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U. S. DEPARTMENT OF AGRICULTURE.

WEATHER BUREAU

CHARLES F. MARVIN, Chief.

MEASUREMENT OF PRECIPITATION

INSTRUCTIONS

FOR THE MEASUREMENT AND REGISTRATION OF PRECIPITATION BY MEANS OF THE STANDARD INSTRUMENTS OF THE U. S. WEATHER BUREAU.

CIRCULAR E, INSTRUMENT DIVISION.

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THE MEASUREMENT OF PRECIPITATION.

1. *Definition.*—The word "precipitation," as used in meteorology, is understood to include moisture that reaches the earth's surface in whatever form, as rain, snow, hail, dew, frost, etc., although in practice dew and frost are seldom measured.

2. *Units.*—All forms of precipitation are measured on the basis of the vertical depth of water, or water equivalent, which would accumulate on a level surface if all of it remained as it fell and none flowed or soaked away or was lost by evaporation. Snow, hail, etc., are also measured on the basis of actual depth. The unit for all United States Weather Bureau measurements of precipitation in whatever form is the inch.

3. *Exposure of gauges.*—The literature of rainfall measurements abounds with experiments which prove that the most disturbing agency to a proper collection of rainfall is the wind. Even the light wind that prevails 2 or 3 feet above the ground may cause a deficiency of 10 per cent in the catch. Records of wind velocity made at Indio, Calif., show two to three times as much wind at 12 feet above the ground as at 1½ feet above the ground in an alfalfa field. This example shows the advantage of a ground exposure for a rain-gauge. It is therefore important to select for the exposure of the gauge a position in some open lot, unobstructed by large trees or buildings. Low bushes, shrubbery, fences, or walls that break the force of the wind are beneficial; but in order that these protecting objects may not themselves intercept rain that would otherwise fall into the gauge, they should be no nearer to the gauge than their own height. Unfortunately the necessity of locating Weather Bureau offices in large cities renders it in some cases impracticable to find a ground exposure, and then the gauge must be exposed on a roof. In such case the middle of a large, flat, or nearly flat, roof should be selected, and all possible advantage should be taken of parapets, pent houses, etc., that will break the force of the wind. In some instances, fences 6 or 8 feet square have been built upon the roof to protect the gauge. There is no satisfactory exposure possible on a pyramidal roof exposed to the wind, or near the edge of any roof exposed to the wind.

4. *Installation.*—In general, at regular Weather Bureau stations the rain- and snow-gauges will be installed side by side, not nearer to each other than 3½ feet, center to center. At stations where a recording-gauge is in operation, a standard 8-inch gauge should also be exposed for use as a snow-gauge in the winter and as a check on rainfall in cases of emergency.

5. *Leveling.*—Rain- and snow-gauges are always installed with their receivers level, no matter what the slope of the ground in the vicinity may be.

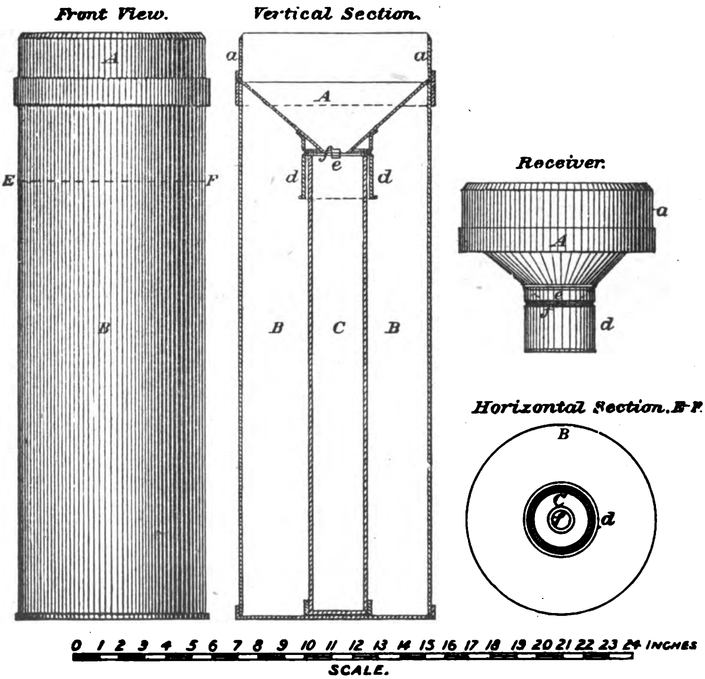

FIG. 1.—Rain-gauge, 8-inch, line drawing.

