Brief Descriptions of Meteorological Instruments at the Hong Kong Observatory Headquarters for Teachers' Reference

A **Station Anemometer**(氣象站風速表)**-** Winds are recorded by a cup-generator anemometer.

B, C **Electronic Pressure Gauge**(電子氣壓表) **& Mercury-in-glass Barometer**(玻璃水銀氣壓表) **-** An electronic pressure gauge is used to measure atmospheric pressure. A mercury-in-glass barometer is used as back-up.

D **Thermometer Screen Box**(溫度表百葉箱)**-** Back-up platinum resistance thermometers for measuring dry-bulb temperature (air temperature) and wet-bulb temperature are placed in the thermometer screen box.

E **Thermometer Shed**(溫度表棚)**-** In the thermometer shed, dry-bulb temperature (air temperature) and wet-bulb temperature are recorded by platinum resistance thermometers placed about 1.2 metres above ground level. It is an open shed with a roof made of two separate layers of matting. The open shed arrangement is more satisfactory than a Stevenson screen which is liable to overheat in hot calm weather. Maximum and minimum temperatures are recorded using the same platinum resistance thermometers.

A pair of conventional mercury-in-glass thermometers, a maximum thermometer and a minimum thermometer are similarly exposed in the open shed as back-up. Parameters such as relative humidity and dew-point temperature are derived from dry-bulb and wet-bulb temperatures measured by the pair of mercury-in-glass thermometres.

F **Nephoscope**(測雲器)**-** A nephoscope was used to estimate the upper-level wind based on cloud movement and has become obsolete for a long time.

G **Ordinary Raingauge (**普通雨量器**)(Official record)-** An ordinary 203-mm raingauge is used to measure hourly rainfall. It is composed of a collecting funnel, a bottle and a measuring cylinder.

H **Jardi Rate-of-rainfall Recorder**(查迪型降雨率測量器)**-** A Jardi rate-of-rainfall recorder keeps a continuous record of the rate-of-rainfall daily on a graph.

I **Soil Thermometers**(土壤溫度表)**-** Platinum resistance thermometers are used for measuring soil temperatures. Observations of the soil temperature are made twice daily at 07 hours and 19 hours at depths of 0.05, 0.1, 0.2, 0.5, 1.0, 1.5 and 3.0 metres. Mercury-in-glass thermometers are used as back-up.

J **Precipitation Alarm**(降雨探測器)**-** A precipitation alarm is used for alerting the weather observer and the forecaster the onset and cessation of rainfall. It consists of a sensor installed on the roof of Centenary Building and an alarm at the Central Forecasting Office. (The sensor located on the front lawn is an exhibit.)

