more frequently in places which are prone for more of vegetative growth due to various reasons.

iii. Once a year, the tower, enclosure, fencing etc., have to be painted in order to avoid degradation in such parts of the AWS/ARG/AAWS /ASG/HWSR Wherever civil work like foundation of the rain gauge, pillar / mast is found damaged take adequate steps to ensure that rectification is ensured to avoid further deterioration.

iv. Before commencing work in a functional AWS / ARG/AAWS/ASG/HWSR it is desirable that the logged data in the memory of the data logger and the set-up file used to run the data logger is copied from the logger to the memory card being carried by the touring officials. This will be helpful under varied circumstances.

v. If it is not possible to solve the problem with any sensor in the field AWS site, then replace it with a spare sensor available in hand and bring the defective one for repairs / troubleshooting in the laboratory.

vi. If a co-located conventional surface observatory is present, data comparison for the touring period may be made with the measured meteorological parameters.

vii. Before leaving the site after completion of the maintenance work, call up AWS Data Receiving Earth Station, Pashan, Pune (Phone: 020-2586 5047/ SIMMS mobile No 94057 99533 and WhatsApp Group – AWS MAINTENANCE GROUP) and ensure that the transmissions from the AWS site are received properly at the Earth Station and whether any problems are noticed in the meteorological data.

viii. Keep a few silica gel pouches in the NEMA enclosure to avoid moisture build-up in the air-tight NEMA enclosure.

ix. Sometimes the gasket of the NEMA enclosure may become worn out leading to rainwater entering the NEMA box. Arrangement may be made to avoid such occurrences.

x. Leave the site after the enclosure is safely locked and hand over one set of keys to the Officer-in-charge in whose office / organization premises the AWS/ARG is installed. Bring the other set of keys to be retained with the respective IMUs / SIMC/RIMC.

xi. Leave the site neat and clean.

9.7 Troubleshooting Tips

Following are some of the common problems &solutions to guide the official while on tour for preventive maintenance of field AWS / ARG sites.

A. Battery voltage going down and not recharging

The battery voltage could go down for a few days due to several reasons:

- Bad weather
- No sunlight for a couple of days
- Loose Connections in the AWS Enclosure wiring
- Solar charge regulator becoming defective
- Solar panel cable damaged or cable got cut due to rodents or other reasons
- Solar Panel could have been stolen.
- Ideally, the battery 12 V, 42 AH / 65 AH needs to be replaced with a new one at least once in two years for effective and round the clock performance.

B. Solar Charge regulator

- Check whether the red LED in the charge regulator is on during sun shine. If the LED is glowing it means the battery is being charged by the solar panel and the voltage is less than 14.5 V. Check the voltage with a multimeter.
- If the voltage from the solar panel is around 14-16V then the solar panel connections are ok.
- Disconnect the battery and get the battery charged from a local mechanic / car shop to increase the battery current. If you have a battery charger available with you, then you can do it in the office itself.
- Then connect the battery to the AWS system. Disengage the fuse holders of the AWS while reconnecting the battery.
- After the connections are over and voltage is checked, then engage the fuses by following the standard procedure.

- Clean the solar panel periodically and whenever you visit the AWS / ARG/ASG/AAWS/ HWSR site.

C. No data Reception from the AWS / ARG/ASG/AAWS/ HWSR site.

- Confirm from the earth station what was the last battery voltage was when the system stopped transmissions.
- If the battery is below 11V the satellite transmitter /GPRS modem will not transmit.
- Check whether there were high winds on the AWS site which may have caused the yagi antenna to get dislocated from its assigned position. Go to the AWS site and check the status.
- The recording status of the AWS should be "running". If the recording status is "stopped" analyse to see what the possible reasons could be.
- Check whether the satellite ID and transmission window are the same as what is required to be for that particular station. If the ID has changed then change it to the original satellite ID of the station.
- Visually inspect antenna, cables and RF surge suppressor for damage and corrosion.
- Check that antenna cables are securely connected. Check whether water has seeped into the connector ends after a heavy rain. If so, disconnect the cable, dry it thoroughly and reconnect the antenna cable. Seal the connector ends with a water-proof tape.

D. Rain Sensor (Tipping bucket rain gauge) not working

- Check the wiring. Remove the MS connector from outside the enclosure and connect the voltmeter between the A & B to check the continuity. Each time the rain gauge tip you should get a close contact.
- If the sensor is OK up to the MS connector then connect it back and check on the AWS logger terminal connection. If the sensor is OK on the terminal connector end, and still not measuring rain position, there might be other reasons for the non-functionality.
- After a heavy lightning activity, there are possibilities of the reed switch in the measuring circuit of the rain gauge getting damaged. In such cases, reed switch may be replaced. Always carry spare reed switches to AWS sites before undertaking preventive maintenance work.
- If erratic pulses are observed, check whether the tipping bucket is properly fitted to the connector.

- Check whether the underground cabling has got damaged. This will also lead to random generation of pulses.

E. AT/RH sensor not working

- Check the wiring as per the wiring diagram. Check for loose Connections inside the enclosure and MS connector. Tight all the connection on the terminal strip of 9210.
- If you have spare sensor connect it to the outside of enclosure to verify that the problem is outside in the sensor and not inside the enclosure wiring or the 9210.
- Check whether any wiring has got desoldered at the MS Connector end at the NEMA Enclosure side. Then also readings may not be proper.
- If the wiring has got desoldered, then remove the sensor cable and bring it to the lab for soldering the wires in their proper connector-ends.
- Sometimes wasps build mud homes around the AT/Sensor thereby blocking measurements. So, every time, the radiation shield has to be dismantled after carefully removing the AT/RH sensor and the plates have to be cleaned of the fine mud deposits. The plates can be washed with clean water, dried and again assembled for further mounting of the AT/RH sensor.

F. WS/WD not working

- Check the wiring as per the wiring diagram provided for the type of AWS / ARG in your region. Check for loose connections inside the enclosure and MS connector. Check and tighten all the connections on the terminal strip.
- If you have a spare sensor connect it to the outside of enclosure to verify that the problem is outside in the sensor and not inside the enclosure wiring or the data logger.
- Sometimes after a heavy downpour of rain, if the MS connectors are not properly sealed with a water-proof tape, water enters inside the connectors. At such instances, wind sensor will report erroneous values. At such instances, the MS connector shall be disconnected carefully and cleaned thoroughly
- After it has dried up, the connector can be fitted to its slot and covered with a waterproof tape. Then the wind data recording will start normally. Check the same by the values logged in the data logger.
- Check whether the orientation of the wind sensor has been disturbed due to wind / wind / lose connections. Orient the yellow / red notch on the ultrasonic wind sensor (which is an indicator for orientation towards north direction) towards north. Use a compass to find out the direction. Check the connector end at the top of the mast (10m height) for any water and clean it.

- Check whether any wiring has got desoldered at the MS Connector end at the NEMA Enclosure side. Then also readings may not be proper. If the wiring has got desoldered, then remove the sensor cable and bring it to the lab for soldering the wires in their proper connector-ends.

G. Solar Radiation sensor not working

- Check whether the optical glass dome has been physically damaged. The optical surface shall be clean and devoid of dust, bird shit, stains of paint etc.
- Check the wiring as per the wiring diagram. Check for loose Connections inside the enclosure and MS connector. Tighten all the connection on the terminal strip of the data logger.
- If you have a spare sensor connect it to the outside of enclosure to verify that the problem is outside in the sensor and not inside the enclosure wiring.
- Check for the voltage output (in the range of mV) from the sensor with the voltmeter. Cover the sensor with a cloth or hand and see if the voltage drops.
- Then use a Flash Light on top of the sensor and check if the voltage increases.

