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COMPARATIVE STUDY OF SELF-RECORDING RAINGAUGES

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ABSTRACT

Measurement of precipitation with gauges dates back to more than 2000 years. With the development of civilization and science, the demand for intensity of precipitation and its distribution in time has increased. Recording raingauges are used to keep a continuous record of rainfall amount against time. Three types of precipitation recorders are in general use:

i) the float type

ii) the tilting or tipping bucket type and

iii) the weighing type

In India, the float type natural syphon recording raingauge is widely used by the India Meteorological Department (IMD) and state organisations. The tipping bucket type raingauges have been used by IMD for developing Radio reporting raingauges. IMD has also made some further developments in the recording raingauges by developing a high resolution electronic rainfall intensity recorder.

Very few comparative studies of self recording raingauges were reported in literature. Most of the studies reported related to comparison of the recording raingauges with the standard non-recording raingauge.

The vibrating wire strain gauge developed by the Norwegian Geotechnical Institute is found to be a reliable measuring and recording instrument especially in view of its

capability for use at long distances upto 1 kilometre away without loss of any information.

It would be necessary to make comparative studies of recording raingauges at selected observatories in India using the float type syphon recording raingauge, the tipping bucket type recording gauge and the weighing type so that the results from these studies could be extended for use in the field with the relatively less expensive float type and tipping bucket type recording raingauges.

1.0 INTRODUCTION

Precipitation in the form of rain and snow is the principal water resource which nature has bestowed on planet earth. Mankind has been fascinated by precipitation since times immemorial. References to precipitation, its formation and its role in food production could be seen in the Manusmriti, the Vedas and Bhagavadgita. According to several sources the measurement of precipitation with some sort of receptacle (gauge) dates back to more than 2000 years. Vivid description of the shape and size of raingauges, its location and exposure was given in Kautilya's Arthsastra.

Exact information on the total amount of rain received during a season or a whole year is of paramount importance to agriculturists, meteorologists, hydrologists and economists. This information can be easily and cheaply obtained by the use of integrating or totaling storage type raingauges which are read manually and emptied by hand after every 24 hours or other interval. With the advancement of civilization and scientific development, the demand for precipitation intensity and its distribution in time has increased over the years for purposes of flood forecasting, water resources planning urban and rural drainage etc. This information could be obtained with the help of rain recorders using either daily or weekly strip charts for continuous recording over longer periods when no supervision may not be possible because of inaccessibility.

Information of shorter duration is very vital for estimating flood and inflows into reservoirs in real time and therefore needs to be observed, recorded and transmitted with precision and clarity. The advancement made in electronics especially solid state technology has made the development of high resolution, precision rainfall recorders and transmitters possible.

Though most of the recording raingauges operate perfectly under moderate rain intensity ranges they fail to work satisfactorily at the extremes, low as well as heavy rainfall intensities.While the low rainfall intensities are not of any consequence for operational purposes, the heavy intensities need to be recorded as accurately as possible.

In India there are more than 600 self-recording raingauges in operation at observatories of India Meteorological Department, and around an equal or more number of recording gauges are in operation under various Central and State Water Resources Organisations and Irrigation Departments. The float type natural syphon recording raingauge is the instrument widely used by all these organisations. For specific purposes like radio reporting from inaccessible areas and use in data collection platforms for transmission through satellite the tipping bucket raingauges are used by the India Meteorological Department. The Central Water Commission is also using the tipping bucket raingauges for automatic data collection and transmission in the Yamuna flood forecasting project.

Because of the inherent inertia in the mechanism, several of the raingauges suffer from sluggishness or mechanical lag and respond late or miss some catch.

For most of the real time analysis, data of rainfall intensities of 1 hour or shorter duration of less than 1 hour are needed. The maximum 1 hour (clock hour) rainfall intensities at many stations in India range from 100 or 130 mm/hr.The 60 minute intensities could be much more. The chances of malfunctioning and loss of catch generally increase with increase in the rainfall intensities. With a view to examine the efficiency of the available recording gauges during rainspells of such intensities a review of the recording rangauges used in India and other countries has been undertaken.

2.0 REVIEW

The first of the recording raingauges was designed by S.P.Fergusson in 1888 to meet the demand of a self contained recording gauge of simple construction. Since then a variety of recording raingauges with different measuring/sensing mechanisms and self recording and emptying techniques have been developed. While some of the gauges have been developed for specific purposes, others have become part of regular national networks set up for both climatological and operational purposes.

Rain recorders are usually installed in conjunction with a standard collecting raingauge. Majority of the rain recorders being used by the weather services in different countries are modified versions of recording gauges which were developed sixty years ago. Three types of precipitation recorders are in general use:

i) the float type,

ii) the tilting or tipping bucket type, and

iii) the weighing type.

Irrespective of the method of sensing the rainfall amount, the movements are to be converted into a form which can be recorded for subsequent analysis. The general and simplest method by which this is done is to move a chart by means of a spring or electrically driven clock past a pen which moves as the float or weighing device moves or a relay is closed.

2.1 Float Type Raingauges

In this type of instrument, the rain passes into a float chamber containing a light float. As the level of the water within the chamber rises, the vertical movement of the float is transmitted by an appropriate mechanism to the movement of the pen on the chart. By suitably adjusting the dimensions of the collector orifice, float and float chamber any desired chart scale can be used. For providing the record of rainfall over a longer time period (say 24 hours) with convenient float chamber size, a mechanism is provided for automatically and quickly emptying the float chamber. Usually a siphoning arrangement is used. In some instruments, the float chamber assembly is mounted on knife edges so that the full chamber over-balances. The surge of the water assists in the siphoning process and when the chamber is empty, it returns to its original position. Other rain recorders have a forced siphon which operates in less than five seconds. The gauges are sometimes provided with heating to prevent freezing of the water in the float chamber and consequent damage to the float and float chamber.

2.1.1 Natural syphon recording raingauge

The natural syphon recording raingauge is the principal self recording raingauge used by India Meteorological Department, state rainfall recording raingauge organisations and other central and state organisations in India. The instrument is capable of recording directly:

i) The total amount of rainfall which has fallen since the record has started.

ii) The time of onset and cessation of rain (the duration of rainfall).

From the above information, the rate of rainfall over a given period of time could be computed.

The syphon recording raingauge is shown in figure 1 and a close up of the syphoning and recording mechanism is given at figure 2.

Rain water collected in the funnel passes to the receiver consisting of a float chamber and syphon chamber. The pen is mounted on the stem of the float and as the water level rises in the chamber, the float rises and the pen records the amount of water in the chamber at any instant on a chart placed on a clock drum. The clock drum revolves once in 24 hours so that a continuous record of the movement of the pen is made on the chart and as the rain continues, the pen rises again from the zero line of chart.

The syphon is arranged concentrically, the long discharge tube being surrounded by the shorter syphon chamber which is directly connected to the float chamber. The passage connecting the two tubes at this joint is of almost capillary dimensions but the sectional area is large enough to discharge