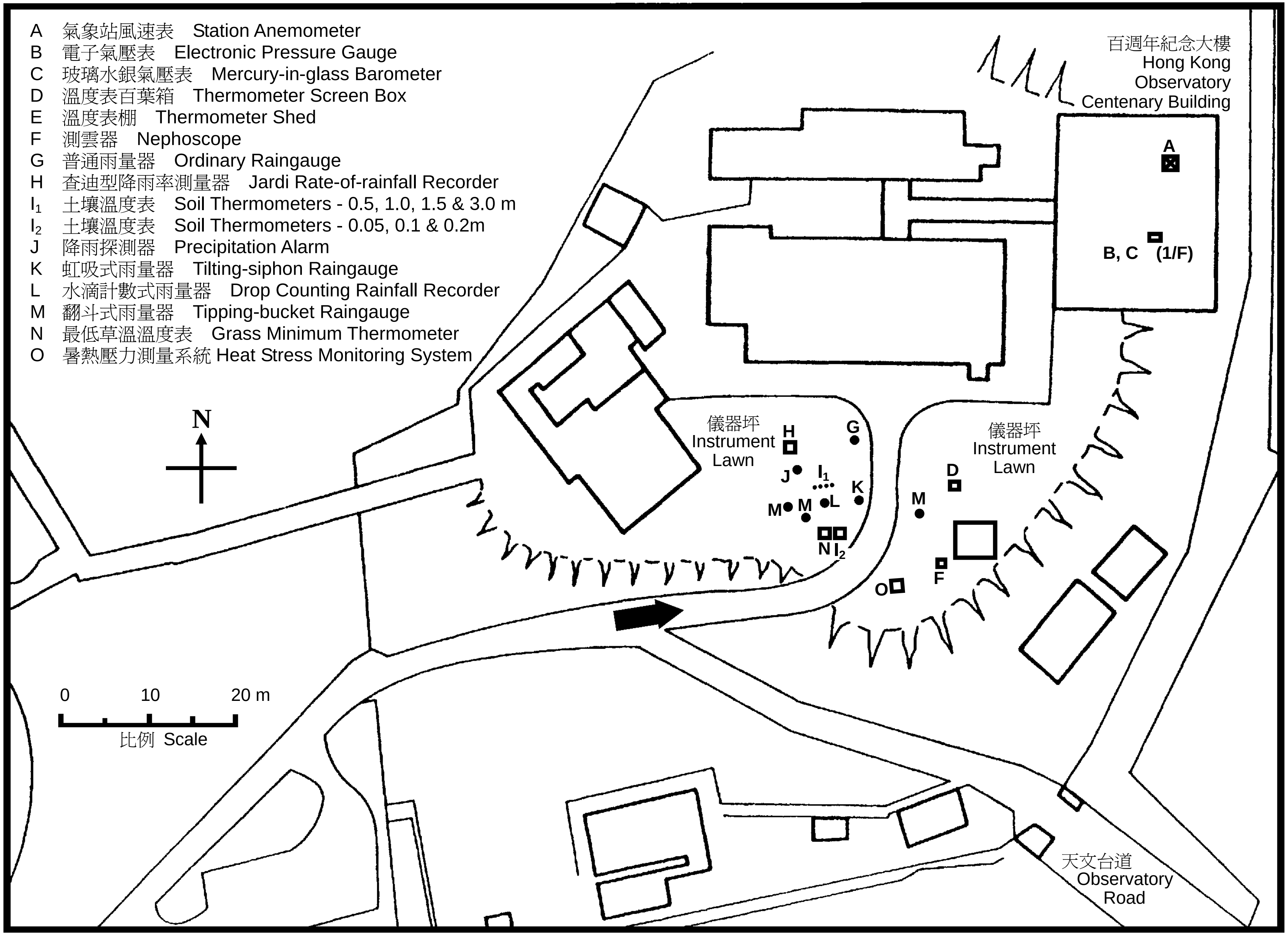
K **Tilting-siphon Rain-gauge**(虹吸式雨量器)**-** A tilting-siphon rain-gauge keeps a continuous record of the daily rainfall.

L **Drop Counting Rainfall Recorder**(水滴計數式雨量器)**-** A drop counting rainfall recorder is capable of measuring the rainfall rate and rainfall amount.

M **Tipping-bucket Rain-gauge**(翻斗式雨量器)**-** A tipping-bucket rain-gauge automatically measures rainfall in units of 0.5 mm and the records are passed to the Central Forecasting Office. Electrical signals from tipping-bucket rain-gauges at the outstations and the raingauge network of the Geotechnical Engineering Office (GEO) are also telemetered to the Hong Kong Observatory Headquarters, this greatly facilitates the operation of the rainstorm and landslip warnings as well as increases the volume of data for hydrometeorological analysis.

N **Grass Minimum Thermometer**(最低草溫溫度表)- A platinum resistance thermometer is used for measuring grass minimum temperature. The temperature is read daily at 08 hours, representing the overnight grass minimum temperature since 19 hours on the previous day.

O Heat Stress Monitoring System (暑熱壓力測量系統)- This weather observing system is specially designed by the Hong Kong Observatory for the 2008 Olympic and Paralympic Equestrian Events to measure the heat stress index (WBGT index). Different weights are used for the above three temperatures in the calculation of the heat stress index (WBGT index), with the natural wet bulb temperature contributes the most.