H. Barometric Sensor not working

- Check the wiring as per the wiring diagram. Check for loose Connections inside the enclosure and MS connector.
- Tighten all the connection on the terminal strip in the data logger. If you have spare sensor connect it to the outside of enclosure to verify that the problem is outside in the sensor and not inside the enclosure wiring of the data logger.
- If a spare sensor is available, connect it and check whether readings are proper.
- If there are no externally visible problems, contact the concerned technical coordinator for assistance.

I. Soil Temperature / Soil Moisture sensor

- Check the wiring as per the wiring diagram. Check for loose Connections inside the enclosure and MS connector. Tight all the connection on the terminal strips. Check whether the data is logging properly.
- If you have spare sensor connect it to the outside of enclosure to verify that the problem is outside in the sensor and not inside the enclosure wiring.
- Remove the sensor from underground and check for physical damages in either the sensing element or cabling. This can happen due to various reasons like rodents, inadvertent cable damage during grass cutting etc.

- Change the sensor with a spare sensor and bring the defective one to the laboratory for troubleshooting.

J. This system is specially designed to suite the meteorological requirements of Data Logger for coastal area. This Data Logger has one analog input for Wind Direction and two Serial inputs for Wind Speed& pressure sensor. The HWSR-LOG continuously monitors all the inputs, converts the parameters to digital values and stores these values with respect to real time. Averages for one minute, three minutes and Ten minutes of Wind parameters & pressure are calculated and are displayed on128x64 graphics LCD display on the front Panel. The method used for calculating average wind parameter is vector averaging and not the scalar averaging method. One-minute average values of the parameters are stored in the HWSR-LOG with respect to real time. Instantaneous data for graphical trend is also stored in the HWSR-LOG with respect to real time.

For more complicated troubleshooting problems, refer to the detailed technical manual, if provided or contact the respective Regional Instruments Maintenance Centre of your region for further assistance. Other state-of-art equipment like data logger, transmitter, GPS antenna etc., which become defective or unserviceable need module level replacement at field sites and cannot be repaired at remote sites. Replace the defective ones with a functional equipment and send the defective item to the respective headquarters for further action.

9.8 General Guidelines for Selection of an AWS Site / ARG / ASG / AAWS / HWSR

In general, the guidelines to be followed while selecting a site for installation of an AWS are the same as prescribed by WMO to establish a Meteorological Observatory. However, a few additional requirements are to be ensured to take care of clear view of AWS antenna (line of site) with location of satellite in the orbit (INSAT).

9.8.1 Norms for Site Selection:

- The AWS is to be located on a level piece of ground, covered with short grass or natural earth ideally 15metres X 12 metres in dimension. In cases of non-availability of space, 10 m x 10 m would be sufficient.
- Sites for Agricultural AWS (planned in 127 Agroclimatic Zones of India) may require a minimum of 36 m x 36 m to grow crops around the Agro-AWS (which requires 15 m x 15 m enclosure) to measure crop related parameters.
- In the case of an Automatic Rain gauge Station (ARG) the size of the plot may be 10 m x 7 m.

- There should not be any obstruction to the AWS transmitting antenna in the South-West (180-240º) direction for azimuth orientation and between 40° to 80° for elevation of the antenna.
- The proposed AWS site must be free from obstructions like tall buildings, trees etc.
- The site should be free from any encumbrance.
- Surroundings should be assessed for potential obstructions to selected sensors. Potential sensor contaminants (e.g., water and dust sources) should be identified.
- Security aspect has to be given due consideration so as to avoid theft of AWS equipments.
- The site should preferably be located on the same level as the roadway of the station.
- The site must be selected in such a way that the distance between the fencing of the site and the proposed AWS mast should be at least 3 metres. This distance is recommended to minimize the effect of the fence on the sensor's readings especially when weeds and/or debris on the fence act as a horizontal obstruction.
- HWSR can be installed on top building

9.8.2 CONDITIONS TO BE AVOIDED

- Obstructions like tall buildings, trees etc.
- Location of the site on the edge of a slope, hillocks, cliff or inside a valley
- Large industrial heat sources
- Location near high-tension power lines
- Rooftops, Steep slopes, sheltered hollows, high vegetation, shaded areas or swamps
- Low places holding standing water after rains.
- Underground obstructions like buried cables or conduits.
- Pollution influence from surrounding farms and towns.

9.9. SCHEMATIC VIEW OF AWS SITE:

The locations where sensors are mounted are shown in the schematic diagram given below.

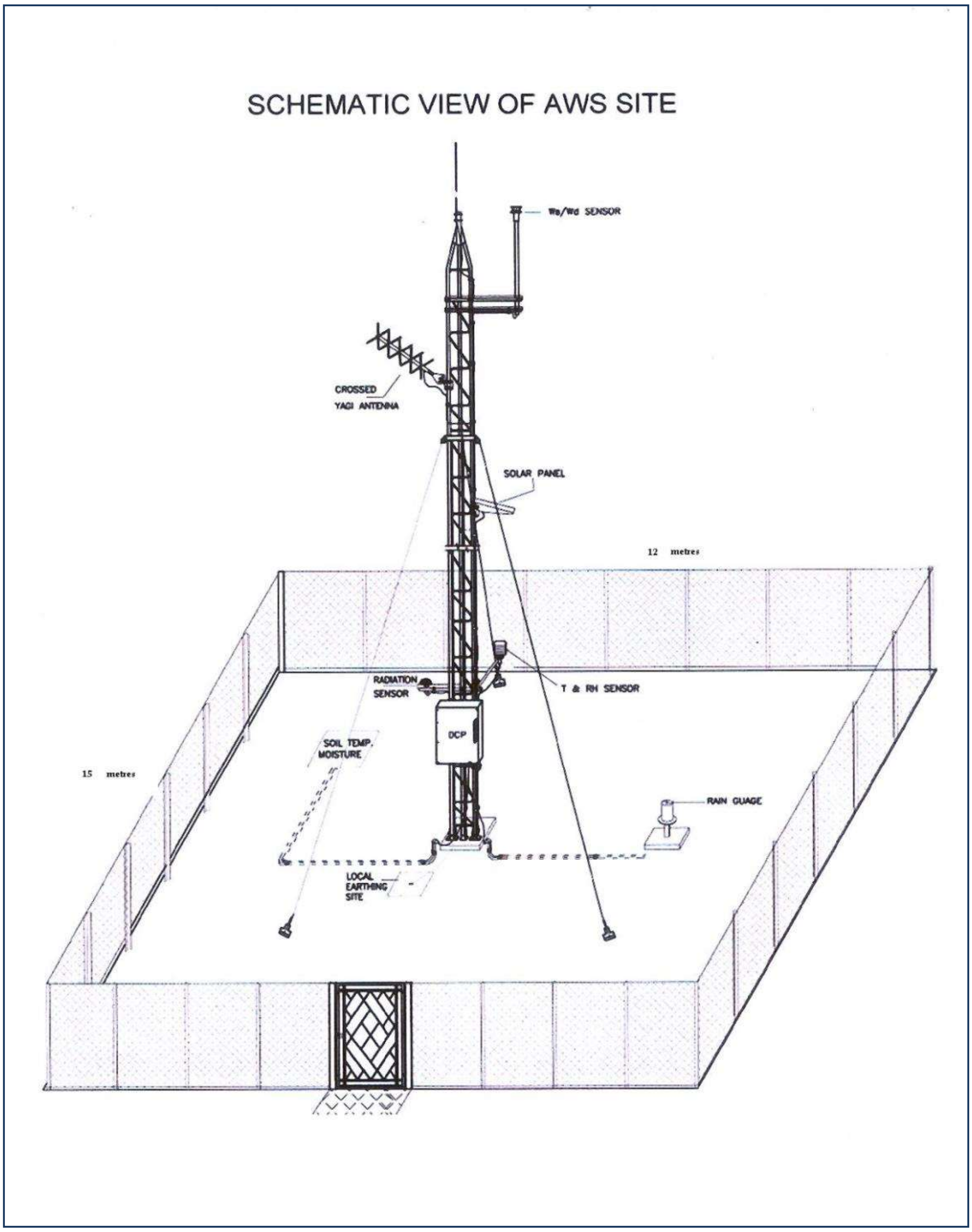


FIG. 57 SCHEMATIC VIEW OF AWS SITE

9.10 Exposure Conditions for Sensors of Meteorological Parameters

1. Wind speed and direction

- The wind speed and direction sensors are required to be installed on a mast, at a height of 10m from ground level.
- The sensors are required to be located on the mast, which is installed at a distance of at least ten times the height of nearby buildings, trees or other obstructions.

