FIELD MANUAL FOR RESEARCH IN AGRICULTURAL HYDROLOGY

Agriculture Handbook No. 224

Coordinators
D. L. Brakensiek
H. B. Osborn
W. J. Rawls

Science and Education Administration
UNITED STATES DEPARTMENT OF AGRICULTURE

Revised February 1979

Library of Congress Catalog Card No. 77-600031

CHAPTER 1. PRECIPITATION

Principal contributors:

W. R. Hamon, SEA hydraulic engineer (chapter coordinator)
USDA/SEA North Appalachian Experimental Watershed
Coshocton, Ohio

L. H. Parmele, SEA agricultural engineer, retired (chapter coordinator)
USDA/SEA Northeast Watershed Research Center
University Park, Pa.

G. H. Comer, SEA hydraulic engineer, formerly
USDA/SEA Hydrograph Laboratory
Beltsville, Md.

W. J. Gburek, SEA hydraulic engineer
USDA/SEA Northeast Watershed Research Center
University Park, Pa.

E. L. Neff, SEA hydraulic engineer
USDA/SEA Northern Plains Soil and Water Research Center
Sidney, Mont.

A. D. Nicks, SEA agricultural engineer
USDA/SEA Southern Great Plains Watershed Research Center
Chickasha, Okla.

H. B. Osborn, SEA hydraulic engineer
USDA/SEA Southwest Watershed Research Center
Tucson, Ariz.

CONTENTS

INTRODUCTION

Precipitation includes any moisture falling from the atmosphere in liquid or frozen form. The total amount of precipitation that reaches the ground in a stated period is expressed as the depth to which it would cover a horizontal projection of the earth's surface if there were no loss by evaporation or runoff, or if any part of the precipitation falling as snow or ice were melted. Snowfall also is measured by the depth of fresh snow covering an even, horizontal surface. The chief aim of any method of measuring precipitation should be to get a representative sample of the fall over the area to which the measurement refers. This is an important requirement for measuring precipitation in the absolute sense. The choice of site, the form and exposure of the measuring gage, the prevention of loss by evaporation, and the effects of wind and splashing are all important.

In its simplest form, a precipitation gage is an open-mouthed can with straight sides. Gages are installed with the open end upward and the sides vertical. Improved gages measure small amounts and record the time and intensity of precipitation. Rain gages are used in (1) climatology, in which nonrecording gages often are used; (2) hydrology, in which forecasting of runoff requires self-recording gages and totalizers; and (3) hydrometeorological studies, in which a rain gage must show rates and amounts of rainfall.

For most climatological studies, today's rain gages are adequate. For hydrological purposes, such as runoff forecasting, the recording gages are satisfactory although measurement of precipitation is limited by such factors as gage sensitivity and network density. For hydrometeorological studies in which rates of rainfall and amounts must be shown accurately for short intervals, today's networks of recording gages are frequently inadequate.

A wide variety of gages has been developed to measure precipitation; some gages were developed for a special purpose. Two types of gages (nonrecording and recording) are used primarily in the United States. The nonrecording gage retains the total precipitation between observations; the recording gage gives the time of precipitation so that intensities can be computed.

Some crude quantitative determinations of rainfall can be made by use of radar, but errors are appreciable (*8*).[1.1] The principal value of radar is to help determine location, areal extent, orientation, and movement of rainstorms (*41*).

INSTALLATIONS

Installation should be geared to conditions of operation and maintenance. Climatic factors, physical conditions of the site, and the anticipated type of observer should be considered. Usually simplicity of operation is the best guarantee of satisfactory performance. Simplicity of procedure insures adequate observations. Where procedures are complicated, the duties of the observer should be reduced to a step procedure. Provision in the installation design often can facilitate such reduction. Gage sites should be selected, designed, and located to provide unconfounded records.

[1.1] Numbers in parentheses refer to References at the end of each chapter.

General Considerations

Site Selection

The location of the gage is the primary consideration for obtaining accurate precipitation measurements. An ideal exposure would eliminate all turbulence and eddy currents near the gage. Individual trees, buildings, fences, or other small groups of isolated objects near the gage may set up serious eddy currents, especially when their height above the gage is appreciable. As a general rule, an isolated obstruction should not be closer to the gage than twice (preferably four times) its height above the gage (*37*). Obstructing objects usually provide a more accurate catch when they are so numerous and extensive that prevailing windspeed in the vicinity of the gage has been reduced and, consequently, the turbulence and eddy currents also have been reduced. The best exposures often are found, therefore, in orchards, in openings in a grove of trees or bushes, or where fences and other objects form an effective windbreak.

Sites on a slope or on ground sloping sharply away in one direction should be avoided especially if this direction is the same as that of the prevailing wind. The surrounding ground can be covered with short grass or be of gravel or shingle; but a hard, flat surface, such as concrete, causes excessive splashing and abnormally high surface temperatures.

The growth of vegetation, trees, and shrubbery, and manmade alterations to the surroundings may make an excellent exposure unsatisfactory in a relatively short time. The angle from the gage orifice to the top of any nearby object should not exceed 30°, thus allowing for growth of vegetation. Under no circumstances should an obstruction be nearer to the gage than its own height (45°). Wilson (*40*) felt, however, that a small clearing in uniform forests, having a diameter about equal to the height of the trees, was best because the measurement would gain more from the reduction of wind than it would lose from interception.

To place a gage in a forest opening of 60-foot (18.3 m) trees, a clearing of about 1/4 acre (1,012 m^2) is required (*23*). If no such openings exist on a watershed or on control watersheds where no cutting is allowed, measuring rainfall at the surface of the tree crown should be considered (*30*).

At exposed sites, lack of natural protection can be compensated for by shielding or by using pit gages. The Nipher shield is recommended if the precipitation is primarily rain. The Alter shield is recommended if a substantial portion of the precipitation is snow.

Height of Receiver Funnel

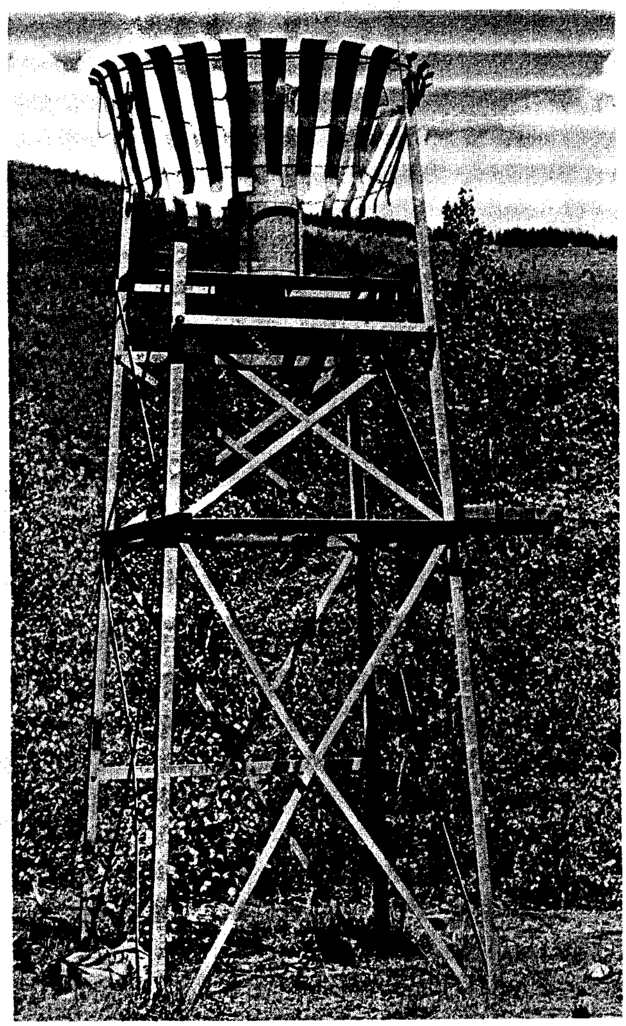
Height of the mouth of the gage above ground should be as low as possible (because wind velocity increased with height) but high enough to prevent insplashing from the ground. In areas that have little snow and few puddles, a 12-inch (30 cm) receiver funnel may be used. In other areas, a standard height or 30 inches (75 cm) is recommended.

All gages in a watershed should be the same height above ground. The 8-inch (20 cm) standard or nonrecording gage, which is only 26 inches (66 cm) high, will require construction of a stand to raise the funnel up to 30 inches (76 cm), which is about the minimum height possible for the weighing-type universal recording gage.

In very exposed places where natural shelter is unavailable, results will be better if the gage is exposed in the middle of a circular turf wall about 10 feet (3 m) across. The inner surface of the wall should be vertical, and the outer surface should slope at an angle of about 15° to the horizontal. The top should be level with the mouth of the gage, and provision should be made for drainage. The main disadvantage of this arrangement is that the space enclosed by the wall may fill with snow in the winter. In areas where heavy snowfall occurs, gages are mounted on supports (towers) at a height well above the average level to which snow accumulates (fig. 1.1). This exposure will be better, however, if the tower is located among trees of comparable height.

Size of Orifice

Small-orifice gages have been developed recently to increase economically the density of rain-gage networks (*26*). Huff (*19*) compared small-orifice gages with the National Weather



PN-5872

FIGURE 1.1—Shielded, weighing-type, recording precipitation gage mounted on a snow tower.

Service 8-inch (20 cm) standard gage.[1.2] The 3-inch (7.6 cm) circular gage and the plastic wedge-shaped gage (orifice 2.3×2.5 in or 5.8×6.4 cm) compared favorably with the standard gage. Small-orifice gages must be read shortly after precipitation has stopped because of high evaporation loss from the gages. These gages are unsuitable for measuring snow, and manufacturers do not recommend plastic gages for use in freezing weather.

[1.2] The U.S. Weather Bureau became the National Weather Service in October 1970.

Gages with different orifice diameters measure rainfall with about the same degree of accuracy. Codman (*6*) found that rain gages with orifices 2 to 24 inches (5.1 to 61 cm) in diameter varied less than 1 percent in accuracy of measurement over 3 years. Stow (*36*) and Mill (*27*), using gages ranging in size from 3 to 24 inches (7.6 to 61 cm) and 4 to 24 inches (10 to 61 cm), respectively, found that catch did not vary by more than 1 or 2 percent.

To lower the cost of making measurements, economical gages can be developed if guidelines for physical characteristics of gages are followed. Gages made from No. 10 cans have been tested by Rogerson (*33*). For 63 storms (0.01 to 4.80 in) or (0.3 to 12 cm), two-thirds of the can readings were within 0.01 inch (0.03 cm) of readings from a standard National Weather Service standard 8-inch (20 cm) gage. Costs of large rain-gage networks can be reduced by eliminating the funnel and inner brass cylinder from the 8-inch (20 cm) standard gage and by measuring the catch in graduates. Evaporation from a gage without the funnel can be controlled by adding transformer oil (*12*).

Gage Supports

Rain-gage supports should be economical, easy to build, and rigid enough so that the pen trace will not be affected seriously by high winds. Several types of gage supports are discussed under section 330.21 of the U.S. Weather Bureau Substation Inspection Guide (*37*). Choice of type should be influenced by the most economical unit, ease of getting and transporting materials, ease of installation, and durability. A permanent installation support and a temporary installation support are discussed in this publication. Provisions should be made for adjustments so that the rim of the gage will be level.

Installations for longtime records should have concrete bases extending to a depth of 3 feet (0.9 m) or below the average maximum frost penetration. Construct a form for any part of the base that will extend above ground. After the concrete is poured and before it sets, place three bolts in the top with heads buried, using the anchor or rain-gage base as a template. After the concrete has taken its initial set, remove the template and trowel the top to a smooth finish. After final set of the concrete, place the rain gage base and level, using shims if necessary.

Where records are to be collected for 5 years or less, or in locations generally inaccessible, construct the base by driving three pointed 2 by 4's, about 30 inches (76 cm) long, into the ground and nailing other pieces of 2 by 4's on top, to which the rain-gage base or stand is bolted. In some heavy soil areas that are subjected periodically to high temperatures or drought long steel pins may be necessary to replace the driven 2 by 4's.

Stands for the standard 8-inch (20 cm) nonrecording gage can be built locally from 1/8 by 1-inch (0.32 by 2.54 cm) strap iron with two rings around the can, three or four legs, and a base or platform to hold the bottom of the standard can 10 inches (2.54 cm) above ground (fig. 1.2).

For correct measurement of precipitation, the open end of the gage (the receiver) must be in a horizontal plane. This can be checked by laying a carpenter's level across the open top of the gage in two directions, one crossing the other at right angles. If the top is not level in both directions, this condition should be corrected. A note should be added to the observation form giving the date the defect was discovered and the date it was corrected.

Enclosures

Since rainfall stations frequently are on private lands, they should be located so that their interference with normal land use is minimal. Figure 1.3 shows the suggested size and shape of enclosures for a rain gage in a permanent pasture, in a fence line, and in a fence corner. Since some posts for these enclosures are only 3 1/2 feet (1.07 m) from the gage, they should not extend more than 1 foot (30.5 cm) above the receiver funnel.

Windshields

Several windshields have been developed to correct for errors due to wind turbulence. The most notable are the Nipher (*28*) and Alter (*2*) shields. Windshields divert the flow of air down and around the rain gage. By eliminating updraft around the orifice, the gage is placed in an undisturbed flow of air (fig. 1.4).

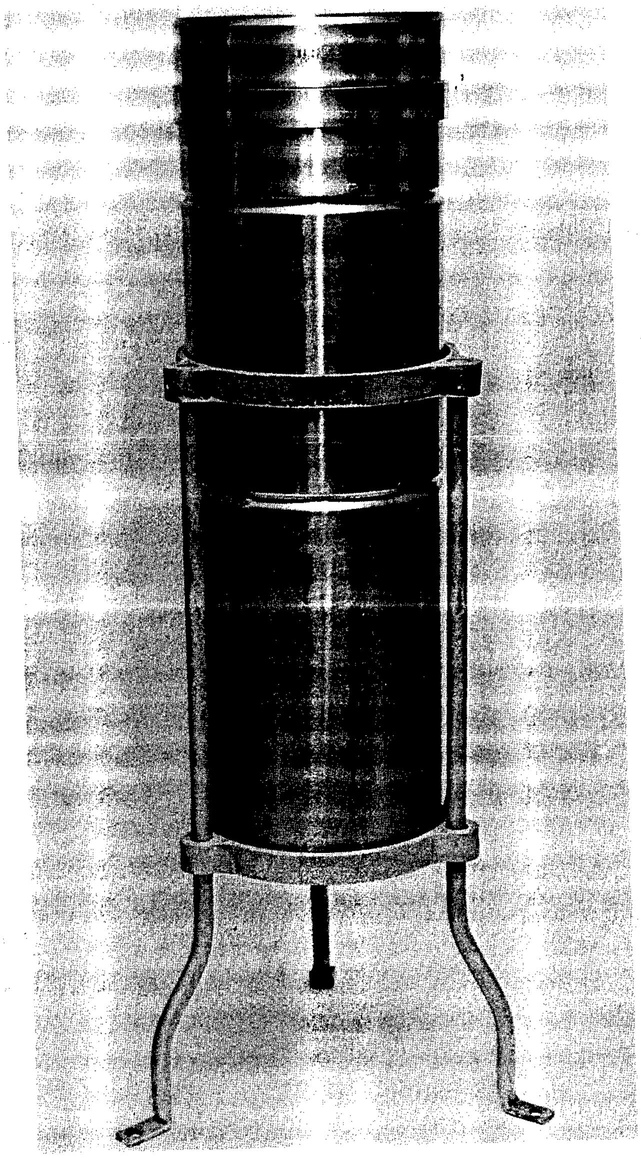


FIGURE 1.2.—Eight-inch (20 cm) nonrecording precipitation gage showing metal support.

An ideal shield should:

- Ensure a parallel flow of air over the aperture of the gage;
- Avoid any local acceleration of the wind above the aperture;
- Reduce speed of the wind striking the sides of the receiver as much as possible;
- Prevent splashing towards the aperture of the receiver, which makes the height of the gage mouth above ground less important; and

- Not be subject to "capping" by snow.

The relative effectiveness of the Alter and Nipher shields (table 1.1) has been investigated on a total catch basis by Larkin (*22*) and Allis and others (*1*). The general consensus is that the Nipher shield seems superior for reducing wind errors. Since snow may build up on the horizontal rim, the Alter shield is the best compromise for unattended gages in areas of appreciable snowfall (*24*).

TABLE 1.1—*Relative effectiveness of Alter and Nipher shields on rain-gage catch*

Shield	Unshielded gage catch		Data source	Duration of tests
	Rain	Snow		
	----*Percent*----			
Alter ____	103.9	171.2	Larkin (*22*)	9 months
Nipher __	107.4	181.0	Larkin (*22*)	9 months
Alter ____	101.5	134.4	Allis and others (*1*)	16 years
Nipher __	103.5	147.4	Allis and others (*1*)	16 years

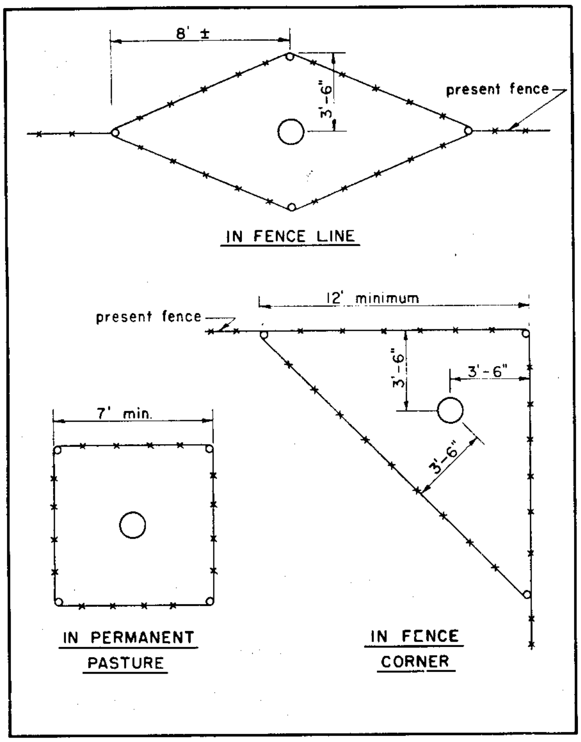


FIGURE 1.3.—Suggested rain gage fence enclosures.

Weiss and Wilson (*39*) have summarized the effectiveness of many shields in reducing catchment error of rain gages under exposed conditions. A recording weighing-type precipitation gage with windshield installed is shown in figure 1.5. A good site provides natural protection for the precipitation gages. The use of a windshield will then result in little or no improvement in rain-gage catch.