天文台總部氣象儀器位置圖

Location of Meteorological Instruments in the Hong Kong Observatory Headquarters

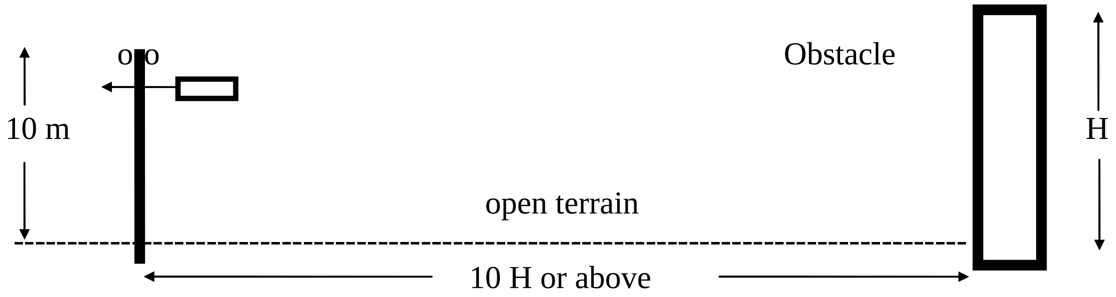
10/2009

MEASUREMENT OF WIND DIRECTION AND SPEED

Exposure of Wind Sensors

The wind speed near the earth's surface varies rapidly with height and is greatly affected by the irregularities of nearby obstacles such as trees or buildings. The standard exposure of surface wind sensors is 10 m above the ground of level open terrain.

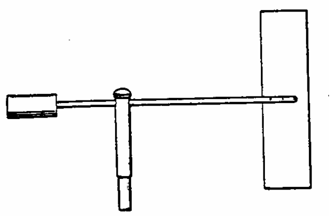
Open terrain is defined as an area where the distance between the instrument and any obstacle (obstruction) is at least 10 times the height of the obstacle.



The adoption of standard exposure is especially important at airports. Where a standard exposure is not possible, the surface wind instrument should be installed at such a height that its indications are reasonably unaffected by local obstruction. It should also represent, as far as possible, what the wind at a height of 10 m would be, if there were no obstructions in the vicinity.

Measurement of Wind Direction

Wind direction is measured by a sensitive and accurately balanced wind vane. It is recorded on chart by means of mechanical, electrical or electronics devices. Most wind vanes do not respond to change in direction when the winds are light. In this case, or when the instrument is not serviceable, wind direction should be estimated.

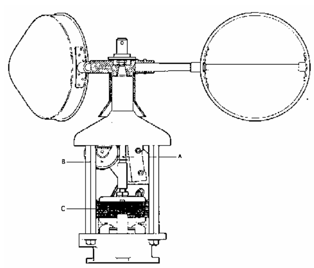


Measurement of Wind Speed

Anemometer is the device for measuring wind speed.

Cup Anemometers

They normally consist of 3 cups mounted symmetrically at right angles to a vertical axis. The force exerted by the wind is greater on the inside surface of the cup than on the outside so the cups rotate. The rate of rotation is approximately equal to wind speed, provided that the wind is steady.



MEASURING SURFACE AIR TEMPERATURE

In meteorological practice, it refers to temperature of the free air (2 to 3 m/s) at a height between 1.25 to 2 m above ground level. If forced ventilation is used for psychrometers, an air flow of 2.5 to 10 m/s should be allowed to past the thermometer bulbs. As far as possible, the soil cover beneath the instrument should be short grass, or at a place where grass does not grow, the natural earth surface of the district. This temperature is the most representative condition experienced by human being living on the earth surface.

To achieve the above standard the temperature sensors should be housed properly as follows:

a) protect the sensor from direct and indirect radiation from the sun, sky, earth and any other surrounding objects,
b) shield the sensor from liquid or solid precipitation, wind blown objects or falling debris,
c) protect the sensor from intrusion by animals or human beings,
d) damp down strong in-rush of air but at the same time provide adequate ventilation for free passage of air.