2. Air Temperature and Relative Humidity

- The standard measurement height for air temperature and relative humidity sensor is 1.25 to 2 m.
- The sensor is to be located at a distance of at least four times the height of obstructions like trees, buildings etc.
- The sensors are generally located in an open level area that is at least 9m in diameter.
- The site enclosure should be covered by short grass or natural earth.
- Large paved areas, bitumen surfaces in the vicinity of at least 30m have to be avoided.

3. Atmospheric pressure

- The Atmospheric pressure being an important meteorological parameter, the elevation of the station to which the station pressure relates is very important and hence the chosen site must be located in a flat terrain.

4. Rainfall

- The rainfall sensor (tipping bucket) is placed in an open area as far as possible at a minimum distance of four times the height of any obstruction.
- The standard measurement height is 30 cm above ground level.
- In places where flooding is more, the height may be 1 m from ground level and such sites have to be decided based on the suggestion of the RMC / MC concerned.

5. Solar radiation

- Solar radiation sensors to be mounted at a minimum height of 3m to ensure easy leveling and cleaning.

9.11 Documentation

- The site location should be documented with maps and photographs.
- Information as to the location of the site, corresponding to cardinal directions on the compass, descriptions of obstructions (height, distance, breadth), vegetation, and soil characterization to be documented.
- A site diagram with all the requisite details and a database about the station need to be prepared.

- Indications of land use in the nearby areas will be useful for study of variations in meteorological parameters.
- Permission (No Objection Certificate) from the land-holder of the site for installation of a semi-permanent AWS/ARG installation has to be obtained and documented.
- The coordinates of a station have to be recorded as under:

    (1) The latitude to the nearest minute.

    (2) The longitude to the nearest minute.

    (3) The height of the station above mean sea level, i.e. elevation of the station to the nearest meter.

- Details regarding accessibility to the site by rail/road, modes of communication, boarding and lodging facilities, important Govt./private offices in the vicinity are to be recorded.
- All other relevant details considered as important for the convenience of touring officials undertaking preventive maintenance trips have to be collected and documented.

9.12 Agricultural Meteorology

1. Principal Agricultural Meteorological Stations (a):

These Stations provide detailed meteorological and biological information and carry out research in agricultural meteorology.

2. Ordinary Agricultural Meteorological Stations (b):

These stations provide meteorological and biological information on a routine basis. The meteorological elements observed by these stations include rainfall, air temperature, humidity, soil temperature, wind speed and direction, evaporation, sunshine hours, the occurrence of weather phenomena like thunderstorm, hail storm, frost, high wind and micro-climatic observations. The observations are reported at 0700 and 1400 hours LMT. However, rainfall and evaporation observations recorded at 0830 hours IST and 1400 LMT. These observatories are maintained by the following agencies in the country for their requirement.

i) Soil conservation research, demonstration and training centers;

ii) Agricultural schools, colleges and universities;

iii) Agricultural research farms (ICAR, Rubber/Coffee/Tea Research) and allied centers;

iv) Various irrigation departments, Forest dept. and other institutes;

3. Auxiliary Agricultural Meteorological Stations (c):

These stations provide meteorological and some other information such as incidence and spread of diseases. This meteorological information generally consists of air temperature, humidity, rainfall and may include some of other meteorological parameters detailed under the ordinary agricultural meteorological stations. Following stations come under this class:

i) Associated with Surface observatories (I.M.D.) recording phonological observations;

ii) Phonological stations for which meteorological data are also recorded by some other Agency.

iii) Pest and disease reporting stations for which meteorological data are also recorded by some other agency.

Some Agricultural Meteorological observatories are Agro Meteorological Field Units (AMFUs) located in the 127 different Agro Climatic Zones under the scheme "Integrated Agro Advisory Services" to provide agro advisory bulletins and weather forecast on real time basis to the farmers. These stations are maintained by I.M.D. and manned by the host institute aided by I.M.D. on annual basis.

4. Pilot Balloon-cum-Micromet Stations (d):

These stations are departmental stations and were started under "Desert Locust Meteorology Scheme". They provide low level winds to assist in the issue of anticipated winds for anti- locust operations.

5. Evapotranspiration Stations (e):

These stations are manned by I. M. D. for measuring evapotranspiration using gravimetric / volumetric lysimeters in order to assess water requirement of different crops.

6. Soil Moisture observatories (f):

These observatories are manned by I. M. D. for estimation of soil moisture by using gravimetric method from bare soil and cropped field.

7. Agrometeorological Automatic Weather Stations (Agro AWS) (g):

These stations are installed at AMFUs located at various state Agriculture Universities, (SAUs) Institutes of Indian Council of Agricultural Research (ICAR), Indian Institute of Technology (IIT) etc., under Integrated Agromet Advisory Services (IAAS).

8. Dew recording stations:

These are departmental stations to record dewfall data. Some of the AMFU and Agrometeorological observatories also record dewfall data.

Beside rainfall, dewfall is one of the secondary sources of moisture available to the crops. It plays significant role in plant growth particularly in arid and semi-arid regions.

9. Evaporation stations:

These are departmental stations to record evaporation data. Apart from these, most of the AMFUs and Agrometeorological observatories also record evaporation data.

List of Agricultural Meteorological Station:

Abbreviation for class of observatory

a – for Principal Agricultural Meteorological stations
b – for Ordinary Agricultural Meteorological stations
c – for Auxiliary Agricultural Meteorological stations
d – for Pilot Balloon-cum-Micromet stations (Desert Locust Monitoring)
e – for Evapotranspiration stations
f – for Soil Moisture Observatories
g – for Agrometeorological Automatic Weather Stations (Agro AWS)
e+f – for Evapotranspiration + Soil Moisture recording station

CHAPTER 10

RADIATION INSTRUMENTS: METHODS OF OBSERVATION AND MAINTENANCE

10.1 Introduction:

As all of us know that the sun is the only source of energy for the life of the earth. The energy emitted by the sun is received by the earth in the form radiation. The radiation emitted by the sun is constant and only a small fraction about 4.5 x 10-^{10}, is intercepted by the earth. The sun emits energy in the form of electromagnetic waves, which covers a very large range of wavelengths of electromagnetic spectrum from gamma rays through X-rays, UV, Visible, infrared and microwaves to radio waves.

These electromagnetic waves travel with the speed of light. Their wavelength ranges from a fraction of nm to hundreds of meters. Various spectrum of electromagnetic waves is known by different names as below depending upon their uses and wavelength:

Name	**Wavelength range**
Radio Waves	few Km - 0.3m
Micro Waves	0.3m – 10^{-3}m
Infrared Rays	10^{-3}m – 7.8 x 10^{-7}m
Visible Light	7.8 x 10^{-7}m - 3.8 x 10^{-7}m
Ultraviolet Rays	3.8 x 10^{-7}m - 6 x 10^{-10}m
X-Rays	10^{-9}m – 6 x 10^{-12}m
Gamma Rays	10^{-10}m - 10^{-14}m

There is no sharp boundary to isolate one type from another because characteristics changes smoothly and many times uses overlap across the boundaries.