6. *Description of standard 8-inch gauge.*—The gauge consists of the following parts: The receiver A, Figure 1; the overflow attachment B; the measuring tube C; the measuring stick.

The top cylindrical portion of the receiver, marked *a* in Figure 1, is exactly 8 inches in diameter inside, and is provided with a funnel-shaped bottom, which conducts rain falling into the receiver into the tall cylindrical measuring tube C, the total height of which, inside, is exactly 20 inches. The diameter of this tube is much smaller than the large receiving tube *a*, being only 2.53 inches. In consequence of this a small amount of rain falling into the receiver and flowing into C fills the latter to a depth greater than the actual rainfall in proportion as the area of the receiver is greater than the area of the measuring tube. In the standard gauges of the Weather Bureau the depth of the rainfall in accordance with this principle, is magnified just 10 times. The receiver A has a sleeve *d*, Figure 1, which slips over the tube C. When the rainfall is very heavy the tube C may be filled to overflowing. In this case the excess of rainfall escapes between the sleeve *d* and the tube C and is retained in the large overflow attachment B. The overflow has the same diameter as the collector B, namely, 8 inches, and is used separately as a snow-gauge in the manner explained in paragraph 4. The several portions of the gauge are also illustrated in Figure 4.

7. *Measuring stick.*—The measuring stick is best made of a strip of straight-grained cedar, nine-sixteenths of an inch wide, seven sixty-fourths of an inch thick, and 24 inches long, and graduated into inches and tenths of inches. Remembering that the actual depth of the rainfall is magnified ten times, as explained above, it is plain that if the water be 10 inches deep in the measuring tube the actual rainfall must have been only 1 inch, or if the water in the tube be only one-tenth of an inch (or written as a decimal, 0.1 of an inch) deep, then the rainfall must have been only one one-hundredth of an inch (or written as a decimal, 0.01 of an inch).

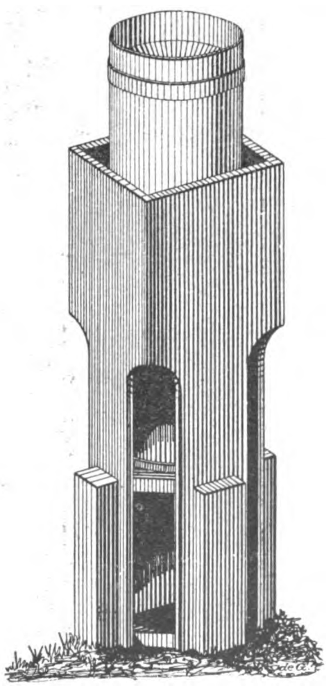

FIG. 2.—Rain-gauge, 8-inch, in box support.

8. *Rain-gauge box support.*—The box in which the gauge is shipped serves well as a stand or support for the instrument and is in some respects superior to the iron tripod for the purpose (see par. 58), although not as lasting. The wooden head may be removed by withdrawing the four screws that hold it in place, after which it is to be lowered to the level of the four screw holes in the sides of the box about 10 inches from the bottom. The same four screws then serve to hold it in the new position. Four flat stakes driven down, to which the box support is attached by nails or screws, serve to anchor it to the ground. Provision for air circulation underneath the bottom board decreases the liability to decay.

9. *Iron-tripod support.*—Figure 3 illustrates the gauge mounted in the standard iron-tripod support, which, when erected upon a roof platform, is easily secured with screws through the feet. When a ground exposure is selected for the gauge, it will be sufficient to