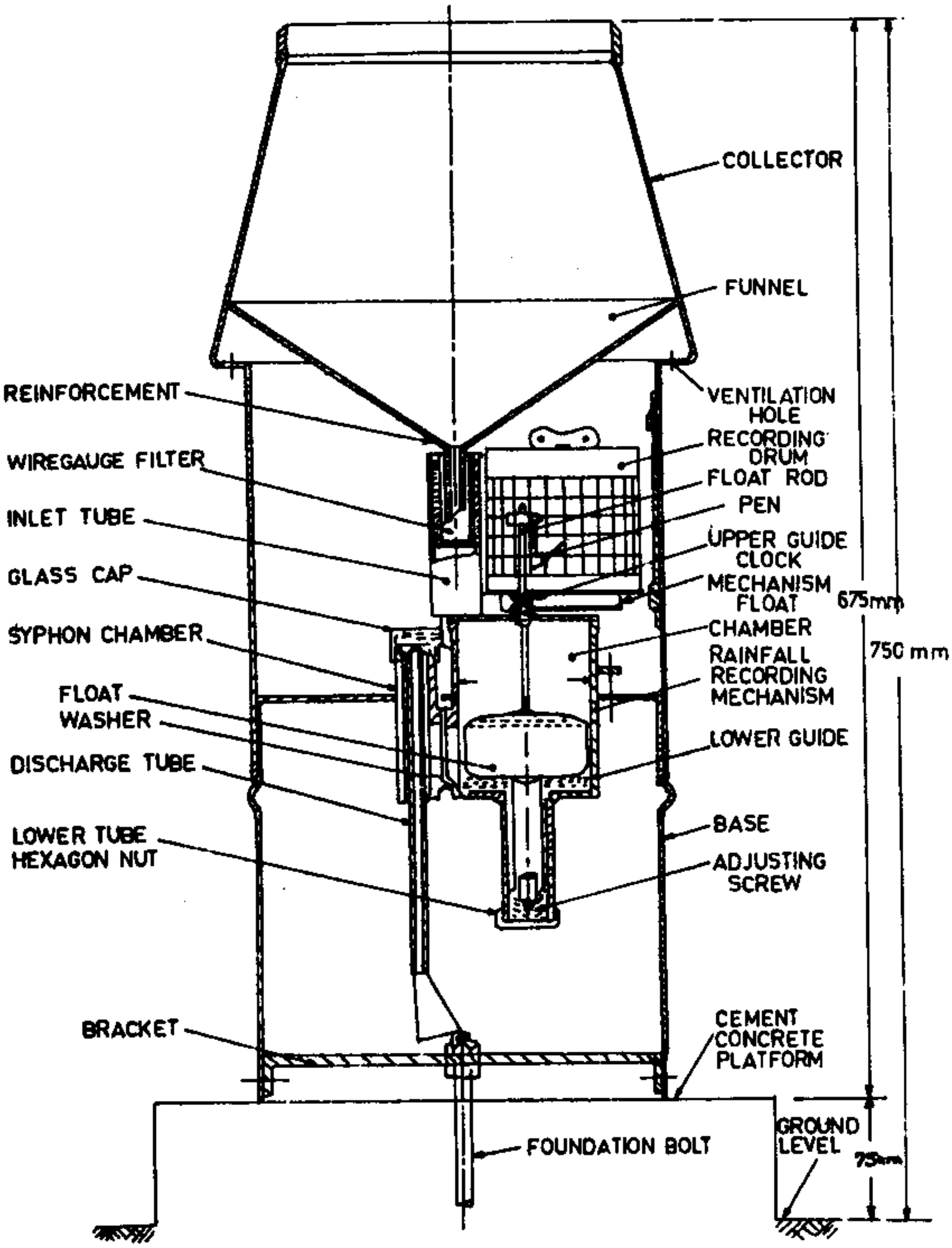

Fig.1- Float Type Natural Syphon Recording Raingauge

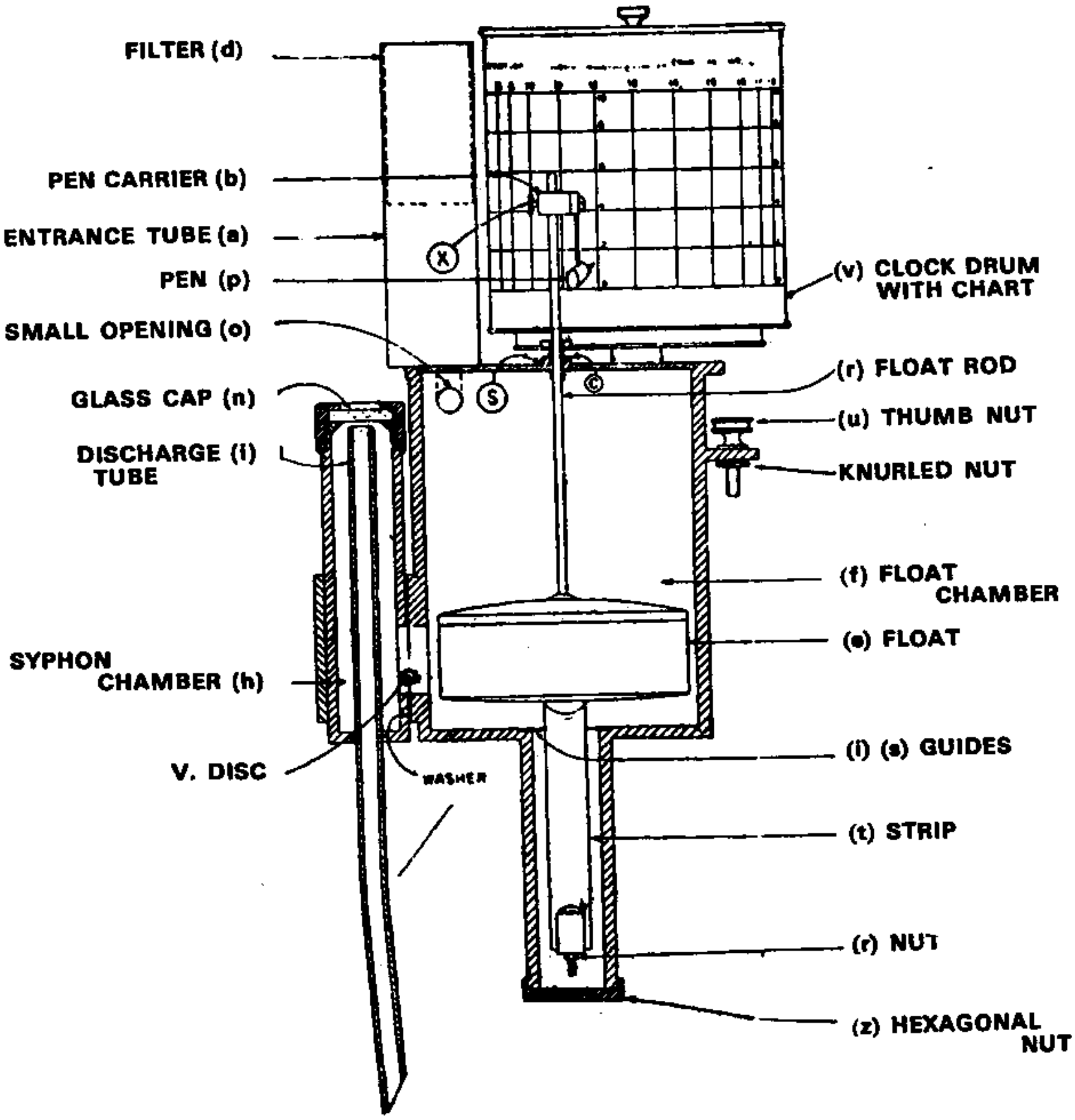

Fig.2 - Syphoning and Recording Mechanism of Float Type Recording Raingauge

the water collected in the receiver with sufficient speed. The upper end of the inside tube is correctly adjusted so as to start the syphon when the level of water has risen to a definite height and the flow continues till the water level falls to a certain depth.

The recording mechanism is mounted on a galvanised iron base with three screws which enable the receiver to be levelled. Rainwater is led into the float chamber (f) through the entrance tube (a). The float (e) is water tight. The float rod (r) at the top and the strip at the bottom move vertically in the guides(s) and (i) at the top and bottom of the chamber. The float rod has the pen carrier (b) and the pen (p) which records on a chart fixed on the revolving drum (v). The strip at the bottom of the float prevents it from turning about its axis. The upper guide is a threaded collar (c) which is screwed into the lid of the float chamber and can be raised or lowered and fixed in position by means of the set screws (s). The syphon chamber (h) is attached to the chamber with four screws and a hallite washer ensuring that the joint is water tight.

2.1.2 Tilting syphon rain recorder

The mechanism of the tilting syphon rain recorder used by Meteorological office, United Kingdom (1982) is shown in figure 3 . Rain water collected by the gauge passes from funnel through the filter G into a float chamber A and raises a plastic float B which is provided with a vertical rod to which the recording pen is attached. The chamber A is

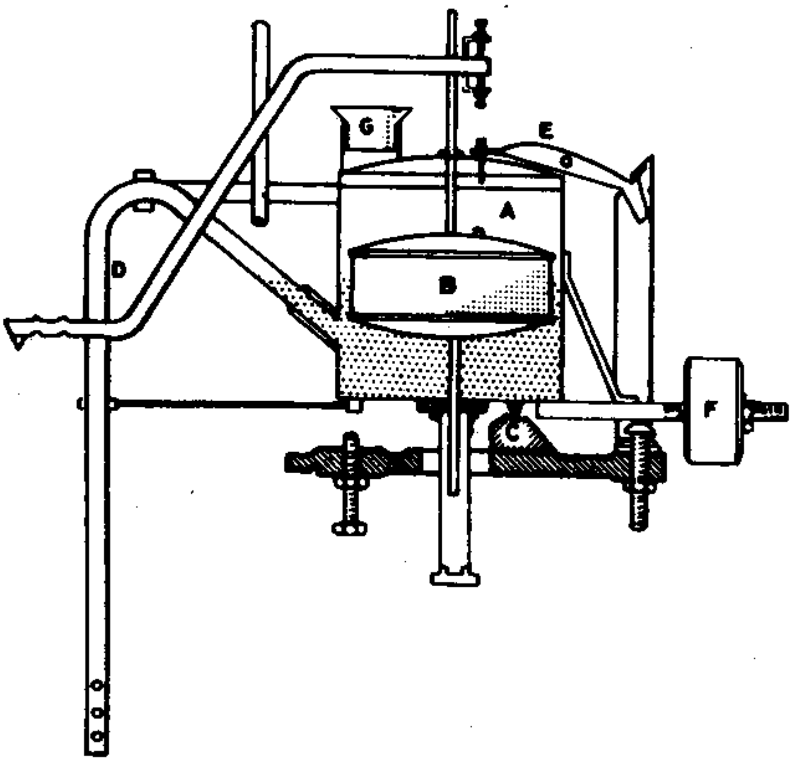

Fig.3 - Meteorological Office, U.K.Tilting Syphon Rain Recorder

mounted on knife edge C and when the float reaches a certain height it releases trip E and the weight of water overbalances the chamber sending a surge of water through the syphon tube D. This syphoning aetion would empty the float chamber and allows the pen to return to the zero of the chart. As the float chamber empties, the centre of gravity shifts to the left and under the action of the counter weight F, the system resets it self to the normal working position.