10.2 Interaction of the atmosphere with solar radiation

Atmosphere contains Nitrogen, Oxygen, O3, CO2, water vapour, Argon, Krypton etc. and suspended dust, haze and various particles. But these constituents, even if they are minor in percentage they are very important from the point of study of radiation.

Ozone selectively absorbs the radiation in UV range, in the visible range and in IR range also.

Water vapour and CO2 selectively absorbs radiation in Infrared region.

Dust and haze particles and other suspended particles scatter radiation. The scattering of radiation attenuates the energy. All the radiation emitted by Sun does not reach us, but some part goes back to the space due to scattering and reflections.

Thus, due to selective absorptions, scattering, reflection by cloud tops etc. the radiation from the sun gets attenuated.

Solar Constant:

To study the solar radiation, one must get an idea at which rate the sun emits this radiation. The radiation received in unit time on a surface of unit area held perpendicular to the sun's rays just at the upper boundary of the atmosphere at a mean Sun-Earth distance is known as **solar constant**. The mean value of solar constant is $1367 \pm 7\ Wm^{-2}$.

When we measure the radiation on the earth's surface we will never get this value as atmosphere comes into picture which is responsible for attenuation of radiation.

Being the ultimate source of energy for life, the study of solar radiation, its measurements are important.

10.3 Radiation instruments & Parameters

Sl No.	PARAMETERS	INSTRUMENTS USED
Short Wave (0.3μ - 4.0 μ):		
1.	Direct solar radiation(S)	Thermoelectric Pyrheliometers on automatic solar tracker/Heliostat. Sun photometer
2.	Global ($S.\cos\theta + D$) θ: Zenith angle	Thermoelectric Pyranometer
3.	Diffuse (D)	Thermoelectric Pyranometer with shading ring/ shading disc.
4.	Reflected	Inverted Pyranometer
Short Wave (0.28μ - 0.4μ):		
5. 6.	UV A radiation (0.315μ to 0.40μ) UV B radiation (0.280 μ to 0.315 μ)	UV A Radiometer UV B Radiometer
Long Wave (4μ - 100 μ)**:**		
1	Net Terrestrial Radiation	Thermoelectric Pyrgeometer
Total (0.3μ - 100 μ):		
1	Net Radiation	Net Pyrradiometer

10.4 General theory of Radiation:

A) Black body concept

When radiant energy impinges upon a body, this energy is partly reflected from the surface of the body, partly transmitted through the body and partly absorbed by the body. If R is the reflectivity of the body i.e. the fraction of the incident radiation reflected by the surface. T the transmissivity and A the absorptivity, then the equation: $R + T + A = 1$.

The relative proportions of these three quantities depend upon the nature of the substance, nature of the surface and the wavelength of the radiation. We can imagine a body in which for all wavelengths $R = O$, $T = O$ and $A = 1$; i.e. the body absorbs all the energy that is incident upon it and this energy goes to raise the temperature of the body. Such a body is called a **Black Body**.

The amount of energy radiated by a body depends largely upon its temperature. A black body for every wavelength radiates the maximum intensity of radiation possible at a given temperature. The radiation emitted by such a body is called Black Body Radiation. Lamp black or soot is a good example of a black body. A black body need not be black in colour. A very good black body is the surface of tips of a bundle of very thin, sharp sewing needles, when the incident rays are nearly parallel to the needle axis. A hollow sphere with a small opening and coated internally with soot is a good approximation of a black body because internal reflection keeps the rays inside the sphere for further absorption. A body, which emits for each wavelength a fixed proportion of the black body radiation at the same temperature, is called a **grey body** and its radiation is called ‘grey radiation’.

The energy radiated by a body per unit surface area per unit time is known as its **Emissive power**. It is expressed in SI units as Watt Per square meter (Wm^{-2}). In Meteorology a unit “calorie per sq. cm. per minute or langleys per minute was in use earlier. One may speak of the total emissive power referring to all wavelengths or the monochromatic emissive power referring to a particular wavelength or spectral band.

The rate at which a unit surface absorbs radiation falling upon it may be called **Absorptive Power**. The absorptive power may be considered for a single wavelength, a band or the entire spectrum.

The ratio of the observed emissive power of a body to that of a black body under identical conditions is called E**missivity**. This is a dimensionless number and ranges between 0 and 1.

The ratio of the observed absorptive power of a body to that of a black body under identical conditions is called **Absorptance**. But a black body by definition absorbs all radiation that is incident on it; hence the fractional part of the incident radiation that is absorbed by the surface is called its absorptivity. This is a dimensionless number and ranges between 0 and 1.

B) <u>Kirchoff's Law:</u>

This law states that a good absorber is a good radiator and a bad absorber, a bad radiator. If a body emits radiation of a given wavelength at a given temperature it will also absorb radiation of the same wavelength at that temperature. It also states that at a given temperature the ratio between the emissive and absorptive power for a given wavelength is the same for all bodies.

Let us consider a closed cavity, the walls of which are kept at a constant high temperature and are radiating as a black body. If a non-black body is suspended in it by a non-conducting thread, a thermodynamic balance between it and the walls will be reached. The balance would involve the blackbody energy emitted by the walls E (λ, T) the radiant energy emitted by the non-black body e(λ, T)and the unabsorbed energy reflected from non-black body. If the absorptivity of the body is a_λ, then the unabsorbed energy is (1 – a (λ, T)) E (λ, T). Mathematically-

$$E(\lambda, T) = e(\lambda, T) + \{1 - a(\lambda, T)\}E(\lambda, T)$$

$$\Rightarrow \frac{e(\lambda,T)}{a(\lambda,T)} = E(\lambda, T)$$

Put in another way, the Kirchoff's law also states:

i.e. the ratio of the Emissive Power to the absorptivity is equal to the emissive power of a black body at the same wavelength and temperature.

C) <u>Stefan's Law:</u>

$$E = \sigma T^4$$

Where

E = energy radiated per unit time per unit surface area of a black body.
σ = Stefan's constant =5.67 x 10^{-8} W m^{-2} K^{-4}
T = temperature in K of the black body.

D) <u>Wien's displacement law:</u>

If λ_{max} is the wavelength (in μm) corresponding to maximum energy in the spectrum of a black body radiation at an absolute temperature T, then

$$\lambda_{max} T = \text{constant} = 2897$$

E) Planck's Law:

At any particular temperature, the distribution of energy in the spectrum of a black body is given by

$$E\lambda, \mathbf{T} = \frac{\mathbf{a}_{\lambda}{}^{-5}}{\mathbf{e}^{(\mathbf{b}/\lambda \mathbf{T})} - \mathbf{1}}$$

where

E_λ = energy in the spectrum of a black body at wavelength λ
a and b are constants. $a = 2\pi hc^2 = 3.74 \times 10^{-16}$ Wm^2. $b = hc/k = 1.44 \times 10^{-2}$ m K.
T = temperature in K of the black body.

F) Solar Radiation

The sun is the sole source of energy for all biological and physical activities on the earth. Its radiation nearly resembles to that of a black body at approximately 6000K. Its spectrum ranges from fraction of a nm to hundreds of meter but the region between 250nm to 3000nm carries 98% of the total emitted energy.

Wavelength region from .25μ to 3.0μ carries 98% of the total emitted energy and the visible spectrum region from 0.4μ to 0.8μ carries 50% of its energy with maxima around 0.55μ.