Number and Distribution of Gages

The number of gages necessary to determine the depth of precipitation on an area depends on (1) size of the area, (2) prevailing storm type, (3) form of precipitation, (4) topography, (5)

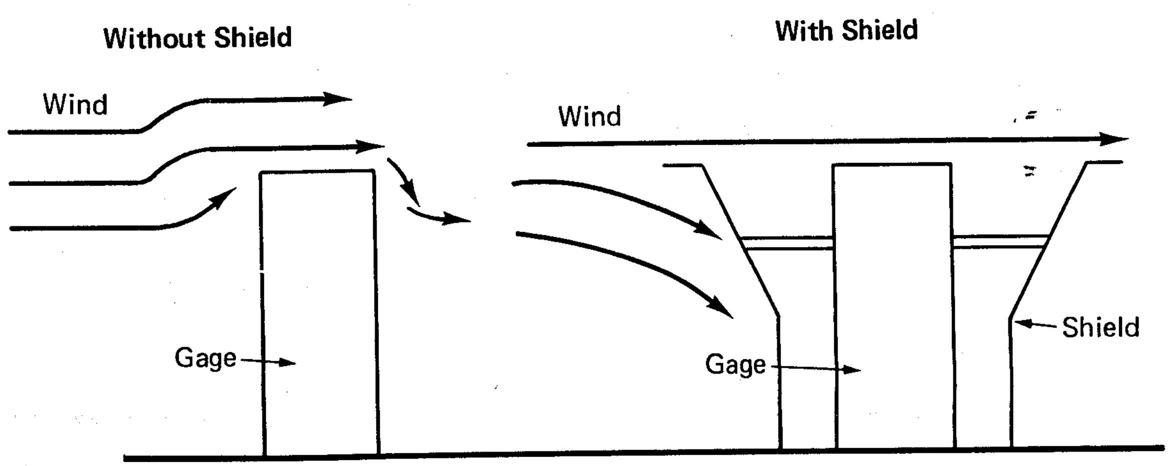
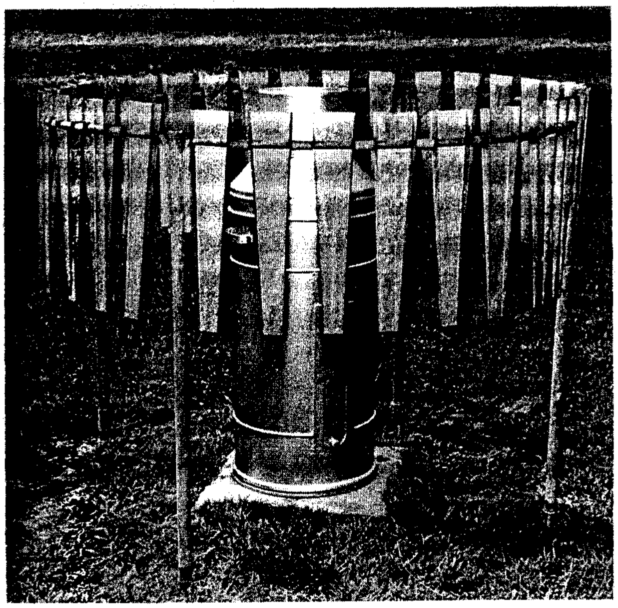


FIGURE 1.4.—Deflection of air by rain gages without shield and with shield.



PN-5873

FIGURE 1.5.—Recording, weighing-type precipitation gage showing windshield installed.

aspect, and (6) season. Where prevailing storms are cyclonic (generally rainfall of low intensities over large areas), a rather sparse network may be adequate (*14*). A more dense network will be required where storms are predominately convective and are characterized by thunderstorms with high intensities and uneven distribution (*29*). Mountainous areas that create orographic-type storms may require more gages than flatter areas. Some areas may be subject to different types of storms, depending on the season. For example, since convective storms rarely occur in the northern sections of the United States during the winter, more gages may be needed during one season than another. Generally, more gages are needed where precipitation is variable.

The objectives of a network are also important in determining the number of gages required. For example, a network designed to relate total watershed precipitation to seasonal or annual water yield might be inadequate for the study of specific precipitation characteristics on a storm-by-storm basis. More gages also will be required for studies in which the results will be extrapolated to other areas than for studies confined to a given area. This is caused by the need for quantitative data for extrapolation, whereas qualitative or index values are adequate for a restricted area. The following tabulation shows the number of gages required for different areas:

Size of area	*Number of gages*
40 acres	2
100 acres	3
600 acres	4
5 mi²	10
10 mi²	15
20 mi²	20
50 mi²	30
100 mi²	50
300 mi²	100
1,000 mi²	300

This tabulation is based only on size of area. Final determinations of the number of gages must depend on additional considerations.

Distribution of rain gages should not be random. Fixed characteristics of areas can be sampled randomly, but random events must be sampled by systematic arrangements of sampling points.

In practice, however, systematic gage distribution is difficult to arrange because access to locations frequently is difficult or disturbs the watershed. Gage networks usually are planned on paper. Gages are placed as close as possible to locations where access will be convenient and normal use of the area will not be disturbed. Gages also must be located so that their exposure is not influenced by nearby buildings, trees, or other obstructions that might cause undesirable wind currents.

Gages should be distributed so that isohyetal maps can be drawn. Some gages must be located near and outside the watershed boundary so that isohyets can be drawn to cover the watershed area completely.

When a network is designated for broad use, such as on a regional or national basis, a few gages may be needed. These should be well distributed and carefully maintained before the complete network is installed. They will provide general information on precipitation characteristics for the area. In research, however, minimum and optimum networks are the same. An optimum network contains the minimum number of gages required for precise data. Additional gages will be extraneous, and fewer gages will negate the experimental results because the precipitation data will be below the specified accuracy (*15*).

Although all stations should have weighing-recording gages, satisfactory results sometimes can be obtained on larger watersheds when a third to half the gages are 8-inch (20 cm) standard gages. Small-orifice plastic gages can be used in place of standard 8-inch (20 cm) standard gages, especially where that part of the rain-gage network will be discontinued during the winter. The use of nonrecording gages depends on the objectives of the project.

Factors Affecting Accuracy

Rain gages measure the amount of precipitation that reaches the ground. Accuracy depends on inherent inaccuracies in the gage itself, wind velocity at the orifice of the gage, and form of precipitation. Inherent errors can result from bent, damaged, or deformed knife edge and orifice; leak in storage container; inaccurate calibration of measuring container or dip stick; tilted orifice due to settling or improper installation; or evaporation between the end of precipitation and when the gage is read.

The most common errors result from evaporation, adhesion, color, inclination of the gage, splash, wind, faulty technique in measuring catch, and physical damage to the gage. Kurtyka (*21*) estimated the percentage of errors for the following factors:

	Percent
Evaporation	−1.0
Adhesion	−0.5
Color	−0.5
Inclination	−0.5
Splash	+1.0
Subtotal	−1.5
Wind	−5.0 to −80.0

The greatest amount of error in rain-gage catch results from wind. Under exposed conditions, rain-gage catch generally is deficient (*39*). This error is related to windspeed and to the type of precipitation. The decrease in catch increases as wind velocity increases and is greater for snow and light rain than for heavy rain. Wind increases pressure on the windward side of the gage, decreases pressure over the gage, and sets up eddy currents over and within the orifice (*4*). Since windspeed increases with height above a surface, the higher the gage orifice is above ground, the greater will be catchment errors due to exposure.

Some inherent errors are caused by the gage being out of calibration; binding or sticking parts in the weighing mechanism; bent, damaged, or malformed orifice ring; or other mechanical damage to the gage. The cause of these errors, except gage calibration, can be detected by brief inspection during routine visits to the station. The observer should watch constantly for errors and correct them as soon as possible to maintain high-quality records.

Sizable errors may occur in recording total catch. They may or may not be compensating and often change sign amount at the pen reversals. Therefore, the total catch in the bucket should be measured at the end of the storm.

A properly installed pit gage accurately measures rainfall at a point. When the rain gage is placed in a pit with its orifice at ground level, the gage no longer obstructs air movement and the effects of turbulent wind around the orifice are diminished. Conventionally exposed gages, even when shielded, catch less rainfall than pit gages (*31*, *35*). Pit gages are inadequate for snow measurements, however, because of problems with drifting snow under windy conditions. Trash and sediment also tend to collect in pit gages. For extensive rain-gage networks, increased accuracy usually does not warrant the increased cost of installing and maintaining pit gages.

The possibility of inaccurate measurements resulting from vertically placed rain gages in watersheds of steep and complex topography was pointed out by several investigators (*9*,*10*, *17*, *25*). Errors were assumed to be due to the incidence of different volumes of precipitation on sloping surfaces of several areas and exposures where wind prevented the rain from falling vertically. It was recommended that gages be placed with their orifice parallel to the slope of the land. Rain-gage catch was divided by the cosine of the gage inclination so that the volume would be on a horizontal area.

Hayes (*13*) and Leonard and Reinhart (*23*) said that tilted gages were less accurate than vertical gages in well-sheltered sites, such as small openings in heavily forested locations where reduced wind velocities cause precipitation to fall vertically into the gage. In general, rain gages should be installed vertically.

If reasonable care is taken in the readings, errors in measuring the catch once it has been collected in the gage are small compared with the uncertainty due to exposure of the instrument. Daily gages should be read to the nearest 0.01 inch (0.025 cm) where possible; weekly or monthly gages should be read to the nearest 0.10 inch (0.25 cm).

The main sources of error will be inaccurate measures or dip rods, spilling of some water when transferring it to the measure, and inability to transfer all water from the receiver to the measure.

Losses by evaporation also can occur. Evaporation errors are most serious in dry climates and in areas where gages are visited infrequently. Losses can be reduced by placing oil in the receiver (this forms a film over the water) or by designing the gage so that (1) only a small surface is exposed, (2) the ventilation is small, and (3) the internal temperature of the gage does not become excessive. The receiving surface of the gage must be smooth so that the raindrops do not adhere to it. It never should be painted.

In winter, rains often are followed immediately by freezing weather. Damage to the receiver and subsequent loss by leakage can be prevented by adding an antifreeze solution, especially when gages are visited infrequently. Allowance for the solution added must be made when measuring the results. All gages should be tested regularly for possible leaks.

The relative accuracy of rainfall measurements, as sampled by different gages, has been investigated extensively. Allis and others (*1*) reported that over a 16-year period the difference in rainfall catch between a standard 8-inch (20 cm) nonrecording gage and a weighing-recording gage was less than 0.05 percent. Using standard gages spaced 6 feet (1.8 m) apart at nine locations, Huff (*19*) and Huff and Niell (*20*) found that the average differences were insignificant for shower-type storms with precipitation up to 0.50 inch (1.27 cm). Renard and Osborn (*32*) found that maximum intensities were greater for convective storms determined from 6-hour rain-gage records than intensities determined from 24-hour rain gage records for intervals up to 10 minutes.

Court (*7*) reported that if the 8-inch-diameter (20 cm) universal weighing rain gage is properly exposed, calibrated, and evaluated, it will yield hourly precipitation values with standard error of about 0.01 inch (0.03 cm). Reliability within 0.02 inch (0.05 cm) may be assumed.

Correct timing of the recorded precipitation trace and the ability to estimate any errors in the record are important. Three causes of error that can affect timing of the record are backlash, clock rate, and change in chart dimension.

Backlash between the chart drum and the clock spindle delays the start of the record and causes a constant error once the record has started. Backlash in the timing gears can be taken up by turning the drum until the indicated time is about 3 hours fast and then turning it back to the correct time.

Another error may be caused by the clock rate or the use of an unsuitable time scale on the chart. If the difference is small, the rate of drum revolution can be adjusted with the clock regulator. All errors of this type probably cannot be removed by adjusting the regulator because clock rate will vary according to temperature and humidity.

Errors due to change in chart dimensions are caused by variation in humidity. Charts expand and contract as relative humidity increases and decreases, and most chart papers will change more in one direction than in another. Whether changes due to humidity are greater in the time scale or the depth scale depends on how the paper is cut. These changes easily can exceed 1 percent and can amount to 15-or 20-minute error in the time scale or several hundredths of an inch in the depth scale. Charts also creep up the drum because of expansion and contraction. Therefore, the bottom of the chart may be above the bottom flange of the drum in an amount equal to the creep.

All errors can be recognized and corrected if accurate time marks and zero checks are made when the charts are put on and taken off the drum, and at intermediate times when convenient.

Nonrecording Gages

Nonrecording rain gages usually consist of a collector above a funnel leading into a receiver. In the United States these gages have been standardized to the shape of a right circular cylinder with an 8-inch (20 cm) collector orifice diameter. Important requirements of nonrecording gages are:

- The rim of the collector should fall away vertically inside and be steeply beveled outside. The gage for measuring snow should be designed to minimize errors due to constriction of the aperture. Constriction is caused by the accumulation of wet snow above the rim.
- The area of the orifice should be known to the nearest 0.5 percent, and it should remain constant.
- The collector should prevent rain from splashing in or out. This can be done by having the vertical wall sufficiently deep and the slope of the funnel sufficiently steep (at least 45°).
- The receiver should have a narrow neck and should be protected sufficiently from radiation to minimize loss of water by evaporation. Rain gages used in places where daily readings are impracticable should be similar to gages used daily but should have a receiver of larger capacity.

Precipitation in nonrecording rain gages usually is measured by pouring from the gage into a calibrated container or by using a calibrated dip stick, or both. (See section on field measurement of nonrecording gages, p. 37.)

The calibrated container should be made of clear glass with a low coefficient of expansion and should be marked clearly with the size of gage with which it will be used. Its diameter should not be more than about one-third the diameter of the rim of the gage and can be made less than this. The graduations should be finely engraved; generally, they should be marked at 0.01, 0.05, and 0.10 inch (0.025, 0.127, and 0.254 cm). For accuracy, the maximum error of the graduations should not exceed 0.005 inch (0.013 cm).

To achieve this accuracy with small amounts of rainfall, the inside of the measuring cylinder should be tapered off at its base. In all measurements, the bottom of the water meniscus should be taken as the defining line. The measure must remain vertical, and parallax errors must be avoided. It is helpful if the main graduation lines are repeated on the back of the measure.

Dip rods should be made of cedar wood or other material that absorbs little water and reduces capillarity. Wooden dip rods are unsuitable if oil has been added to the collector to suppress evaporation of the catch. Therefore, use rods of metal or other material from which oil can be cleaned. These rods should have a brass foot to avoid wear and should be graduated according to the cross section of the gage orifice and the receiving can, allowing for displacement due to the rod itself. Marks should be shown for at least every 0.02 inch (0.051 cm). The maximum error in the dip-rod graduation should not exceed +.005 inch (0.012 cm) at any point.

National Weather Service Standard 8-Inch (20 cm) Gage

The National Weather Service standard 8-inch (20 cm) gage, figure 1.6, consists of an overflow can, measuring tube, rainfall funnel, measuring stick, and wooden or metal support. The top portion of the funnel has an 8-inch (20 cm) inside diameter and a funnel-shaped bottom that conducts any liquid precipitation caught in the receiver into the tall, cylindrical measuring tube. To measure rainfall depth easily to hundredths of an inch, the measuring tube has a cross-section area that is one-tenth the cross-section area of the funnel. Therefore, when 1 inch (2.54 cm) of rain falls into the funnel, the measuring tube is filled to a depth of 10 inches (25.4 cm). Accordingly, the scale of the measuring stick used with the tube is expanded 10 times. Since the scale is graduated to hundredths of an inch, the correct depth of water in the tube is read directly to hundredths from the stick. The measuring stick is 20 inches (50.8 cm) tall and holds exactly 2.00 inches (5.08 cm) rainfall. Additional rainfall will overflow into the outer can. Since rainfall depths in the overflow can are not increased 10 times, this measuring stick should not be used in the can. Instead, water from the can should be poured into an empty measuring tube for direct measurement with the stick. With the rainfall receiver and the measuring tube removed, the overflow can serves as a snow gage and is used in the winter for collecting all forms of precipitation. It also is used to cut snow samples to determine their water equivalent.

Operation and Maintenance

To maintain accuracy of the rainfall catch, protect the measuring tube and rim of the receiver from dents or other damage that might alter their shape. Correct immediately any evidence that the tube or overflow can is leaking or that the receiver is not level.

When freezing temperatures or snow are likely, remove and store the rainfall receiver and measuring tube. The overflow can will be exposed to catch any precipitation. Freezing water may split or expand the measuring tube, rendering it useless.

In winter, the precipitation gage is not equipped with a windshield. Place snow boards (depth markers) on the surface of the snow for

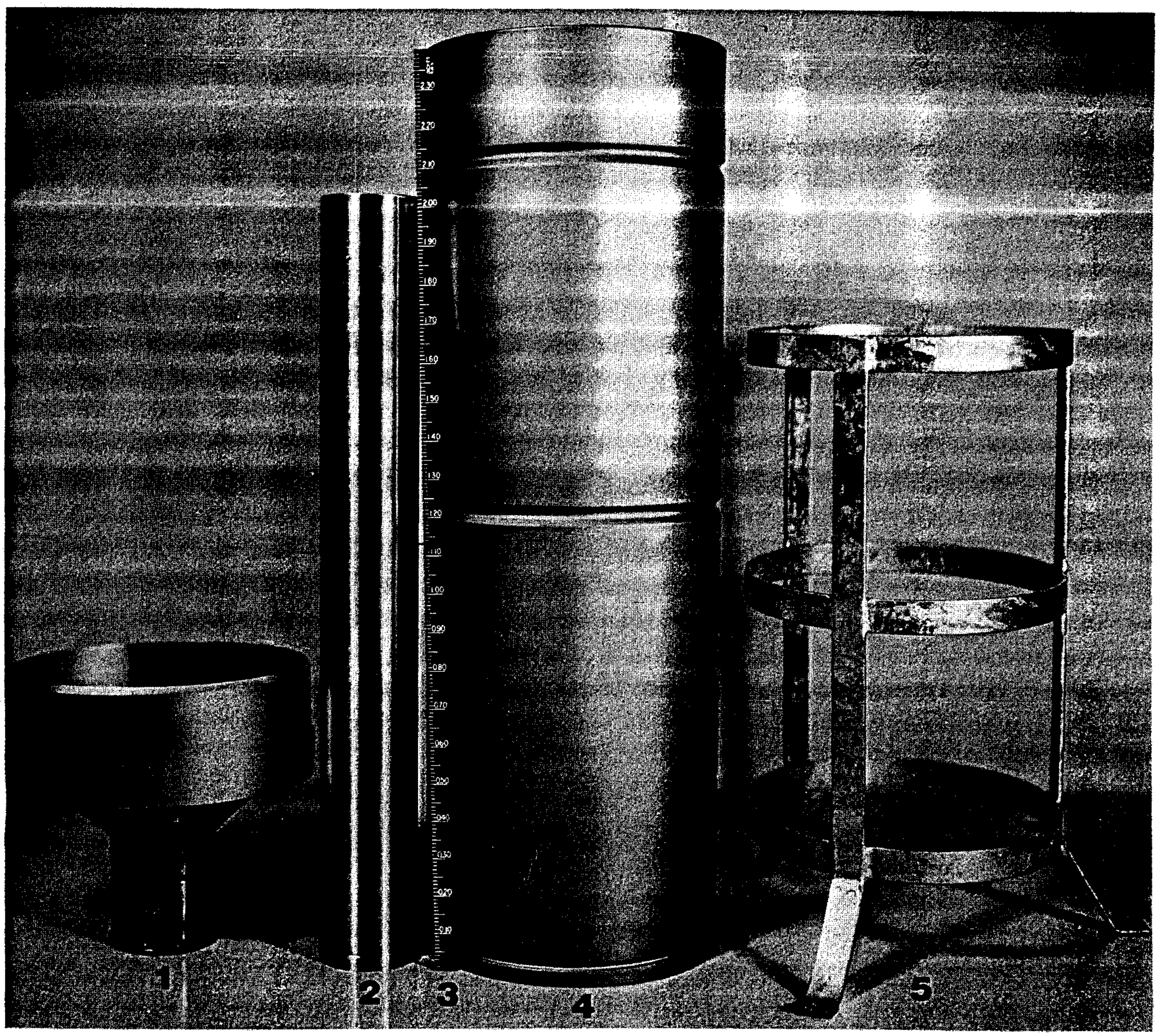


FIGURE 1.6.—National Weather Service standard 8-inch (20 cm) gage. This nonrecording precipitation gage consists of (1) receiver, (2) measuring tube, (3) measuring stick, (4) overflow can, and (5) metal support.

better sampling of snowfall. Place markers where the depth of snowfall represents the average depth over the area surrounding the gage and where drifting is minimal. Where the depth is frequently nonuniform, use several markers, if practicable, to get a representative measurement. Note on the observation form when the gage catch differs significantly from the water equivalent of samples cut from the surface. Differences of more than about 5 percent are significant. Record the larger amount as the snowfall for the observation period. Note the smaller amount and indicate whether it is from the gage or sample.

