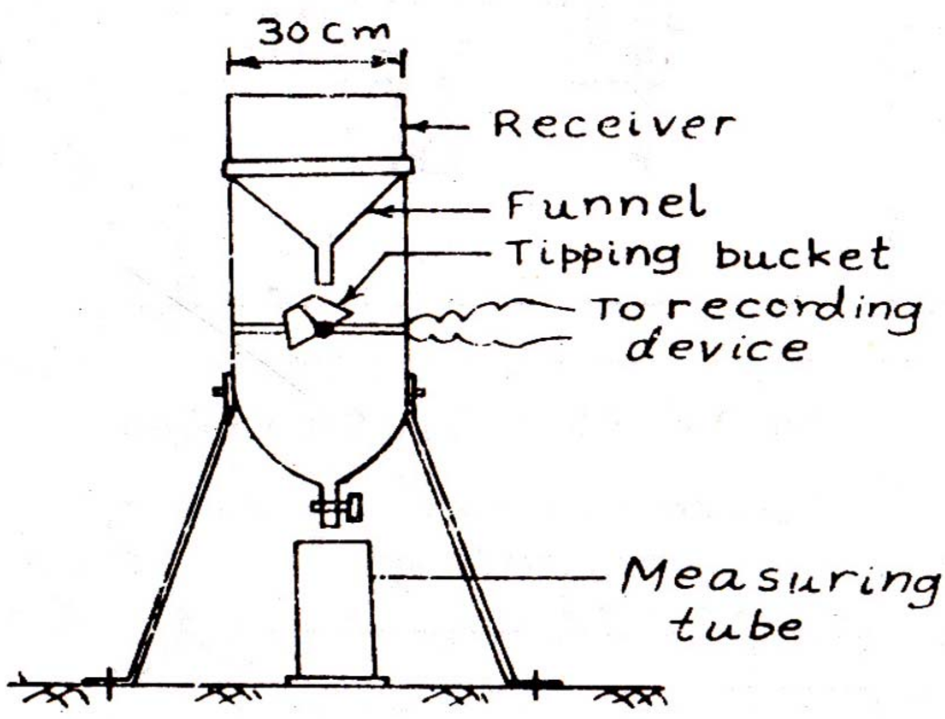
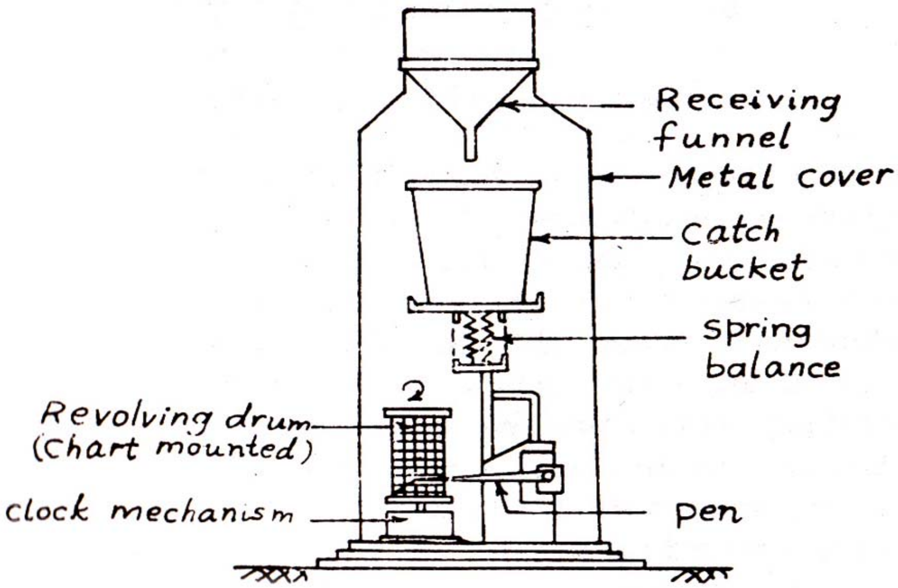
2) Recording rain gauge: It is often important to know, not only the total amount of precipitation, but also its intensity, or rate of fall, recording gauges give a continuous record of precipitation in the form of a pen trace on a clock-driven chart. These gauges may operate over extended periods without attention. This also called self-recording, automatic or integrating rain-gauge. There are many types of the recording rain-gauges:

a) Tipping- bucket gauge : A 12 – in funnel collects the rainfall and conducts it to a pair of small buckets . The buckets are so designed that, when 0.01 in. of rainfall collects in one bucket, it tips and empties the water into a storage can, at the same time bringing the other bucket under the funnel. The tipping of the bucket actuates an electrical circuit, which causes a pen to make a notch on a recorder chart. The water in the storage reservoir is drawn off and measured in a tube, as with a standard gauge. This type is adapted to remote recording .It cannot, however, be used for measuring snow without heating.



Tipping Bucket Gauge

b) Weighing – type recording gauges: are commonly used for field installations, because they record snow as well as rain. The precipitation passes through a collector into a bucket, which is supported on a platform of a spring or a lever balance. By means of linkages, the increasing weight of the bucket and its contents is recorded on a chart. The chart such shows a trace of accumulated amount s of precipitation.