2.2 Tipping Bucket Raingauges

The tipping bucket raingauge is used by several organisations as a remote rainfall sensing device. It contains a stainless-steel bucket divided into two equal compartments and balanced in unstable equilibrium about a horizontal axis (figure 4). In its normal position, the bucket resets against one of two stops so that only one of the compartments would collect the water from the gauge funnel at any one time. Rain water is conducted from a collector into the upper most compartment and after a specified amount (usually 0.1 mm) has entered the compartment, the bucket overbalances, tips and empties bringing the second compartment under the collecting funnel. The bucket compartments are so shaped that the water is emptied from the lower one. The movement of the bucket as it tips over can be used to operate a relay contact to produce

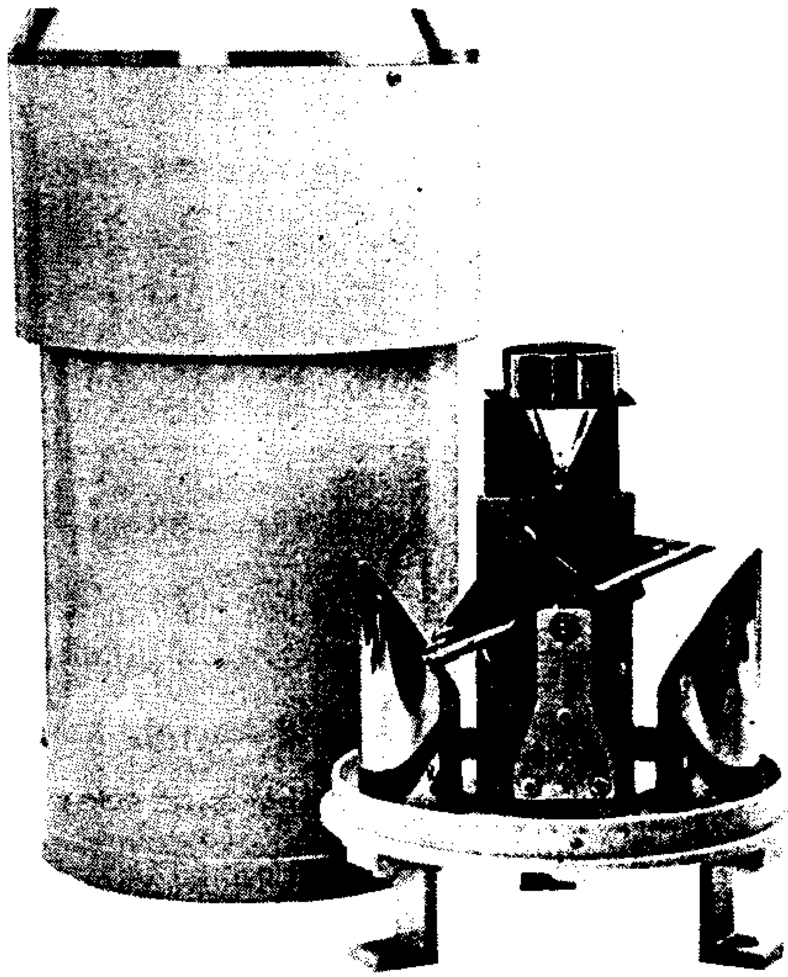

Fig.4 - Tipping Bucket Raingauge

a record consisting of discontinuous steps. The main advantage of this type of instrument is that it could be used for installaltion in remote inaccessible locations and recording at a distance.

2.2.1 Radio reporting raingauge of India Meteorological Dept.

For reporting rainfall from remote inaccessible areas automatically, the instruments division of the India Meteorological Department at Poona has developed an automatic radio reporting raingauge (Bhattacharya et al,1963). A tipping bucket raingauge was used to measure rainfall and operate a 'Morse Code' unit capable of composing rainfall amounts from 000 to 999 mm. The coding unit was read at predetermined intervals and rainfall information was broadcast over a UHF transmitter.

2.2.2 Magnetic tape event recorder of U.K. Meteorological Office

The United Kingdom Meteorological Office (1982 b) magnetic tape event recorder is designed for use in remote locations with the tipping bucket raingauge to provide a record of rainfall over periods of upto three months. The battery powered recorder consists of an incremental tape deck with records on magnetic tape contained in a large cassette. The recorder places a magnetic pulse on two of the four tracks each time the bucket tips and a similar pulse is written on the remaining tracks once per minute following a signal from the recorder's internal electronic clock. Although designed to run for longer periods, the cassette is usually changed at monthly intervals.

2.3 Weighing Type Raingauges

This type of raingauges are widely used for recording and telemetering precipitation data in the United States of America, Canada and some other countries. The weighing type gauges are designed to record the rate of rainfall as well as depth. The gauge consists of a receiver through which precipitation is funneled into a bucket or collector mounted on a weighing mechanism. Two types of weighing gauges are in common use:

i) The universal type weighing/recording rain and snow gauge, and

ii) The Fisher and Porter punched tape precipitation recorder.

2.3.1 Universal recording rain gauge

This weighing and recording precipitation gauge converts the weight of collected precipitation into the equivalent depth of accumulated water in conventional units of inches or millimeters. An 8 inch (200 mm) diameter, knife edge orifice collects all forms of precipitation. Rain travels through a funnel into the galvanised weighing bucket. When sub-freezing temperatures are expected, anti-freeze is added to the bucket.

The bucket rests on a platform (figure 5) mounted on the vertical link of a 4 bar linkage. This vertical link, or movement bracket is supported from below by a

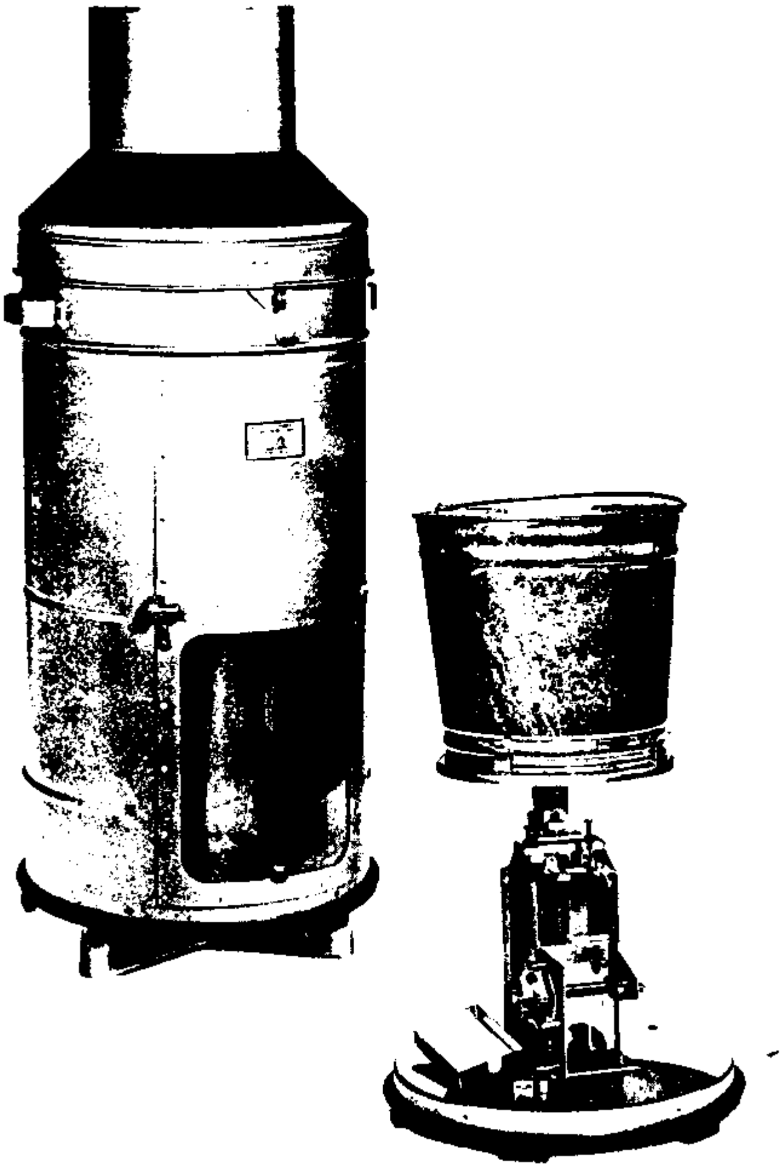

Fig.5 - Universal Weighing Type Recording Rain-gauge.
(Belfort Instruments Company)

precision extension spring assembly. Compression of the spring by the weight of collected precipitation is multiplied and modified for recording by a horizontal lever. This lever is connected to the pen arm through another link and lever assembly. A dual traverse system is used to record the accumulated precipitation on a rotating chart. Half of the gauge capacity is recorded by the upward traverse of the pen, and the other half is recorded by the downward traverse. The pen is damped by a dashpot. The chart drive is either a spring wound or battery operated clock. Each gauge is provided with a standard drum rotation depending on the capacity which is either

12 or 20 inches. The gauges have a resolution of upto 0.01 inch of precipitation depending on the model and manufacturer.

2.3.2 Fisher and Porter punched tape precipitation recorder

This recorder measures the depth of accumulated rain during a pre-selected time and records the total accumulation at the end of each time cycle. The record is in the form of a binary-decimal code punched on paper tape. The measuring device consists of a standard US Weather Bureau orifice and a weighing bucket mounted on the centre column of a weighing scale as shown in figure 6.