Storage Gages

Storage gages are used in remote areas where inspections are infrequent. They are used commonly in isolated mountain areas to measure winter snowfall, and their size depends on the expected precipitation. The Sacramento totalizer is a popular storage gage in the United States (fig. 1.7). It has a truncated right circular cone mounted on a tower above the maximum expected depth of snow and surrounded by a windshield to reduce the effects of wind on catch. The Sacramento gage with an 8-inch (20.3 cm) orifice may be capped by snow if the snow is frequently wet and sticky. In such locations, gages with 12-inch (30.5 cm) orifices are recommended to prevent capping.

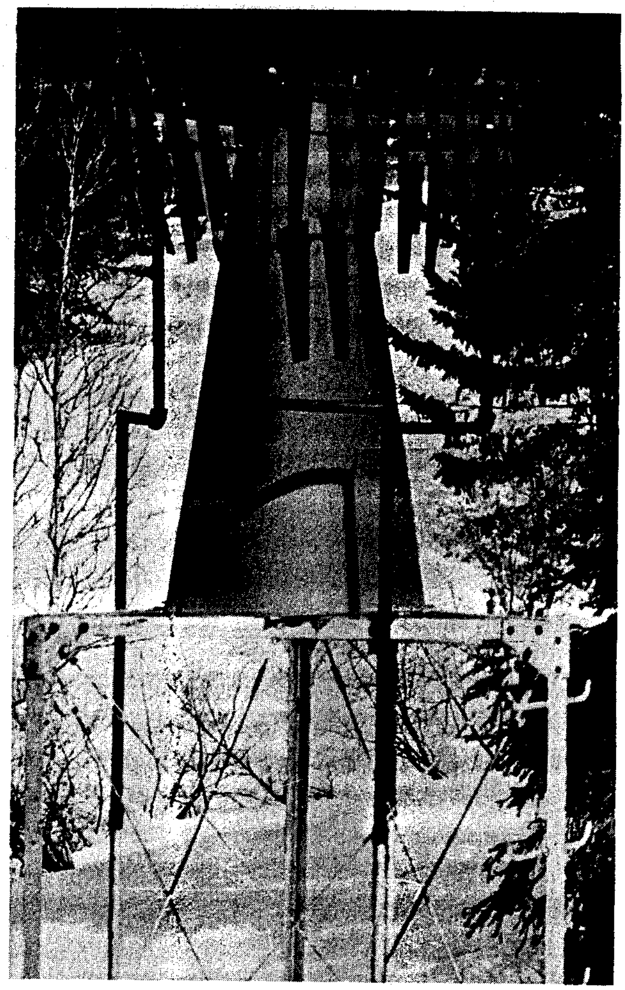


FIGURE 1.7.—Sacramento storage gage.

Operation and Maintenance

In operation, charge the storage gages with an oil-antifreeze solution. This will melt the snow, prevent the solution from freezing, and preserve the catch by retarding evaporation. Use an automotive antifreeze such as ethylene glycol or alcohol. A solution of 30 percent calcium chloride and 70 percent water by weight will result in an antifreeze with a freezing point of −60°F (−51°C). If calcium chloride solution is used, add 2 pounds (907 g) of potassium chromate and 3/4 pound (340 g) of hydrated lime to reduce corrosion.

To suppress evaporation, use an oil that allows easy passage of the precipitation and at the same time completely covers the solution. A light motor oil with specific gravity of 0.8 to 0.9 can be used, or new or used electrical transformer oil can be obtained from a local electric company.

The quantity of oil-antifreeze solution required is based on the expected maximum precipitation between observations. Generally, the initial charge should equal 1.5 times the normal precipitation but should not exceed one-third the capacity of the gage. The most reliable method of measuring precipitation in storage gages is to weight the catch, subtract the weight of the initial charge, and convert the results to inches of water. Taps in the bottom of the gage permit quick draining.

During winter the solution may freeze in the upper layers due to stratification of the antifreeze. Occasional stirring during routine visits will usually forestall such action. If the problem becomes serious, the U.S. Department of Agriculture Forest Service has developed a system whereby the solution is in a constant state of agitation by allowing nitrogen bubbles to rise through the solution from the bottom of the gage.

Other Nonrecording Gages

Nonrecording gages of other shapes and dimensions (fig. 1.8) sometimes are used either as primary gages or secondary gages to fill in gaps in a network of standard or recording gages. These gages usually have a support that can be mounted on metal or wooden posts. In a network, all gages should be installed with the orifice level and at the same height above the ground. Because most plastic gages will suffer from freezing and thawing, their use generally is restricted to rainfall measurements. Metal gages can be used in winter just as the National Weather Service standard 8-inch (20 cm) gage is used. Gages with orifices 3 inches (7.6 cm) or more in diameter are usually accurate enough for supplementary use in an intensive network. Gages with small orifices are less accurate primarily because they are read directly and do not have the magnified scale of larger gages.

Recording Gages

Three types of recording precipitation gages in general use are weighing, tipping bucket, and float. The only satisfactory instrument for measuring both liquid and solid precipitation is the weighing-type gage.

Several rainfall intensity recorders have been designed and used for special purposes. They are not recommended for general networks, however, because of their complexity. A satisfactory record of rainfall intensity can be determined from a float- or weighing-type recorder by providing the proper time scale.

Whether the rainfall recorder operates by weighing the rise of a float, the tipping of a bucket, or other method, these movements must be converted into a form that can be stored and analyzed later. The simplest method of recording is to move a time chart by a spring or electrically driven clock past a pen that moves as the float or weighing device moves. Two main types of charts are:

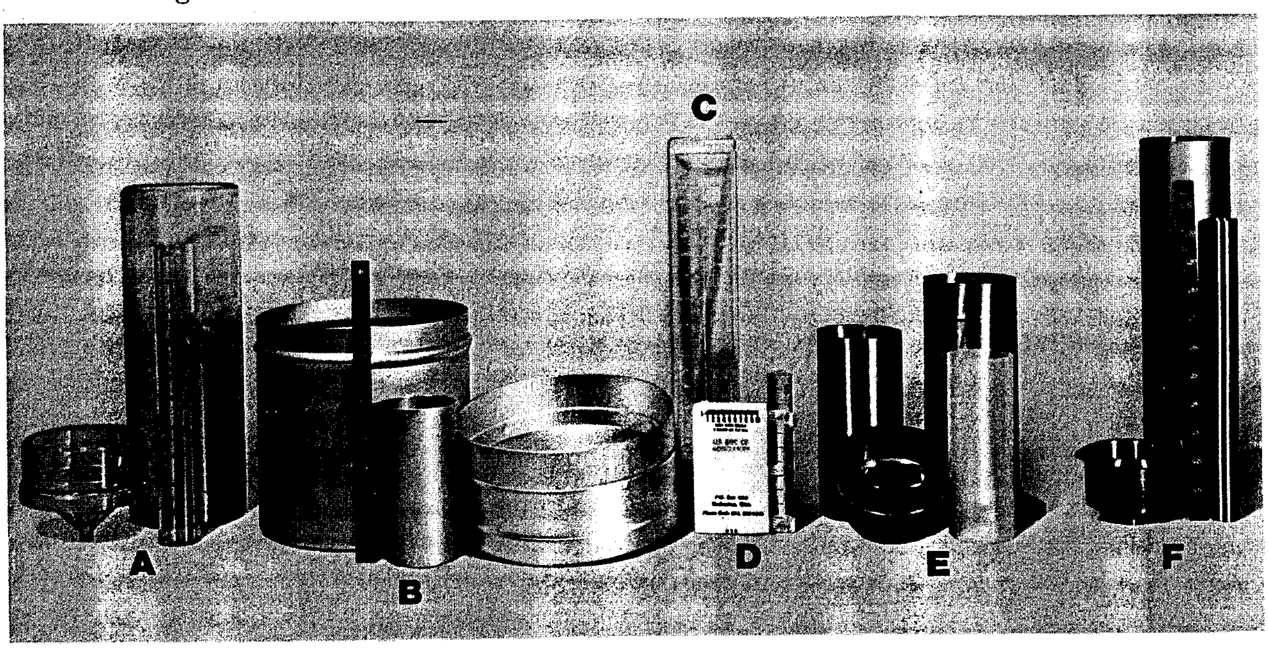


FIGURE 1.8.—Nonrecording rain gages: (*A*) 4-inch (10.2 cm) self-reading, three-piece plastic gage; (*B*) 7⅝-inch (19.4 cm) three-piece metal gage with dip stick; (*C*) 2½-inch (6.4 cm) by 2¼-inch (5.7 cm) wedge-shaped self-reading plastic gage; (*D*) ¾-inch (1.9 cm) self-reading glass gage with support; (*E*) 3½-inch (8.9 cm) four-piece, metal and plastic, Canadian standard gage; and (*F*) 3-inch (7.6 cm) three-piece metal gage with dip stick.

1. The drum chart, which is secured around a drum that should revolve once a day (exactly), once a week, or another period as desired;

2. The strip chart, which is driven on rollers past the pen arm. By altering chart speed, the recorder can operate from 1 week to a month, or even longer. The time scale on this chart can be large enough to calculate intensity easily.

The movement of a float, bucket, or weighing mechanism also can be converted into an electric signal. This signal can be transmitted by radio or wire to a distant receiver where records can be made from several rain recorders on data-logging equipment.

Most clocks for rain gages can be geared to provide one drum revolution in 6, 12, 24, or 192 hours. The time scale selected will depend on the storm characteristics being studied, the shortest interval to be read from the charts, and the frequency or ease of servicing gages. Table 1.2 is a guide for deciding which time scale to use. Generally, the shorter the interval, the more difficult it is to extract data from the charts because of the crossing and recrossing of trace lines between chart changes. For ease in chart reading, use the longest interval that is compatible with the study objectives.

Universal Weighing-Type Gage

The Universal weighing-type gages in common use consist of a collecting bucket resting on a weighing platform and frame, which are suspended from an isoelastic spring. Precipitation collected in the bucket increases the load on the spring, which lowers the platform and frame. This deflection is proportional to the amount of precipitation collected. The movement of the frame is transmitted through a system of links and levers to the pen, which marks a graduated revolving chart. The ratio of the frame movement to the pen movement is controlled by the position of the pinions relative to the pen-arm system pivot. Calibration is accomplished by adjusting these pinions. The gage normally has no provision for emptying itself, but a system of levers can make the pen traverse the chart any number of times.

TABLE 1.2—*Guide for selecting time scale for recording rain-gage clocks*

Time for 1 revolution of drum (hours)	Shortest interval between chart time lines	Shortest interval on chart
	Minutes	*Minutes*
6	5	1
12	10	2
24	20	5
192	120	30

Falling precipitation is directed into the bucket through a collecting ring and funnel. The diameter of the collecting ring is 8 inches (20 cm), providing a catchment area of 50.26 in^2 (324 cm^2). The weight of this volume of water is usually about 1.8 pounds (816 g).

The universal weighting-type gage has been designed to prevent excessive evaporation losses, which may be reduced further by adding oil or other evaporation suppressant to the container. Difficulties due to oscillation of the balance in strong winds can be reduced by fitting a damping mechanism. The main usefulness of the weighting-type gage is in the direct recording of both solid and liquid precipitation. Solid precipitation does not need to be melted before it can be recorded.

Most universal weighting-type gages are the dual traverse type with a 12-inch (30.5 cm) capacity. Many single-traverse gages have a capacity of 6 inches (15.2 cm), however, and a few triple-traverse gages have a capacity of 3 inches (7.6 cm) per traverse and a capacity of 9 inches (22.9 cm) in use. All these gages have basically the same design. The only difference is in the lever system used to transmit platform deflection to the pen arm.

Operation and Maintenance

Clocks should be cleaned, oiled, and adjusted by a qualified jeweler once a year or during the year when necessary. At locations where several recording gages are in operation, have several spare clocks on hand. Replacement clocks permit continuous operation of a gage when a clock needs to be removed for servicing or repair.

The ideal trace should be as thin as possible without becoming illegible or without the pen scratching the paper. To achieve and maintain such a trace, treat the pens carefully. Clean them regularly, using warm water, commercial pen cleaner, carbon tetrachloride, and so forth. Pens used on most weighting-recording rain gages are simple triangular reservoirs attached to a short holder that slides over the end of the pen arm. When the pen fails to feed ink, start the flow by drawing a piece of thin, strong paper, such as cellophane or bond, between the nibs of the point to clean and wet the inner faces. The nibs must not be permanently bent or separated. Insert the paper into the slot only about half the slot depth. Hold the pen away from the chart with the pen bar during the operation. The paper should be drawn through the nibs with a motion directed away from the ink reservoir and toward the point.

A trace that is too wide sometimes can be improved by pinching the nibs together with the finger to produce a finer trace. Carry spare pens to replace pens that have been damaged or produce too wide a trace. Damaged pens may be restored by cleaning the points and then sharpening them by honing on a hard Arkansas stone. A magnifying glass of about 7 power is necessary to make certain the nibs are square, true, and sharp.

Ink that is exposed to air absorbs water and becomes diluted, especially in damp weather. When the trace on the chart becomes faint or otherwise unsatisfactory, remove the ink from the pen reservoir with blotting paper and refill the pen. Keep the ink bottle tightly closed when it is not in use.

When freezing temperatures or snow are likely to occur, the gage must be placed at a height greater than the expected snow accumulation. The weighing mechanism should be cleaned, and, if lubricated at all, a dry graphite should be used. The bucket should be charged with an oil-antifreeze solution to melt the snow by chemical action, prevent the solution from freezing, and preserve the catch by retarding evaporation. Add ethyl glycol antifreeze (approximately 400 ml (0.1 g)) to the bucket until the pen rests on the 1/2-inch (1.3 cm) line. Add a lightweight oil until the pen is raised to the 3/4-inch (1.9 cm) line. Use motor oil with a specific gravity of 0.8 to 0.9, or, use new or used electric transformer oil from the local electric service company. To prevent freezing because of stratification, stir the solution lightly during each visit. The bucket should be emptied and recharged when the pen reaches the 3-inch (7.6 cm) line because the solution will be diluted and may freeze. If more than 2 1/2 inches (6.4 cm) of precipitation is expected between visits, increase the initial charge of antifreeze proportionally but never allow it to exceed one-third the capacity of the gage.

Once a year on a clear, warm day, wash all moving parts of the weighing mechanism and spring with a grease-dissolving solvent such as gasoline, benzine, or carbon tetrachloride. Carefully observe all safety requirements. Reliability can be attained without using any lubricants on the moving parts if all parts are disassembled before gage installation; all shafts and bushings are cleaned with fine steel wool and polished with crocus cloth; and all parts are washed in solvent, rinsed in hot water, blown dry, and carefully reassembled. Do not use lubricants when the gage is in a dusty environment or when it is operated during extremely cold weather. Use a nongumming oil or graphite if lubrication is desired.

Assemble the following items to be taken to the field:

- A chart for each instrument, a clipboard, nd a fieldbook.
- An assortment of screwdrivers, and both fixed and adjustable open-end wrenches.
- A few cleaned and sharpened recorder pens and a pen cleaner.
- A bottle of grease-dissolving solvent; a small syringe or oil can for washing the mechanism with cleaning solution; and, if lubrication is desired, a bottle of nongumming oil or graphite with a small camel's hair brush for applying it.
- A piece of fine steel wool and a piece of crocus cloth or a honing stone.
- A set of calibration weights each equal to 1.8 pounds (816 g) per inch of precipitation.
- A 2–H pencil and blotter.
- Extra spindles.
- Clock spindle washers of various thicknesses, such as 0.060, 0.075, 0.090. 0.105, 0.120, and 0.140 inch (0.15, 0.19, 0.23, 0.27, 0.31,and 0.36 cm).
- Thin, noncorrosive metal bands for placing on the pen arm to lengthen the distance from pen-arm shaft to pen.

• A three-sided windbreak to shield the gage during field calibration.

Before attempting field calibration, carefully study all field notes and chart notations of gages to be calibrated to find errors or discrepancies noted by the observer during weekly servicing. Spare clocks should be available to replace those showing consistent time errors on the charts. Wherever possible, spare gages should be available to replace network gages that that are to be brought into the shop for major maintenance or repairs. To maintain a network at peak efficiency, each gage should be brought into the shop at regular intervals of about 2 years. It should be completely disassembled, cleaned, polished, reassembled, and carefully calibrated. High-quality records can be assured only by regular maintenance.

The techniques of servicing single-, dual-, and triple-traverse gages are essentially the same. Since the dual-traverse gage is the most popular, detailed instructions for servicing and calibrating it will be given with a short description of the differences between dual-traverse and single-traverse gages.

Dual-Traverse Gage

The dual-traverse gage (fig. 1.9) has a capacity of 12 inches (30.48cm) precipitation. The first 6 inches (15.24 cm) are recorded on the rising traverse, and the second 6 inches (15.24 cm) are recorded on the falling traverse. The identifying numbers in figure 1.9 refer to specific parts of the gage mechanism involved in the calibration. The specific calibration steps are as follows:

1. Upon arriving at the rainfall station, set up the windbreak. Remove the collector ring by giving it a slight clockwise turn and lifting it from the case. Raise the inspection door and remove the pen from the chart. Remove the bucket and the weighing platform. Remove the screws that hold the case to the base and lift the case from the base. Replace the weighing platform and the bucket. The entire weighing mechanism is now exposed for primary adjustments and calibration. Wash the spring and all moving parts with the cleaning solution, lubricate if desired, and work the mechanism by moving the bucket platform up and down.

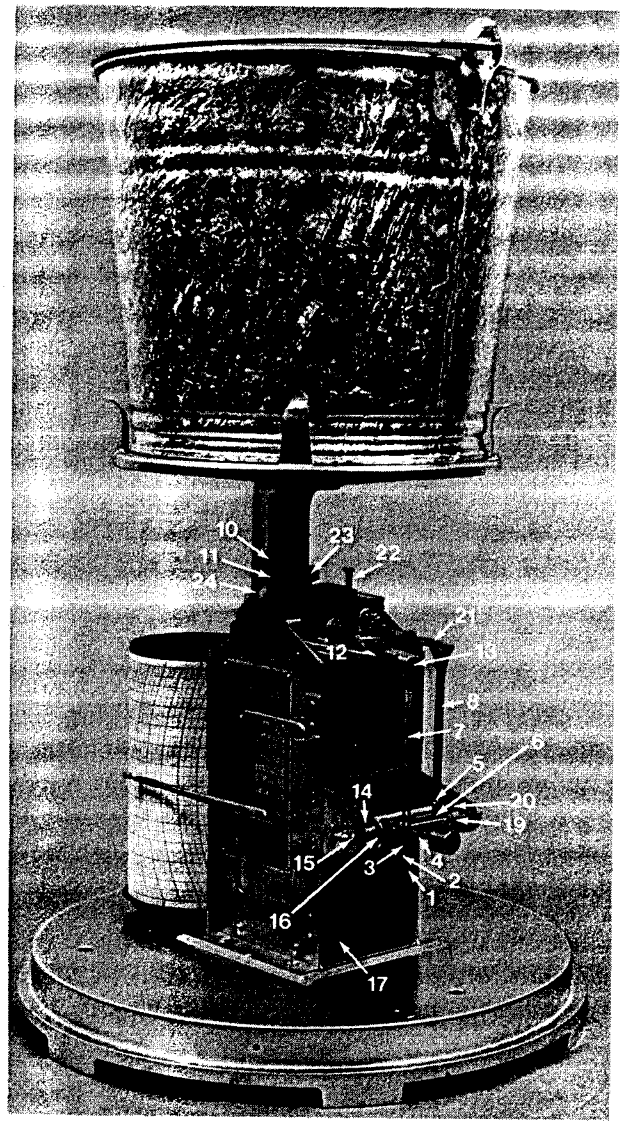


FIGURE 1.9.—Dual-traverse rain gage showing the location of some stops and lintages.