Atmospheric effects on incoming solar radiation:

1. Solar radiation having wavelength less than 0.24μm (UV) is absorbed by air in stratosphere to break up oxygen molecule into atoms.
2. These atoms combine with oxygen molecules to form ozone molecules. The O_3 molecules again absorb solar radiation upto 0.286μ to get dissociated. Thus, the atmosphere cuts off most of the ultraviolet part of solar radiation having wavelength less than 0.286μ.
3. The solar radiation, that traverses the atmosphere further, is subjected to depletion by scattering and reflection by air molecules, aerosols and clouds.
4. The infrared portion of the solar radiation, which traverses the atmosphere downward, also suffers depletion by selective absorption at various wavelengths by water vapour and CO_2.

G) Albedo

It is defined as the ratio of the reflected radiation to the total intercepted radiation. It is described in terms of percentage of reflected radiation. The albedo of the earth-atmosphere system is 0.30. The moon has an albedo of only about 0.07, indicating that it absorbs most of the solar radiation striking its surface. Thus, viewed from space, the earth shines more brilliantly than the moon. The major reason for this is the presence of clouds. The moon has no atmosphere and no cloud.

Some typical albedo is:

Fresh snow	0.75 – 0.90
Cloud tops	0.60 – 0.90
Old snow	0.50 – 0.70
Sand	0.15 – 0.35
Seas (high sun angle)	0.05 – 0.10
Forests	0.03 – 0.10

H) Terrestrial Radiation

The radiation emitted by the earth is called terrestrial radiation. Its radiation nearly resembles to that of a black body at approximately 300K. Its spectrum ranges from fraction of a few μm to hundreds of meter but the region between 4μ - 120 μ carries most of the total emitted energy.

Atmospheric effects on outgoing radiation:

1. The long wave radiation (4μ - 120 μ), which is emitted upward by the earth, also suffers selective absorption by water vapour and Co2, which leads to heating of the atmospheric layers.
2. Upward and downward radiation by all atmosphere layers and clouds.
3. The atmosphere is transparent for 8μ - 12μ and most of the terrestrial radiation escapes into space through this window. Maxima is at about 10μ.

I) Beer's Law:

Consider a layer of absorbing medium of thickness h. If S is the incident radiation intensity and dS is the portion absorbed in passing through a small distance dh, then the fractional absorption is proportional to the density ρ of the medium and the path length traversed.

$$\frac{dS}{S} \propto -\rho . dh$$

Negative sign is because of negative change dS. If a is the constant of proportionality, then

$$\frac{dS}{S} = -a\rho . dh$$

Integrating over the entire path length-

$S = S_0 \, e^{-am}$

where m is the mass per unit area around the path traversed.'a' is known as extinction coefficient or absorption coefficient.For a monochromatic radiation the above equation becomes

$S_\lambda = S_{0\lambda} \, e^{-a_\lambda m}$

m is also called optical airmass or optical path length For simplicity m is taken unity for sun elevation 90°, station level pressure 1013 hPa during clear sky condition. The relative optical path length or relative airmass for sun elevation other than 90° is discussed above.

10.5 Terminology used: (WMO Recommended)

1. Irradiance:

   Amount of radiant flux incident upon per unit surface area per unit time.

   Unit: Wm^{-2}.

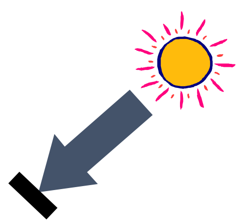
2. Radiant exitance

   Amount of radiant energy emerging from per unit surface area per unit time.

   Unit: Wm –2

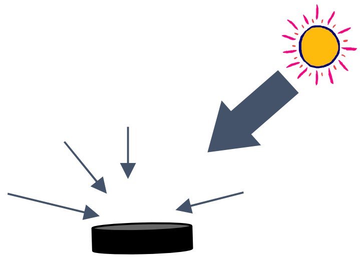
3. Direct solar irradiance

   Solar irradiance received on a surface held perpendicular to sun rays and diffuse radiation cut off. For this purpose, a sensor is fixed at the bottom of a collimator tube and blackened from inside so that any diffuse coming inside is absorbed and only direct solar radiation is received.



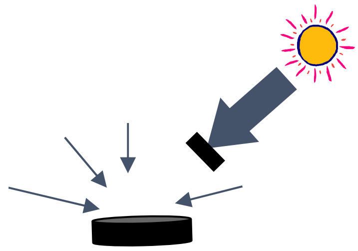
4. Global solar irradiance

Solar irradiance received on a horizontal surface including direct and diffuse radiation.



5. Diffuse solar irradiance:

Solar irradiance received on a horizontal surface when direct rays are cut off with the help of a shading ring or a shading disc.



6. Reflected solar irradiance

Upward radiant exitance in the short-wave range.

7. Solar spectral irradiance

Solar irradiance per unit wavelength upon a surface held perpendicular to sun rays and diffuse radiation obstructed.

8. Net terrestrial radiation

(Upward radiant exitance – downward irradiance) in long wave range through a horizontal surface near earth surface.

9. Upward radiant exitance

Upward radiant exitance in the entire wavelength range through a horizontal surface near earth surface.

10. Downward total irradiance

    Downward irradiance in the entire wavelength range upon a horizontal surface near earth surface.

11. Net total irradiance

    Downward total irradiance - Upward radiant exitance

10.6 Description of different sensors

Basically, almost all the instruments measuring solar radiation are having a thermopile as a sensor except UV-radiometer which is having silicon photocell/photodiode as a sensor.

What is a thermopile - A thermocouple is a point fused with two dissimilar metals having different characteristics such as temperature coefficients? A series of such thermocouples form a thermopile, with which a thermo-emf is generated when heated with sunlight. Thus, we get an output in millivolts. The mV output thus converted to engineering units like Watts per square meter, or the integrated value over a period of time will be MJ per square meter.

An advantage of a thermopile is that its spectral response over the entire wavelength region is constant, whereas silicon photocell/ photodiode has a spectral response and deteriorates fast when exposed to sunlight to a considerably larger period.

10.7 Radiation Instruments

A) Thermoelectric Pyranometer (Global Solar Radiation)

- Measures solar irradiance from 0.3µm to 4.0 µm
- Sensor: Blackened copper-constantan thermopile covered with **two concentric glass domes,** which are transparent to radiation from 0.3µm to 4.0 µm.
- Generated emf by thermopile is proportional to incident radiation. The typical value is approx. 5µv $W^{-1}m^{2}$.
- Used for instantaneous measurement and continuous recording of:

    1. Global irradiance
    2. Diffuse irradiance

3. Reflected Solar irradiance

The most widely measured component of solar radiation is the global solar irradiance. (G). It is the addition of Diffuse and Direct solar irradiance.

Global = Diffuse + Direct

i.e. $G = D + I \sin h$

The sensor is thermopile, painted black with optical black lacquer. It is guarded by two hemispherical glass domes which prevent convective currents due to heating. The transmission range of the domes is 0.3 µm to 3.0 µm. A guard plate is fixed over the body of the Pyranometer so that direct sun rays do not irradiate the body of the Pyranometer at any time of the day.

Fig. 58 Thermoelectric Pyranometer

- Installed on a terrace where the exposure conditions are suitable (free from obstructions like tall buildings trees, tall obstacles etc.) i.e. no shadow should fall on the sensor any time during the day.

