Chapter 6　Measurement of Precipitation

CONTENTS

Chapter 6 Measurement of Precipitation

6.1 Definitions and Units

Precipitation is defined as liquid or solid condensation of water vapor falling from clouds or deposited from air onto the ground. Precipitation in the form of ice flakes, such as snow, is called solid precipitation, and that in the form of water drops is sometimes called liquid precipitation for distinction.

Precipitation is measured as the amount of water that reaches horizontal ground or the horizontal ground projection plane of the earth's surface, and is expressed as a vertical depth of water or the water equivalent of solid precipitation. The unit of precipitation in Japan is the millimeter.

6.2 Observation Instruments

Instruments for measuring precipitation include rain gauges and snow gauges, and various types are manufactured according to the purpose at hand. Rain gauges are discussed in this chapter.

Rain gauges are classified into recording and non-recording types. The latter include cylindrical and ordinary rain gauges, and measurement of precipitation with these types is performed manually by the observer. Some recording types such as siphon rain gauges have a built-in recorder, and the observer must physically visit the observation site to obtain data. Other types such as tipping bucket rain gauges have a recorder attached to them, and remote readings can be taken by setting a recorder at a site distant from the gauge itself to enable automatic observation.

As rain gauges measure the volume or weight of precipitation collected in a vessel with a fixed orifice diameter, the size of the orifice needs to be standardized. CIMO provides that its area should be 200 cm^2 or more, and types with an orifice area of 200 to 500 cm^2 are widely used. In Japan, the rain gauge orifice diameter is set as 20 cm (314 cm^2).

The receptacle (Figure 6.5) has a rim at the top to keep the receiving area constant and a funnel to collect rainwater. The inside of the rim is vertical, and its outside has a sharp angle at the top to prevent external rainwater from splashing into the vessel.

6.2.1 Cylindrical Rain Gauges and Ordinary Rain Gauges

These instruments work according to a simple principle of measurement, and also have a straightforward structure. They offer the advantage of having a low rate of problem occurrence.

6.2.1.1 Cylindrical Rain Gauges (Figures 6.1 and 6.2)

As this type of rain gauge can also be used to measure snow, it is alternatively known as a cylindrical rain/snow gauge. It consists of a cylindrical vessel with a uniform diameter from top to bottom and an orifice at the top. It does not have a funnel.

Rainwater enters through the orifice and accumulates in the cylindrical vessel, which is weighed at regular intervals with a precipitation scale. As the amount of precipitation is determined by subtracting the vessel weight from the total weight, the dry vessel is weighed before observation.

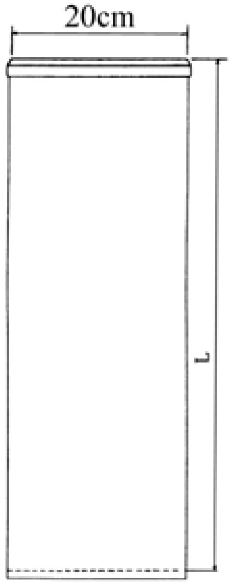


Figure 6.1 Cylindrical rain gauge (L = 100 cm, 60 cm or 30 cm)

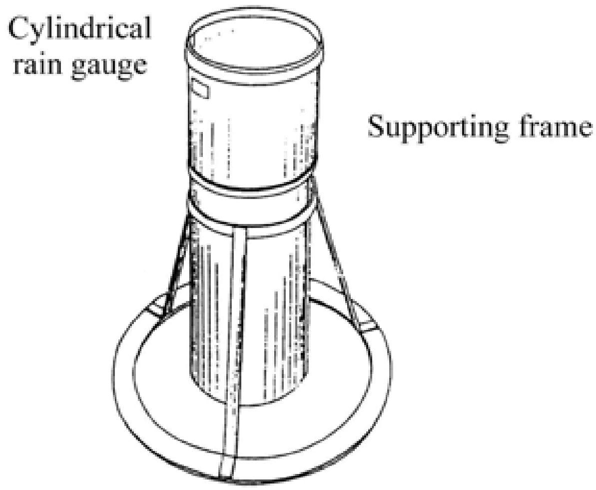


Figure 6.2 Cylindrical rain gauge and its supporting frame

A rain-measuring glass may be used instead of a precipitation scale. To measure solid precipitation such as snow and hail with such a device, a known amount of warm water is added to melt the precipitation; the total amount is then measured with the measuring glass, and the amount of warm water added is subtracted from the total to obtain the precipitation amount.

The precipitation scale is graduated in millimeters based on the size of the rain gauge orifice.

6.2.1.2 Ordinary Rain Gauges (Figure 6.3)

Ordinary rain gauges are the type used at non-automated observatories. With such devices, the observer takes measurements using a rain-measuring glass at regular intervals.

(1) Structure and Operation

This type of rain gauge consists of a receptacle, a shell, a storage bottle, a storage vessel and a rain-measuring glass, which is a measuring cylinder graduated in precipitation amounts based on the diameter of the receptacle's orifice. The shell acts as a container for the storage bottle and the storage vessel. The storage vessel is a cylindrical metallic container that houses the storage bottle. The measuring cylinder (Figure 6.4) is transparent, and is graduated in units of precipitation.

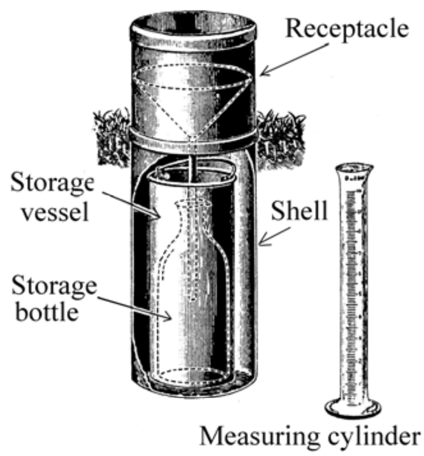


Figure 6.3 Ordinary rain gauge

Rainwater entering through the receptacle accumulates in the storage bottle, and the precipitation amount is measured with the measuring glass. Rainwater that overflows from the storage bottle enters the storage vessel. The amount of overflow is also measured with the measuring glass, and is added to the amount of precipitation in the storage bottle.

(2) Methods of Observation

When performing observation, remove the receptacle, take out the storage bottle and pour the rainwater in the bottle into the measuring glass. After measurement, reset the storage bottle and the receptacle.

If the amount of precipitation is too large or precipitation is in progress, replace the storage bottle and vessel first and then perform measurement indoors.

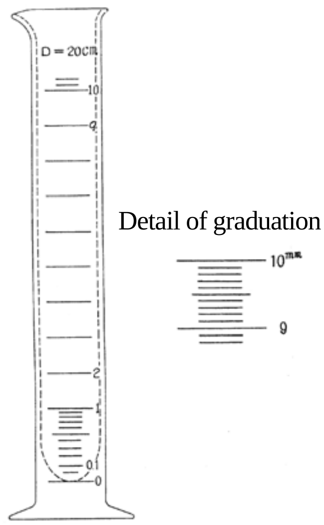


Figure 6.4 Measuring cylinder

If snow or other solid precipitation accumulates in the receptacle, pour in a known amount of warm water to melt it and measure the total amount of water, then subtract the amount added from the total. If the amount of precipitation is large, repeat measurement and then add the individual totals obtained.