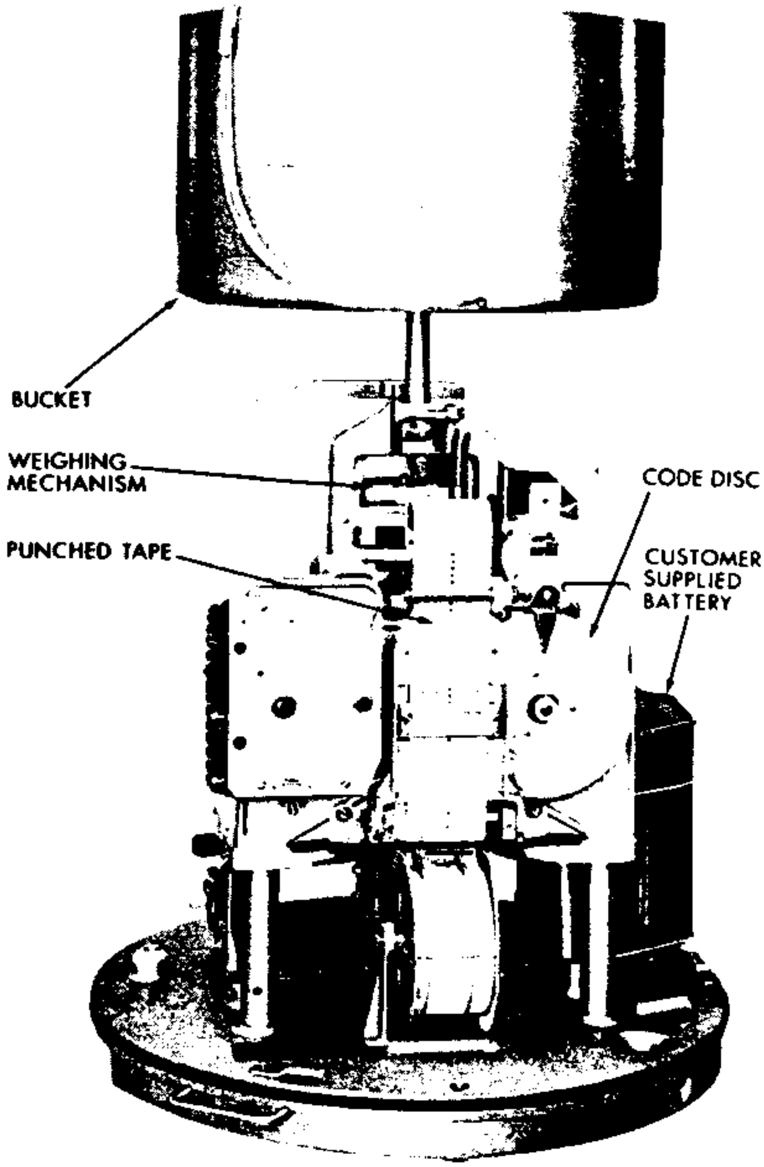

Fig.6 - Fisher & Porter Punched Tape Precipitation Recorder. (Belfort Instruments Company)

By means of an optional rain trace device, the time period in which the first trace of rain was received would be indicated on recording tape. This would occur even if the amount of precipitation collected is well below the minimum recordable increment of 0.1 inch.

The binary-decimal punched tape output of the recorder can be automatically converted by a translater to computer input from-punched cards, punched tape or magnetic tape. The instrument could be remotely located, and the data telemetered to a central point without interruption of the tape output.

2.3.3 United Kingdom Meteorological Office Gravimetric Gauge

The Meteorological Office, U.K.(1982) has developed a flush type of gauge called a gravimetric raingauge which collects the precipitation in a pan of diameter 1.21 m mounted on a weighing machine placed in a concrete lined pit in the ground. The rim of the pan is level with the surrounding ground. The whole pan is covered by a stainless steel mesh. The mesh and a circular area extending 2 m from the rain-gauge are covered with granite chips to form a homogeneous surface. The water can flow readily through the layer of granite chips into the pan. This construction of the collecting area of the gauge, together with its surroundings has been designed to minimise the effect of airflow over the instrument and the net effect of splashing. The weight of the pan and its contents is converted to give a millivolt analogue output which is registered on a recorder. Experiments have shown that this gauge would measure precipitation more accurately than other gauges used by the Meteorological Office, U.K.

2.4 Rate of Rainfall Recorder

Lewis and Watkins (1955) mentioned about two rate of rainfall recorders used in U,K,, one by the Meteorological office and the other by the Road Research Laboratory. While the Meteorological Office recorder was similar to the one described at 2.1.2 above, the Road Research Laboratory instrument combined the total rainfall recorder and rate of rainfall recorder into one.

2.4.1 Road Research Laboratory rate of rainfall recorder

This instrument comprises of two units, one of which records the rate of rainfall and the other the total rainfall. In the first unit a continuous weighing of the quantity of rainfall collected during a small period of time was made. This period of time was so small that almost an instant record of rate of rainfall was provided.

The record unit was similar to that of the standard Meteorological Office (UK) total rainfall recorder. The rain was collected in a funnel 30 inches (762 mm) in diamter. The recording unit comprised of a synchronous motor or a clock work motor to drive a strip chart with a total width of 3½ inches (88.9 mm) between the minimum and maximum readings. The instrument was warmed by a thermostat. It has a range of 0 to5 inches (0 - 127 mm) per hour on the rate of rainfall scale of 0.1 inch (2.54 mm) on the total rainfall scale.

2.4.2 Belfort Rate of rainfall transmitter

M/s Belfort Instrument Company, USA is marketing a rate of rainfall transmitter under Cat No.6069 A. This is a remote sensing instrument which translates instantaneous rate of rainfall data into a signal suitable for on-site recording or telemetering. In operation, rainfall is intercepted by a 12" diameter collector and directed to flow through a funnel and between the electrodes of a capacitor (figure 7).

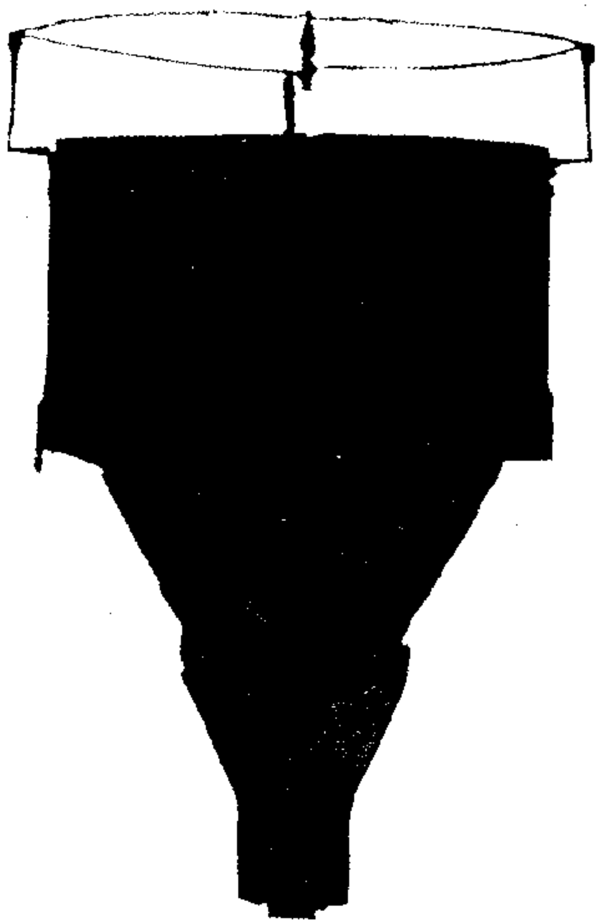

Fig 7 - Belfort Rate of Rainfall Transmitter

The capacitor forms one leg of an R F bridge. Changes in capacitance unbalance the bridge to a degree proportional to the amount of water present in the capacitor. The bridge output is fed into a difference amplifier the output of which is an analogue voltage or current directly proportional to rate of rainfall.

This output is suitable for on-site recording, or digital conversion or transmission by wire for short distance.

2.4.3 Rate of rainfall gauge

The model 6070-A raingauge marketed by Weathertronics, USA(1984-85) is an exceptionally sensitive instrument measuring rainfall in increments of only 0.0003 inch (0.0083 mm). This high sensitivity allows the determination of the rate of rainfall.

Precipitation is collected by an 8 inch diameter orifice (Fig. 8) which directs the water to the first of two cylinders. This cylinder is filled with water covered by a special kerosene reservoir fluid, and it acts as a constant head reservoir. A U-shaped tube rises from near the bottom of the reservoir to the top of the adjacent optical chamber. When both the reservoir and the tube are filled with water, any additional water input will cause water to flow from the precision orifice at the end of the tube. This orifice forms the water into uniform size droplets, each equivalent to 0.0003 inch (.0083 mm) of rainfall.