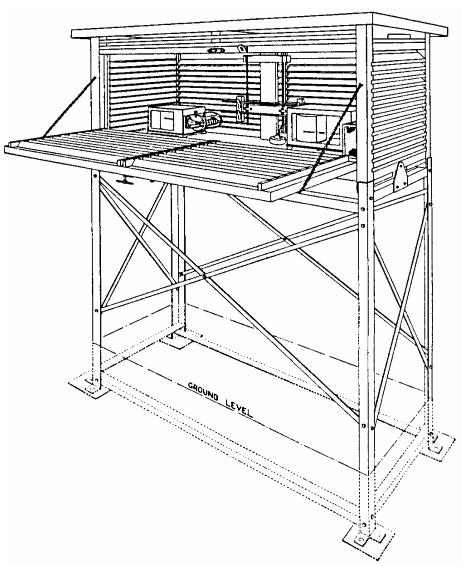
Temperatures not measured in this way can differ considerably. It has been recorded by the Hong Kong Observatory that the temperature of a Tarmac block (which is representative of the road surface) placed on the lawn reached 67°C while that of the air was only around 32°C. By contrast, it can be much lower than the air temperature on cold frosty nights.

Housing/Mounting for Temperature Sensors

To satisfy the exposure requirements, the following types of housings are designed for common use:

a) **Mat Shed**
This is specially designed to allow good ventilation in tropical regions so that unrealistically high temperatures would not be registered on calm sunny hot days.

b) **Louvred thermometer screen box**
This is the most commonly used type of thermometer housing. The standard screen box uses louvres in the sides and doors, a double roof with an air space between the inner and outer components and a floor consisting three partially overlapping boards separated by an air space. It is painted in white to reflect as much solar radiation as possible.



The screen box is mounted on a stand so that the temperature sensors are at 1.25 m above the ground which should be covered by short grass.

The orientation of the screen is such that it would minimize the sunrays shining onto the sensors when the door is opened for taking readings. In Hong Kong, it is installed with the door facing north.

Thermometers in the Screen Box or Shed

Thermometers in the screen or shed include a dry-bulb, a wet-bulb, a maximum and a minimum thermometer. In some stations, a thermograph, a hygrograph or a thermohygrograph is also kept.

a) **Dry-bulb** --- This is an ordinary thermometer for acquiring the air temperature.

b) **Wet-bulb** --- This is an ordinary thermometer whose bulb is covered by a piece of muslin which is kept wet with distilled water from a container through the muslin by capillary action.

   Air can always contain some moisture and is able to take up more until saturation. When water evaporates into air, it takes away heat energy (latent heat of evaporation) from the bulb thus creating a cooling effect on the sensor. By measuring the wet-bulb depression, we can calculate the dew-point temperature and the relative humidity.

c) **Maximum thermometer** --- The most common maximum thermometer is the mercury-in-glass thermometer with a constriction in the bore below the lowest graduation. When temperature rises, the expansion force pushes the mercury through the constriction. When temperature falls after reaching the maximum value, mercury in the bulb contracts but there is no force to push the mercury thread beyond the constriction back to the bulb. As a result, the mercury thread breaks at the constriction leaving the thread indicating the maximum temperature reached since the last reset. The mercury thread in the stem side will also contract, but error so caused will be negligible because of the small amount.

   In practice, the maximum thermometer rests bulb end downwards at an angle of about 2° to the horizontal to prevent the mercury from drawing away from the constriction.

d) **Minimum thermometer** --- The alcohol-in-glass thermometer is usually used for measuring minimum temperature. Within the alcohol column, there is a very light, dumb-bell shaped dark glass index. The index may be moved freely in the alcohol, but does not emerge from the liquid due to surface tension.

   In practice, this thermometer is also supported with the bulb end downwards at about 2° to the horizontal. When temperature falls, the alcohol contracts; the index will be dragged towards the bulb by the surface of the alcohol meniscus. The slight sloping of the thermometer stem will assist this movement slightly by gravity. When temperature rises again, the alcohol will flow over the index which remains stationary. Consequently, the end of the index nearest to the meniscus indicates the lowest temperature reached since the last reset.