6.2.2 Siphon Rain Gauges

A siphon rain gauge enables automatic, continuous measurement and recording of precipitation.

(1) Structure and Operation

This type of rain gauge consists of a receptacle (Figure 6.5) to collect precipitation and a measuring part (Figure 6.6) to measure and record its amount. The measuring part consists of a float with a recording pen attached, a storage tank with a siphon to drain a fixed amount of water, and a clock-driven drum.

Rainwater gathered by the receptacle is led from the rain receiver ① to the storage tank ⑥ through an adjustment vessel ⑰. As a result, a float ② in the storage tank moves upward (Figure 6.7). A recording pen ⑪ is connected to the float. When rainwater in the storage tank reaches a level equivalent to a fixed amount, it is drained by the siphon. This procedure is repeated as long as rainfall continues, and the pen repeats traces from zero to the maximum on the recording paper as shown in Fig. 6.7. When the rainfall stops, the pen traces a horizontal line.

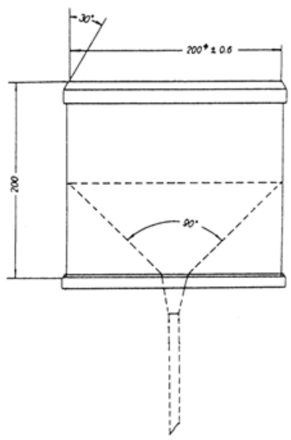
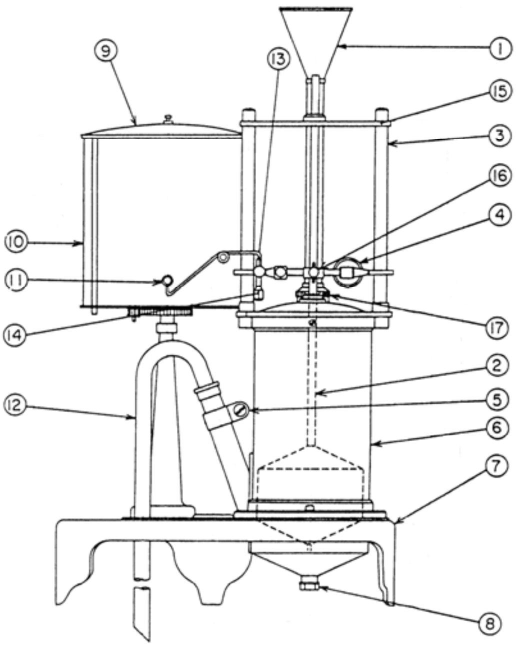


Figure 6.5 Receptacle



①: Rain receiver
②: Float
③: Stay
④: Balancing weight
⑤: Siphon-fixing attachment
⑥: Storage tank
⑦: Base stand
⑧: Drain cap
⑨: Cover
⑩: Clock-driven drum
⑪: Recording pen
⑫: Siphon
⑬: Pen arm
⑭: Pen position adjuster
⑮: Support plate
⑯: Pen arm-fixing screw
⑰: Adjustment vessel

Figure 6.6 Siphon rain gauge

(2) Methods of Observation

The traced mark on the recording paper is read to measure the amount of precipitation. For one-hour precipitation, for example, intersection points at the two consecutive hour lines and the tracing of precipitation are read. The one-hour amount is calculated from the difference between the two readings.

The siphon operates when the pen reaches the maximum position on the recording chart. During heavy rain, however, it may start this action before the amount of precipitation reaches the predetermined level because of the wet interior. As the top of the tracing mark in such cases will not indicate the maximum level, the amount should be calculated as the sum of the readings for the top of the mark.

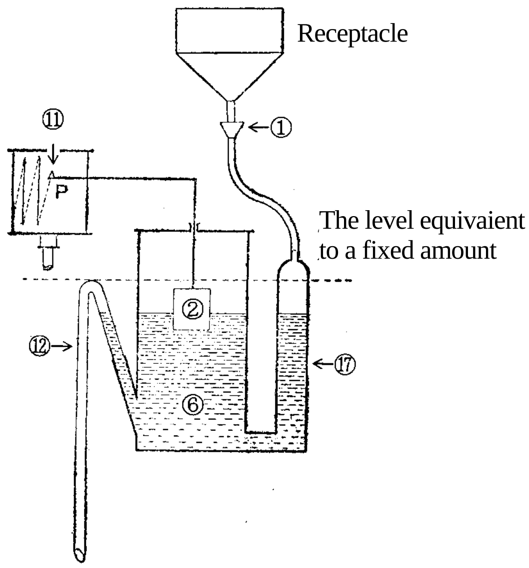


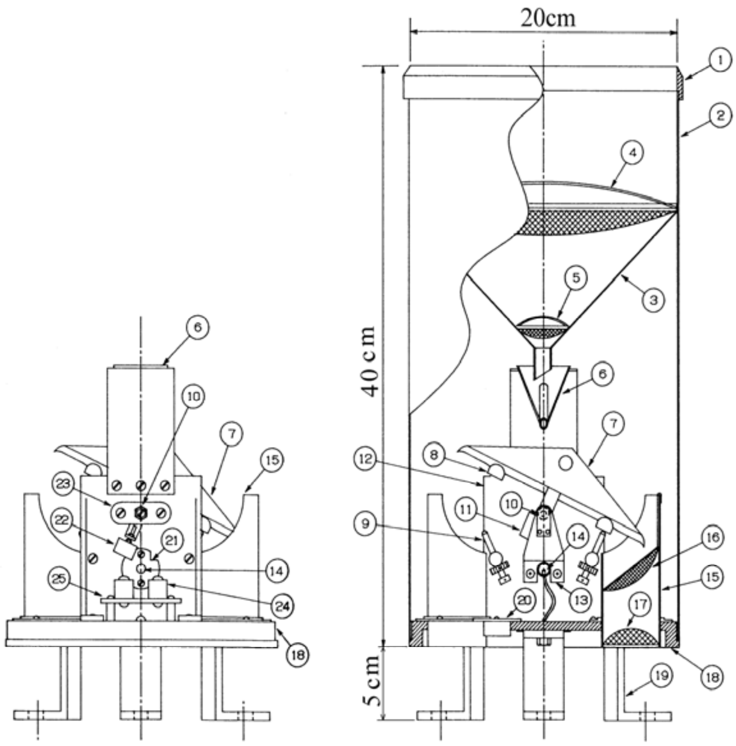
Figure 6.7 Principle siphon rain gauge

6.2.3 Tipping Bucket Rain Gauges

This type of rain gauge generates an electric signal (i.e., a pulse) for each unit of precipitation collected, and allows automatic or remote observation with a recorder or a counter. The only requirement for the instrument connected to the rain gauge is that it must be able to count pulses. Thus, a wide selection of configurations and applications is possible for this measuring system. Solid precipitation can also be measured if a heater is set at the receptacle.