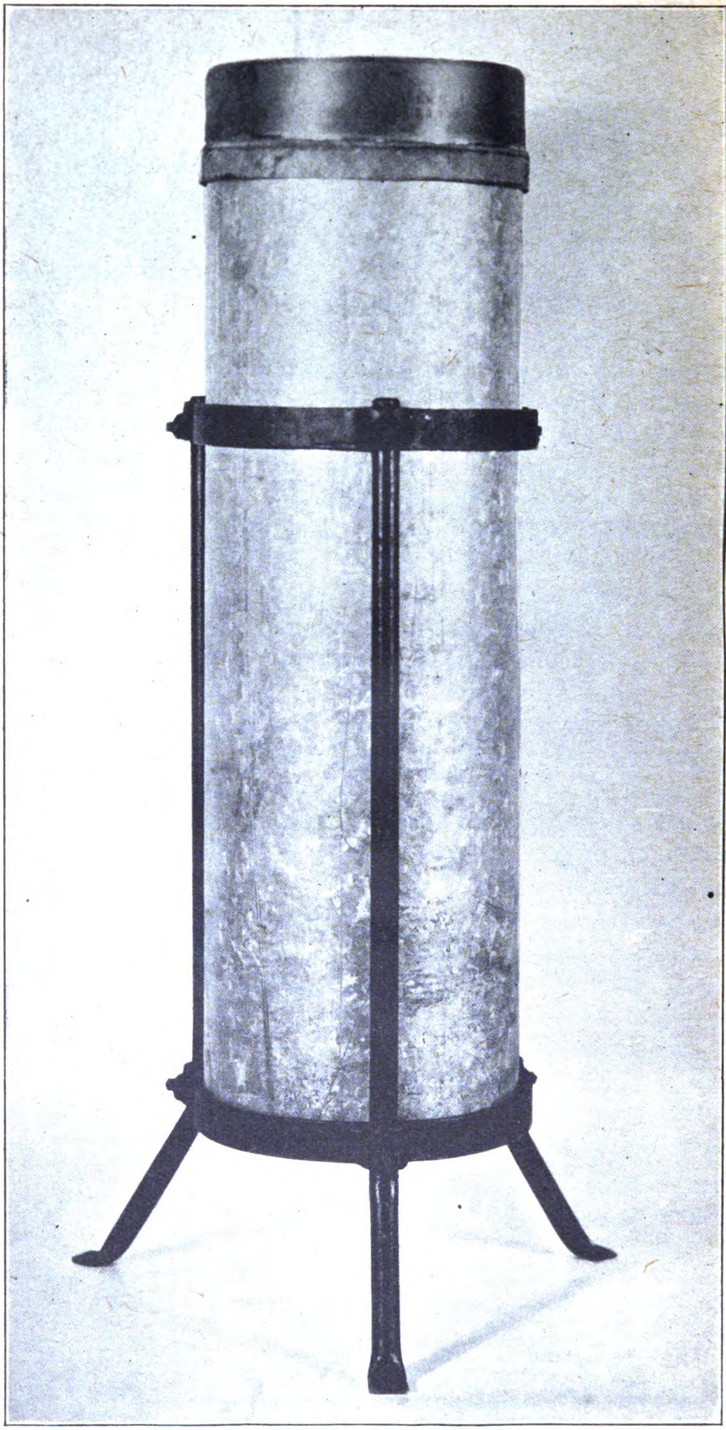

FIG. 3.—Rain-gauge, 8-inch, in iron-tripod support.

drive down three substantial wooden stakes until about flush with the surface and screw the feet of the tripod to them. If the ground is so hard that the tops of the stakes are bruised in pounding, it will be best to stop driving a few inches short of the surface and saw off the projecting stakes to the proper level, then secure the screws firmly in the stakes. A better method is to fasten the feet to a concrete walk with lead-sheathed anchor screws.

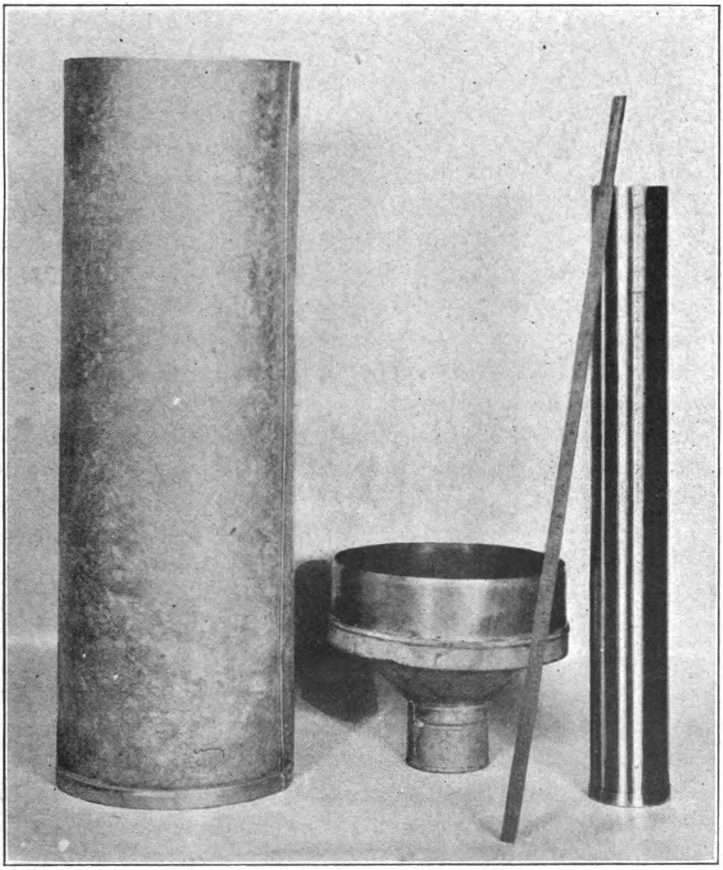

FIG. 4.—Rain-gauge parts.