2. If the gage has a dashpot, lift its cover and check to see if the fluid level is high enough to cover the piston at its highest position. A small amount of fluid can be added without removing the dashpot. If it is necessary to remove the dashpot, remove the two thumbscrews holding it, lift the cover, and slide the dashpot forward while swinging the damper piston forward. At most locations gages should be operated with dashpots empty to provide more accurate records of the intensity of short rainfall bursts. However, dashpots should be

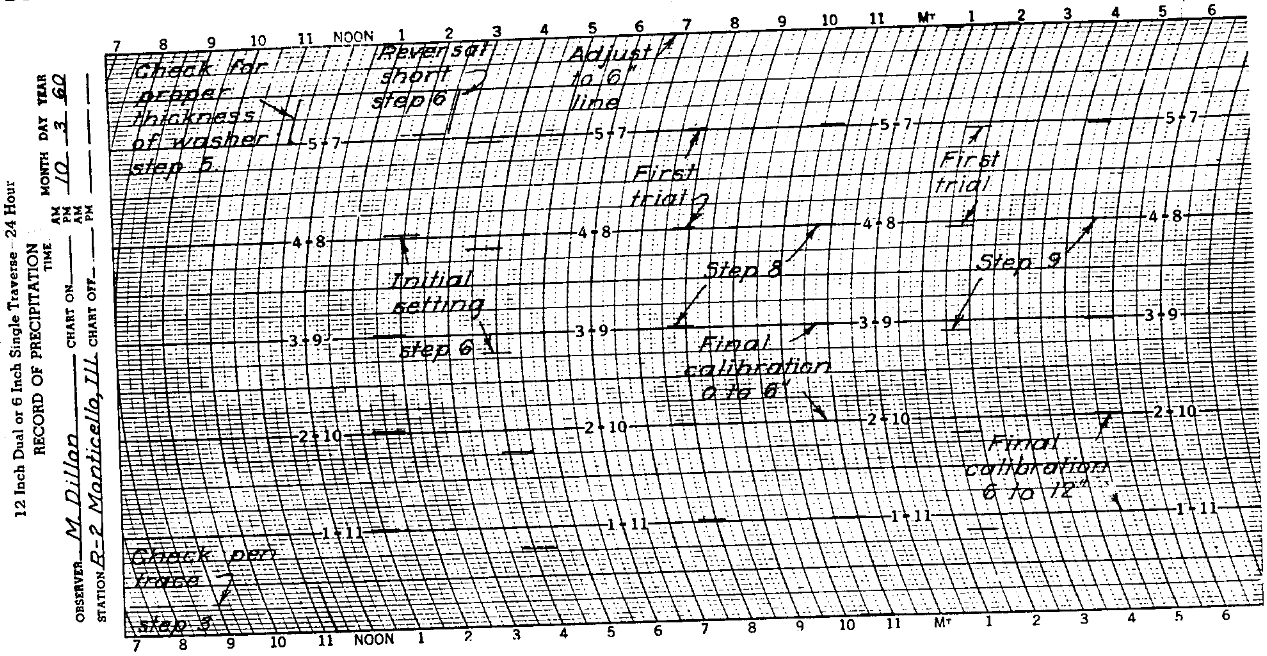


FIGURE 1.10.—Chart record of a dual-traverse rain gage calibration.

filled at locations where wind causes pen vibration when dashpots are empty.

3. Place the calibration chart (fig. 1.10) on the clock cylinder and install it on the clock. Be sure the chart fits snugly and rests on the flange of the drum throughout the circumference. Place a clean pen on the pen arm and fill it about half full of ink. Place a small weight in the bucket and place the bucket on the platform with the handle opposite the overflow pipe. A displacement of the center of gravity of the weight in a direction perpendicular to the rotational axis of the casting does not affect the accuracy greatly. If the bucket does not have an overflow pipe, the axis of the bucket handle should be parallel to the rotational axis of the casting and the handle should always be in the same position. Test the pen by rotating the drum to make a trace about 1 inch (2.54 cm) long. If the trace is too thick or ragged, clean, pinch, and hone the pen until a clear, fine trace is obtained. If more than one trial is necessary, place a larger weight in the bucket to raise the pen above the first trace.

4. After a satisfactory trace is obtained, check the gage for binding by slightly depressing the platform by hand and then slightly raising it. Allow the pen to return to its normal position in each case by gently releasing the force. Rotate the drum after each operation to give two pen traces. A vertical distance between these two lines of more than 1/50 inch (0.051 cm) indicates binding, which should be corrected before proceeding. If the source of the binding cannot be found easily in the field, replace the gage with a spare gage and take the binding gage into the shop for a major overhaul. Check the base with a small level and adjust, if necessary, to make sure it is horizontal.

5. To see if the pen trace follows the time line, place the pen on the chart and depress the platform to make a 1-inch (2.54 cm) line near the bottom of the chart. Depress the platform further to mark a 1-inch (2.54 cm) line near the top of the chart. (Shift the pen from the chart when moving from one position to another.) The two lines should be made within 1 minute of each other. Failure of these lines to agree within 1/50 inch (0.051cm) may indicate a bent spindle. Remove the clock, replace the spindle, and repeat the check. If the arc described by the pen is the same for two or more spindles but still does not follow a time line, it indicates improper thickness of the washer between the base and the gear. When the arc falls to the

right of the time line at the top of the chart, the clock spindle washer is too thick and vice versa. Change the washer as indicated and check until agreement with the time line is good.

6. Remove the small weights used in step 3 from the bucket and adjust the pen to the zero line of the chart with the adjusting nut (10) of figure 1.9. Place weights, each equivalent to 1 inch (821 g) of precipitation, in the center of the bucket one at a time and record the pen reading for each in the fieldbook (fig. 1.11). Determine the adjustment needed by plotting the pen error against the total amount of the weights and connect the points with a smooth curve, (fig. 1.12). If the plotted points define a smooth curve, make the first adjustment according to step 7. If the points for each traverse fall on a straight line, proceed as in step 8.

7. This step covers the primary adjustment of levers and linkages and usually will be necessary only for repaired or reassembled gages in the shop. Add weights equal to half the gage capacity (normally 6 in. (15.2 cm)). The milled surface of the casting [12] should now be horizontal. (This may be checked by using a small level or by measuring up from the base to the top surface of the casting at two extreme positions, using a thin piece of stiff cardboard or a small scale.) Change the spring tension with the large knurled nut [23] until the casting is horizontal. With weights equal to one-fourth the gage capacity in the bucket (normally 3 in. (7.62 cm)), loosen the setscrew [5] on the rear link [8] and adjust the slide [6] so that the axis of the pinion and the rotational axis of the rear 6-inch (15.2 cm) range lever [20] are in a horizontal plane. Loosen the setscrew on the

WATERSHED AND HYDROLOGIC STUDIES

FIELD NOTES

PROJECT NO. Monticello (Town) Illinois (State) STATION NO. Recording Gage R-2 FARM (RANCH)

DATE 10 (Month) 3 (Day) 60 (Year) WEATHER: 60 °F. CLEAR ~~CLOUDY RAIN SNOW WINDY~~ CALM. (Cross out words not applying) OBSERVER M. Dillon (Name)

Calibration of Rain Gage 1298 (Dual Traverse)

Initial Wt. in Bucket.	Check Chart Line	Error	
0	0	0	
1.00	1.01	+0.01	
2.00	2.01	+0.01	Curvilinear
3.00	3.01	+0.01	Perform step 7
4.00	4.03	+0.03	
5.00	5.05	+0.05	Reversal short at 5.50 inches
6.00	7.05	+1.05	
7.00	8.13	+1.13	
8.00	9.20	+1.20	Curvilinear
9.00	10.22	+1.22	
10.00	11.22	+1.22	
11.00			
12.00			

FIGURE 1.11.—Field notes for a dual-traverse rain gage calibration.

pen-arm holder until the pen arm is parallel to the bracket [16]. Loosen the bracket setscrew [14] and rotate the pen and bracket until the pen is on the 3-inch (7.62 cm) chart line. Tighten the bracket setscrew. Loosen the setscrew on the front 12-inch (30.5 cm) range lever [4], hold the pen at the 3-inch (7.62 cm) line and rotate and set the range lever in a horizontal plane. (To set the range levers in a horizontal plane, set the axis of the pinions at the elevation of the pen-arm axis shaft by measuring up from the base.) When setting the front and rear range levers, be sure the links [7 and 8] remain in a plane perpendicular to the pen-arm axis shaft.

Adjust the stopscrews [11 and 22] so that when the bucket is removed, the pen will set halfway between the zero line and the bottom

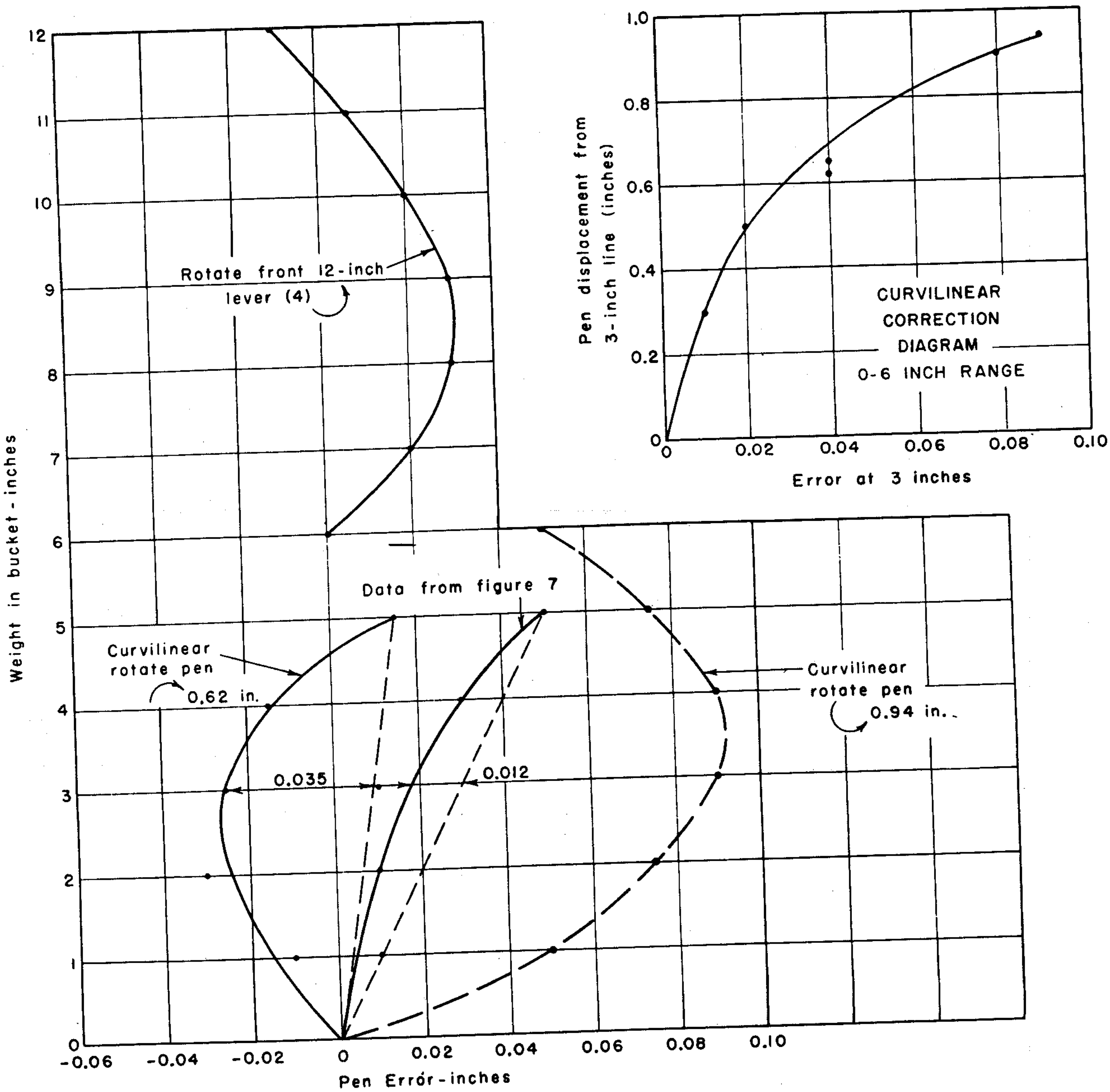


FIGURE 1.12.—Graphs to determine type and extent of adjustment necessary for dual-traverse rain gage.

flange of the clock cylinder. Adjust the high range stopscrew [24] so that the pen will set halfway between the 12-inch (30.5 cm) line and the bottom flange when the capacity of the gage is exceeded. If necessary, these stops should be checked and reset during calibration to prevent damage to the pen arm.

8. Place weights equal to half the gage capacity in the bucket. Lower screw [1] on the bottom of link [7] until it almost falls out. Loosen screw [2] on the side of the link and let the slide [3] fall to its lowest position. Loosen screw [5] on the rear link [8] and set the slide so that the pen is at the 6-inch (15.24 cm) line. Minor adjustments may be made with the knurled knob [10]. Remove all weights and note the pen registration. If the pen is above the zero line, lengthen the lever arm of the rear calibration lever [21]. If the pen is below the zero line, shorten the lever arm of the rear calibration lever. Again, add six weights, adjust the slide on the rear link [8] and repeat the calibration check at 6 inches (15.24 cm) and 0 until the pen registers correctly at both points. If the calibration lever [21] has been moved as far as possible and the gage cannot be calibrated at 0 and 6 inches (15.24 cm), change the number of active spring coils and repeat step 7. If the calibration lever [21] has been shortened as much as possible, decrease the number of spring coils. If the calibration level [21] has been lengthened as much as possible, increase the number of spring coils.

Place weights in the bucket, one at a time, and record the pen reading for each increment from 0 to 6 inches (15.24 cm). Plot the pen error as in step 6. If step 7 has been performed carefully, the error should be negligible. If error exists, correct it by placing three weights in the bucket and checking to see if the milled surface of the casting [12] is horizontal. If it is, determine the error at 3 inches (7.62 cm), loosen the pen bracket setscrew [14], and rotate the pen clockwise or counterclockwise according to the correction curve shown in figure 1.12. For example, if the pen error at 3 inches (7.62 cm) is 0.03 inch (0.076 cm) and positive, rotate the pen counterclockwise and set at 3.0 minus 0.6, or 2.4 inches (7.62 minus 1.52, or 6.1 cm). The pen should then be reset at 3 inches (7.62 cm) by adjusting the stop [6] on the rear link [8]. Check the 0- to 6-inch (15.24 cm) calibration with weights and repeat step 8 until the maximum error is acceptable. A total error range of 0.02 inch (0.05 cm) in the 0- to 6-inch (15.24 cm) range is not difficult to achieve.

9. Place six weights in the bucket. The pen should now be at the 6-inch (15.3 cm) line. Turn the adjusting screw [1] until the stop [3] just touches the pinion of the front 12-inch (30.48 cm) range lever [4]. Tighten the setscrew [2]. The pen should now reverse at the 6-inch (15.24 cm) line as the slightest amount of weight is added to the bucket. If necessary, file down the end of the slide [3] on link [7] to meet the requirements of primary adjustments and to have the reversal occur at the correct location. Add weights equal to 12 inches (30.48 cm). If the pen falls short of the 12-inch (30.48 cm) line, shorten the front lever arm [13]; if it goes beyond the 12-inch (30.48 cm) line, lengthen the lever arm. Repeat this procedure until the gage registers correctly at 6 and 12 inches (15.24 and 30.48 cm). Each time the lever arm [13] is adjusted, it changes the reversal point, therefore, slide [3] also must be readjusted. Check the gage registration between 6 and 12 inches (15.24 and 30.48 cm). A negative error can be corrected by rotating the front 12-inch (30.48 cm) range lever counterclockwise on the pen-arm shaft. Make the reversal adjustment each time the range lever is rotated. Make adjustments until the maximum error is acceptable.

10. Remove all weights and set the pen at zero with the adjusting nut [10]. Check the gage over the 0- to 12-inch (30.48 cm) range, and record the pen registration for later reference. The maximum error at any inch line should be no greater than 0.04 inch (0.1 cm). Although greater accuracy is possible, the time required for adjusting must be considered.

11. Carefully check the collector ring for damage or malformation since gage chart measurements are based on the assumption that the orifice is a circle, 8 inches (20.3cm) in diameter. The knife edge should be sharp, and the ring should be a true circle. Minor irregularities can be corrected by light filing and polishing. An orifice slightly out of round sometimes can be corrected by pressing on the outside of the collector ring or by rolling the ring, under hand pressure, across a hard object

such as a board. If these methods fail to correct the situation, the collector ring must be replaced.

12. Remove the bucket and weighing platform, place the case over the weighing mechanism, and screw it to the base. Replace the weighing platform and the bucket, and replace the collector ring by putting it on the case and giving it a slight counterclockwise turn. Check the collector ring with a level to make sure it is in a horizontal plane.

Single-Traverse Gage

Calibrating the single-traverse gage is essentially the same as calibrating the dual-traverse gage. Follow steps 1, 2, 3, 4, and 5 of the previous section. In calibrating the single-traverse gage, refer to figure 1.13. If evidence of binding is found in step 3, check the link between members [I] and [W], the shaft that supports [W] and the pen arm, and the shaft and castings [B]. Proceed as follows:

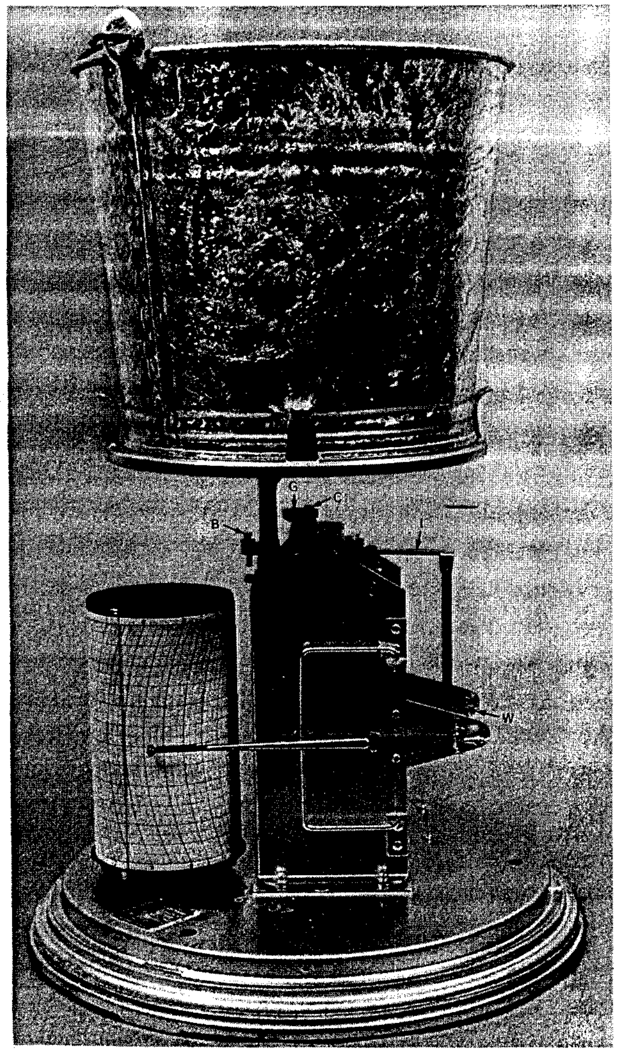


FIGURE 1.13.—Single-traverse rain gage showing the location of some stops and lintages.