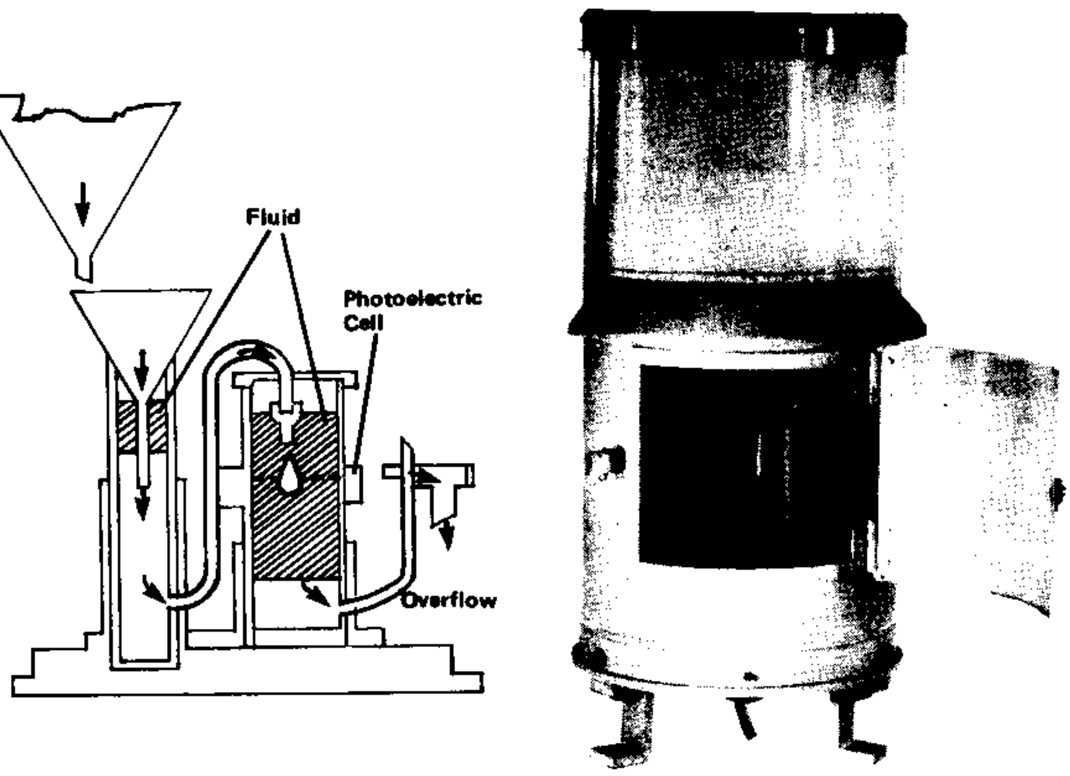

Fig. 8-Rate of Rainfall Recorder of Weathertronics

The droplets fall through the optical chamber, which is filled with reservoir fluid. A lightsource on one side of the chamber produces a narrow beam of light, illuminating a photo cell detector on the opposite side of the chamber. Each droplet interrupts the beam as it falls, and the photocell generates a pulse for each interruption. The droplets form a small pool at the bottom of the chamber and leave the gauge through an overflow pipe. The gauge can generate upto 200 pulses per minute, corresponding to a precipitation rate of 100 mm/hr. Rate of rainfall determinations are made by adding a time base to the output pulse train.

2.5 Latest Developments and Innovations

Measuring rain in the usual way, rainfall is recorded on a paper or displayed in a digital form. However, these raingauges are sluggish in action. The response time is delayed i.e. it has to rain for some time before they respond. The response is dependent on intensity. Light rain might some times go undetected and unregistered. In the Federal Republic of Germany a rain drop distometer has been developed which was in use since 1970.

2.5.1 Raindrop Distrometer

Kreuels and Breuer (1977) reported the development of a rain detector based on electrodynamic principle, which could measure the rain much more exactly with regard to intensity amount and duration.

The Electrodynamic raindrop distrometer developed in the FRG was a measuring equipment capable of registering the time structures of rain falling over a short time base of one minute without statistical errors. The distrometer registers each raindrop which contacts its transducer receiving area and analyses its size from the mass induced pulse in the same moment. Consequently no delay exists in the moment of rain onset and each slight rain event is registered as soon as its drops have a minimum diameter of 0.3 mm or more. The equipment was constructed in such a manner that the size of the 50 cm^2 transducer receiving area was chosen with regard to the feed back system and the sensitivity time control (STC). A minimum time base of 30 seconds was made an integral part of the optimally designed system.

Breuer (1977) described the further improvements made in this system for measurement of rainfall on a five second time base. During heavy rain, the drop numbers and sizes accumulate in such a manner that the STC could not eliminate some drops following too closely one after another. The receiving area was increased to attain 200 cm^2 by installing four transducer units on the corners of a square with a side distance of 2 meters as shown in figure 9.

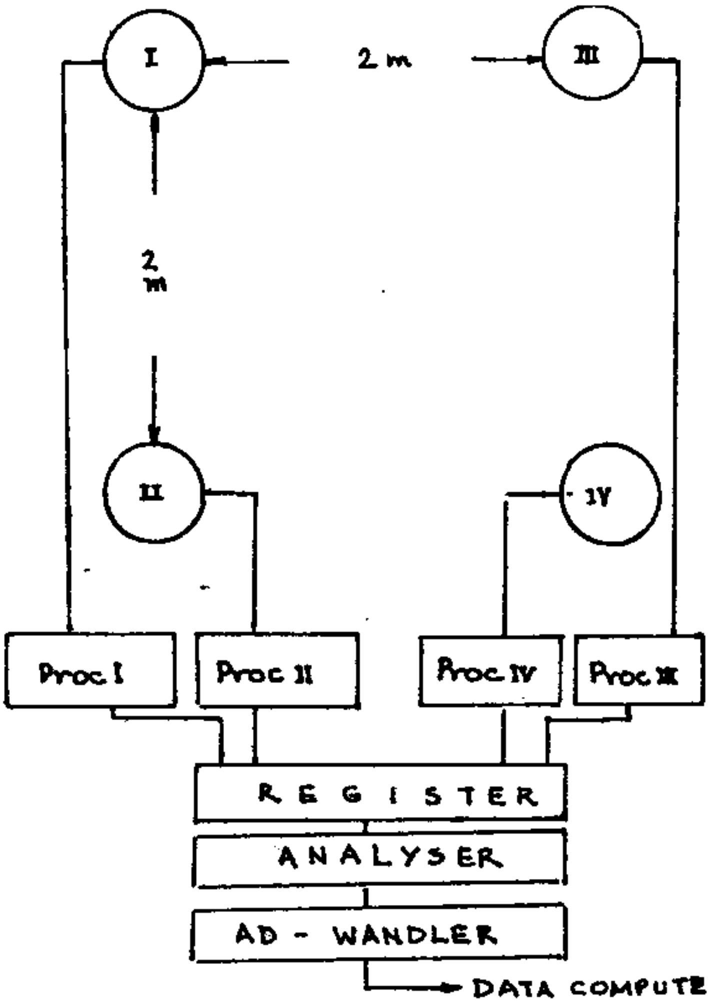

Fig 9 - Arrangement of Rain Drop Distrometer

(Reproduced from Bruer,1977)

2.5.2 Vibrating wire strain gauges

The Norwegian Geotechnical Institute (NGI) has recently developed and tested a new automatic precipitation gauge for rain and snow which can measure accumulated precipitation with a resolution better than 0.1 mm (Bakkehoi et al, 1985). The gauge is a direct weighing device and is based on the principle of vibrating wire strain gauges. When the gauge wire is caused to oscillate the natural frequency of vibration is dependent on the tension in the wire. The principle is shown in figure 10.

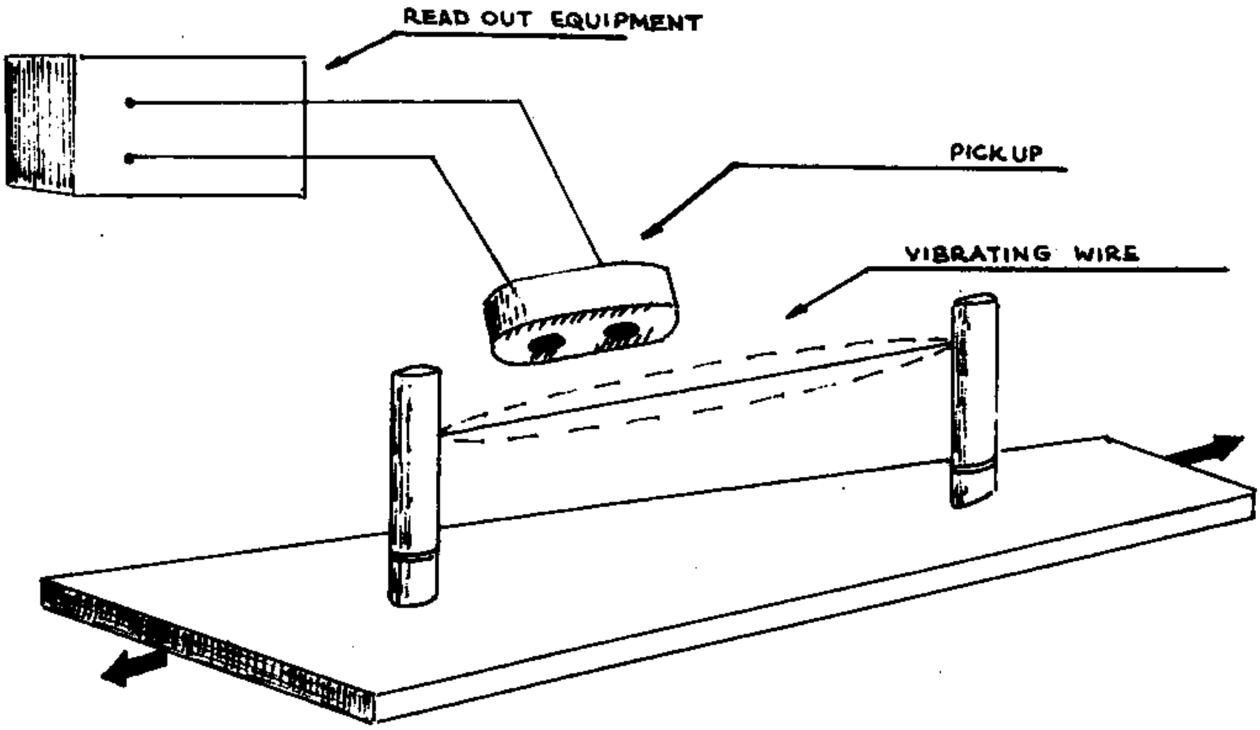

Fig.10 - Principle of the Vibrating Wire Gauge

(Reproduced from Bakkehoi et al,1985)