10. *To measure rainfall and snowfall: Rainfall.*—The depth of the water in the 8-inch gauge is measured by inserting the measuring stick into the gauge through the small hole in the funnel. When the stick reaches the bottom of the measuring tube, it should be held for one or two seconds and then withdrawn and examined to see at which division of the graduation the top of the wet portion comes. The numbering of this division, as stamped on the stick, gives the

actual depth of rainfall. In making out records and reports observers should always use the decimal expressions.

11. After measuring and recording the precipitation, the receiver of the gauge should be removed, the measuring tube emptied and drained, and the parts placed in position again. Observers should be careful to replace the measuring tube so that the bottom stands within the ring or bead in the middle of the bottom of the overflow, and in putting on the receiver to see that it passes over the measuring tube and rests squarely upon the overflow.

12. *Measuring tube overflowed.*—When the amount of rain that has fallen more than fills the measuring tube, first carefully remove the receiver, so as not to spill any of the water in the measuring tube, which should be exactly full. If some of the water has been spilled into the overflow, a proper allowance for the amount should be made, or that remaining accurately measured with the stick, as already described. The tube is carefully lifted out, so as not to spill any of the water into the overflow, then emptied, and drained. The water remaining in the overflow is now poured into the measuring tube, and the depth obtained in the usual way. Suppose this is found to be 0.47-inch rainfall; then, remembering that the measuring tube contains 2 inches, the total amount is 2 inches plus 0.47 of an inch= 2.47 inches. Or, in case some water was spilled from the measuring tube, the 0.47 inch should be added to the first-measured amount to give the total rainfall.

13. *Snowfall.*—Snowfall should be measured as to depth of the layer of the snow itself, also the equivalent depth of the same layer supposing it reduced to the liquid state. Special methods and apparatus are required to effect these measurements in a satisfactory manner, and the assumption sometimes made that the water equivalent is one-tenth the snow layer is only coarsely approximate. During the winter season, especially in those climates where the precipitation is nearly all in the form of snow, only the overflow attachment will be exposed in the support as a snow-gauge, the receiver and measuring tube being removed to the house. These parts can not be used for measuring snow. However, since the method of manufacture renders the knife-edged funnel more accurate in area than the overflow attachment the former should be given preference in measuring rain.

14. *Overflow used as a sampler.*—When the overflow collector is unprotected from the wind its catch represents the true amount of snow only in the unusual case of precipitation during calms or very light winds. On windy occasions the catch is often highly inaccurate, and in the absence of special appliances such as described in later paragraphs the true quantity must be found, if possible, by measuring a section of the freshly fallen snow cut out by forcing

the overflow mouth downward through the layer and then slipping a thin board or sheet of metal underneath so as to separate and lift up the section of snow thus cut out. The special appliances described in paragraphs 75 to 80 will be used when available.

15. *Melting the sample.*—Assuming that a representative quantity of snow has been obtained in the overflow, a measurement may be secured by placing the vessel in a warm room until the snow has melted, and then measuring the water in the measuring tube in the usual way.

16. *Addition of measured water.*—The method just described is objectionable, owing to the time required and to the loss of the snow or water by evaporation. The following plan is much better: Take the overflow into the room and pour into it one measuring tube full of water to the brim, preferably warm. In cases of deep snowfall more water will be required. This will melt, or at least reduce to a fluid slush, a considerable amount of snow. The measuring tube should then be filled to the brim from the melted contents of the overflow and emptied, thereby discarding a quantity of water equal to that added. The remaining water in the overflow when measured in the tube then gives the actual depth of melted snow.