1. With the bucket empty, set the pen at zero by using the adjusting screw [G]. Adjustment of [G] will not affect the calibration of the gage. Adjust stops [B] and [C] so that the pen will travel slightly below the zero line without touching the drum flange when the bucket is lifted, and slightly above the printed part of the chart without getting off the chart when the bucket is full or weighted beyond the capacity of the gage. When adjusting stops [B] and [C], shift the pen from the chart when moving it from one stop to another. Check the zero setting and reset if it was disturbed in adjusting the stops.

2. Place weights in the center of the pail, one at a time, and record the pen reading for each weight. On regular graph paper, plot the pen error as the abscissa and the correct reading as the ordinate (see fig. 1.14). If the error plots as a straight line, proceed as in step 4; if it plots as a smooth curve, proceed as in step 3.

3. If the pen error plots as a curved line, place calibration weights equal to half the capacity of the gage in the center of the bucket. At this pen reading, the link [W] should be horizontal. This can be checked and adjusted by sighting. Place yourself about 3 feet (0.91 m) from the gage and line the top of the pen-arm shaft into the chart reading 0.05 inch (0.127 cm) above the centerline of the chart (on 6-in(15.24 cm)) gage, this would be 3.05 in. (7.75 cm) or center the shaft onto the chart centerline. Keeping the eye at this level, bring the rectangular link [W] into a horizontal position by adjusting screw [G]. This adjustment will cause the pen to read something other than half capacity. Correct this by loosening the setscrew that holds the pen arm on its shaft and rotating the pen arm until the pen rests on the horizontal centerline of the chart. Maintaining this parallelism of pen arm and link [W] insures simultaneous movement through the same central angle.

WATERSHED AND HYDROLOGIC STUDIES

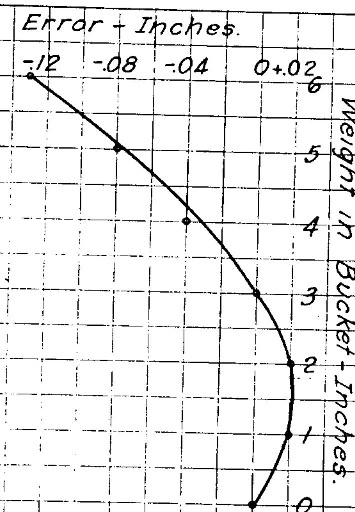
FIELD NOTES

PROJECT NO. Fennimore, Wisconsin (Town) (State) STATION NO. Recording Gage R-1 FARM (RANCH)

DATE 10-15-1941 (Month) (Day) (Year) WEATHER: 55 °F. CLEAR ~~CLOUDY~~ ~~RAIN~~ ~~SNOW~~ ~~WINDY~~ CALM. (Cross out words not applying) OBSERVER N. E. Minshall. (Name)

Calibration of Gage Chart No. 356

Weights in Bucket Inches of Rain	Chart Line Reading	Error	
1.00	1.02	+0.02	
2.00	2.02	+0.02	
3.00	3.00	0	Original Setting of Gage
4.00	3.96	-0.04	
5.00	4.92	-0.08	
6.00	5.87	-0.13	
3.00	3.00		← Original Setting
3.00	3.37	0.37	← After levelling link "W"
3.00	3.00		← Reset pen to 3.00"
5.00	4.92	-0.08	
5.00	4.99	-0.01	Adjusted link "I"
1.00	1.00		
2.00	2.01	+0.01	
3.00	3.00		Final check at each inch
4.00	4.00		
5.00	4.99	-0.01	



16—74917-1-F GPO

ORIGINAL

FIGURE 1.14.—Field notes for a single-traverse rain gage calibration.

4. If the pen error is not curvilinear, remove the weights from the bucket, reset stops [B] and [C], and check the zero setting. Place weights in the bucket to within 1 inch of the gage capacity. Place the pen on the chart and rotate the clock cylinder to mark a trace about ¼ inch (0.64 cm) long. If the chart reading is in error by more than 0.02 inch (0.05 cm), adjust the length of link [I] and repeat the step. If the chart readings are too small, link [I] must be moved out. If the short readings are too large, link [I] must be moved in. Repeat step 2 until the error throughout the range of the gage is acceptable.

5. Replace the gage cover and collector ring, check the collector ring with a level to be certain it is horizontal, and place the gage in operation.

Tipping Bucket Rain Gage

The tipping bucket rain gage consists of a collector orifice, 12 inches (30.48 cm) in diameter, that funnels rainfall to a small outlet directly over a tipping bucket mechanism (fig. 1.15). The tipping bucket is divided into two equal compartments, each holding exactly 0.01 inch (0.025 cm) of rainfall. When one compartment fills, the bucket tips (momentarily closing a mercury-in-glass contact) and empties into the overflow reservoir. Simultaneously, the opposite compartment is positioned below the nozzle to receive the incoming rainfall. Electrical impulses are transmitted to a recorder or indicator, each impulse representing 0.01 inch (0.025 cm) of rainfall.

When the bucket tips, its contents fall into a

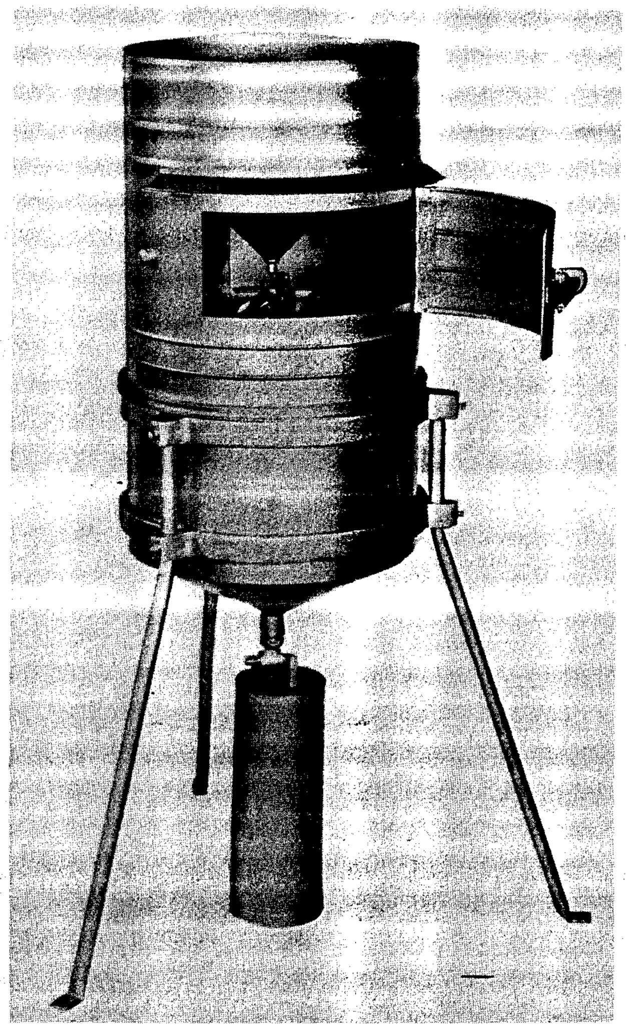


FIGURE 1.15.—Tipping bucket rain gage.

funnel beneath the bucket. At the base of the funnel is a cock that, in its open position, permits the rain to collect in the measuring cylinder below the funnel, where it can be measured with the measuring stick. Accuracy is about 2 percent for rainfall at a rate less than 1 in/hr (2.54 cm/hr), 4 percent for 3 in/hr (7.62 cm/hr), and 6 percent for 6 in/hr (15.24 cm/hr). A cylinder and measuring stick are supplied to check measurements. The gage normally is operated on 6 volts d.c. and will not function satisfactorily in below-freezing weather unless a heating unit is provided. Its diameter is 12 inches (30.48 cm) and its height is 37½ inches (95.25 cm). The diameter of the tripod mounting is 24½ inches (62.23 cm).

A single-channel event recorder and digital indicator operate with the tipping-bucket rain gage. A permanent record of each 0.01 inch (0.025 cm) of rainfall is made on a chart marker for each minute and hour so that duration and total accumulation rate (up to 2 in/hr (5.08 cm/hr)) can be determined. At normal chart speed of 4 inches per hour (10.16 cm/hr), a single chart roll of 250 feet (76.2 m) will record without attention for 30 days.

The recorder is designed with reset-type, built-in digital counter to show cumulative rainfall. It has a chart drive mechanism requiring 115-volt a.c., built-in transformer and silicon diode rectifier supplying 6 volts d.c. for operation of mercury switch in tipping-bucket rain gage. The recorder has a flat bottom for table or shelf mounting, and a slotted hole on back permits wall mounting. A motor-operated chart rewind attaches to the bottom of the recorder case.

The main advantage of the tipping-bucket gage is that it can record at a distance or simultaneously record rainfall and river stage on a water-stage recorder. Its disadvantages are:

- The bucket takes a small but finite time to tip over. During the first half of its motion, the rain is led into the compartment already containing the calculated amount of rainfall. This error is appreciable only during intense rainfall.
- Since the water surface exposed in a typical bucket is relatively large, evaporation losses can occur, especially in hot regions. Losses are highest in light rains.
- Due to the discontinuous nature of the record, the gage is unsatisfactory in light drizzle or rain. The time of beginning and ending cannot be determined accurately.
- Due to its small diameter, the opening that drains the collecting funnel often becomes clogged with such debris as leaves, nuts, bird droppings, and large insects. Water frequently will build up on the collector, resulting in a loss of record as to the time distribution of the storm. The total rainfall is shown in the measuring cylinder.

Maintenance

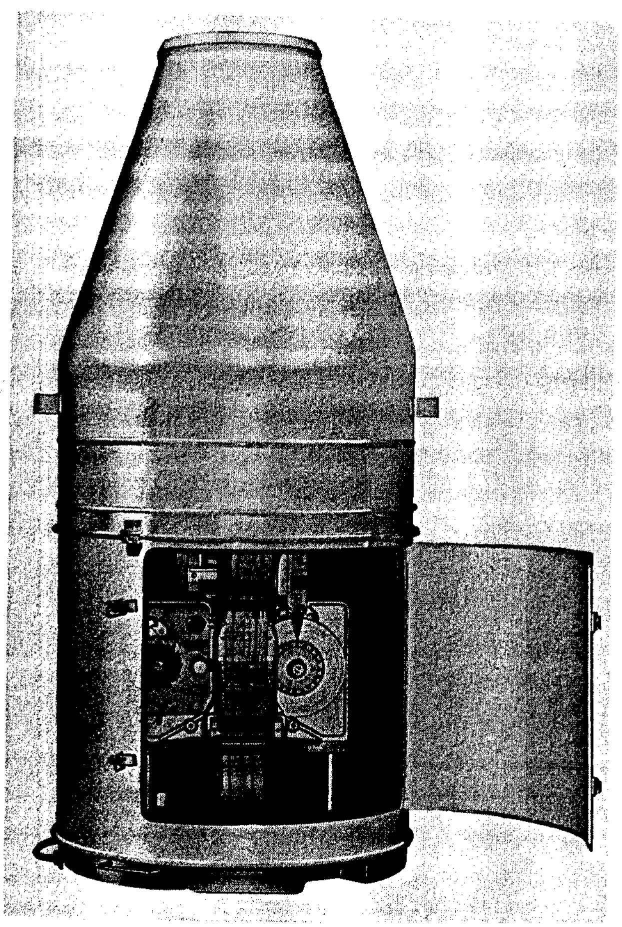
The tipping bucket assembly and measuring cylinder should be inspected for corrosion or deterioration. The bucket should move freely in its casting, and the mercury switch should be inspected to be sure it is intact.

The tipping-bucket gage is built simply and seldom requires overhauling. Check regularly to see that:

- The tipping bucket has 0.015 end play at its pivots.
- The mercury switch is functioning.
- The magnet has not lost its strength.
- The drain cock is clean and not dripping.

Digital Precipitation Gage

The digital precipitation gage (Fischer and Porter) shown in figure 1.16 is a weighing-type gage that records the weight of accumulated precipitation (rain or snow, or both) on punched paper tape at selected intervals in digital code.



PN-5874

FIGURE 1.16.—Digital precipitation rain gage recorder. (Courtesy of Fischer and Porter Co., Warminster, Pa.)

A dial readout is provided for manual reading. The main advantage of this recorder is that the precipitation data can be put rapidly and accurately into a form suitable for computer analysis. For this reason, the digital recording gage has been adopted by the National Weather Service for its primary recording rain-gage network. Other Government agencies involved in hydrology data collection also use this instrument because of its automatic data-processing capability.

The digital gage recorder consists of (1) the orifice, (2) the weighing mechanism, (3) the drive shaft and gearing assembly, and (4) the punch programing cycle system. The orifice, which is 8 inches (20.3 cm) in diameter, defines the area over which the precipitation is measured. The input weighing mechanism has a collector for receiving and storing the precipitation and a cross flexure spring scale for measuring the varying weight of accumulated precipitation. Motion of the scale is converted to an angular position of an input shaft assembly by a pulley arrangement. The shaft's position is converted to successive positions of a code disk.

At predetermined intervals the code position of the disk is punched on paper tape, thereby recording the amount of accumulated precipitation to the nearest 0.10 inch (0.25 cm). The total capacity of the rain gage is 19.5 inches (49.5 cm).

The recorder can be programed to automatically punch the readings at preselected intervals of 5, 6, 15, 30, or 60 minutes, or 12 hours, as desired. The interval is selected by installing the proper cam in the mechanical timer unit or by choosing the electronic timer with the correct cycle. The recorder is designed to operate with minimal care by persons with little technical training. It is designed for permanent installation in remote areas. Power may be provided by either a 7½-volt dry cell battery or standard 117-volt, a.c. service. A battery-powered unit can operate unattended for more than 3 months while recording at a readout rate every 5 minutes.

Recording is done in a standard binary decimal code on a 16-channel paper tape that is suitable for computer processing after automatic translation of the data onto punchcards or magnetic tape. The paper tape shown in figure 1.17 permits visual reading with minimal effort. A horizontal row of punched holes represents the total amount of accumulated precipitation in digital form at the time of punching. Each row is divided into sections representing the tenth's, unit's, and 10's digit of the number. Each section is binary coded 1–2–4–8, and a summation of the holes punched will establish the digital value. A hole punched in the 8 column at the extreme left of the tape is made by the rain trace indicator whenever rainfall occurs (if the gage is equipped with the indicator). On instruments without the rain trace indicator, a hole is punched in the 80 column at the extreme left of the tape. Absence of this hole indicates the end of the tape to an automatic translator.

With auxiliary equipment, a combination of electrical contacts may be operated simultaneously to present an output for telemetering. This capacity permits remote reading by interrogation through radio or telephone. A binary-decimal transmitter serves this function as adjunct equipment.

Maintenance and Service:

Check and calibrate each instrument thoroughly before placing it on station. The following procedure is recommended as the basic check to assure carefree and reliable service.

Place the base assembly on a bench for ease in service preparation. Remove the latch cover (taped to the case), rotate the outer cover counterclockwise to release it from its latches, and carefully lift the cover up from the weighing and recording mechanism. Remove all shipping lashings and inspect immediately for damage. Pay careful attention to the thin metal flexures on which the cantilever beam pivots.

These flexures are damaged easily by improper handling and will cause gage insensitivity. An undamaged flexure will have no creases or kinks and will bend smoothly. A damaged flexure must be replaced to assure proper sensitivity although the recorder will seem to work correctly.

Carefully follow instructions on tags attached to the instrument. Note the tag attached to the shipping screw protruding from the base casting of the scale support assembly. Loosen this screw, turning out until the end is flush with the casting surface. Retain the screw for reshipment by tightening the lock nut securely.

Insert the force post into the weighing scale just ahead of the zero adjust knob and place the collector on the force post. Place the sensor for the trace indicator (if included) on the post inside the collector. Secure the purple wire to the force post with the rubber rings provided and loosen the wiring to allow the weighing mechanism to move freely.

The weighing assembly of the instrument is shipped in a locked position. Rotate the zero adjust knob (on top of the weighing assembly) counterclockwise until the code disk moves freely. Turn the adjusting knob until the code disk zero is alined with the pointer.

Contrary to the manufacturer's instructions, the dashpot cylinder should not be filled initially with oil during the checkout period. If damping oil is placed in the dashpot, binding in the dashpot assembly cannot be determined. Instructions for installing the paper tape supply roll will vary, depending on the type of supply spool and paper tension assembly.

Detailed instructions for operating and maintaining the digital gage are given in the Fischer-Porter instruction manual (fig. 1.18). Routine service depends on physical conditions of the area.

Float-Type Gage

In these gages (fig. 1.19), rain passes into a chamber containing a light float. Vertical movement of the float as the level of the water rises is then transmitted, by a suitable mechanism, into the movement of the pen on the chart. By adjusting the dimensions of the receiving funnel, float, and float chamber, any desired scale value on the chart can be obtained.

To provide a record over a useful period (at least 24 hr is normally required), the float chamber must be very large (showing a compressed scale on the chart) or automatic means must be provided for emptying the float chamber quickly whenever it becomes full. The pen will return to the bottom of the chart by one of several siphoning arrangements.

If freezing is possible, a heating device should be installed inside the gage to prevent damage to the float chamber. A minimal amount of

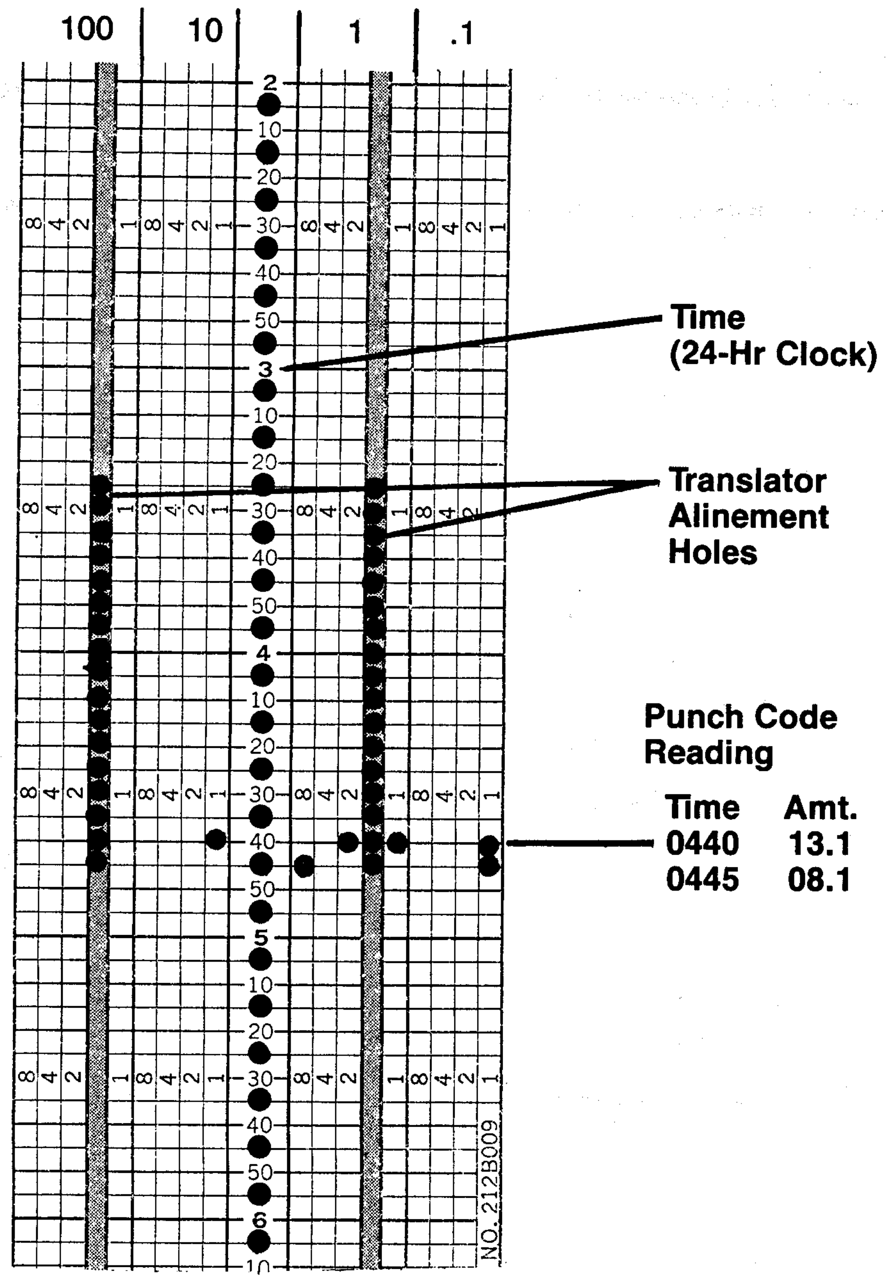


FIGURE 1.17.—Paper tape for digital recorder.