In the NGI prototype version, the precipitation container is suspended from three small steel wires, each of which is in effect the sensing element in a vibrating wire type strain gauge. When these gauge wires are set into vibration by an electromagnetic exciter, their resonant frequency of vibration is proportional to the squre of the tension in the wire. Thus change in the frequency signals is a measure of the change in tension in the wires and correspondingly a measure of the accumulative weight of precipitation in the container.

In the new Geonor version (figure 11) a standard 121 bucket is hung in three flexible supports. The gauge contains two electromagnets. One of the magnets is the exciter while the other is the pick up. When the wire is forced to oscillate,

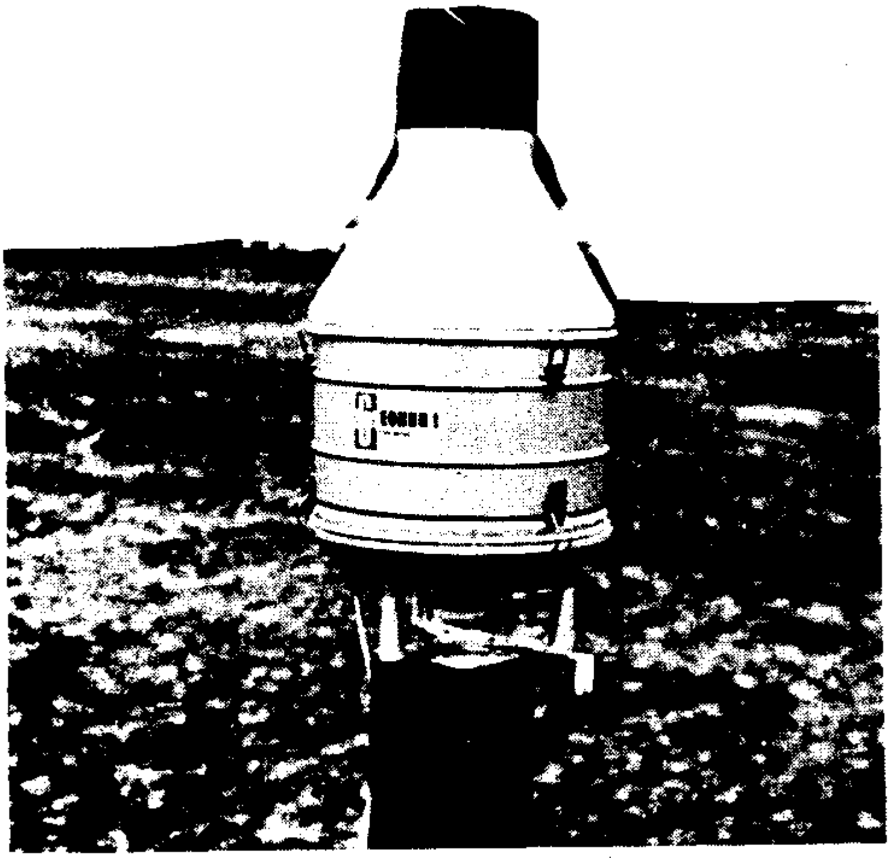

Fig.11- Geonor Version of Vibrating Wire Strain Recording Gauge
(Reproduced from Bakkehoi et al,1985)

an alternating current will be induced in the second electro-magnet which has the same frequency as the natural frequency of vibration of the gauge-wire. This signal when amplified, provides a measurable quantity which could be easily determined. The distance between the vibrating wire strain gauge and the frequency counter could be upto 1 km without any loss of information.

2.5.2 Computerised Rainfall Logger System

Casella London (1985) is marketing a computerised Rainfall Logger System. This system employs a tipping bucket rain gauge that generatesa pulse every time a predtermined small quantity of rainfall is received. The information generated in the form of pulses is stored in data cartridges by the data logger fitted alongside the tipping bucket (figure 12)

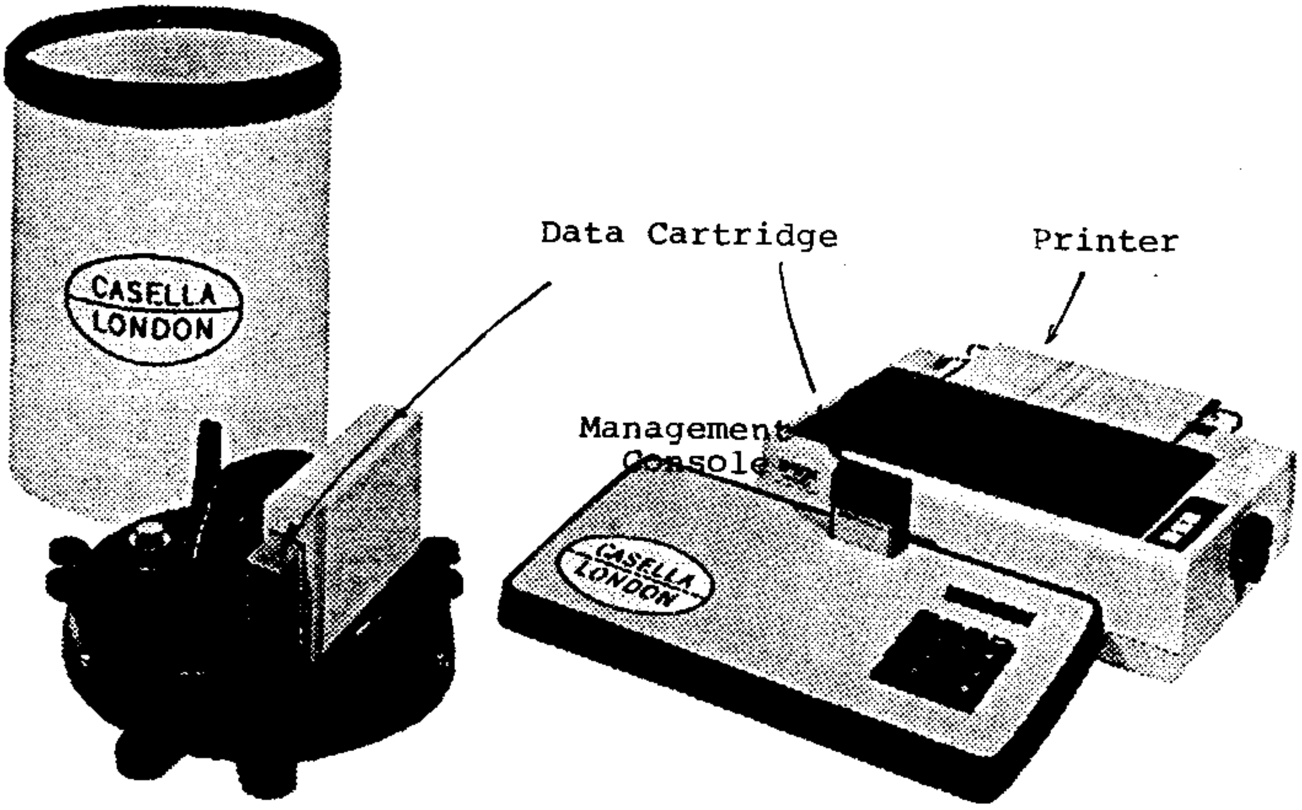

Fig.12 - Computerised Rainfall Logger System

Cortocy Casella, London

The data logger contains a microprocessor, a control circuitry address decoding and data compacting firm ware able to store data in the most economic manner. The cartridges are solid state storage media capable of storing a minimum of 2 k. They also contain a real time clock/calender . The cartridges when filled with data are transferred from the raingauge site, often remotely located, to a console unit at a central location. The cartridges are charged in a charger/tester which has a capacity to charge upto 8 cartridges at a given time and check for any faults.

The console unit interrogates the data cartridges received from various locations and communicates with the associated printer or to a main frame computer via a standard RS232C (V24) interface. The unit also contains printer control software which immediately generates charts and graphical representation of rainfall on compatible printers. A sample print out is given in figure 13.