17. *The one-tenth rule.*—In addition to this measurement by the gauge, a measurement will be made of the actual depth in inches of the snow on the ground. Select a level place of some extent where the drifting is least pronounced, and measure the snow in at least three places. The mean of these measurements will give the snowfall, which is to be entered in the column of the report headed "Depth of snowfall in inches." Whenever it is impracticable to melt the snow as described in the preceding paragraph, one-tenth of this mean will give an approximate value, in water, for the snow which could not be melted. This value must be set down in the proper column of the report in precisely the same manner as rainfall or snow melted in the gauge, but with an appropriate explanatory note on the margin of the sheet. After snowfall has once been measured the same snow should not be measured at subsequent observations. Any fresh snow, however, should be measured and recorded as it falls. For additional instructions for measuring snow see detailed description of methods and apparatus beginning with paragraph 56.

18. *To determine amount by weighing.*—When there is at hand a trustworthy spring balance or other form of weighing device, the contents of the gauge may be weighed, and the corresponding depth of water determined from the table below. It is best to empty the water or snow into a light-weight container such as a pail made of thin sheet metal or aluminum in order that the tare may not be too great. It is, however, possible to weigh the entire gauge and

contents, a plan of considerable advantage when rain is frozen in the gauge and the observer is limited for time.

19. *Conversion Table.*—Depth of water corresponding to the weight of snow (or rain) collected in an 8-inch gauge is given in the following table:

[1 pound equals 0.55 inch.]

Weight.	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
Pounds.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
0.0.....	0.00	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05
.1.....	.06	.06	.07	0.07	.08	.08	.09	.09	.10	.10
.2.....	.11	.12	.12	.13	.13	.14	.14	.15	.15	.16
.3.....	.17	.17	.18	.18	.19	.19	.20	.20	.21	.22
.4.....	.22	.23	.23	.24	.24	.25	.25	.26	.26	.27
.5.....	.28	.28	.29	.29	.30	.30	.31	.31	.32	.33
.6.....	.33	.34	.34	.35	.35	.36	.36	.37	.38	.38
.7.....	.39	.39	.40	.40	.41	.41	.42	.43	.43	.44
.8.....	.44	.45	.45	.46	.46	.47	.47	.48	.49	.49
.9.....	.50	.50	.51	.51	.52	.52	.53	.54	.54	.55

20. *Description of the tipping-bucket gauge.*—The gauge comprises five principal parts Figures 5 and 6, namely:

(1) The tripod support.
(2) The collector and inclosing case, which are in three pieces.
(3) The bucket frame.
(4) The tipping bucket.
(5) The measuring tube.

The collector is detachable from the remaining portions of the inclosing case, in order to facilitate access to all parts. This is also true of the middle section of some gauges.

21. *The collector.*—The top section, called the receiver or collector, is made of a sharp-edged brass rim, 12 inches in diameter, inside, and provided with a funnel-shaped bottom and a small tubulure at the center so that the water falling within the collector is conducted to a point directly over the center of the tipping-bucket bearings. The middle section is made of galvanized iron, with a hinged door. The lower section, or reservoir, is also of galvanized iron, and is provided with a brass stopcock at the bottom for emptying the gauge of water.

22. *Tipping-bucket and frame.*—The tipping-bucket and a portion of the frame are shown in figure 6. The bucket is mounted on a detachable brass frame carried on insulated brackets within the inclosing case. A central partition, indicated by dotted lines in Figure 6, divides the bucket into two equal compartments. The trunnions forming the axis upon which the bucket tips are placed below its center of gravity, and the bucket is further supported in one or the other of two limiting positions by either of two blunt knife-edge-like stop-pins located on the side of the bucket opposite that shown in the picture. In either position of the bucket one or the other of the

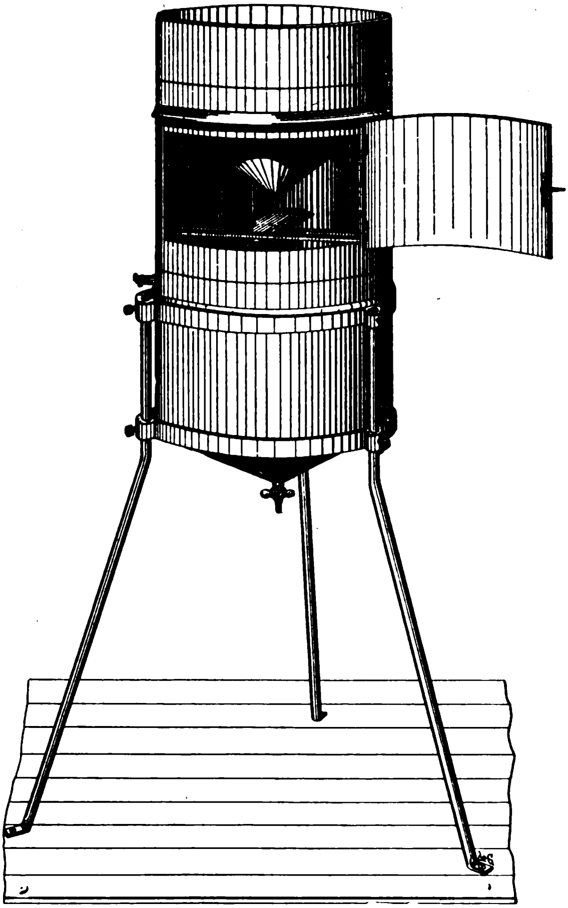

Fig. 5.—Tipping-bucket gauge.