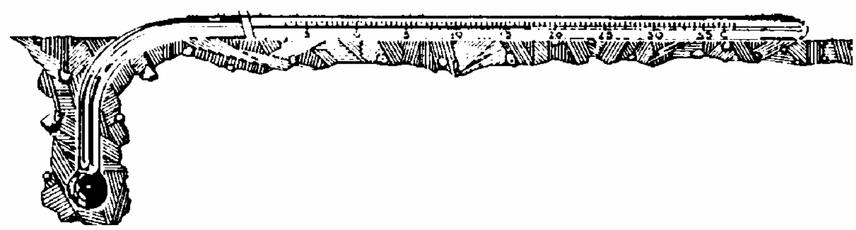
In the Hong Kong Observatory, platinum resistance thermometers are used for measuring both the dry-bulb and the wet-bulb readings in addition to the liquid-in-glass thermometers. The readings are processed by a microprocessor to give the dew point, relative humidity, maximum and minimum temperatures.

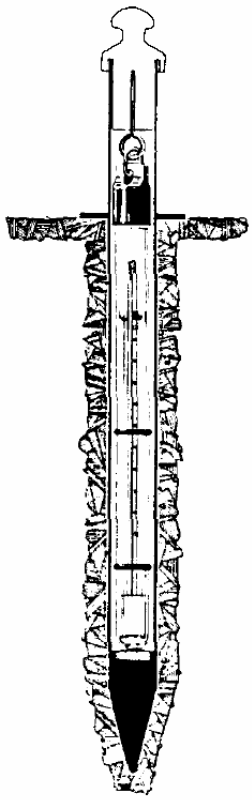
Measuring Overnight Grass Minimum Temperature

The thermometer should be freely exposed to the sky and mounted on supports so that it is inclined at an angle of about 2° from the horizontal with bulb lower than the stem, and placed at 25 mm to 50 mm above the ground and in contact with the tips of the grass.

In the Hong Kong Observatory Headquarters, the grass overnight minimum temperature is measured by the platinum resistance thermometers sensors and relayed to the Hong Kong Observatory's main computer.

Measuring Soil Temperature





At depths greater than 20 cm, mercury-in-glass thermometers, mounted in glass tube with their bulbs embedded in wax or metallic paint are recommended. The thermometer-tube assemblies are suspended in thin-walled metal tubes sunk into the ground to the required depth. The wax serves as a means to provide a large time lag in response to temperature changes, so as to enable the thermometers to be removed from the outer tubes and read before their temperature has had the time to change appreciably from the soil temperature. The site for measuring soil temperature should be a level plot of bare ground, about 75 cm square, typical of the surrounding soil.

In the Hong Kong Observatory Headquarters, these temperatures are measured by the platinum resistance thermometers sensors and relayed to the Hong Kong Observatory's main computer.

MEASUREMENT OF PRECIPITATION

Exposure of Rain-gauge

It is assumed that the amount of rain water collected per unit area of the aperture of the rain-gauge is the same as the amount per unit area on the surrounding ground. However, the measurable amount of rain collected is generally less than the actual rainfall at the site. This effect arises from various causes such as evaporation, adhesion of rain to the rain-gauge and "out-splash". But by far, the exposure of the rain-gauge to the wind generally causes a larger error than all the other causes combined. The effects of the wind are twofold:

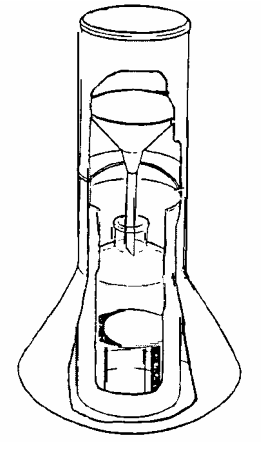
a) Reduces the amount of rain collected;
b) Eddies in the airflow may also reduce the precipitation in one place and increase it in another. The effect of the eddies would be particularly marked if they are blowing upslope locally around the gauges and reducing the vertical velocity of the raindrops.