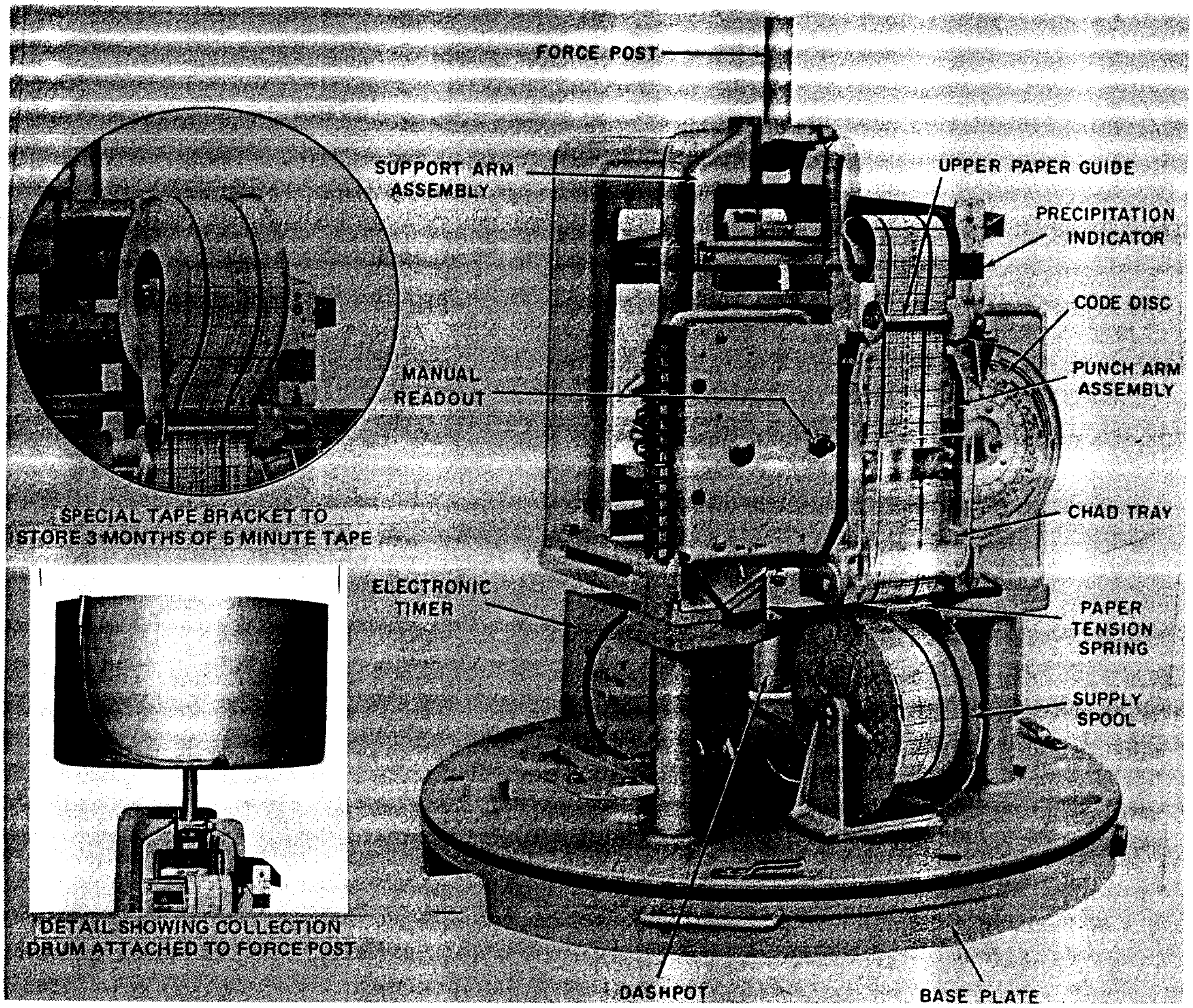


FIGURE 1.18.—Digital precipitation gage recorder, preparation for service. (Courtesy of Fischer and Porter Co., Warminster, Pa.)

heat should be supplied to prevent freezing. The heat will affect the accuracy of the observations by changing vertical movements of air above the gage and by increasing losses from evaporation.

Snowfall

Snowfall is the amount of new snow deposited over a given period. Because of the variability of snowfall, the redistribution of snow on the ground, and the water stored in the snowpack, accurate measurement of snow is difficult. Snowfall should be measured at enough places to represent cover, conditions, slopes, and aspects within the basin. In snow hydrology, the measurement of snowfall is vital.

Direct Measurement

Direct measurements of fresh snow in open areas are made with a graduated scale. Special precaution should be taken not to measure any old snow. This can be accomplished by placing a "snowboard" of suitable material (such as

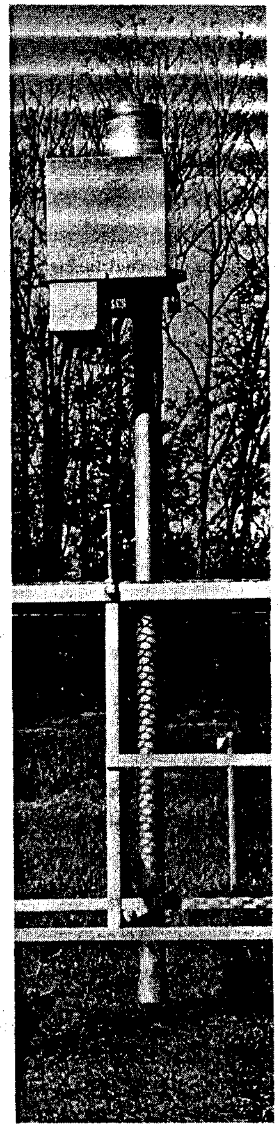


FIGURE 1.19.—Float gage.

rough-surfaced wood, painted white) on top of the previous snow. After each snowfall, the depth down to the snowboard is measured. The board is removed, cleaned, and replaced on the surface of the snow. The difference between two consecutive measurements of total depth cannot be used as snowfall because of the continuous settling of the snowpack.

Where drifting exists, enough measurements must be taken to obtain an average of representative depth. The snowfall also may be measured in a fixed container of uniform cross section. The container should be placed above the maximum expected snow depth so that it is not exposed to drifting snow. The receiver should be at least 8 inches (20 cm) in diameter and deep enough, or divided into quadrants, to prevent the catch from being blown out. The container should be used cautiously because an unshielded receiver is unreliable in high winds. However, a shield may catch drifting snow and cause errors.

The water equivalent of snowfall should be determined by:

- Taking samples of the snowpack with a suitable sampler and weighing or melting them.
- Using ordinary rain gages equipped for winter operation.
- Using snow pillows.
- Using gamma radiation to measure density from which the water equivalent can be calculated.

Several measurements should be taken over an area to give a representative sample.

Recording Snow Gages

The most common recording snow gages are the weighing-type rain gage and the snow pillow.

Weighing-type Rain Gages:

Recording rain gages, such as those discussed, can measure the water equivalent of snowfall. The gage must be serviced before it is used. The funnel in the receiver should be removed so that the snow can fall directly into the bucket. Two to 4 inches (5 to 10 cm) of a solution of $CaCl_2$ and water should be placed in the receiver bucket. This solution melts any solid precipitation that falls in the gage and prevents errors due to snow blowing out of the gage. The gage should be placed so that the top of the receiver is well above the maximum expected depth of snow.

Snow Pillows:

The snow pillow is a large flat rubber pillow, generally 12 feet (3.66 m) in diameter and 9 inches (23 cm) thick (fig. 1.20). The pillow is filled with 4.66 ft^3 (1.32 kiloliters) of a 1:1 mixture of methyl alcohol and water. The snow pillow is connected to an instrument that records the pressure.

The snow pillow should be installed on a firm,

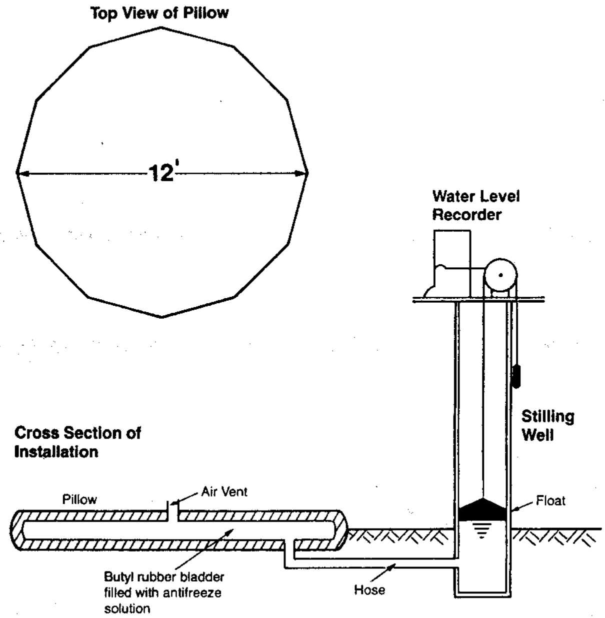


FIGURE 1.20.—Diagrammatic sketch of a snow pillow installation.

level, and permeable base to reduce the effect of frost heaving and to prevent burrowing rodents from damaging the pillow. A packed and leveled area of sand makes a good base. The surface of the base should be even with the surrounding ground. The top of the pillow should be painted white. Use a good paint that is recommended for rubber. The pillow is placed on the base and filled with the alcohol-water mixture. Avoid leaving air pockets in the filled pillow. Connect the filled pillow by pipe to a stilling well equipped with a liquid level recorder or a pressure transducer for recording changes in the pressure of the liquid caused by changes in the weight of snow on the pillow. Figure 1.20 shows the installation of a pillow by using a stilling well and liquid level recorder. The liquid level recorder should have a sensitivity of 0.06 inch (1.5 mm). The size of the stilling well will depend on the diameter of the float required with the recorder. A chart speed of 2.54 in/hr (1 cm/hr) is adequate.

Only the liquid level recorder needs servicing. The density of the alcohol solution must be determined for the range of temperatures encountered in operating the pillow. The density is used to convert changes in pressure on the pillow to increments of snow water equivalent.

During the snow season when the pillow is covered, no maintenance can be performed without disturbing the snowpack. Avoid puncturing the pillow with snow tubes, stakes, or probes. The area should be fenced to reduce the possibility of animals, vehicles, or people damaging the pillow. Each year before installation, carefully check the pillow and repair any leaks. If the white surface of the pillow becomes marked or discolored, repaint it before installation.

The response of the snow pillow is rapid. Changes in water content of 0.04 inch (1 mm) can be measured with properly designed equipment. The greatest source of error results from ice bridging in the snowpack. When thick ice layers are in the snowpack, the readings from the snow pillow may be unreliable. Frost can change the position of the pillow and cause errors in the readings. Air pockets in the pillow also will introduce errors into the readings.

Snowpack

Snow Surveys

The accumulation of snow in a basin is a natural storage reservoir from which most of the water supply for an area may be derived. At the same time, a rapidly melting snowpack may result in costly flooding. Forecasting of flows from snowmelt for water supply and flood control is important to many people and agencies concerned with these problems. Understanding and predicting the rates of snowmelt are also important for many hydrologists.

Selection of Snow Courses:

A snow course is a permanently marked area where snow surveys are taken each year. The snow courses should provide an estimate of the snowpack conditions in environments within the basin and the average watershed condition. Some requirements for selecting snow-course sites are:

- The site should be open and large enough so that it is not affected by interception.
- The site should be protected from high winds.

- The site should be on a well-drained area.
- The site should be accessible so that contionous measurements can be made throughout the season.
- The site should represent the snow conditions at a given exposure, cover, and elevation complex.

The number of snow courses will depend on the diversity of topographic and meteorological conditions and local environmental features, such as aspect and ground slope. Planned use and required accuracy of the data also should be considered in determining the number of snow courses.

Several snow courses should be selected in a basin. Short courses are preferable to a few long courses. The courses should give an adequate sampling of cover, aspect, and elevation differences within the basin. The number of courses depends on planned use of the data, the variability of basin relief and cover, and the basin size.

Sites should be mowed and cleared in the fall. The course should be marked conspicuously with markers that extend above the deepest snow. The sites should be fenced, when practical, to prevent the course from being disturbed by snowmobiles, skiers, or animals.

Layout of Snow Courses:

Snow courses need not be on a straight line. Snow courses vary in length from about 49 feet (15 m) to more than 3,281 feet (1 km) with sampling points spaced from 10 to 164 feet (3 to 50 cm) apart. More samples will be required in areas where snow drifts because of wind. Once the prevailing length and direction of drifting are determined, the number of measurement points might be reduced. Each sampling point should be located by measuring the distance from fixed reference points.

Snow-Sampling Equipment:

The equipment used to sample snow consists of a metal or fiberglass tube with a snow cutter fixed to the lower end and a scale marked or stamped on the surface of the tube; a scale with a wire cradle to support the tube while weighing to determine the water equivalent of the snow cores; and tools for operating the snow sampler. Two typical sets of equipment are shown in figure 1.21. The cutter must be designed to penetrate the snow through crusted and ice layers and sometimes solid ice layers at the ground surface. The cutter must not compact the snow so that too much is forced into the sampler.

The cutter must size the core base so that the core will not fall out when the sampler is withdrawn. Small-diameter cutters retain the sample better, but larger samples increase the accuracy of weighing. The cutter may be smooth or serrated and should be as thin as practical. Its diameter should be slightly larger than the outside diameter of the snow tube. The sampling tube should have an inside diameter slightly larger than the inside diameter of the cutter. The core can go up the tube with minimal wall friction. The inside walls of the tube should be as smooth as possible; but wet, coarse-grained spring snow will still stick to the tube.

The standard method of getting the water equivalent of the snow samples is to weigh the core taken by the sampler (fig. 1.22). The weight of the core is obtained by subtracting the known sampler weight from the weight of the sampler and core. Some scales are calibrated so that the core weight is read directly by putting in a tare for the weight of the sampler. The weighing is done with a spring scale or a special balance. The scale balances are more accurate but very difficult to use in wind.

Water equivalent also can be obtained by storing samples in plastic containers or bags and returning them to a station where they may be weighed or melted, and measured. Unfortunately, data can be lost because of errors not recognized in the field where readings can be repeated. When designing or selecting a sampler, remember that measurements frequently are taken under difficult physical conditions.

Gamma-Ray Method

The measurement of snow density with radioactive isotopes depends on the attenuation of gamma rays when traversing a medium. The attenuation is a function of the energy from the source and the density and thickness of the

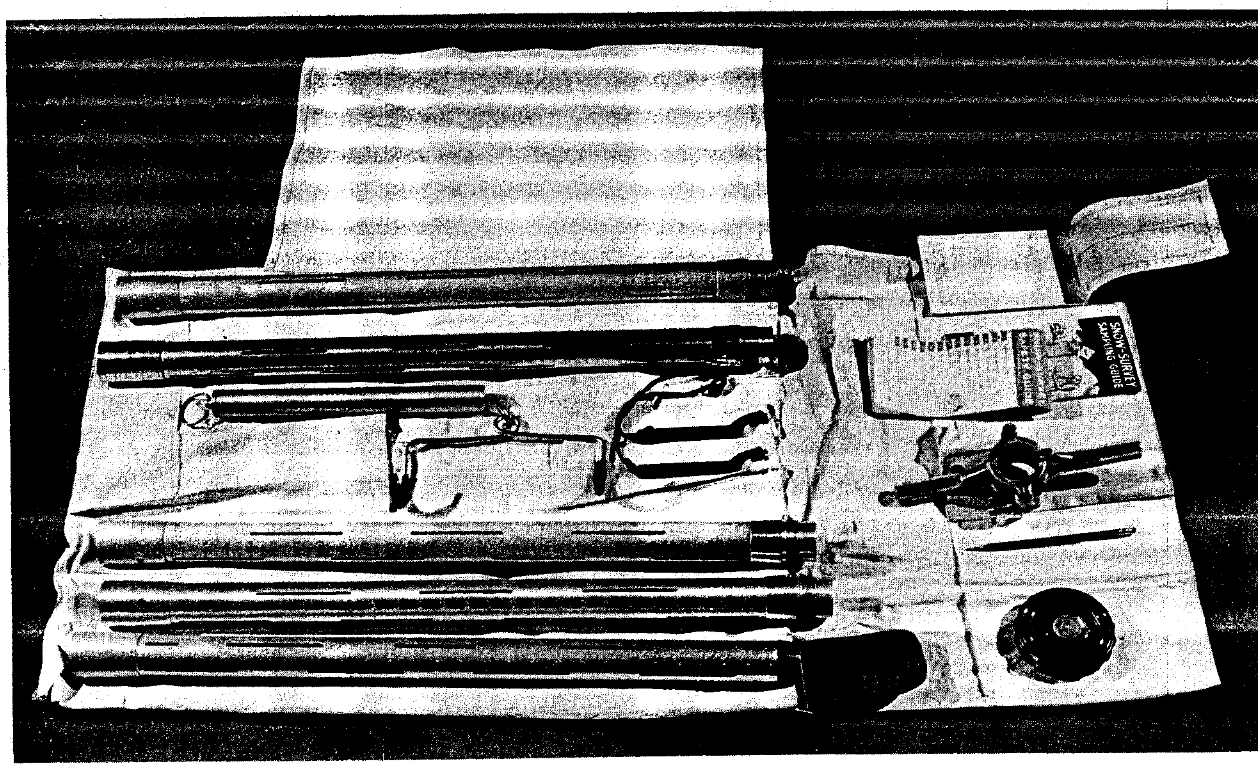


FIGURE 1.21.—Snow-sampling equipment.

substance traversed. Since a high-energy source of gamma radiation is required, cobalt-60 and cesium-137 are used frequently. Three methods used in placing the sources for measuring snow are:

- The source is placed at ground level, and the detector is placed above the snow surface.
- The detector is placed below the ground surface, and the source and shielding are placed above the maximum expected snow depth.
- The gamma-ray source and the detector are moved synchronously through parallel tubes placed vertically in the snowpack. This method gives a density profile of the snowpack in addition to the average or composite density.

The installation and operation of the gamma-ray gages are not standard. Most systems are specially made and not commercially available. Installation requirements and operational procedures for representative installations are discussed here.