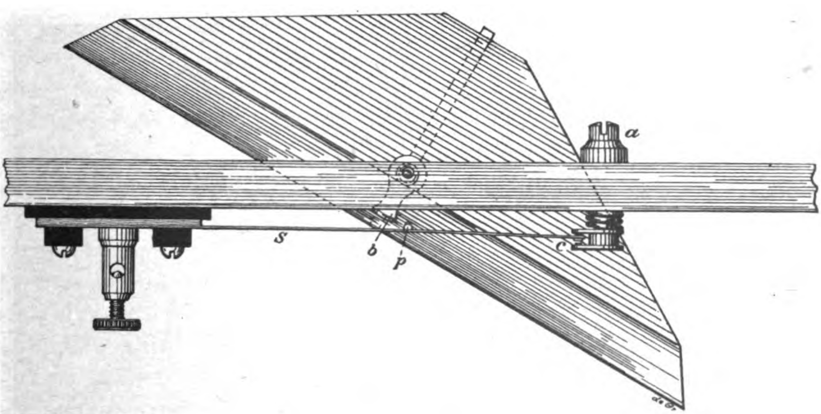

Fig. 6.—Tipping-bucket and frame.

compartments will receive and retain the water delivered through the funnel of the collector. The weight of the bucket and the position of its center of gravity have been so adjusted in relation to its supports that when one of the compartments has been charged with the quantity of water representing one one-hundredth of an inch of rain in the 12-inch gauge, the bucket tips upon its bearings, emptying the water from the one compartment, and at the same moment presenting the other compartment to receive the incoming water. The water thus delivered from the buckets is retained in the reservoir section for subsequent measurement in bulk.

23. *Automatic registration.*—The automatic registration of each hundredth of an inch of rainfall, that is, each tip of the bucket, is effected by aid of the electrical circuit-closer shown in Figure 6. Short sectors *b* are attached to each trunnion of the tipping bucket. When the bucket is at rest in either of its limiting positions the sectors stand near to, but not in contact with, a pair of circuit-closing springs of which the insulated one is shown at S.

24. *Electric contact.*—In the act of tipping, after the bucket has moved a little, the sectors *b* make contact with the springs and rub over them during the greater part of the subsequent motion. This closes the electric circuit which is formed between the whole metallic framework, including the bucket, and the insulated spring S. During the last portion of the tip of the bucket the sector *b* slips off and moves a small distance away from the springs, thus opening the electric circuit, and also leaving the bucket perfectly free to tip with the next hundredth of an inch of rain.

25. *Contact insurer.*—The contact of the sectors *b* with the springs will generally close the electric circuit; nevertheless, when the contact spring S is deflected by the passage of the sector *b* the platinum-tipped end at *c* makes contact with the platinum point attached to the adjustable post *a*, thus providing a second simultaneous independent closure of the electric circuit.

26. *Adjustment of contact spring.*—The contact spring is in proper adjustment when the end *c* rests against the insulated point on the adjusting screw *a* and when, upon tipping the bucket, the sectors *b* rub rather easily over the springs; at the same time the platinum tip at *c* must make contact with the platinum point on the adjustable screw *a*. If *p* is but slightly touched by the sector *b*, or is missed entirely, or if *p* must be pushed aside considerably and presses hard against the sector while passing, these defects may, in general, be remedied by properly turning the screw *a*. In some cases it may be necessary to bend the spring slightly as well as to adjust the screw *a*. Observers are particularly cautioned to remedy faulty adjustments of the contact springs. All instruments are in perfect adjustment when sent out, and little or no occasion should

arise for readjustment if the mechanisms are properly cared for. The holes in which the axis of the bucket rests are intentionally about twice the diameter of the pinions in order to diminish the friction to the minimum. One of the holes is slotted on top to permit the removal of the bucket for cleaning or other purpose.