Weighing Type Rain Gauge

c) Storage gauges: The greatest depths of snowfall generally occur in mountain regions difficult of access during winter .To obtain records from such regions ,storage gauges are used .

These gauges are the same in principle as the non-recording and weighing type gauges, but they are designed to hold much greater amounts of precipitation. Storage gauges are customarily charged with Calcium Chloride or other antifreeze solution to liquefy the snow and prevent the damage of the gauge (29.6% anhydrous Calcium Chloride brine, i.e. 37.5% commercial $CaCl_2$ of 78% purity)

Standpipe-type storage pre-cipitation gage equipped with Alter shield. (U.S. Weather Bureau.)

Errors of the precipitation measurement

The most important errors are at the following:

1) Mistakes in reading the scale of the gauge.
2) Instrument errors may be quite large and are cumulative.
3) The water displaced by the measuring stick increases the reading about 1percent.
4) Bends or dents in the collector rim may change its receiving area.
5) Each rain with a gauge initially dry is required to moisten the funnel and inside surfaces, this loss could easily 1in/y (25mm/y).
6) Another loss results from raindrop splash from the collector.
7) Fractional effects in the recording pen linkage can result in inaccurate indications of rainfall rates.
8) The most serious error is the deficiency of measurements due to wind speed.

The Precipitation–gauge Network

The following minimum densities of precipitation networks have been recommended for general hydrometeorological purposes:

a) For flat regions 600-900 km^2 per station.
b) For mountainous regions 100-250 km^2 per station.
c) For small mountainous islands 250 km^2 per station.
d) For arid and polar zones 1500-10000 km^2 per station.

Radar measurement of precipitation

Radar transmits a pulse of electromagnetic energy as a beam in a direction determined by a movable antenna. The radiated wave, which travels at the speed of light, is partially reflected by cloud or precipitation particles and returns to the radar which is called ***target signal***, the amount is termed ***returned power and*** it's display on the radarscope is called ***echo.***

The reflectivity of a group of hydrometeors depends on such factors:

1) Drop size distribution,
2) Number of particles per unit volume,

3) Physical state i.e. solid or liquid,

4) Shape of the individual elements, and

5) If asymmetrical, their aspect with respect to the radar.

*Generally speaking, the more intense the precipitation the greater the reflectivity.

The accuracy of radar measurement of precipitation varies with duration, area, storm type and **range (Distance between the radar and the target).

Satellite Estimates of Precipitation

It has been suggested that the observational data from meteorological satellites might be used for estimating rainfall amounts for 1 month or longer.

The chief problem is that satellites cannot measure rainfall directly, and solution requires evaluation of a rainfall coefficient on the basis of the amount and type of clouds and the probability of the approach as a whole depends on precipitation process over seas resembling those over land.

Satellite- borne microwave radiometers, which can be used to calculate the liquid-water content of clouds, may provide the ultimate answer to precipitation measurement from space.

Estimating Missing Precipitation Data

Many precipitation stations have short breaks in their records because of absence of the observer or because of instrumental failures. It is often necessary to estimate this missing record. In ***U.S Environmental Data Service*** procedure for estimating the missing data: precipitation amounts are estimated from observations at three stations as close to and as evenly spaced around the station with the missing record as possible.

If the normal annual precipitation at each of the index stations is within 10% of that for the station with the missing record, a simple arithmetic average of the precipitation at the index stations provides the estimated amount.

If the normal annual precipitation at any of the index stations differs from that at the station in question by more than 10%, it becomes necessary to supplement the missing record by one of the following methods:

1) Station-year method: In this method the records of two or more stations are combined into one long record, the missing record at a station in a particular year may be found by the ratio of averages.

For Example : In a certain year the total rainfall of a station A is 750mm and for the neighboring station B there is no record . But of the average annual rainfall (a.a.r) at A and B are 700mm and 800mm respectively , the missing year rainfall at B (say P_B) can be found by simple proportion as:

$(750/700) = (P_B /800)$

Thus $P_B = 857$ mm

2) The normal ratio method: In this method the amount at the index stations are weighed by the ratios of the normal-annual precipitation values. That is ,precipitation P_x at station X is

$$P_x = 1/3\ [\ (N_x/N_A)P_A + (N_x/N_B)\ P_B + (N_x/N_C)\ P_C\ ] \ldots\ldots(7)$$

Or it can be written as

$$P_x = 1/3\ [\ (P_A/N_A)\ N_x + (P_B /N_B)\ N_x + (P_C /N_C)\ N_x\ ] \ldots\ldots(7^*)$$

This method is illustrated by the following example:

Rain-gauge station X was inoperative for part of a month during which a storm occurred. The storm rainfall recorded in the three surrounding stations A,B and C were 8.5,6.7 and 9.0cm respectively .If the a.a.r of the stations are 75,84,70 and 90cm,respectively, estimate the storm rainfall at station X.

$$P_A/N_A = P_B /N_B = P_C /N_C = P_x /N_x$$

$$8.5/75 = 6.7/84 = 9.0/70 = P_x/90$$

$$P_x = 1/3\ [(8.5/75)\ 90 + (6.7/84)\ 90 + (9.0/70)\ 90]$$

$$= 9.65 \text{ cm}$$