The gamma-ray gage consists of a detector using a Geiger-Muller tube and cobalt-60 source in a lead shield mounted flush with the ground surface. The cobalt-60 emits high-energy radiation that is essentially monochromatic. The gamma photons cause pulses of electricity to flow in the Geiger-Muller tube. These pulses are proportional to the intensity of the radiation. They can be radio telemetered or sent directly into scaling equipment, where they are recorded. Figure 1.23 is a sketch of a typical gage. The instrument must be calibrated to give count rate versus water content. The radioactive source must be shielded with lead because of the health hazard from gamma radiation. This type of installation has been used to measure snowpacks containing over 50 inches (127 cm) of water. The error depends on the count rate or the water content of the snow; namely, the higher the water content, the lower the count and the greater the percentage of error.

This system has the same principle of operation as the system with the source and detector reversed and requires the same health hazard precautions. The advantage over the reverse system is that the Geiger-Muller tube is temperature sensitive. By placing it under the snow, the temperature fluctuations are reduced (*16*). Most instruments used in this method are not commercially available. The method is described in detail by Houghton and Howe (*18*).

A watertight sheet-metal box buried in the ground contains the motors, racks, pinions, and other apparatus associated with the drive mechanism. Fastened to the top of the box are two polyvinyl-chloride tubes sealed at the top and spaced 1.9 feet (57.9 cm) apart. A tube with a 3/4-inch (1.9 cm) diameter contains the 5-millicurie source, and a tube with a 3-inch (7.6 cm) diameter contains the photon detector. Both are mounted on racks driven by synchronous motors in the control box. The rack motors are operated by a control panel located away from the instrument. A calibration bar of known density is installed permanently between the tubes below ground for calibrating the instrument before each run.

PN–5875

FIGURE 1.22.—Measuring water equivalent of snow by weighing the core taken by the sampler.

To get a snow profile the operator sends source and detector in search of the calibration bar. Both stop automatically when directly opposite the bar with the source exactly opposite the 1/2-inch (1.27 cm) window of the detector. A count is taken as the energy flows through the calibration bar of known density, the instrument is adjusted, and actual profiling is ready to begin. The source and detector move synchronously up the tubes at the rate of 1 ft/min (26.9 cm/min).

The signal from the photon detector flows to a pulse-height analyzer (PHA) that filters out all random "noise." From the PHA, the selected signal flows through a processor to a recorder that produces a profile of snow depth versus density. Repeatability with this system is excellent. Some detail of the density variations is lost because of time averaging within the signal processor. Small errors can be made in measuring depths.

Descriptions of similar instruments and discussions of the accuracy and sources of error are given in references *11* and *34*.

Precipitation Quality

With the increasing emphasis on water quality in agriculture and the considerations being given to the chemical balance of a watershed in addition to the hydrologic balance, the researcher must be able to estimate the chemical input to his system by precipitation so that its relative importance can be evaluated. Considerations must be given to the collection of precipitation for chemical analysis that need not be given to collection for the determination of precipitation quantity.

A rain gage collects a sample of the amount of precipitation falling during an event. A precipitation quality collector shows the chemical quality of this precipitation. Because of the relatively small amounts of chemicals usually found in a precipitation sample, care must be taken in the construction, location, and operation of a precipitation quality collector so as not to contaminate the sample gathered by the collector.

The container in which the precipitation is collected, and any part of the collector that the precipitation touches before it reaches the con-

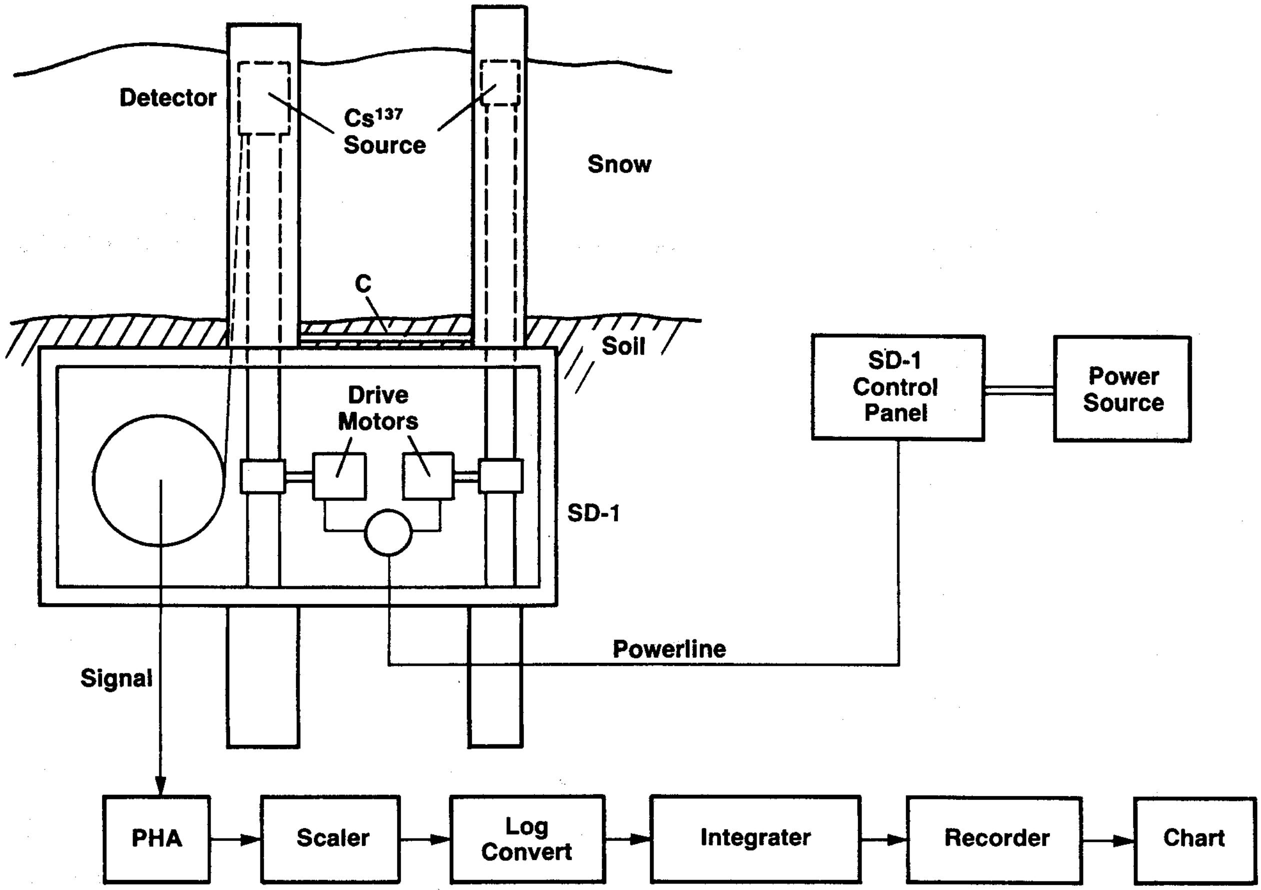


FIGURE 1.23.—Sketch of a gamma-ray snow density gage showing the principal components.

tainer, should be of a material that would not interfere with the chemical analyses being run on the precipitation sample. Polyethylene is a good choice where inorganic chemicals are being analyzed, while glass would be required for organic analysis.

The collector must be covered when there is no precipitation to eliminate contamination of the container by dust, birds, and so forth. The cover can be removed manually at the start of precipitation and can be replaced once precipitation ends. If the collector is in a field, this process can be automated. The cover must be removed at the first sign of precipitation since the initial precipitation usually contains most of the total contaminants deposited by the storm.

Researchers have used many collectors, ranging from a simple glass funnel and bottle to completely automated collectors. Since automated collectors are more practical for field applications (and since simple collectors are easy to visualize and construct), two automated collectors will be discussed here.

One automated collector that works well is available from Wong Laboratories in Cincinnati, Ohio. This collector was used by the Public Health Service in its nationwide precipitation quality network, by the National Center for Atmospheric Research, and by independent researchers. It consists of an 11-inch-diameter polyethylene bucket mounted in a supporting frame. The entire frame and bucket are covered when no precipitation occurs. A grid moisture sensor is activated by the first precipitation falling, which activates a small motor that swings the cover from over the bucket. As long as precipitation occurs, the cover stays in its retracted position. Once precipitation stops, a heater in the moisture sensor evaporates the remaining moisture bridging the grid and the cover closes. Both the temperature and sensitivity of the moisture-sensing grid are adjustable. This installation requires 110-volt, 60-cycle power.

The North Appalachian Experimental Watershed at Coschocton, Ohio, has designed and constructed a precipitation-quality collector (fig. 1.24). This collector is similar to the Wong collector, but the temperature and sensitivity of the moisture grid are not adjustable. The bucket is made of stainless steel and is the same size as the National Weather Service 8-inch (20 cm) nonrecording rain gage. Its installation also required 110-volt, 60-cycle power.

Operation and Maintenance:

A precipitation quality collector should be installed with a standard rain gage. The amount of precipitation should not be measured from the catch of the quality collector because of contamination problems, differing catch efficiencies of the precipitation quality collectors, and so forth. The collector should be located where no local condition, such as an incinerator or smokestack, could contaminate the sample and make it nonrepresentative of conditions at the site.

The collector should be chemically cleaned before each sampling period with a cleaner that will not interfere with the chemical analyses being done on the sample. After precipitation, empty the collector as soon as possible. The sample should be stored or preserved, or both, as the chemical analyses dictate. Avoid contamination in transferring the sample.

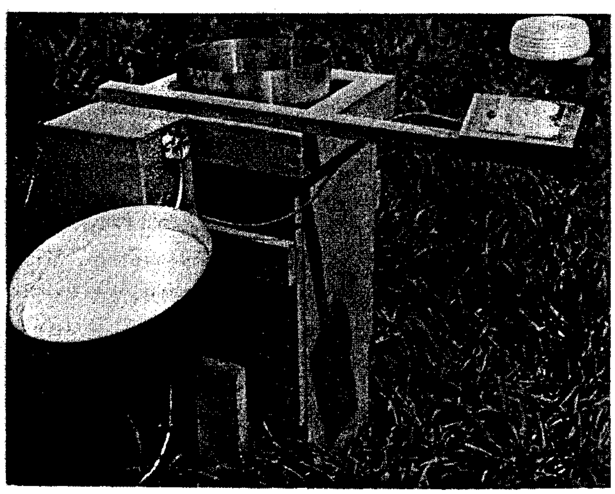
The collecting container must be kept free of contamination. It must be cleaned after each sample, and the bucket should be checked periodically during extended periods of no precipitation. If the bucket gets dirty between sampling, it should be cleaned.

The moisture-sensing grid also must be kept clean to insure instant response to the start of precipitation. Continued evaporation from the surface of the grid can cause a buildup that makes the grid increasingly insensitive to precipitation. Periodic cleaning of the grid face with a mild abrasive helps alleviate this problem.

Maintenance of the mechanical parts of the collector depends on the construction of the instrument. Check periodically to make sure all mechanical parts of the gage are working. If the gage is equipped with a mechanically operated cover, the cover must be free to move when the motor is activated by the moisture sensor. It must be maintained in as tight a position as possible when no precipitation is occurring to minimize contamination.

Winter operation of a precipitation quality collector poses the same problems as winter operation of a standard rain gage. These problems are in catch efficiency caused by wind and freezing of the mechanisms. The collector can be enclosed with a plywood base that has a thermostatically operated heat bulb within the base. The amount of snow in the gage increases because the snow melts when it reaches the bucket. It has less tendency to bridge the opening and consequently eliminate further catch. Higher operating temperatures of this enclosure also help preclude additional cold-caused problems with the gage mechanism.

Limitations of this type of data are basically the same as those of precipitation quantity data. Both the sample's representativeness of precipitation at that point and its ability to be extrapolated over an area are questionable. As long as the collector catches a sample constantly proportional to what is falling, the



PN-5876

FIGURE 1.24.—Precipitation quality gage.

sample will be representative and concentrations in all or part of the sample will be constant.

Subsequent extrapolation of this point measurement to an area, remains subjective, however, and must be based on experience and local conditions. The question is whether the concentration or the total (concentration times amount of precipitation) chemical contaminent sampled should be extrapolated. If there is a point during precipitation after which additional precipitation brings no appreciable contaminants, the total amount should be extrapolated. The total amount applied also should be considered where precipitation amounts differ significantly over the area in question. Where precipitation lasts a short time or where it is relatively uniform over the area in question, the chemical concentration sampled should be extrapolated.

The most probable source of error in the data is contamination of the sample by the collector or by sample-handling procedures before analysis. Because small amounts of contaminant usually are found in these samples, this aspect of the problem requires careful consideration to make the data meaningful.

FIELD MEASUREMENTS

Field observations are made to record accurately events for complete data tabulation, analysis, and interpretation. Many conditions or phenomena must be noted personally. Records from instruments that did not function properly often provide usable data if adequate notes are taken concerning the nature and cause of the failure. Observers should realize that many notes are needed.

Observers should be prepared to make systematic field notes by using standard forms or a fieldbook with columnar pages. Before leaving for the field, the observer should assemble a notebook, charts for the recording gages, a bottle of recorder ink and blotter, a pencil, and an accurate watch that is checked with a radio time signal before departure. It is convenient to have a small toolkit consisting of pliers, two or three screwdrivers, a small adjustable wrench, and two or three open-end wrenches for routine adjustments or minor repairs in the field.

General Reporting Procedures

Instructions to Observers

Clearly written instructions for all observers should include:

- Brief description of instruments, with diagrams.
- Routine care and maintenance of instruments and action to be taken if serious breakage or malfunctioning occurs.
- Procedure for taking observations.
- Times of routine observations.
- Criteria for beginning, end, and frequency of special nonroutine observations (that is, river-stage observations while water level is above a predetermined height).
- Procedure for making time checks and putting observations on charts at stations with recording instruments.
- Completion of fieldbook or station journal.
- Completion of report forms including methods of calculating means and totals and examples.
- Sending report forms to central office.

These instructions should be supplemented by verbal instruction to the observer by the inspector at the time of installation of instruments and at regular intervals thereafter.

These instructions should emphasize the importance of regular observations with perhaps a brief account of how the observed data are used in water resource development, river forecasting, or flood-control studies. Observations during special periods, such as floods, or any special reports that are to be filed, should be specifically outlined. Observers must fill in station names, date, and observer's signature. Instrument failure or significant modification of the observing site should be reported immediately.

These instructions apply to observers at stations with continuous 24-hour-per-day observational programs to observers who measure only precipitation or stage once a day. The instructions must be more detailed in the 24-hour observational programs than in the once-a-day observational programs.

Observers at stations equipped with automatic recording instruments must be provided with instructions on the method of changing charts and taking check observations. At stations with full-time personnel, the staff should be sufficiently well trained to abstract data from charts of recording rain gages. Carefully worded instructions on the method of abstracting data from the charts and the completion of report forms must be provided. At stations where observers may not be thoroughly trained, observers should not be required to abstract data from charts. Charts should be forwarded to a central office for abstraction of data.

At some locations, gages are being introduced for water-level and precipitation requirements that produce the required data on punched paper tape or other digital output, instead of on graphical charts. Instructions to observers need only contain information on routine maintenance, taking check observations, and method of forwarding the tape or card output to the central office for machine processing.

Inspection of Stations

To maintain good observations, stations must be inspected periodically. Principal climatological stations should be inspected at least once every 2 years. Ordinary climatological stations should be inspected at least once every 4 years. At some locations inspectors from offices visit at least once a year, with less frequent visits being made by inspectors from the central office.

The inspector must:

- Note and record any change in observation site (a sketch map and photographs are useful).
- Make local arrangements for improving or restoring the observing site (that is, removal of trees affecting rain-gage catch).
- Check the instruments and make necessary repairs and adjustments.
- Inspect the observer's fieldbook.
- Instruct the observer on procedures and routine instrument maintenance.
- Emphasize the importance of filing promptly complete and accurate returns.
- Brief the observer on special observations that may be required (that is, more frequent readings during storm periods).
- See that the observer has sufficient forms, mailing envelopes, and other supplies to perform his duties.

The inspector must be advised of errors made by observers, especially recurring errors made by a particular observer. Such advice should be forwarded regularly to the inspector by the officers responsible for preliminary checking and error detection.

Special Data Collection

Data on severe storms and floods are important in determining design criteria for many hydraulic structures. Regular observation networks generally do not give enough detailed information on storm rainfall distribution. Therefore, valuable information can be obtained by a field survey crew after a severe storm. Data from instruments such as weather radar are often valuable in hydrological studies.

Rain can be measured in receptacles, such as pails, troughs, and barrels, that were empty before the storm. Rainfall data can be augmented from the regular observing network. Eyewitness reports can be obtained of times of beginning and ending of rain and of periods of very heavy rain. Data from bucket surveys must be interpreted carefully. Where discrepancies exist between data from a bucket survey and the regular observation network, greater weight usually should be given to the latter.

Nonrecording Gages

Observers should have fieldbooks or station journals, or both, in which to enter their observations. Forms also should be provided for daily, weekly, biweekly, or monthly observations. The fieldbook or station journal should be retained by the observer in case a report form is lost in transit.

The report forms should permit easy copying of results from the fieldbook or station journal.

A good arrangement is to have the report form identical to a page in the fieldbook or journal. The elements should be in the same columns or rows to minimize copying errors. The journal and the report form should have space for any conversions or corrections from the original readings.

Alternatively, an observation fieldbook with carbon paper between successive sheets will permit easy preparation of an original form for the central office and a copy for the local station record. This may be impractical if the observer's office or home is far from the observation site and the fieldbook would be subject to frequent inclement weather.

National Weather Service Standard 8-Inch (20 cm) Gage and Storage Gage

Before measuring rainfall in the 8-inch (20 cm) nonrecording gage, remove the receiver. If the measuring tube is partially full, place the rainfall measuring stick vertically in the tube with the zero end resting on the bottom. After 2 or 3 seconds, remove the stick and read the depth of rainfall to the nearest hundredth of an inch (0.025 cm), as indicated by the wetted portion of the stick. Empty the measuring tube, allow it to drain, and replace it.

If the tube is overflowing, carefully remove it without spilling water into the overflow can. Empty the tube and allow it to drain for several seconds. Each full tube represents exactly 2.00 inches (5.08 cm) of rainfall. To avoid any serious loss of record if rainfall is spilled when emptying the overflow can, take a stick measurement of the depth of water in the overflow can before it is emptied. The stick reading from the overflow can will be approximately one-tenth that of the measuring tube. Carefully fill the measuring tube, when necessary, with the water remaining in the overflow can. When the water in the overflow can partially fills the tube, take a stick reading, add individual measurements (fig. 1.25), and enter the date and time of observation in the fieldbook.

The water equivalent of samples of frozen precipitation is determined by melting each sample and measuring its liquid content, or by weighing the frozen sample. Weighing the sample is the fastest and usually the most accurate method if scales are available that read directly in ounces or in inches of precipitation from 8-inch (20 cm) gages.

In winter, the receiver and measuring tubes are removed, and the overflow can be used as the gage. Snow samples are obtained from catch in the gage or by inverting the overflow can and using the rim to cut a cylindrical vertical sample to the required depth. A piece of sheet metal is slipped beneath the mouth of the can to hold the sample as the can is withdrawn. Whenever the depth of snow to be sampled is deeper than the can, cut the sample and remove a portion at a time until the required depth has been sampled. The sample is taken where it will most nearly represent the average fall and where the snow cover seems least affected by drifting.

Measure a quantity of warm water (to the nearest hundredth of an inch) in the measuring tube and pour it into the overflow can, or other container, with the sample of snow and ice. Put melted contents back into the measuring tube and measure it like rainfall. Subtract the amount of warm water from the total, and the remainder will be the water equivalent of the sample.

Attach an empty dry container to the scale and read the weight to the nearest hundredth of an inch precipitation or to the nearest ounce. Place the sample in the container and read the scale again. Subtract the first reading from the second to arrive at the amount or weight of water in the sample. If the scale is calibrated in ounces, convert the difference to inches precipitation by multiplying by 0.0358 since 1 ounce (30 ml) of water in an 8-inch (20 cm) gage equals 0.0358 inch (0.9 cm) precipitation. When the sample exceeds the capacity of the container, get the water equivalent of each portion of the sample as stated previously. Add the values for the portions to get the value of the total sample.