27. *Double-contact springs.*—To insure electrical connection during tipping, buckets are provided with two spring contacts similar to the one described above, except that the end and the contact at *c* are omitted in some cases. The second spring, with its corresponding sector, is placed on the opposite side of the bucket from that shown in Figure 6.

28. *Back-tipping, or rebounding, of bucket.*—If the bucket is placed in the frame with the stop-pins on the front side, that is, so as to strike on the side of the supporting frame having the slotted opening and binding posts, it will be found that during rainfall the recoil of the bucket, on tipping, will frequently cause it to rebound and produce two steps of the recording pen in quick succession. These are apparent on the record and are due to the faulty position of the bucket which must be placed with the stop-pins on the *rear* side of the frame, in which position there is scarcely any rebound.

29. *Instructions for mounting.*—When shipped, the brass frame carrying the tipping bucket is generally separate from the gauge, and the tripod support is in parts. The manner of putting the latter together will be easily understood from a view of the completed tripod in Figure 15. The bucket frame is readily placed in position within the inclosing case and secured to the brackets. The binding posts on the frame should come on the side nearest the door in the middle section.

30. *Accuracy of measurement.*—The accuracy with which any given bucket will deliver a certain quantity of water at each tip has been experimentally investigated. Although every precaution has been taken to secure the greatest accuracy in the adjustment of the buckets, yet, owing to unavoidable irregularities in the action of the water in the buckets, and to the fact that a very small discrepancy in the volume of a single tip may become important in the total volume of one or two hundred tips, it will often be found that the total volume shown by the automatic record fails to agree with the actual volume of water retained in the reservoir.

31. This may result from one or more of several unavoidable causes. The buckets have been adjusted to deliver the proper volume of water for slow and moderate rates of rainfall, such as most frequently prevail. During heavy showers, when, for example, rain is falling at the rate of 5 or 6 inches per hour, each bucket will be filled to the tipping point in from six to seven seconds, or thereabouts. Inasmuch as a very small but nevertheless perceptible

amount of time is required for the bucket to tip far enough to cut off the inflow of water, it is obvious that during such rapid rainfall an appreciable quantity of water will flow into the bucket after it has begun to tip. Accurate measurements made at this office have shown that the time required by the standard buckets to tip from the starting point to a point where the inflow of water is cut off is about three-tenths of a second. It therefore follows that when the water is flowing into the bucket at a rapid rate—such, for example, as will fill the bucket to the tipping point in six seconds—then during the three-tenths of a second occupied in tipping water will continue to flow into the bucket, and the excess thus delivered will be about one-twentieth of the whole amount; that is, an inch of rainfall will cause the bucket to tip only about 95 times, whereas the same amount of rain at a slow rate would cause the bucket to tip 100 times. The discrepancy from this cause has been reduced as much as possible. but it can not be entirely eliminated in the case of small buckets—such, for example, as will make 100 tips per inch of rainfall.

32. *Effects of dirt.*—It will be found also that the different hygroscopic conditions of the metal surfaces cause the water to wet the buckets in a different manner on different occasions. This will lead to a slight difference in the volume of water delivered per tip of the bucket.

After being thoroughly wetted with more or less dirty rain water, which afterwards dries away, a sediment is left upon the metal surfaces; as this alters their hygroscopic character, it is desirable that at least the inside surfaces of the buckets be kept as clean as possible. The bucket should be removed from the supporting frame from time to time as may be required by the atmospheric conditions at the several stations, and the compartments thoroughly cleaned. The use of a mild scouring agent is recommended. No deposits of dirt should be allowed to accumulate in the bearings of the axis or about the small pinions of the bucket. Special pains must be taken to avoid bending trunnions, as slight changes here will have an important effect in changing the volume of water delivered per tip.

33. *Corrosion.*—The most serious cause of error in the amount of water delivered per tip has been found to be due to the effects of dust and corrosion on the frame and stop-pins of the bucket. It is absolutely necessary that the stop pins and points on the frame where the pins strike be frequently cleaned. Of course the bucket and frame should be kept clean elsewhere also, but as soon as the pins and points of contact on the frame become dirty a slight adhesion is established between the two then in contact. When the dirt at these points becomes wet or damp, as it does during long rains, the adhesion becomes aggravated, and more water must enter

the bucket in order to overcome the sticking at the stop-pins, thus causing a more or less serious deficiency of record.