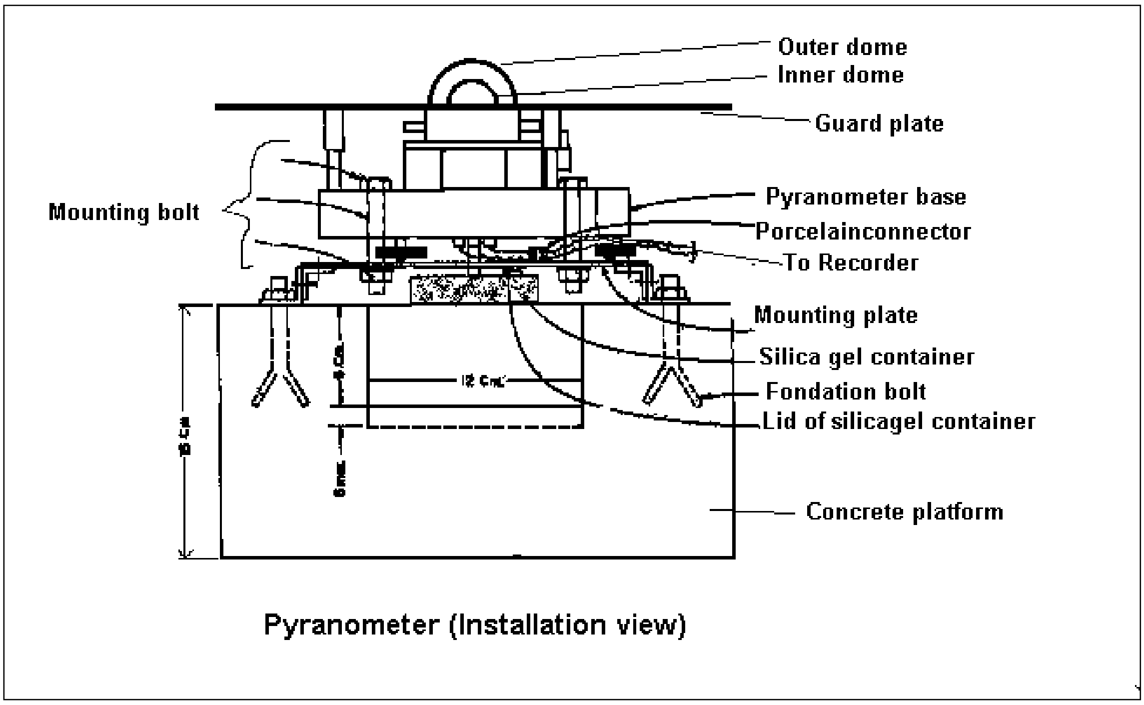


Fig. 59 Installation of Thermoelectric Pyranometer

B) Thermoelectric Pyranometer with shading ring / disc (Diffuse solar radiation)

When the Pyranometer sensor is shaded with the help of a shading ring or shading disc, direct rays of the sun are cut off and the radiation (scattered and reflected) comes to the sensor is known as diffuse solar irradiance or sky radiation. The diffuse component plays an important role in energy exchanges as well as in the human comfort levels. Hence its measurement is of great importance. The sensing surface is permanently kept shaded from the sun's rays to obtain the diffuse solar irradiances.

A shading disc which will subtend 5° at the Pyranometer and whose shadow will just cover the glass hemispheres is an ideal device.

Fig. 60 Diffuse shading ring assembly

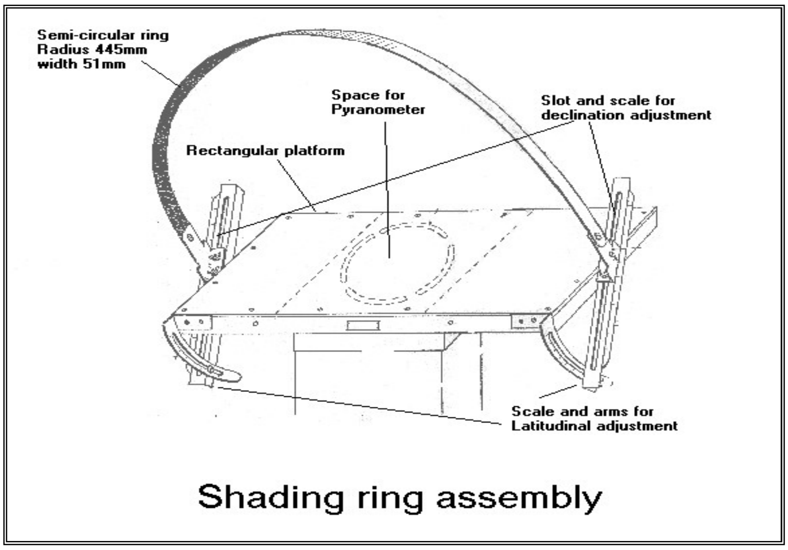


Fig. 61 Construction details

C) Thermoelectric Pyrheliometer (Direct Normal Incidence radiation (DNI))

- Measures direct solar irradiance from 0.3μm to 4.0 μm at normal incidence.
- Sensor: Blackened copper-constantan thermopile.
- Sensor mounted in a long metallic tube to avoid diffuse radiation.
- Heliostat maintains the Pyrheliometer directed towards the sun.
- Generated emf by thermopile is proportional to incident radiation (approx. 5 to 8 $\mu V\ W^{-1}\ m^{2}$).
- Used for continuous recording of direct solar irradiance**.**

Fig. 62 Pyrheliometer

D) Reflected Solar Radiation

When a Pyranometer is kept **inverted** in a field, the irradiation that is reflected from the earth's surface is measured by the sensor. This is called as **reflected solar radiation.**

Fig. 63 Albedometer

E) Net Pyrradiometer (Net radiation)

- Measures total irradiance from 0.3 µm to 50.0 µm
- Sensor: Blackened copper-constantan thermopile - both sides exposed to radiation.
- Sensor covered with polythene domes, which are transparent to radiation from 0.3µm to 50.0µm and kept inflated by injecting dry air.
- Generated emf by thermopile is proportional to difference of radiation incident on both sides. (approx.: 15µv W^{-1} m^{-2}).
- Used for instantaneous measurement and continuous recording of net irradiance (incoming - outgoing).