(1) Structure and Operation

This type of rain gauge consists of a receiver and a measuring part, with the receiver serving as the container for the device (Figures 6.8). The measuring part consists of a tipping bucket and a pulse-generating reed switch (or mercury switch) assembled within the receiver.



①: Orifice
②: Shell
③: Funnel
(①-③: Receiver)
④: Filter net (large)
⑤: Filter net (small)
⑥: Water filter
⑦: Tipping bucket
⑧: Tipping bucket stopper pad stone
⑨: Tipping bucket stopper screw
⑩: Bearing and cover
⑪: Balancing weight
⑫: Base plate
⑬: Bearing-support plate
⑭: Reed-relay switch
⑮: Drain cylinder
⑯: Splash-guard net
⑰: Mosquito net
⑱: Base stand
⑲: Fixing leg
⑳: Level vial
㉑: Reed-relay switch holder
㉒: Permanent magnet
㉓: Bearing-support plate2
㉔: Terminal
㉕: Terminal block

Figure 6.8 Tipping bucket rain gauge

The tipping buckets consist of two triangular vessels attached to the left and right of a rotation shaft, each with a capacity equivalent to a specific amount of precipitation. The reed or mercury switch is connected to these tipping buckets to generate an electrical signal (i.e., a pulse) each time the buckets tip.

(2) Operation

Rainwater collected in the receptacle is channeled through the funnel and poured into a tipping bucket. When it reaches a predetermined amount, the bucket tips and dumps the water into a drain cylinder, causing the reed switch to generate a pulse. Subsequent rainwater is poured into the other bucket. As long as precipitation continues, this operation is repeated and a pulse is generated each time a bucket tips.

6.2.4 Tipping Bucket Rain Gauge Recorder

This recorder counts and records pulses (signals) from a tipping bucket rain gauge, anemometer, etc. For each pulse counted, an electromagnet rotates a gear by one step, causing an eddy-type cam on the same shaft of the gear to drive a recording pen and mark a trace on the recording paper of a clock-driven drum.

(1) Construction

The recorder consists of an electromagnet, a pawl, a ratchet gear to count pulses and an eddy-type cam, a recording pen and a clock-driven drum to drive it.

(2) Structure and Principles of Operation (Figures 6.9 and 6.10)

When a contact point in the connected measuring instrument closes, the electromagnet ③ raises the pawl ⑦, which catches the ratchet wheel ⑫ at the next notch. When the contact point opens, the electromagnet operates the pawl to rotate the ratchet gear by a notch. As a result, the gear rotates by one notch per pulse.

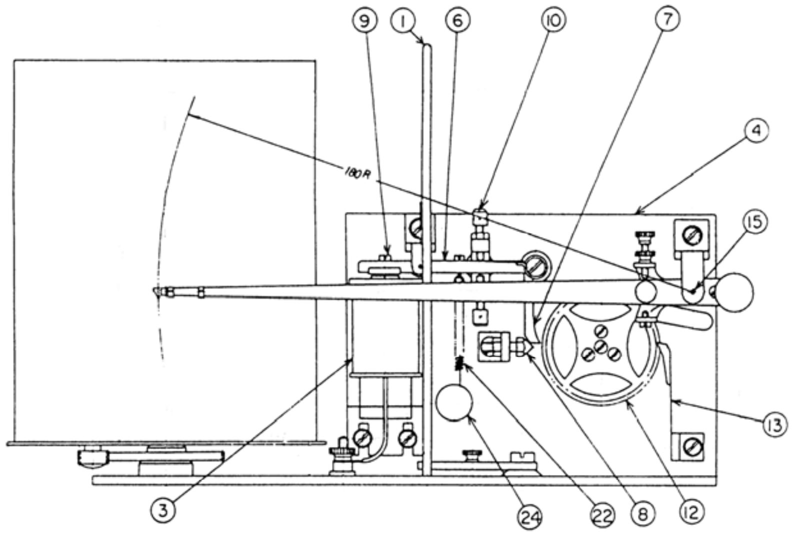


Figure 6.9 Recorder(Front view)

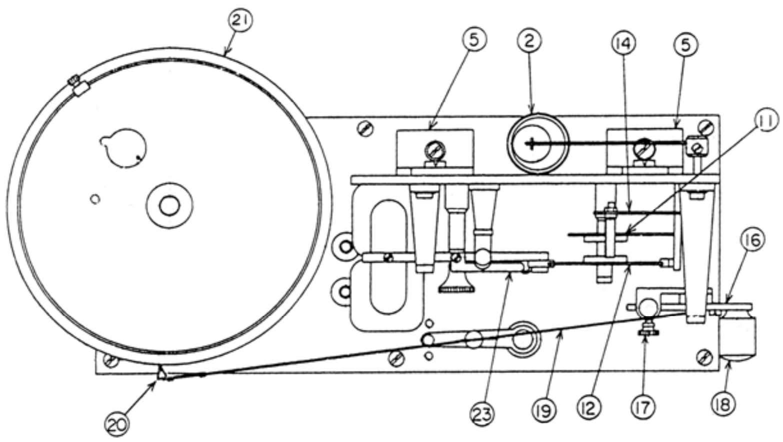


Figure 6.10 Recorder(Top view)

①: Release rod
②: Damper
③: Electromagnet
④: Base plate
⑤: Stay
⑥: Electromagnetic lever
⑦: Pawl
⑧: Stop screw
⑨: Armature
⑩: Adjustment screws (upper and lower)
⑪: Eddy-type cam
⑫: Ratchet wheel
⑬: Detent spring
⑭: Pen-driving lever
⑮: Pen arm axis
⑯: Pen arm attachment
⑰: Pen press adjuster
⑱: Balancing weight
⑲: Pen arm
⑳: Recorder pen
㉑: Clock-driven drum
㉒: Coil spring
㉓: Pawl press spring
㉔: Tensioning adjuster

The eddy-type cam ⑪ is located on the same shaft as the ratchet gear, and its movement is transmitted to the recorder pen ⑳ through the pen-driving lever ⑭ via the knife edge. This action is repeated for each pulse. When the pen tip reaches the maximum position on the recording paper, the knife edge separates from the cam to move the pen tip to the zero position. The damper ② absorbs any abrupt movement.

6.2.5 Exposure

As the environment of the instrument's location significantly influences observation of precipitation, the surroundings must be considered when selecting the observation site.

(1) Conditions of Exposure

To ensure representative observation, the following environmental conditions should be considered as far as possible:

a. The airflow around the rain gauge should be as horizontal as possible. Avoid sites that are concave, elevated or tilted. Choose a site far from precipices or mountain ridges, where local winds are strongly distorted. Avoid sites where wind blows through or stagnates. Building rooftops should not be considered.
b. Choose sites away from other instruments, trees or buildings. Ideally, the instrument should be installed at a distance from such objects equivalent to at least two to four times their height.
c. As the wind speed near the ground increases with height, the efficiency of precipitation collection decreases the higher a gauge is placed. Accordingly, the receptacle should be placed as low as possible. However, too low a setting will result in the entry of splashed rainwater from the ground or the introduction of ground snow in the case of a snowstorm.
d. The ground surface around the rain gauge should be flat and covered with short grass (lawn) or gravel to prevent raindrops from splashing into the unit from outside.