2.5.3 Development of high resolution recorder in India

An electronic distant reading rainfall intensity recorder capable of measuring minute to minute values of the intensity of rain and recording them on a strip chart recorder has been designed and constructed at the Instruments Division of India Meteorologial Department, Poona (Venugopal and Radhakrishnan, 1976). The system is based on the same principle as that of Weathertronics rate of rainfall gauge & measures the intensity of rainfall by converting rain water into drops of

N.B. They are reduced for reproduction purposes

TIPPING BUCKET RAINFALL GAUGE HOURLY AND DAILY SUMMARY RECORD | STATION NO. : 0 | MONTH: September - October

Incremental rainfall in mm. during the hour beginning at:

Day	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	TOTAL
4				0.2																					0.2
5																									0.0
6																									0.0
7																									0.0
8																									0.0
9	0.2							5.4	0.2																5.8
10																									0.0
11																									0.0
12																									0.0
13																									0.0
14	0.6	1.4	1.4	0.6	0.6		3.0	7.0	1.6					0.2											16.4
15																									0.0
16																							0.2		0.2
17	1.8	2.6	7.0	0.6	0.8		0.8																		13.6
18			0.4	0.6																					1.0
19																					3.6	3.6	1.0	1.8	10.0
20	1.2	0.4	0.8	2.4	7.0	0.6	0.2												1.2	2.2	2.0	0.8	0.2		19.0
21					1.6																		0.4		2.0
22																						1.2	0.2		1.4
23				0.2	0.4		0.4	0.8	2.4	2.4			0.2												6.8
24				1.2		3.2	1.0	0.2													0.2				5.8
25																									0.0
26																									0.0
27																									0.0
28													1.6												1.6
29																			0.4	0.8	0.8	0.2	0.2		2.4
30																									0.0

Logger number 00018 Process date 17/10/84

Station name No. 0

Analysis start date 04/09 time : 09:07
finish date 05/10 time : 09:16 ???

Tipping bucket size - 0.2 mm.

TIPPING BUCKET RAINFALL DATA and ANALYSIS

	(—— RAINFALL LOG | | ——)	(— EVENT ANALYSIS —)		
DATE		mm.	mm.	mm.	day hh:mm
04/09	12:31	0.2	0.2	0.2	00:00
04/09 (Daily totals)		0.2			00:00
09/09	09:52	0.2	0.4	0.2	00:00
	16:32	0.4	0.8		
	16:33	1.4	2.2		
	16:34	1.0	3.2		
	16:35	1.0	4.2		
	16:36	0.2	4.4		
	16:37	0.2	4.6		
	16:38	0.2	4.8		

Logger number 00018 Process date 17/10/84

Station name No. 0

Analysis start date 04/09 time : 09:07
finish date 05/10 time : 09:16 ???

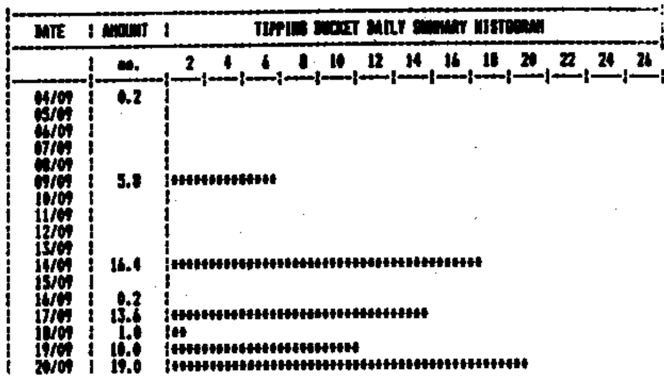

Fig.13 - Sample Print out from Management Console of Computerised Rainfall Logger System

SOURCE: CASELLA LONDON LIMITED

equal size and counts the number of drops by an optical cum electronic device as shown in figure 14. The number of counts during every minute interval which constitutes a measure of the intensity of rainfall are recorded on a conventional strip chart. For every 1 mm of rainfall an additional mark is printed on the chart to facilitate the measurement of rainfall in a given time period. The system has a resolution of 0.5 mm of rain per hour and was found to record accurately during the testing for several rainspells at Poona.

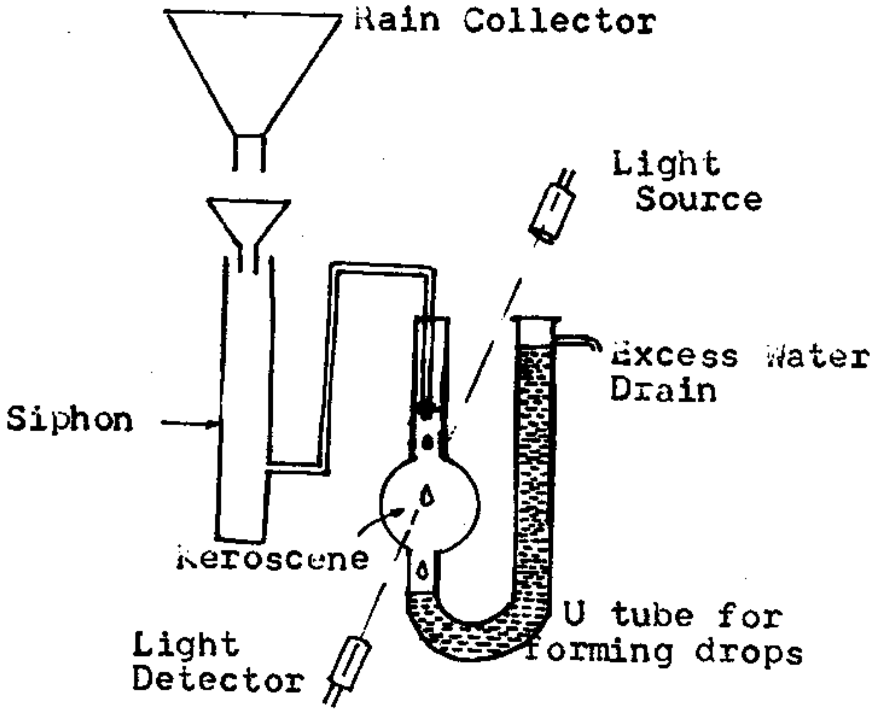

Fig. 14 - Bubble Formation and Detection Device
(Reproduced from Venugopal and Radhakrishnan 1976)

2.6 Comparative Study of Raingauges

WMO (1973) provides an annotated bibliography of precipitation measuring instruments. Very few studies of intercomparison of raingauges are available in literature. Most of these studies were comparisons carried out between measurements from a particular type of recording raingauge with measurements from standard (non-recording) raingauge used in the particular country (WMO, 1973). In many other studies, measurements from the recording raingauges have been used as ground truth for estimation of rainfall with radar.

Roberts and Yen (1952) made a comparative study of two recording raingauges, the Bendix-Friez. 775-B.S. recording gauge and the Stevens Type 06 recording gauges in Illinois, U.S.A. The mechanical lag was reported to be negligible and the accuracy of the gauges was within 2 per cent when 1 inch rainfall was measured. The authors concluded that the Stevens recorder was superior because of ease of calibration (no springs), while the Friez was easier to use because it was not bulky. They recommended a composite gauge using the accuracy of Stevens and compactness of a Friez.

Lewis and Watkins (1955) had made a comparative study of four raingauges in the United Kingdom. The gauges used were:

i) Standard Meteorological office total rainfall recorder

ii) Meteorological office rate of rainfall recorder

iii) Road Research Laboratory combined total rainfall and rate of rainfall recorder (orifice type)

iv) The channel type rate of rainfall recorder of Road Research Laboratory

While all the instruments in general recorded substantially the same amount of rainfall for any given storm in the 49 storms observed, the Road Research Laboratory total rainfall recorder appeared to have given the most reliable records. The least reliable records were obtained with the channel type rate of rainfall recorder.

Other conclusions from the study were:

a) Mean rates of rainfall over any selected period of time greater than about 6 minutes could be measured with a high order of accuracy for the records of all the four instruments.

b) The chart speed of the Meteorological Office total rainfall recorder was too slow for peak periods of short duration to be located accurately.

c) The Road Research Laboratory combined total and rate of rainfall recorder provides a clear picture of shape of rainfall curves which is very helpful in the analysis of storm records.

Renard and Osborn (1966) reported of experiments carried out on the Walnut Gulch experimental watershed near Tombstone, Arizona, USA. Precipitation intensities were measured at four locations in the watershed using 6 hour/rev and 24 hour/rev time scale recording raingauges. Maximum intensities determined from the 6 hour/rev gauge records were found to be significantly greater than intensities determined from the 24 hour gauge records for intervals upto 10 minutes.

Painter (1975) had reported the preliminary results from a gravimetric raingauge in the UK Meteorological Office Rainfall recorded by a gravimetric raingauge has been measured and compared with the daily amounts collected in a standard 5 inch MK_2 gauge with its rim 30 cm above the ground, in two types of gauges with their rims flush with the ground and in a 750 cm^2 gauge with its rim 45 cm above the ground and fitted with a tipping bucket mechanism.

The gravimetric raingauge has a 1.21 m diameter pan mounted on a weighing machine placed in a concrete pit in the ground so that the rim of the pan was level with surrounding ground. The catch ratio Q of the rainfall from tipping bucket to that from gravimetric gauge has been related to wind as

$$Q = 1.070 + 0.009\ U \mp 0.24 \qquad \text{.... (1)}$$

where U is the wind speed in metres per second at 1 metre height.