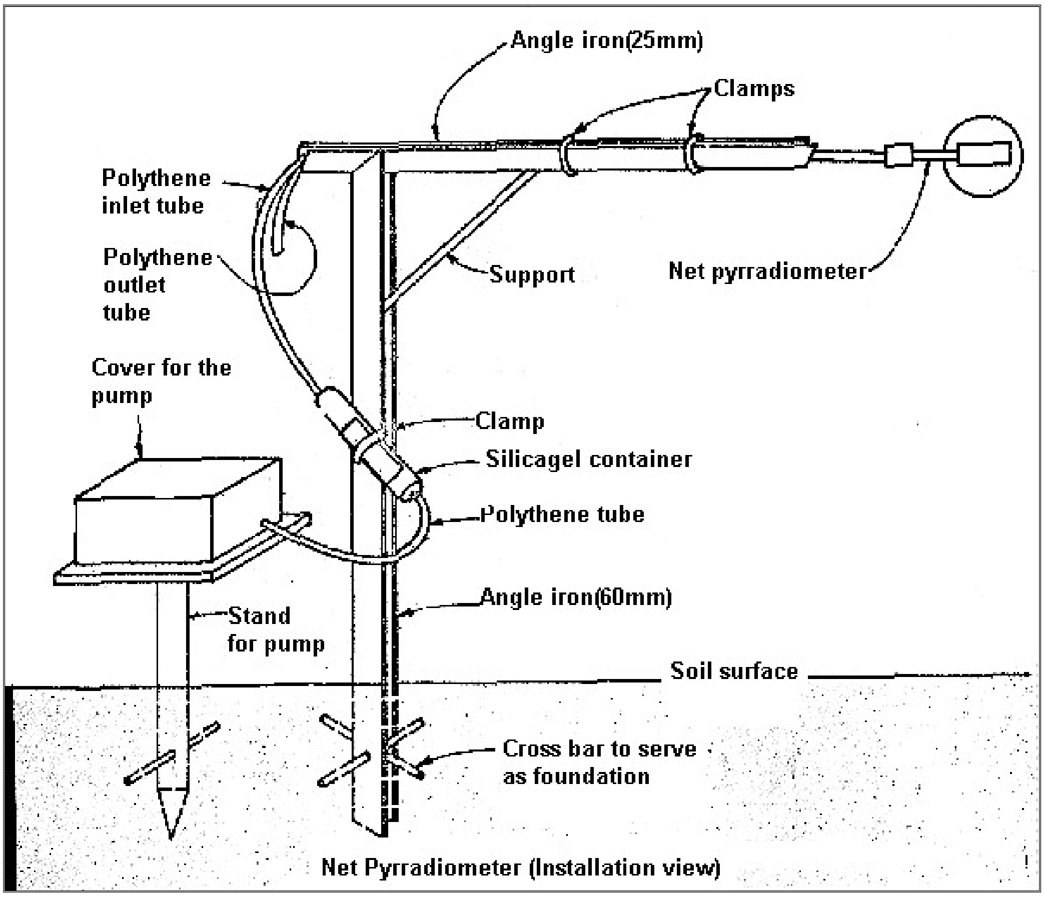


Fig. 64 Schematic diagram of Net Pyrradiometer

F) <u>Thermoelectric Pyrgeometer (Precision Infrared Radiometer – PIR)</u>

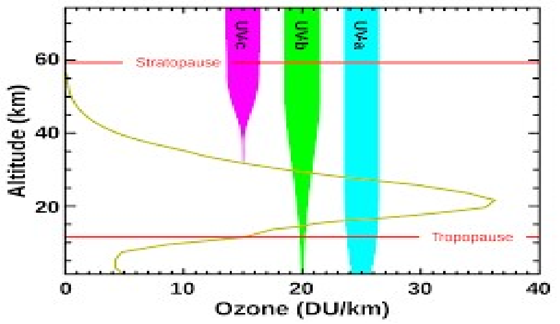
- Radiation emitted by the earth is termed as **Terrestrial radiation**.
- Measures net terrestrial irradiance from 3.5 µm to 50 µm.
- Sensor: Blackened circular multi-junction wire-wound thermopile.
- Temperature compensation of detector is incorporated.
- Generated emf by thermopile is proportional to incident radiation. The typical value is approx. 4 µV $W^{-1}m^2$.
- The silicon dome transmits long-wave radiation with a transmission range of approximately 3.5µm to 50 µm. from solar short-wave radiation in daytime and in night time only long-wave radiation.
- So, the incoming – outgoing = net terrestrial is measured (continuous measurement)

Fig. 65 Thermoelectric Pyrgeometer

G) <u>Measurement of UV irradiances:</u>

Designing an instrument for measuring ultraviolet is a challenging problem, because of the very low energy levels to be measured and the filtering out the remaining parts of the solar spectrum, viz. visible and infra-red regions where the energy levels are very high. The filters, mostly interference type, have to absorb the higher irradiances. These filters are, therefore, subject to heavy doses of irradiances and in addition they are to withstand the thermal shocks due to passing clouds. Thus, the stability of the transmission characteristics of the filters and consequently the calibration of the instrument has to be checked as frequently as possible.

Sunlight in space at the top of Earth's atmosphere is composed of about 50% infrared light, 40% visible light and 10% ultraviolet light, for a total intensity of about 1400 W/m^2 in vacuum.



Levels of ozone at various altitudes and blocking of different bands of UV radiation.

- UVC (100–200 nm) is blocked by oxygen or by ozone (200–280 nm) in the atmosphere.
- The ozone layer then blocks most UVB. (280-315 nm).

While, UVA (315-400 nm) is hardly affected by ozone, and most of it reaches the ground.

i) Beneficial effects of UV radiations

- UVB induces production of vitamin D in the skin. This vitamin helps to regulate calcium metabolism (vital for the nervous system and bone health), immunity, cell proliferation, insulin secretion, and blood pressure.
- People with higher levels of vitamin D tend to have lower rates of diabetes, heart disease, and stroke and tend to have lower blood pressure.
- The amount of the brown pigment melanin in the skin increases after exposure to UV radiation at moderate levels depending on skin type; this is commonly known as a sun tan.

ii) Harmful effects of UV radiations

- UVA does not cause immediate reaction, but rather UV begins to cause photokeratitis and skin redness at wavelengths starting near the beginning of the UVB band at 315 nm, and rapidly increasing to 300 nm. The skin and eyes are most sensitive to damage by UV at 265–275 nm.
- The eye is most sensitive to damage by UV in the lower UVC band at 265–275 nm. Light of this wavelength is almost absent from sunlight, but is found in welder's arc lights and other artificial sources. Exposure to these can cause the cornea, the lens, and the retina can be damaged.
- UV degradation is one form of polymer degradation that affects plastics exposed to sunlight. The problem appears as discoloration or fading, cracking, loss of strength or disintegration.

(i) UV-A Radiometers:

The sensor is a photodiode used in combination with a UV filter and a diffuser. The diffuser ensures correct angular response. The voltage output of the photodiode is made to be linearly proportional to the solar UV irradiance. The sensor unit is mounted in the same Pyranometer body.

- Measures solar irradiance from 0.315μm to 0.400μm.
- Sensor: is a photodiode used in a combination of filter and a diffuser.
- Voltage output is proportional to solar UV irradiance.
- The typical value is approx. 25 mV $W^{-1}m^{2}$.
- Used for instantaneous measurement and continuous recording of: UV-A Radiation
- Linearity output is within 1 %

Fig. 66 UV-A Radiometer

(ii) UV-B Radiometers:

- Measures solar irradiance from 0.280µm to 0.315µm.
- Sensor: is a photodiode used in a combination of filter and a diffuser.
- Voltage output is proportional to solar UV irradiance.
- The typical value is approx. 20 mV $W^{-1}m^{2}$.
- Used for instantaneous measurement and continuous recording of: UV-B Radiation
- Linearity output is within 1 %

Fig. 67 UV-B Radiometer

H) Data Logger System

A data logger is a device to measure signals from various types of electrical or electronic sensors and store the measured values along with time of measurement in its electronic memory. The measured values may be stored as it is or after conversion into engineering units. A data logger may have several input channels, a real time clock, a detachable memory module and interface for connecting to a PC and printer. Normally, a data logger need to be configured depending upon the requirement. The one used for radiation measurements is described below:

<u>Components of data logger system</u>

The radiation data logger system consists of following items:

1. Data logger
2. Maintenance free battery – 12 V, 7AH/ 42 AH
3. Battery charger
4. Desktop Computer (i5/i7)

<u>Time setting</u>

- Data logger is to be kept "ON" round the clock.
- Local Apparent Time is set in the data loggers to keep the uniformity at all the places.
- Time setting of data logger is to be done daily once, preferably in the morning at about 6 AM.
- Calculate Local Apparent Time by applying correction (given in the LAT correction tables) and set the time as per detailed instructions given in the respective manual.

<u>Taking printout of radiation data recorded by data logger</u>

- The printer connected to the data logger should be "SWITCHED ON".
- Ensure that the paper is loaded.
- Tabulate the printed data of selected time interval as per detailed instructions given in the respective manuals.

10.8 Routine maintenance of radiation instruments

1. Cleaning and wiping the glass domes of pyranometer and all other instruments with a soft muslin cloth on daily basis. Otherwise dust, dirt or water deposits on it will give errors in the data.