Other Nonrecording Gages

Nonrecording gages are available in so many shapes and sizes that specific instructions cannot be listed for each. Carefully follow the manufacturer's literature for each type of gage.

Do not use plastic and glass gages in winter because they are damaged easily by freezing

STANDARD RAINGAGE S-3 FENNIMORE, WISCONSIN

(1) Date	(2) Time of Observ. 1/	(3) Depth-Meas. Incr.	(4) Inches Totals	(5) Depth in Overflow	Remarks
					AUGUST, 1943
					1/ Times are Central Daylight Saving.
9	8:30 a		0.35		
12	11:15 a	2.00			
		1.30		.14	Very hard rain during early morning,
			3.30		strong winds, some hail.
13	11:30 a		1.85		
16	8:30 a		0.24		Drizzle all day.
23	8:20 a		1.26		
27	4:00 p		0.77		Light intermittent showers 25th, 26th, 27th.
Monthly total			7.77		
					JANUARY, 1944
					2/ Central Standard Time.
10	2/ 9:00 a	0.42			--Total in measuring tube
		- 0.35			--Warm water added
			.07		--Net precipitation or water equivalent.
24	9:30 a	0.67			
		- 0.50			
			.17		
31	10:00 a	2.45			Sum of two measurements.
		-1.50			
			.95		sleet & snow
Monthly total			1.19		

FIGURE 1.25.—Field notes for a standard rain gage.

and thawing. If water equivalent is determined by weighing, use a scale calibrated for the orifice size. If catch is measured in ounces, use the correct factor to convert to inches of precipitation. To convert ounces weight to inches precipitation, multiply the weight in ounces by the factor, $F = \frac{2.29}{D^2}$ where D is the orifice diameter in inches.

Recording Gages

The design of report forms for summarizing information from continuously recording gages measuring precipitation is a special problem. Relative values must be assessed of the ways in which the data could be abstracted and tabulated.

One difficulty is that the hourly rainfall data usually are calculated for calendar days and local standard time. The nonrecording rain gage is read and the recording gage chart changed according to a precipitation day, which is often 0800 EST to 0800 EST the next day. Consequently, the maximum amounts for durations are tabulated for the "precipitation day" instead of the calendar day. A simpler form and easier data tabulation would be possible if the recording gage data were not corrected to be compatible with the standard gage observations.

While many forms can be used for summarizing data from recording charts, summaries of the most frequently used data should be abstracted from the charts. The abstraction should begin immediately after the chart is removed from the instrument to check on the functioning of the instrument and to verify unusual events indicated on the recorder as soon as possible. It is easier to spend a few minutes abstracting the chart data each day, week, or month, than to deal with a large backlog of data abstraction at one time.

Universal-Type Recording Gage

Visit each recording gage as often as practicable to see if the clock is running and if the pen is making a trace. At each inspection, mark a time check on the chart by gently touching the weighing mechanism to make a 1/4-inch (0.64 cm) vertical mark on the trace. If the clock is not running, mark the trace by turning the cylinder slightly to the left and right to produce a short horizontal line across the trace. This will identify the top of the trace although vibration may have caused the pen to rise above this level on the chart. If the pen is not making a trace, place a circle on the chart to mark the position of the pen. For all time checks, note the date, time, and initials of the inspector on the chart and in the fieldbook.

Before a chart is placed on the cylinder, it should have the proper station designation, chart number, date and time of placement, name or initials of observer, and any other information required. Military time is recommended, and the chart should note whether standard or daylight saving time is used. Standard time usually will be used for continuity although the surrounding area may be on daylight saving time during part of the year.

Charts on weighing-type rain gages should be changed weekly or as soon as possible after precipitation. To change the chart, remove the receiver and open the inspection door or remove the outer shield of gages not equipped with a door. Make a time check and remove the pen from the chart by shifting the pen bar. Record the date and time of removal in the fieldbook (fig. 1.26). Empty and replace the bucket, except during the winter when the bucket is charged with antifreeze. Remove the cylinder by gently grasping the top and lifting it over the spindle. Release the clip holding the chart but avoid touching the trace or storing the chart so as to smear the trace. Note the time of removal and initials of the observer on the chart (fig. 1.27). Wind the clock and wrap a new chart around the cylinder.

The new chart should have the correct station designation, date and time of placement, and initials or name of the observer. The chart should fit smoothly and snugly, with its base uniformly in contact with the flange of the cylinder. Replace the cylinder by lowering it gently over the spindle until the gears are fully meshed. Fill the pen to slightly less than level so that it will not overflow as the ink absorbs moisture from the atmosphere. If the trace becomes faint, remove the ink with a blotter and replace it. With the pen almost touching the chart, errors in time are corrected by turning the cylinder until the indicated time is about 3 hours fast, then turning the cylinder back to the correct time. This will take up any backlash in the timing gears. Place the pen on the chart and make a time check. Record the placement time and date on the chart and in the fieldbook. Replace the outer shield if it has been removed, close the inspection door, and replace the receiver. Note the form of precipitation, clock failures, or any malfunctioning of the gage in the fieldbook.

If recording gages are equipped with battery-operated, electrically driven, or electrically wound clocks, use a portable voltmeter. Note the battery voltage at each inspection while the clock motor is running in case the voltage drops during operation.

After a chart has been removed, enter the time and date of removal at the end of the chart. Verify the time and record discrepancies between the chart time and watch time. Add other notes that will explain unusual or missing parts of the trace.

When visiting the station in the winter, do not empty the bucket until the pen reaches the 3.00-inch (7.6 cm) line. When the accumulated precipitation in the gage reaches this point, oil-antifreeze-water solution may freeze. Therefore, empty the bucket and recharge it.

RECORDING GAGE R-4 FENNIMORE, WIS. (1943)

	PLACEMENT			REMOVAL			
Chart No.	Date	1/ W.T.	Remarks	Date	W.T.	Measured Prec.	Remarks
353	7/29	12:30 p		8/2	9:10 a	0	Clock slow, adjusted
354	8/2	9:13 a	Windy, low humidity	8/9	9:10 a	.31	
355	8/9	9:15 a		8/12	11:59 A	1.92) 1.41) 3.33	Hard rain around 5a, some hail.
356	8/12	12:05 p		8/13	11:04 a	1.90	
357	8/13	11:10 a		8/16	9:01 a	.37	All day rain on 15th
358	8/16	9:10 a		8/23	8:52 a	1.28	
359	8/23	9:00 a		8/27	4:28 p	1.00	Rains on 25, 26, & 27.
360	8/27	4:35 p		8/30	9:40 a	0	
361	8/30	9:45 a		9/6	11:14 a	.84	Lt. shower 8/31 - p.m. most on 9/4 & 9/6.

1/ Central daylight saving time

FIGURE 1.26.—Field notes for a recording rain gage.

Tipping-Bucket Rain Gage

Inspect each tipping-bucket rain gage and remote recording system as often as practical to see if the recorder is working and if the pen is making a trace. At each inspection, make a time check with a ballpoint pen or other permanent marker. If the pen is not making a trace or the recorder is out of time synchronization, place a circle on the chart to mark the position of the pen. Replace the pen if it is not working and adjust the recorder tape to the proper time synchronization. For all time checks, note the date, time, and initials of the observer on the tape and in the fieldbook. Check the tipping bucket assembly and measuring cylinder for corrosion and deterioration. The tipping bucket should move freely on its pivots, and the mercury switch should be intact and operational. If the funnel hole has become clogged and is backing up rain water in the collector, remove the obstruction to allow the water to drain through the gage assembly and into the reservoir at the base of the gage. Note any malfunction in the fieldbook.

While the bucket tips during an intensive rainfall, the rainfall will continue to flow from the collector into the reservoir. Slightly more water will be in the reservoir than the tape record indicates. Thus, the total amount of precipitation in the reservoir should be measured. This measurement should be taken shortly after the rain to minimize evaporation loss from the reservoir.

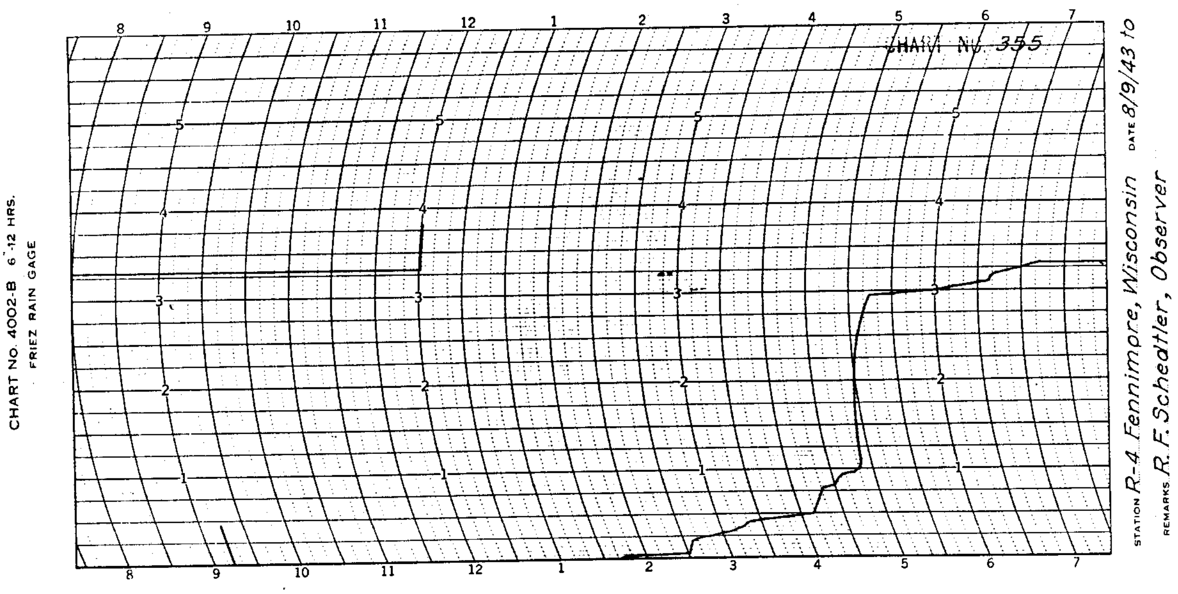


FIGURE 1.27.—Rain gage chart record with placement and removal marks.

Before a tape is placed in the recorder, make sure it has the proper station designation, chart number, date and time of placement, name or initials of observer, and any other information required. Military time is recommended, and the chart should note whether standard or daylight saving time is used. Standard time usually is used for continuity throughout the year although the surrounding area may be on daylight saving time during part of the year.

Remove the recording tape on the tipping bucket recorder each week, and install a new tape if the supply is insufficient for the period between servicing. Remove the record as soon as possible after precipitation.

At the beginning and removal of each paper tape spool, record the following directly on the chart in ink.

- Gage number (serial no.).
- Gage location number.
- Time and date.
- Value of precipitation indicated by measuring tube and dip stick.
- Person servicing gage.
- Watershed location.
- Tape time (EST only).
- Watch time (EST only).
- Record information, as needed.

Digital-Recording Gage

Inspect the digital rain gage at regular intervals to determine that the recording mechanism is operating and the tape is at proper time. A schedule of checking and servicing the gage will give accurate records for each instrument and will reduce the periods of missing or incomplete records. This servicing should be for 1 month or less and should include:

- Checking battery voltage (greater than $6^1/_2$ volts).
- Checking amount of tape on spool.
- Checking time synchronization.
- Draining collector when greater than 10 inches.
- Checking to see that trace indicator contacts are clean.
- Spraying motor switch contacts with contact cleaner.

The gage should be inspected for other malfunctions, and adjustments should be made when necessary.

A checklist (fig. 1.28) will aid the observer in servicing the equipment and in recording gage operation. This checklist will be valuable in maintaining a network of rain gages with minimal malfunction and loss of records.

Instrument No: ____________________

Timer No: ____________________ Watershed: ____________________

Location No: ____________________ Location: ____________________

Date to be Serviced					
Date Actually Serviced					
Synchronization					
Correct E.S.T.					
Tape time					
Time correction					
Tape day No.					
Tape Supply					
Supply tape released					
Tape No.					
Days remaining on tape					
Record removed					
Notation on tape					
Instrument Reading					
Dial reading					
Tape reading					
Punchout in line					
Punchout clean					
Sensitivity checked					
Range adjusted					
Zero adjusted					
Collector emptied					
Calibration made					
Battery Supply					
Battery Replaced					
Voltage across battery					
Voltage across motor					
ma drain of timer					
ma drain of punchout					
Operation					
Evap. suppression oil					
Dashpot fluid added					
Contacts cleaned					
Material in collector					
Mechanical malfunction					
Seasonal Operation					
Trace (in or out)					
Trace battery voltage					
Funnel (in or out)					
Antifreeze installed					
Gage Serviced By					

(Make additional comments on back.)

FIGURE 1.28.—Field checklist for precipitation gage.

Snowfall

Direct Measurement

Measure snowfall at all precipitation rain gage stations. These measurements complement the regular precipitation measurements.

The water equivalent of new snow may be determined from recording rain gages. The snow pillow will record additions of water to the snowpack. Snow tube sampling and gamma-ray methods can be used to determine the water equivalent of new snow. Use of the snow tube or gamma-ray method to determine the density of new snow assumes that snow did not melt between measurements. If any melting occurs, the determinations may be in error by significant amounts.

Recording Gages

How to handle the measurement of snow with a weighing-type rain gage was discussed on page 29.

When using recording gages, inspect the snow pillow site to ensure that snow on the pillow has not been disturbed. If possible, check the area for leaks in the pillow. Check the liquid level recorder for proper operation when the record is changed. Check the stilling well and connection lines for leaks whenever possible.

When the record (chart) is put on or taken off, note the date and time. Note the amount of precipitation during the period of record. Any unusual behavior, such as jumps in the record, should be noted and explained, if possible.

Snowpack

Snow Courses

Snow courses provide data on depth, density, and water equivalent of the snowpack. They also provide information on the spatial variation of the snowpack over a drainage basin. Such data as ground condition, type of snow (including granular snow, ice layers, or corn), and stream conditions are also part of the snow-course data.

Before going to the field to take snow-course data, check the equipment thoroughly. Test the scales, check the snow tube, and make sure the cutter is sharp and firmly attached to the snow tube. Identify the stations before going to the field so that only the recorded data have to be entered during the sampling. This procedure saves time and helps reduce errors in making observations.

The snow course sampling points should be marked carefully or located precisely by measuring from a given reference mark. Unless samples are taken at the proper location, the data will be inconsistent and basin averages or other calculations using the data will have errors. To cut a core with the snow tube, force the sampler downward (cutter end first) through the snowpack until it reaches the ground. If conditions permit, the core should be taken with a steady downward thrust of the tube. A minimum amount of turning should be made to reduce sampling error. When turning is necessary, rotate the tube clockwise to help the cutter penetrate ice layers within the snowpack.

The cutter normally should penetrate to the ground. A trace of ground litter on the end of the cutter indicates that none of the core has been lost. The weight of the core is the water content of the snowpack at that point. The depth of the snow is read at the surface of the snow on the outside of the tube before the core is lifted. When the cutter has penetrated below ground, the depth of penetration is determined. The snow depth is obtained by subtracting this depth from the depth reading at the surface of the snow with the tube in the snowpack. The weight of the soil plug must be subtracted from the weight of the core to determine the water content. When the snow is melting and the snowpack is "wet," take a soil plug with each sample to hold the core in the tube. The sample should be weighed as quickly as possible to prevent water from draining out of the core. The density of the snow is computed by dividing the water equivalent of the snow by the depth of snow. The density of snow should be reasonably constant over a course. Because a large deviation from the average usually indicates an error, the snow should be resampled.

Gamma-Ray Method

This method provides a point measure of the snow density of the snowpack. The water content of the snowpack can be determined from the density measurements when the depth is known. The requirements for this method depend on the system used and how the data will be used. Some general requirements are outlined regarding the instruments and the installation of the system. The components of the detection system should be stable, easy to calibrate, and easy to maintain. The radioactive source should have sufficient strength to measure the maximum expected snowfall. It should not saturate the detection system under shallow snowpack conditions. Strict precautions will prevent unnecessary exposure of operation personnel, hunters, or other persons to the radiation from these installations. Installation of gamma-ray density gages requires expensive and complex instrumentation.

Data from radioisotope snow gages generally are recorded as a count rate (counts per minute, CPM) on a strip chart or as a number of counts taken over an interval as read from a scaler. Regardless of the recording method used (chart or scaler), the signal pulses must be processed in some manner. Two signal processing systems and method of recording the data from each will be discussed in this section. These systems are similar to the gamma-ray method except that each reading represents the entire water content of the snowpack at the time of the reading. The recording scheme and requirements are the same as those of the gamma-ray method.

The instrument described on page 31 records data in chart form. The chart moves at a given speed through the recorder, that is 5 in/s (12.7 cm/s). One centimeter represents 6.1 centimeters of snow depth. The density is recorded on a scale graduated from 0 to 1 gram per cubic centimeter. The chart output thus shows a profile of density versus depth for the snowpack. The signal-processing equipment gives an immediate reading of average density on a display. The average density, the date and time, and the depth of snow should be noted on the chart. The soil-snow and snow-air interfaces should be indicated on the density curve from the system. Figure 1.29 shows an annotated chart from this system. Similar systems that produce only a chart record of count rate from the detector, PHA, and rate meter units are used in the United States. This record requires similar notation on the chart and a calibration curve for converting count rates to densities in centimeters per cubic grams.

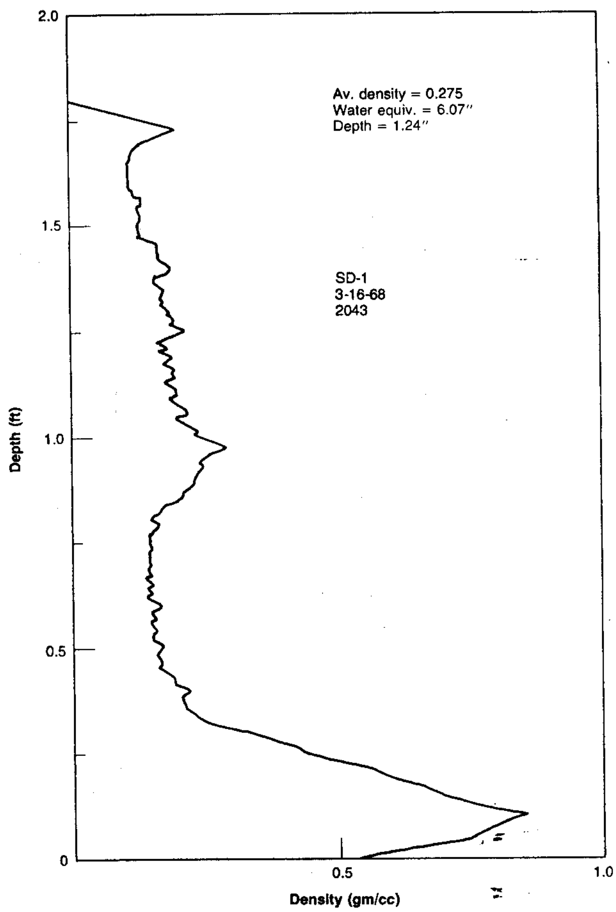


FIGURE 1.29.—Chart from a gamma-ray snow density gage.

DATA REDUCTION

Many field observations become useful only when properly transcribed. Field data are no better than office tabulation and reduction. Accurate final results require care through all processing steps.

Data should be compiled under the premise