(2) Limitations of Accuracy

The most significant influences on the accuracy of precipitation measurement are the environment and wind at the installation site rather than the performance of the instrument itself. Such influences are difficult to eliminate. Additionally, because precipitation is strongly characterized by locality, it is difficult to choose observation sites with a sufficient level of representation. Site selection without such consideration may result in observations that have very poor accuracy. It is strongly advisable to shield rain gauges from the wind or install them in an optimum observation environment. Satisfying the installation conditions outlined in (1) will ensure high accuracy of observation.

6.2.6 Windshields

Wind exerts a significant influence on the observation of precipitation with snow and rain gauges, and there is no way to avoid its effects. However, accurate collection of precipitation in a rain gauge is possible when the wind around the receptacle is horizontal and its speed is equal to that at ground level or when no vortices develop near the gauge. A windshield is effective in reducing the influence of wind.

Figure 6.11 shows how wind affects precipitation collection. Points A, B and C are located at the top of the receptacle.

Assume the wind is blowing from the left. As it blows at the windward side (A), the amount of rainwater entering the receptacle at A is less than that in the case of no wind. This effect diminishes toward the lee side (C), but the total amount of rainwater entering through the plane A – C is less than that falling on the ground. If raindrops are large and the wind is weak, the effect of the wind is also weak, but otherwise, or in the case of solid precipitation, its influence can be considerable.

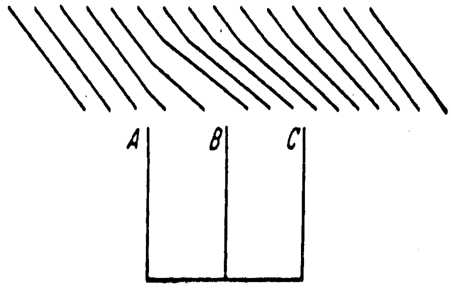


Figure 6.11 Influence of wind on a rain gauge

Nipher designed the first windshield (Figure 6.12). A funnel around the rain gauge (M) is supported by arms (D). The rim at the top forms a flat ring (BC) that guides wind downward to prevent disturbance around the orifice (A). On the flat ring (BC), a 6-mm mesh net is set to prevent rain from splashing. This type of windshield is so effective that it is referred to as a Nipher after its designer. However, it is ineffective during snowfall because snow accumulating on the funnel and the flat ring may reach the orifice. A funnel with holes at the bottom and one without a flat ring were developed to address these problems, but wind tunnel experiments showed that such types caused wind to blow up near the orifice and increased the wind speed. As shown in Fig. 6.13, various types of windshield have been proposed.

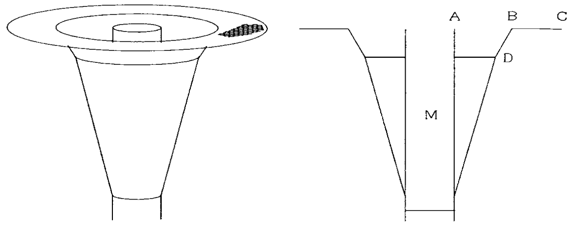


Figure 6.12 Nipher windshield

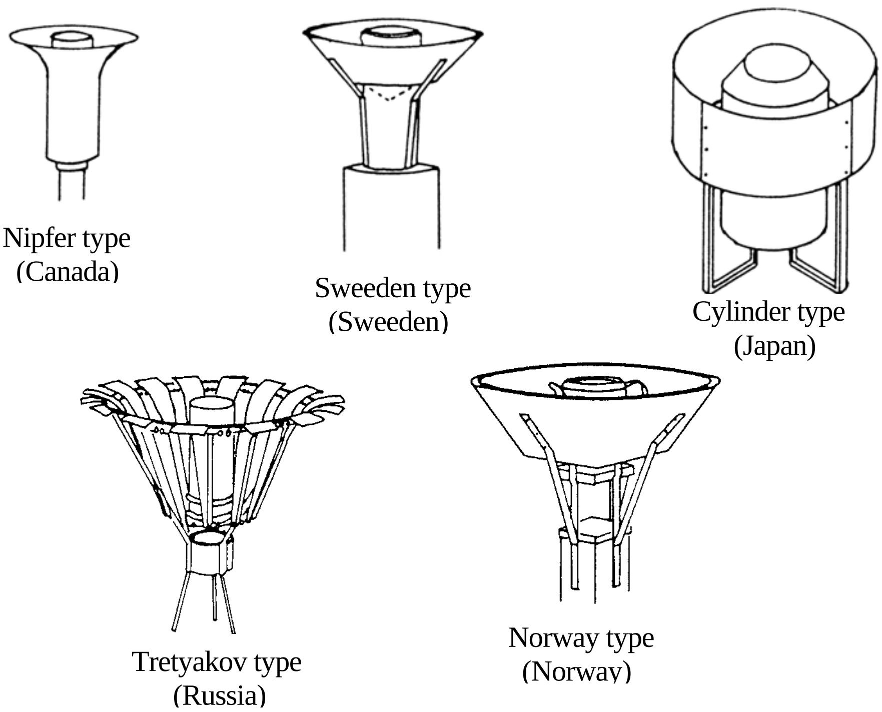


Figure 6.13 Windshield types

6.3 Maintenance

6.3.1 Sources of Errors

Observation errors in measuring precipitation are caused by the influences of the environment, instrument errors and errors due to wetting and evaporation.

(1) Instrument Errors

A well-adjusted siphon rain gauge has an accuracy of 0.2 mm for precipitation of up to 20 mm per hour. A tipping bucket rain gauge has an accuracy of 0.5 mm for precipitation of up to 20 mm per hour, but may have errors of up to 3% for stronger precipitation. In Japan, the minimum observation unit is 0.5 mm, and precipitation less than this amount is not measured. Errors increase with higher precipitation intensity, and exceed 3% for precipitation of more than 150 mm per hour.

(2) Errors from Wetting

If the inner wall of the receptacle and the funnel surface are not sufficiently water-repellent, rainwater adheres to them and does not reach the storage bottle or the tipping bucket, thereby causing errors.

Residual rainwater in the storage bottle or storage vessel of a storage rain gauge causes measurement errors. If rainwater is measured repeatedly with the measuring glass, the residual water for each measurement also causes measurement errors. Dirt, dust and other contaminants adhering to the inside of the storage tank in a siphon rain gauge absorb water, resulting in residual water that causes errors. If the inside of the siphon is soiled, it will not operate properly and will result in errors. Water remaining in a tipping bucket after tipping also causes errors.

(3) Errors from Evaporation

Water remaining in the tipping bucket and subsequently evaporating causes errors.