The prototype of automatic precipitation gauge based on the vibrating-wire strain gauge principle described in 2.5.2 has been installed at the Norwegian Meteorological Institute's testing field at Oslo from 4th October 1983 to 22 November 1983. From 2 December 1983 to 10 May 1984 the gauge was located at NGI's avalanche field station at Strynefjell 950 m a.s.l. Both the precipitation gauges were equipped with wind shields, the automatic had an Alter Shield while the manual had a Nipher Shield. Observations from the automatic precipitation gauge have been compared with the manual observations from standard Norwegian precipitation gauge by Bakkehoi et al (1985). The results are presented in figure 15.

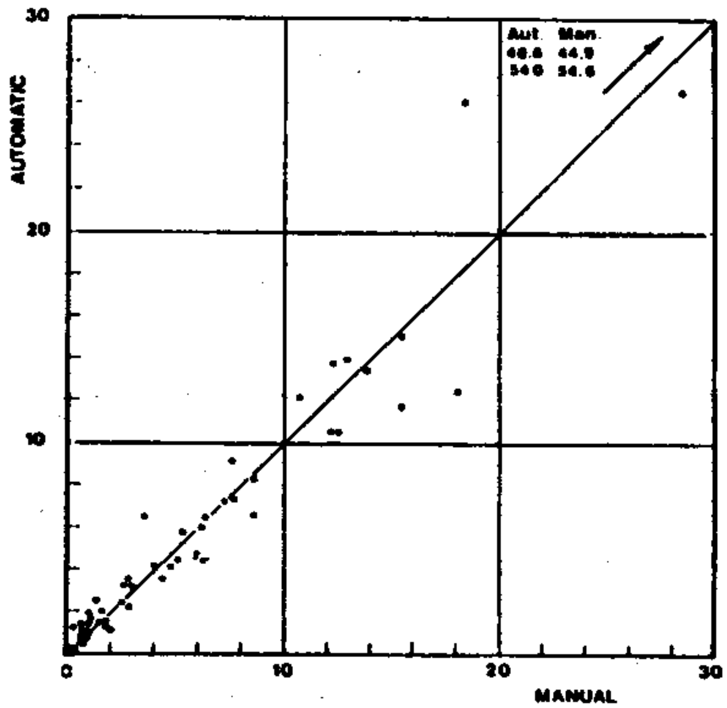

Fig.15 - Manual Observation Compared with Automatic Observations During the Winter 1983-84. (Reproduced from Bakkehoi et al,1985)

Further experiments using a revised version of the automatic precipitation gauge (figure 11) have been conducted at Oslo from 13th December 1984 to 5 March 1985 and the comparison is shown in figure 16. The precipitation observations

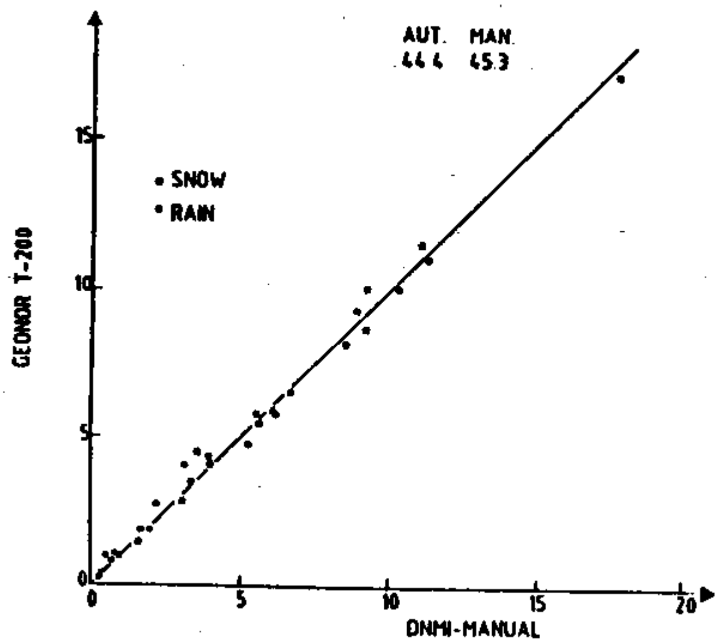

Fig.16 - Manual Observations Compared with Automatic Observations During the Winter 1984-85. (Reproduced from Bakkehoi et al,1985)

from both the gauges were well related, the difference being very small.

2.6.1 Comparative studies in India

No studies on comparison of the self-recording rain-gauges are reported in India. Kalyanasundaram (1966) had reported on a comparative study of raingauges in routine use in India with International reference Precipitation Gauge (IRPG) adopted as standard by WMO. The study was aimed to assess the reliability of rainfall measurements made in India. A snowdown precipitation gauge with Alter Shield has been adopted as the IRPG. The experiments were conducted at Poona, Bombay, New Delhi, Calcutta, Nagpur and Madras for a period of 16-28 months spread over three years 1963-65. The differences between the IRPG and IMD gauges which includes the natural syphon self-recording raingauge varied between 0.3 and 2.4 per cent. The differences between the gauges were statistically significant at Madras, Bombay and Calcutta.

3.0 REMARKS

Recording rain the common way, one can designate each event as 'rain' which finally appears on the recorder paper, as a digital readout or an analogue output. To characterize a rain event, besides the total amount of precipitation, the duration and intensity are most important. With the increasing need for rainfall intensities of detailed resolution, and precision, more rigorous and sensitive instruments capable of automatic data collection and transmission have been developed. In large countries of the size of India, it may, however, be not possible to equip the observatories with the advanced types of recording gauges in view of the cost limitations. Thus for operational and other uses in India, there is a need for identifying less expensive and reliable recording raingauges. The efficacy of the different types of raingauges described earlier is to be examined with this perspective.

3.1 Sensitivity

Unlike electronic sensors all the three types of recording gauges i.e. the float type, tipping bucket and weighing type are slow in their response. The reaction time depends on the intensity. The rain drop distrometer and other recording devices using optical rain drop sensing devices are more sensitive in this respect.

3.2 Catch Efficiency

Since most of the recording gauges use funnel type rain collectors, the catch efficiency of all such gauges with their collector rims at some height above the ground level would be less because of the eddy effects created by wind and the raingauge projecton.Compared to snow, in case of rainfall, loss of catch from the funnel is minimal though splashing of rain into the funnel is a common problem with gauges whose rims are close to ground level.

In the case of tipping bucket raingauge an additional problem is the loss of catch due to loss of rainwater in between tips though the latest instruments have a tipping time of 0.1 second only. The efficiency thus decreases with increasing intensity with measurement errors ranging from 1% for 25 mm/hr rainfall to about 6% for a 150 mm/hr rainfall intensity. (Belfort Instrument Company).

Where heating arrangement is used for preventing freezing of rain water some portion of the catch is lost due to evaporation.

3.3 Recording Mechanism

In the float type recording gauges, the rainfall is generally recorded on strip charts. In heavy rains because of high humidity, the chart becomes damp and the ink spreads rendering the record blurred. Also, the float on which the pen is mounted does not move freely and the clock work mechanism stops. The resolution of the chart is generally poor and does not facilitate accurate rainfall intensity determination especially during heavy rains when the records are placed very close. Also these are not amenable for use as automatic transmission gauges.

The tipping bucket is most suited for radio reporting and automated data transmission. The gauge is, however, susceptible to dubious records due to mechanical snags likely in the tipping operation.

The weighing gauge records the weight of the accumulated precipitation in a storage bucket. The problems of mechanical inefficiency are also associated with this type of gauges because of the spring mechanism. However, the deficiencies are minimal and can be further reduced by ' using a potentiometer or strain gauge (Houghton,1980). Bakkehoi et al (1985), however, felt that the potentiometer often induces too much electrical noise on the resistance values resulting in lack of accuracy in the precipitation intensity measured.

3.4 Use in Automation

Though the float type gauges are used in inaccessi ble areas with weekly or monthly strip charts, they are not suited for automatic data transmission. The tipping bucket or weighing type are generally used for the telemetering of data and in automatic weather stations. The tipping bucket is often used because it is simple and light in weight. The tipping bucket, however, needs to be heated in cold weather whereas the weighing type could be used in cold weather also without any heating.

3.5 Cost Effectivenss

The float type and tipping bucket type of rain-gauges are relatively inexpensive in comparison to the weighing type gauges. The weighing type gauges would be more expensive if they are provided with potentiometer or used with strain gauges.

3.6 Gauges for Use in India

In India more than 90 percent of the recording rain-guages are of the float and natural syphon recording gauges. Some of these are also used as part of the flood forecasting network in an operational system. For reasons discussed earlier it is evident that the float type is not suited for this purpose. For obtaining reliable observations of rain-fall intensitieis and using them in real time when information needs to be transmitted quickly the recording raingauges invariably are to be either the tipping bucket or the weighing type. However, due to cost prohibitiveness and financial constraints it may not feasible to equip all the observing sites with the weighing type. The weighing type may be used at India Meteorological Department observatories along with tipping bucket and float type gaugesand comparative studies carried over a range of storm rainfall intensities so that the results from these studies could be extended for use in the field with tipping bucket raingauges for operational purposes and float type raingauges for climatological purposes by applying necessary correction factor obtained from the comparative studies.

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