Installation of Rain-gauges

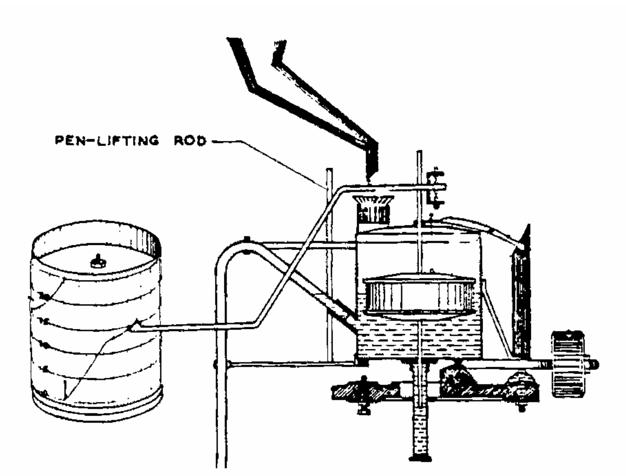
1. The gauge should be set in the ground firmly so that it will not be blown over or tilted by the strongest winds.
2. The surrounding surface should be of short grass, if this is not possible the gauge may be set up in gravel.
3. A hard smooth surface such as concrete should be avoided because of the increased risk of splashing which may be carried into the gauge by eddies.
4. The soil should be pressed firmly around the outer case.
5. The rim of the rain-gauge should be 30 cm above the surrounding ground and set horizontally.

Ordinary Rain-gauge

- It consists essentially of a collector, with a knife-edged circular rim and a funnel leading into a receiver.
- The outer case supporting the collecting funnel is splayed-base shaped to increase stability.
- The outer case is partially sunk into the ground.
- The receiver consists of a plastic bottle into which the funnel tube dips and a cylindrical metal collecting can fitted with a wire handle.
- The rain water is collected in the plastic bottle or, when exceptionally heavy, it may flow into the collecting can.



Tilting Siphon Rain-gauge



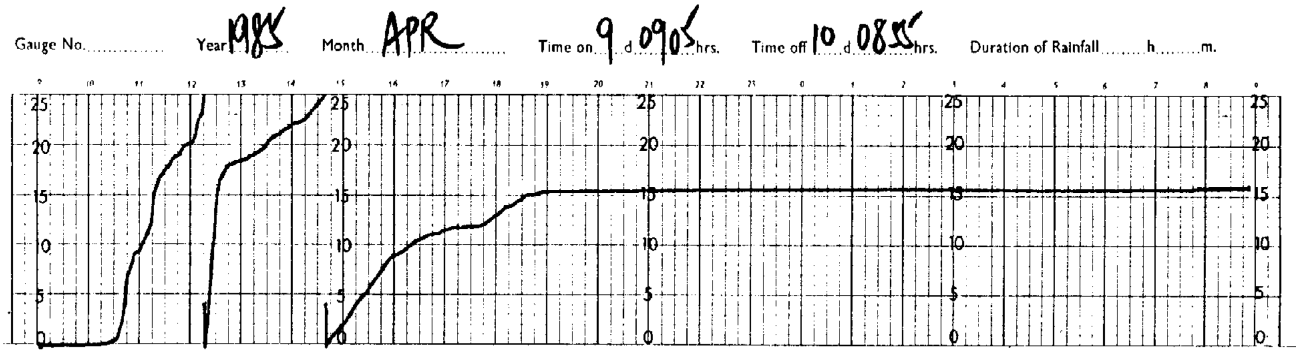
Rain is collected in a funnel and passes through a filter gauze into a float chamber. The resulting movements of the float are transmitted to a pen bearing on a slow rotating chart drum (which turns one round in 24 hours). As rain continues, the trace gradually rises up the chart. When the float reaches the top of the chamber, it trips a retaining catch, and the weight of the water causes the whole chamber, which is supported at one side on a knife edge, to overbalance. This sends a surge of water through a siphon tube leading from the base of the float chamber. The siphoning action continues until the chamber is empty. The counterweight then swings the empty chamber back to its original position. During siphoning, a fixed rod holds the pen away from the chart; after siphoning, the pen returns to start a new trace on the base line.