If a heater attached to a tipping bucket rain gauge to melt snow heats the gauge by +5 to +10°C, weak precipitation or snowfall may evaporate, thereby causing errors.

(4) Errors from the Lack of a Windshield

As the amount of weak precipitation entering the receptacle is reduced by wind, the lack of a windshield causes significant errors.

(5) Errors Related to Tipping Bucket Rain Gauges in Heavy Rain

In tipping bucket rain gauges, rainwater enters the bucket even when it in a tipping state, and water that is drained without being measured causes errors. These errors increase with heavier precipitation, and the amount measured becomes less than the actual amount.

Water equivalent to precipitation of 50 mm was dripped from a standard rainfall simulator vessel with different precipitation intensities, and the number of resulting tips was found to decrease almost linearly with increasing precipitation intensity. The error exceeded the allowable level of 3% when the intensity was more than 150 mm/h, causing the precipitation amount measured to be less than the actual amount.

6.3.2 Maintenance

6.3.2.1 Maintenance before Operation

(1) Cylindrical Rain Gauges and Ordinary Rain Gauges

a. Check the receptacle for deformation.

b. The diameter of the measuring glass is predetermined. Check that it matches the diameter of the receptacle.

(2) Siphon Rain Gauges

a. Pour water into the storage tank to check that the siphon drains water when it reaches the predetermined amount.

b. Check the clock-driven drum for deformation. Inspect the clockwork device to ensure proper operation of the connecting drum (see Section 2.2.3, Clock-driven drums, in Chapter 2, Measurement of Temperature).

(3) Tipping Bucket Rain Gauges

a. Verify that the tipping bucket tips smoothly.

b. Connect a tester to the terminals and check that the contact point operates properly upon tipping.

(4) Tipping Bucket Rain Gauge Recorders

a. Attachment and adjustment of the recording pen

(a) Adjust the pen length from the center of its rotation part to the position where its tip touches the recording paper. Perform adjustment by moving the pen tip on the pen arm.

(b) Adjust the pressure of the pen on the recording paper so that its tip moves away from the paper when it is tilted about 30 degrees forward. Perform adjustment by tightening or loosening the pen arm screw.

b. Adjustment of graduations

(a) Push the armature by hand and rotate the eddy-type cam so that the pen tip indicates zero on the recording paper.

(b) Push the armature to check that each push moves the pen tip by half a division of the graduation on the recording paper. Additionally, check that the tip reaches the maximum line at the 100th push and returns to zero quickly.

(c) Check that the deviation of the pen tip position is less than a quarter of a graduation division.

c. Inspection of curvature

(a) Turn the drum so that the pen tip is located at a time line on the recording paper and sway the pen arm up and down by hand. Check that the pen tip moves over the entire range along the time line.

(b) If the pen tip deviates from the time line as it sways up and down, the axis of the clock-driven drum is inclined. Also check that the recording paper is cut properly.

(c) For details of how to adjust a clock-driven drum with a tilted axis, see Section 2.6.2.2 in Chapter 2, Measurement of Temperature.

6.3.2.2 Periodic Maintenance

(1) Cylindrical Rain Gauges

a. Inspect the level of the orifice.
b. Inspect the cylindrical vessel for dents or deformation.
c. Inspect the cylindrical vessel for corrosion or leakage.
d. Remove leaves, dirt and dust from the vessel, then rinse and dry it.

(2) Ordinary Rain Gauges

a. Inspect the receptacle for deformation, especially at the rim, and check the funnel for leakage or corrosion.
b. Remove leaves and dust from the receptacle, then rinse and dry it.
c. Inspect the storage vessel and the storage tank for leakage or corrosion.
d. Carry out inspections a, b and c when there is no precipitation, and perform repair as required.
e. Mow the grass around the rain gauge regularly.
f. To prevent deposition on the rain-measuring glass, rinse and dry it after each use.

(3) Siphon Rain Gauges

Clean each part and confirm proper operation.

a. Receptacle and leading tube

   Inspect the receptacle and the leading tube for clogging with dust, and check the connection part and other parts for damage or leakage. Rinse the leading tube by pouring in water from the receptacle.

b. Siphon tube

   If the siphon tube becomes soiled at its bent portion, rainwater will not drain properly. Check the siphon tube. If it is heavily soiled, replace and wash it.

   Hold the siphon tube with the bent portion downward and pour in diluted hydrochloric acid. Leave for about a day and then rinse well with water, dry, and keep as a spare.

c. Cleaning of the float shaft

   Clean the float shaft and posts to minimize friction. Do not lubricate, as oil increases friction and dulls their movement.

d. Cleaning of the storage tank

   Remove the drain cap (⑧ in Fig. 6.6) and rinse the tank. Remove the glass rod and rinse it, then tighten the drain cap fully to prevent leakage. If the drain cap washer is deteriorated, replace it.

e. Inspection of the clock-driven drum

   If the clock runs fast or slow, adjust it with reference to Section 2.6.3 (2) in Chapter 2, Measurement of Temperature.

f. Keeping the unit warm in winter

   Keep the storage tank warm if necessary to prevent freezing in winter.

(4) Tipping Bucket Rain Gauges

a. Routine inspection

(a) Inspect the receptacle and the funnel and remove dust or leaves. Inspection should be carried out after periods of strong wind.

(b) Inspect the receptacle for deformation, especially at the rim, and check the funnel for leakage or corrosion.

b. Periodic inspection

(a) Tip the tipping buckets and check the operation of the recorder and the indicator.

(b) Mow grass around the rain gauge regularly.

(5) Tipping Bucket Rain Gauge Recorders

a. Carry out the following inspections when the recording paper is replaced:

(a) Clean the tip of the recording pen.

(b) Supply ink if needed.

(c) Check curvature.

(d) Check the pen pressure and ensure that the pen arm does not touch the release rod.

(e) Set the clock time and check its accuracy occasionally.

(f) Inspect the amount of water in the damper (see Section 6.6.1.5).

b. Periodic inspection

Check operation with electrical signals.

6.4 Calibration

6.4.1 Instruments Required for Calibration

(1) Standard Instruments

a. A vessel containing water equivalent to precipitation of 20 to 50 mm

Its capacity should be coordinated with the diameter of the rain gauge orifice. As shown in Figure 6.14, a glass vessel is a convenient option. A rain-measuring glass may also be used.

b. A gauge to measure the receptacle diameter (Figure 6.15)

Use a gauge coordinated with the receptacle diameter, or vernier calipers.