2. Utmost care of the domes should be taken as they are quite expensive.

3. Ensure that the outer glass dome is not loosely fit as it may be swept out by wind.

4. The pyranometer (having 2 glass domes-1 – inner, 1- outer) (and other sensors having glass domes) should be inspected frequently. The glass dome should be dried with a soft dry muslin cloth after any rain or fog.
5. The silica gel should be examined every week and replaced in order to prevent damages to thermo junctions through dampness and also to prevent condensation in the space between the glass domes, which will give errors in the records obtained. The dryer can be removed from the container by opening the lid after unscrewing the container from the tube. The silica gel must be reactivated whenever condensation on the glass dome is noticed and the silica-gel becomes pink. To reactivate the dryer, heat it on a stove until the colour changes to blue. Keep it stirred for uniform heating, taking care not to overheat it. Allow it to cool and store in an airtight tin supplied, which will be kept closed during the cooling. When cool, remove the reactivated dryer from the tin and immediately transfer it to the container. The container should be kept as tightly closed as possible.
6. Inspect and test the wiring every six months or immediately in case any fault is suspected. The cable should be examined for insulation between different cores and for continuity in the same core.

A) <u>Adjustment of shading ring for diffuse radiation (Daily)</u>

- Shading ring is mounted on two arms of shading ring assembly on which graduated marks are provided ranging from -25 to +25.
- For ensuring current diffused radiation reading, the shading ring of the Diffused Pyranometer <u>should be set once daily, preferably before sunrise</u>. After sunrise, check that the Pyranometer glass dome is fully shaded by the shading ring and if not, re-adjust the ring.
- Any adjustment in the position of shading ring can be done by sliding the ring according to the value of declination of Sun (by referring to the chart provided) on that particular day.

B) <u>Solar tracker for pyrheliometer</u>

Stations equipped with pyrheliometers, have Automatic computer based controlled tracker model. Purpose of any solar tracker is to continuously track the Sun so that pyrheliometer mounted over the tracker will always be tracking to the Sun so that sun's direct rays fall on the sensor continuously from sunrise to sunset. This enables a pyrheliometer (mounted on the solar tracker) to measure Direct Normal Incidence radiation (DNI).

C) Sunshine Recorder

Sunshine duration is defined by World Meteorological Organization (WMO) as the time during which the direct solar radiation exceeds the level of 120 W/m² and is normally measured in hours.

The instrument (CSD 3) measures solar radiation through a high-quality glass tube. It has no moving parts and uses 3 photo-diodes with specially designed diffusers to make an analogue calculation of when it is sunny. The output is switched high or low to indicate sunny or not sunny conditions. The calculated direct irradiance value is also available.

Fig. 68 Sunshine Recorder

D. Calibration facility

Maintaining the instruments in the network to generate a reliable database involves a close monitoring of the stability of the calibration factors of the instruments being used in the network. Even the instruments in use at the filed locations need regular calibrations with reference to the standards, if possible, without disturbing the data collection process. To achieve this, the calibrations have to be done in situ as well. Thus, a series of standards have to be maintained. The Central Radiation Laboratory has a hierarchy of standard equipment-primary, secondary, transfer, working and touring standards.

The laboratory also maintains electrical standards for checking and standardizing the auxiliary equipment like datalogger, potentiometric recorders and milliammeters. These electrical standards also undergo periodic standardization with reference to Wheatstone's Bridge and other standard equipment.

The primary and secondary standards are subjected to a series of careful inter-comparison for several days. These calibration results are transferred to the transfer and other standards by regular inter-comparisons in the laboratory. The working standards are used to calibrate the new instruments submitted by the manufacturing entrepreneurs and various institutions. The travelling standards are taken to the filed for in situ calibration works.

Central Radiation Laboratory, Pune maintains the three primary standards of the laboratory and the calibration factors are always with reference to this WRR. To ensure the stability of the primary standards, one instruments regularly participates in the International Pyrheliometer Comparison held once in five years at the World Radiation Centre (WRC) at Davos, Switzerland. The laboratory also provides its facilities for calibration of radiation instruments of the member countries (of WMO) whenever the demand is made. India also participates in the Asian Regional Pyrheliometer Comparison whenever these are arranged.

Fig. 69 Calibration at Central Radiation Laboratory, Pune

<table>
<tr><td>Absolute Cavity Radiometer
</td><td>Control and Display Unit
</td></tr>
</table>

Fig. 70 Calibration of Cavity Radiometer (Primary Standard) at Davos

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APPENDIX I

CLASSIFICATION OF SURFACE OBSERVATORIES

The surface observatories of this department are divided into the following six classes: -

S.No.	Type of Observatory	Nature of Observatory
1.	CLASS I (Special stations with autographic Instruments)	Observatories taking three or more observation per day at fixed times, having autographic instruments for recording at least three of the elements, pressure, temperature, wind and rainfall and communicating (bye-mail, fax, telephone) at least two sets of observations daily.
2.	CLASS II (Airway and Synoptic stations manned by Departmental Observers)	(a) Stations manned by departmental staff (combined surface, pilot and aviation stations) communicating (by e-mail, fax, telephone) and taking at least two sets of observations daily.
3.	CLASS II (Synoptic Stations manned by Part-time communicating (by telegram, telephone, or Observers)	(b) Part-time observer stations taking and communicating (by e-mail, fax, telephone) and taking at least two sets of observations daily.
		(c) Part-time Observer stations taking at least two sets of observations daily but communicating (by e-mail, fax, telephone) and taking only one set of observations.
		(d) Part-time Observer stations taking at least two sets of observations daily and reporting them by monthly registers only.
4.	CLASS III (Synoptic stations manned by part-timeObservers)	(a) Observatories communicating (by e-mail, fax, telephone) and taking only one set of observations daily. (b) Observatories taking only one set of observations daily and reporting the same by monthly registers only.

5.	CLASS IV (Climatological stations manned by Part-time observers)	(a) Observatories not equipped with barometers (climatological stations manned but taking two sets of all or most of the by Part-time Observers) remaining observations daily and reporting them by monthly registers only (b) Observatories not equipped with barometers but taking all or most of the remaining observations once daily and reporting the same by monthly registers only.
6.	CLASS V (Rainfall stations manned by Part-time Observers)	(a) Observatories taking once daily instrumental observations of rainfall only and communicating (by e-mail, fax, telephone or AMSS,SMS or Mobile) the same along with non-instrumental observations in the brief code. (b) Observatories recording only rainfall once, daily and communicating the same (by e-mail, fax, telephone) during certain seasons and by monthly or weekly registers during the rest of the year. (c) Observatories recording only rainfall once daily and reporting the same by monthly or weekly registers.
7.	CLASS VI (Miscellaneous non-instrumental stations and also those with a few instruments which do not come under any of the above classes)	(a) Non-instrumental stations recording clouds, wind directions and speed and visibility without any instrument and reporting the same by monthly registers. (b) Stations recording observations with a few instruments and which cannot be shown under class IV or V.

		(c) Stations recording observations with a few instruments, and communicating (by e-mail, fax, telephone) the same throughout the year, or part of the year and reporting the same by monthly Registers during rest of the year, and which cannot be shown under class IV or V.

APPENDIX II

USE OF MINI-THERMOMETER SCREEN

It is designed for use at urban climatological stations for measurements of air temperature.

It is essentially a portable thermometer screen, designed for housing three thermometers (namely maximum, minimum and ordinary dry bulb) having clear internal dimensions of 400 mm x 200 mm and 377 mm high and supported by a central G.I column 110 mm long, 30 mm in diameter with suitable flange attachments for installation with foundation bolts.

Essential features like slant double roof, louvered sides, hinged door etc. of a standard screen have been retained while reducing the overall size to make it compact and portable.

The support is erected by fixing the base flange by means of four foundation bolts grouted in the cement-concrete platform sank into the ground, such that, the mini-screen when installed, opens to the north with D.B. thermometer bulb at a height of about 1.3 meters above ground level.

The usual stipulations of site selection and exposure conditions may have to be relaxed to considerable extent depending on the local environment and specific requirements of urban climatological studies.

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द्वारा जारी/ ISSUED BY

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