The rainfall amount during the siphoning process is not recorded by the instrument. The error is proportional to the rate of rainfall and the time of siphoning which takes about 15 seconds. To overcome such drawbacks, new tilting siphon gauges are designed with:

a) two parallel siphon tubes to speed up the siphoning to about 8 seconds, and

b) a rain-trap consisting of a nearly semi-circular bowl attached to the filter housing to reduce the loss of rain during the siphoning process.

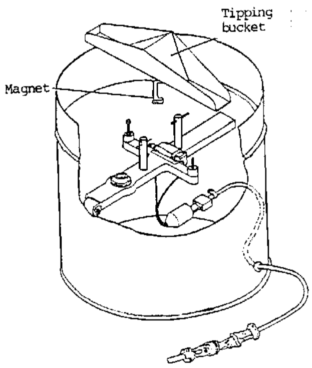
   During siphoning any rain entering the funnel collects in the rain-trap. When the system resumes an upright position, water in the rain-trap passes through a drain into the float chamber.



Ogawa Drop-Counting Rainfall Recorder

In this type of recorder, the rainwater collected by the funnel is led into a closed chamber which is already filled with water. The overflow rain drops are drained away through a tiny aperture. The number of drops passing through is counted by an infra-red opto-coupler against a time base.

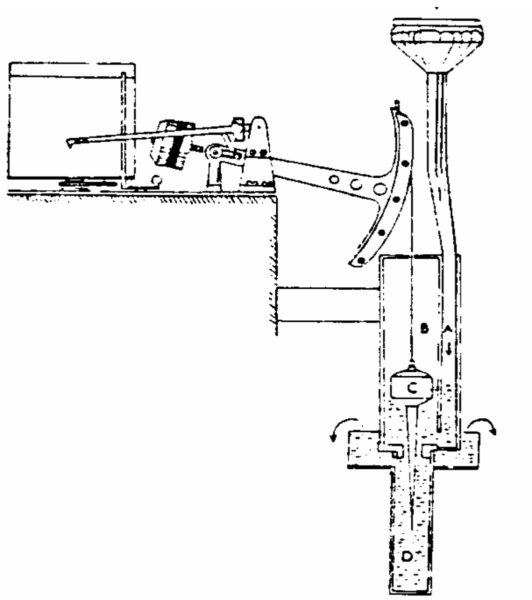
Tipping Bucket Rain-gauge



It consists of a light bucket, divided into two equal compartments and pivoted at its centre like a seesaw. Rain is led into one compartment and when a predetermined amount (0.1, 0.2 or 0.5 mm) is received, the bucket overbalances and tilts, discharging the collected water and allowing the other compartment to begin filling. The alternate filling and discharging continue so long as rain is falling, and, at each tilt, a magnet attached to a spindle beneath the bucket momentarily actuates a reed relay (switch) causing a contact closure which can be monitored through wires over a long distance. The advantage of this instrument is that it can be arranged for recording over a long distance thus enabling real time monitoring the rainfall amount. However, its disadvantages are :

a) The bucket takes a small but definite time to tip over. During the first half of its motion the rain is still being led into the compartment already containing the calculated amount of rainfall. This error would be appreciable in heavy rainfall.
b) Evaporation loss, especially in hot regions.
c) The time of beginning and ending of very light rain or drizzle cannot be measured. This difficulty arises from the fact that the tipping action can only be recorded when the pre-determined amount of rain water is collected.
d) It does not keep a strictly continuous record of rainfall, but instead records rainfall in discrete increments.
e) Power source required. The tipping of the bucket has to be translated to recordable signals by electrical means. This makes it unsuitable for use in areas where power supply is a problem.

Jardi Rate-of-rainfall Recorder



This type of recorder is an example of the float gauge for recording rainfall intensity. The rain water from a large collecting funnel falls through tube A into the float chamber B. The float C has an appendix of diminishing cross-section extending through an aperture into a lower chamber D. The water can flow into D only through the annular space between the bottom of B and the tail of the float. The higher the float rises, the larger this space will be, and the float will continue to rise until as much water flows out of B as enters at A. The motion of the float is transmitted to a pen by a system of levers. The tail of the float is given a shape that will produce a linear relationship between the rate of the flow and the height of the float.