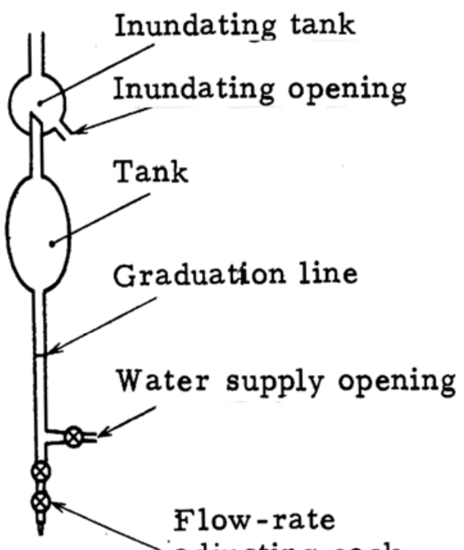


Figure 6.14 Standard water vessel

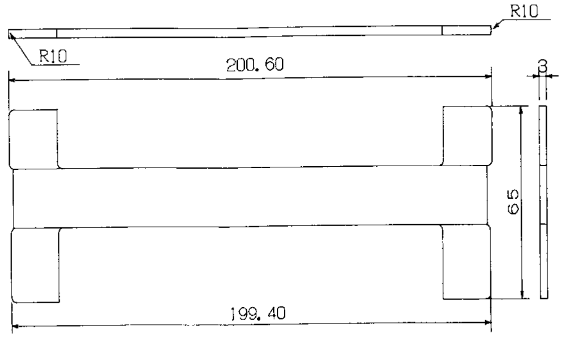


Figure 6.15 Gauge to measure receptacle diameter

(2) Counters

An electromagnetic counter or a recorder to count signals from the tipping bucket rain gauge

(3) Miscellaneous

a. A stand for the standard vessel in (1) a, a sink and a small vinyl tube with an inner diameter of about 1 mm

b. A cloth to wipe the rain-measuring glass

c. A wooden wedge to make the rain gauge level

6.4.2 Methods of Calibration

The following methods of calibration are used in Japan:

6.4.2.1 Ordinary Rain Gauges

(1) Receptacle

a. The joint portion should be defect-free and without leakage. Place the receptacle upside down, fill the space around the funnel with water and leave it for a day. Check that no leakage occurs.

b. Use a caliper gauge or vernier calipers to measure the receptacle orifice. The diameter error should be within 0.5% of a true circle.

(2) Storage Vessel

Fill the vessel with water and leave it for a day. Check that no leakage occurs.

(3) Rain-measuring Glass

a. Drip the standard amount of water into the rain-measuring glass from a standard rainfall simulator vessel.

b. The graduation error should be within 0.02 mm.

c. Cautions for reading

i) The water surface will be concave due to surface tension. Read the graduation aligned with the lowest part of the concave surface. Divide the graduation into 10 equal divisions by eye and read to one decimal place.

ii) Keep the measuring glass vertical and read graduations with the water surface at eye level.

iii) Drip water slowly. Overly rapid dripping cause errors because water splashes onto the inner wall of the measuring glass and remains on the inner surface of the standard rainfall simulator vessel.

6.4.2.2 Siphon Rain Gauges

(1) Receptacle

See Section 6.4.2.1 (1).

(2) Test of Operation

a. Supply water slowly from the receiver funnel. Let the siphon operate once to drain water from the storage tank. Align the pen with the zero mark on the recording paper and rotate the clock-driven drum slowly. Check that the tracing does not deviate from zero during rotation.
b. Move the float shaft upward and downward slowly and check that the pen moves along the vertical axis of the recording paper. Check for friction with movements of the float shaft.
c. Drip water into the receiver funnel and obtain a tracing on the recording paper. The dripping speed should be such that the daily clock movement forms an angle of about 45 degrees to the vertical axis on the recording paper (representing a rainfall intensity of 2 to 5 mm/h). An example of normal tracing is shown in Figure 6.16 (A), while (B) to (F) are examples of undesirable tracing. In particular, that in (F) is an example of frictional movement. Observe the tracing carefully to identify even slight signs of friction.
d. The siphon should drain water within 15 seconds. If the vent hole in the top lid of the storage tank is clogged, drainage may not proceed smoothly.

6.4.2.3 Tipping Bucket Rain Gauges

(1) Test of Operation

Place the tipping bucket on a stand table, connect it to a recorder and drip water continuously for a period of one day, then check the following points:

a. Ensure that water does not splash outside the drain cylinder upon tipping.
b. Check that each tip is not represented as several movements by the recorder or the indicator.
c. Verify that the amount of water needed for tipping is constant.

(2) Inspection of Errors

a. Use a standard rainfall simulator vessel with an amount of water equivalent to precipitation of 50 or 100 mm. Drip water from the vessel into the instrument while it is level and count the number of tips to determine the error.
b. Carry out the same inspection for precipitation intensities of 80 and 20 mm/h.
c. In Japan, errors within 3% are acceptable.

(3) Receptacle

See Section 6.4.2.1 (1).

6.5 Inspection and Repair (Adjustment)

As all operations of the siphon rain gauge and the recorder in a tipping bucket rain gauge are mechanical, operation issues may arise if moving parts undergo friction or wear.

Although the operation of the tipping bucket rain gauge itself is also mechanical, its simpler construction makes it less prone to problems.

Methods of inspection and adjustment to address related problems are described below.

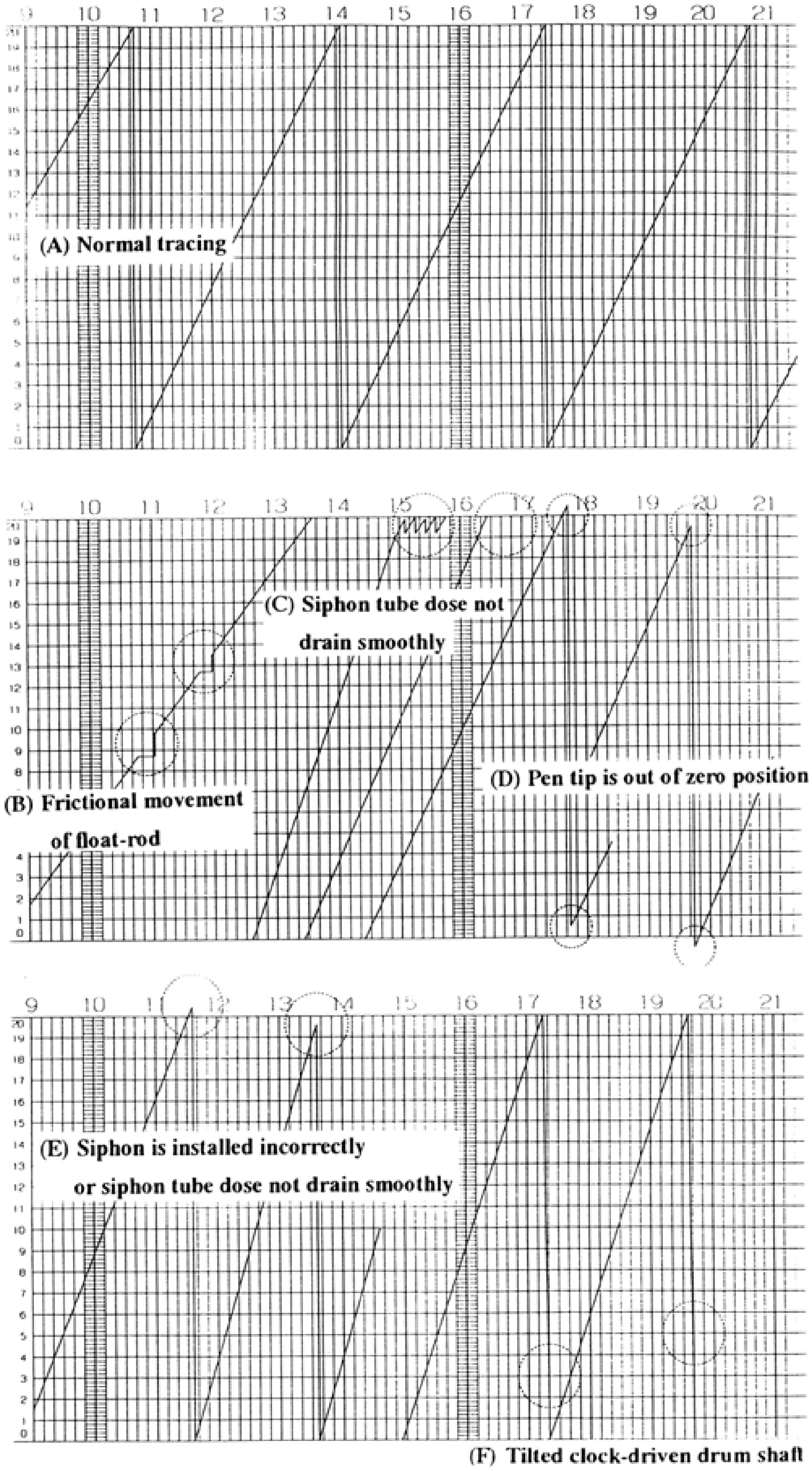


Figure 6.16 Example of a siphon rain gauge record

6.5.1 Inspection in Response to Problems

6.5.1.1 Siphon Rain Gauges

(1) Procedure for Inspection and Repair in Response to Problems

a. Problems with tracing on the recording paper

(a) There are significant lags behind the onset or end of precipitation.

i) The receptacle or leading tube may be clogged or damaged.

ii) The leading tube may be too long.

(b) Drainage is incomplete or non-existent despite the recording pen reaching the set level.

i) The bent portion of the siphon tube may be soiled.

ii) Water may be leaking at the joint portion of the siphon tube.

iii) There may be significant friction around the float shaft.

(c) Drainage occurs before or after the recording pen reaches the set level.
The siphon may be installed incorrectly.

(d) The zero-point position is unstable after drainage.

i) There may be excessive rattling at the pen arm attachment.

ii) The configuration of the storage tank may be inappropriate (not repairable in this case).

(e) The pen moves irregularly under constant precipitation intensity.
There may be significant friction around the float shaft, the rods or the pen.

(f) The times on the recording paper between the pen reaching the maximum level and returning to zero after drainage are different.
The central shaft of the clock-driven drum may be tilted.

(g) Tracing on the recording chart is scratchy or intermittent.
The pen tip may be defective, or there may be significant friction at the pen support part.

b. Problems with smooth drainage of the siphon tube

(a) The vent hole in the top lid of the storage tank may be clogged.
Clean it with a thin wire.

(b) The bent portion of the siphon tube may be soiled with oily matter or be extremely dry.
In such cases, the tracing takes on a zigzag form at the top of the recording paper. Rinse the siphon tube with reference to Section 6.3.2.2 (3) b.

(c) The joint portion of the siphon tube leaks.
The siphon clamp may need to be tightened.

c. Problems with clock stoppage

(a) See Section 2.6.3 (1), Clock stoppage, in Chapter 2, Measurement of Temperature.

(b) If a spare is available, replace the clock. Also replace the main shaft and the stand table of the clock-driven drum.

(2) Adjustment (Figure 6.6)

a. Adjustment of the recording pen attachment

(a) Adjustment of the pen arm

The diameter of the pen support wire must be appropriate for the hole size of the pen adjustment jig. Excessive friction will cause the pen to leave the recording paper, and excessive rattling will cause irregular pen movement.

(b) Adjustment of the pen attachment angle

Adjust the angle of the pen to the recording paper by turning the pen arm attachment screw so that the pen tip points downward to an appropriate degree. If the angle is excessive, the pen will scratch the recording paper upon drainage. Conversely, too shallow an angle will cause a shortage of ink. Shift the counterbalance so that the float rises and falls smoothly.

(c) Adjustment of the pen tip's zero position

Supply water slowly from the receiver funnel and watch the pen rise. When the siphon begins to drain, stop the water supply. After drainage, set the pen tip to the zero position. Repeat this procedure until the pen tip always indicates zero upon completion of drainage.

b. Adjustment of the clock-driven drum's central axis

If the pen movement does not match the curvature of the time lines on the recording paper, see Section 2.6.2.2 (2), in Chapter 2, Measurement of Temperature.

Similar phenomena will occur if the recording paper is cut improperly.

c. Adjustment of the siphon tube attachment

The attachment position of the siphon tube is indicated by either a transversal engraved line or a ring on the rim. Insert the siphon tube at the position of the indication and tighten the clamp screw to fix it. Supply water from the receiver funnel and check that it is drained at a fixed level on the recording paper. If not, loosen the siphon clamp and adjust the level of the siphon tube.

d. Adjustment of magnification

Magnification is adjusted by changing the number of glass rods in the adjustment vessel. The correct adjustment of magnification has already been set in a to c, above, so further adjustment is unnecessary.

6.5.1.2 Tipping Bucket Rain Gauges

(1) Non-existent or Small Signal During Precipitation

a. The receptacle may be clogged with dust.

b. The reed or mercury switch may be defective.

c. There may be discontinuity in the signal line or defective contacts.

d. There may be problems with the recorder or the power source.

(2) Excessive Precipitation Compared to Other Observatories

a. Deposits of dirt in a tipping bucket may reduce the amount of water needed for tipping, resulting in a higher number of tips.

b. The reed or mercury switch may be rattling.

(3) Inspection Procedure

a. Check that the connected power source is generating a normal output voltage. Isolate the recorder and ensure that it operates normally by itself. If no problems are found, perform the following:

b. Visually inspect the receptacle for blockage with leaves or dust.

c. Check that the tipping bucket tips smoothly. Visually inspect for deposits or dust in the buckets.

d. Disconnect the signal cables and connect a tester to the signal line terminals. Supply water slowly to one of the tipping buckets and check that the tester's pointer moves once and returns immediately upon each incidence of tipping.

e. In the inspection of d above, if the pointer does not move, does not return or sways several times, replace the reed or mercury switch.

f. If no signal is generated in the inspection, check the status of the cable connection from the rain gauge.

6.5.1.3 Tipping Bucket Rain Gauge Recorders

(1) Causes of Electromagnet-related Problems

a. There may be defective contact at the contact point in the rain gauge.

b. There may be a disconnection in the circuit containing the rain gauge.

c. The battery voltage may be insufficient.

d. There may be a disconnection in the electromagnetic coil.

In a to d, above, defective portions are identified through conduction testing or by voltage measurement using a tester. Repair or replace any defective parts found.

(2) Causes of Gear Movement Problems (Figure. 6.9 and 6.10)

a. The coil spring ㉒ may be too strong or too weak.

b. The pawl press spring ㉓ may be too strong or too weak.

c. The detent spring ⑬ may be too strong or too weak.

d. The upper and lower adjustment screws ⑩ limiting lever movement may be protruding too much.

e. The stop screw ⑧ may be protruding too much.

f. Adjustment

(a) Push the armature ⑨ to set the electromagnet in operation. The pawl ⑦ should shift to the next notch. The upper adjustment screw ⑩ limiting the movement of the electromagnetic lever ⑥ should come into contact with the lever. If it does not, turn the screw until it makes contact.

(b) Leave the armature ⑨ as if the electromagnet were turned off by the coil spring ㉒. The pawl ⑦ should cause the gear to rotate by one notch. The head of the stop screw ⑧ should come into contact with the lowest part of the pawl ⑦, and the lever should come into contact with the lower adjustment screw ⑩. If there is a gap, turn the screw until contact is made.

(c) Adjust the interval at which the pawl ⑦ and detent spring ⑬ engage with the gear to be 70 percent of the notch pitch.

(3) Causes of Irregular Pen-tip Movement

a. The distance between the upper and lower adjustment screws limiting level movement may be too large.

b. The stop screw ⑧ may be too far away.

If either of these issues are found, adjust with reference to (2) f (a) to (c).

(4) Notes

a. When the pen tip is replaced or if the pen has moved due to looseness or tightening, adjust the length of the pen from the center of the rotation axis to the pen tip and coordinate the tip's movement with the curvature of the time lines on the recording paper.

b. Use the prescribed power source voltage.

6.6 Miscellaneous

6.6.1 Installation Environment and Procedures for Exposure

The conditions of the installation environment are described in Section 6.2.5. Here, the installation method is described for each type of instrument.

6.6.1.1 Cylindrical Rain Gauges

Cylindrical rain gauges are buried under the ground or placed on it. Select a flat place as the observation field and install the gauge so that the receiver orifice is level. Once it is buried, plant grass around the gauge and keep it mowed to prevent raindrops from splashing into the receptacle from outside. For installation on the ground, use a firmly fixed support (Figure 6.2) to prevent wind-related tilting. As a deformed receiver orifice or any leakage from the cylindrical vessel may cause measurement errors, the setting should be inspected regularly.

6.6.1.2 Ordinary Rain Gauges

Bury the gauge in a flat place so that the top of the receptacle is level at a height of about 20 cm. As shown in Figure 6.3, set the storage vessel in the container and place the storage bottle in the storage vessel. Set the receptacle so that rainwater from it enters the storage bottle. Plant grass and keep it mowed to prevent raindrops from splashing into the receptacle from outside.

6.6.1.3 Siphon Rain Gauges

Build a hatch at the observation site and fix the receptacle on the roof to prevent raindrops from splashing into it from outside. Captured rainwater should run through the pipe to the measurement part in the hatch. Place the measuring part on a firm horizontal stand in the hatch.

6.6.1.4 Tipping Bucket Rain Gauges

Build a square concrete foundation with edges measuring 30 to 40 cm, and install the gauge on it so that the receptacle is level. Install a recorder in the observation room. Lay the necessary cables through a conduit from the gauge foundation to the recorder site and connect as required. Plant grass and keep it mowed to prevent raindrops from splashing into the receptacle from outside.

6.6.1.5 Tipping Bucket Rain Gauge Recorders

(1) Install the recorder in a location that is free from the effects of vibration. Select a site that allows convenient recording paper replacement, indicator reading and spring winding.

(2) Supply water to the damper dashpot along with a small amount of oil on top of it to prevent evaporation. If freezing is likely in winter, use glycerin or kerosene instead of water. The amount of water should be adjusted to keep the damper under the surface even when the pen reaches the highest scale line on the recording paper.

(3) Connect the recorder, the tipping bucket rain gauge and a battery (3 V DC) in series. Check the cable insulation and fix the cable correctly. Choose the cable type in consideration of the distance from the tipping bucket rain gauge to the recorder. Cables with a sectional area of 0.75 mm^2 may be used for distances of up to 50 m.

6.6.2 Transportation

6.6.2.1 Common Items

(1) Preparation

Clean each part of the main unit's components and dry them well.

(2) Packing

a. Protect the rim of the receptacle with cardboard.
b. Wrap the main unit in paper and place it in a wooden box with sufficient cushioning on the bottom.
c. Place cushioning around the main unit to protect it from vibration in transit.
d. Place accessories in the same box to avoid loss. Keep them from coming into contact with each other.
e. Once packing is complete, bind the box with rope.

(3) Transportation

Instruct the carrier to avoid laying the package horizontally or stacking, and mark the container "Handle with care" and "This way up."

6.6.2.2 Cylindrical Rain Gauges

Preparation, packing and transportation should be performed as outlined in Section 6.6.2.1.

6.6.2.3 Ordinary Rain Gauges

(1) Wrap the storage bottle with cushioning.

(2) Follow the instructions outlined in Section 6.6.2.1.

6.6.2.4 Siphon Rain Gauges

(1) Preparation

a. Remove the drain cap (⑧, Fig. 6.6) at the bottom of the storage tank and completely drain the water from the tank. Supply fresh water from the receiver funnel to rinse the inside of the tank. Drain water from the tank well, dry the inside of it and tighten the drain cap.
b. Clean the recording pen with warm water or alcohol and dry it.
c. Remove the siphon tube and rinse it following the instructions outlined in Section 6.3.2.2 (3). Wrap it in paper and bind it lightly with string.
d. Remove the clock-driven drum and put it in a polyethylene bag together with a desiccant.
e. Tie the float shaft to the rod with string.

(2) Packing

a. Wrap the siphon tube in cardboard and place it vertically in the corner of a wooden box.
b. Wrap the clock-driven drum in cardboard and place it in the wooden box. Apply sufficient cushioning to prevent vibration or contact with the main unit.
c. Follow the instructions outlined in Section 6.6.2.1.

(3) Transportation

See Section 6.6.2.1.

6.6.2.5 Tipping Bucket Rain Gauges

(1) Preparation

a. Pour any remaining water from the filter and the tipping buckets, then rinse and dry.
b. Fix the tipping buckets using a fixture or string.
c. If the filter has a lid, fix it with adhesive tape.

(2) Packing

See Section 6.6.2.1.

(3) Transportation

See Section 6.6.2.1.

6.6.2.6 Tipping Bucket Rain Gauge Recorders

(1) Preparation

a. Pour out water and oil from the damper dashpot and wipe it well.
b. Place folded paper between the electromagnet and the armature and fix the armature firmly.
c. Adjust the position of the pen tip to the zero point and hang the pen arm on the hanger or fix it with string.
d. Stuff the dashpot with paper and fix it.
e. Fix the clock-driven drum.
f. Shut the case lid and place plywood or cardboard over the glass portion.

(2) Packing

See Section 6.6.2.1.

(3) Transportation

See Section 6.6.2.1.