34. *Effect of faulty leveling.*—If the brass frame which carries the bucket is not properly leveled, one of the compartments will deliver a greater, and the other compartment a less, volume of water, per tip than the normal amount, although the average of the two will still remain very nearly the normal volume. While the errors resulting from small defects of level are not serious, it is desirable that some pains be taken when installing the gauge to make the frame upon which the bucket is mounted as nearly level as practicable.

35. *Recording mechanism.*—The apparatus designed to record the tips of the bucket is attached to the so-called triple register. The record sheet upon this instrument moves at a relatively rapid rate. Nevertheless, in order to render the registration of the most rapid rates of rainfall legible, the recording pen traces its record in a zigzag line of steps, each step represents a hundredth of an inch of rain, and one complete zigzag comprises ten steps. In the majority of cases the individual steps are perfectly legible, but in records of very rapid rates each individual step can not always be discerned. The points of the zigzag, however, are separated by ten tips or steps and are distinguishable under even the most rapid rates. The recording mechanism is described in detail in Circular D, Instrument Division.

36. The recording pen on the zigzag trace should be adjusted to fall within the available space on the record sheet so as not to encroach upon the anemometer record.

37. When a record sheet is to be changed, the whole pen arm is lifted a short distance upon the staff supporting it, and turned to one side, thus providing free access to the cylinder. In replacing the pen, care must be exercised to place the steel pin within the groove of the cam wheel, which produces the zigzag motion.

38. When the pen of the rainfall magnet has been lifted from the sheet temporarily, care should be exercised not to disturb or move the armature of the magnet or to make any change in the position of the ratchet cam, except such as results from the closure of the electric circuit. If these parts are not disturbed, the pen, when replaced, will continue its trace of steps in proper sequence relative to the original trace. By this precaution the pen may be lifted from the sheet for a short time while record is being made, and although a few steps of the cam may be taken during the interruption of the record and of which no corresponding trace is made, yet an examination of the record with respect to the complete zigzag will show the number of steps less than ten that may have been lost.

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39. *Check readings.*—Owing to unavoidable sources of errors in the volume of water delivered per tip of the bucket under various circumstances already explained it is necessary that when rain has been recorded the total volume of water in the gauge shall be checked with the automatic record, and for this purpose the observer will enter upon the record sheet, when changed, the "stick measurement" of the gauge.

40. *Check readings, how made.*—To ascertain the total volume of water in the gauge the water retained in the reservoir will be drawn off into the brass measuring tube, with which each gauge is provided, and the amount measured in hundredths of an inch by stick in the usual way.

41. Observers are cautioned against using the small brass measuring tube belonging to the ordinary (8-inch) gauge for measuring the rainfall collected in the tipping-bucket (12-inch) gauge. If, from necessity, the small tube is used, the apparent depth of rainfall measured in the smaller tube must be divided by 2.25, in order to ascertain the true depth of rainfall in the 12-inch gauge.

42. *Precautions against freezing.*—As the tipping-bucket gauge does not record snow or similar precipitation in the solid form, observers will use all necessary precaution to prevent the collection of partly melted precipitation which may subsequently freeze and injure buckets, or otherwise make the gauge unserviceable. When such injuries are probable, the cylindrical portions of the gauge should be removed to the office.

43. *Instructions for use of Marvin float rain-gauge.* A few stations are provided with the weekly gauge of the float type designed by Prof. C. F. Marvin in 1913. The instrument is intended to record rain only, and hence can not be operated in freezing weather.

44. *Description.*—Figure 7 shows the complete gauge. The collector A at the top is exactly 8 inches inside diameter across the brass rim and is surrounded by the rectangular wind shield B. This shield is nearly 21 inches square at the upper edge and curves downward and inward to the copper cover C, to which it is screwed. The cover is about 15 inches square inside, and together with the 8-inch collector forms the top, the two being soldered to each other. The cover is ordinarily hinged to the top plate of the support and is locked in position by a small bolt. The support E, which is a little over 2 feet high, is made up of two iron castings, one at the top carrying the recording apparatus and cover, and one at the bottom forming the base for the receiver D. The two castings are connected together at the center by a 1¼-inch pipe, which also serves to inclose the small brass counterweight. Four small iron pipes at the corners form posts, which are screwed into the upper casting and fastened to the lower casting by means of set screws. The lower

ends of the corner posts form feet for the gauge. Figures 8 and 9 illustrate more clearly the recording apparatus. The registration is a record of the motion of a float upon the surface of the water in the receiver. To eliminate inaccuracies and uncertainties, the float is suspended by means of a fine, flexible brass chain, such as jewelers use, permanently attached to one end of the drum H. When the

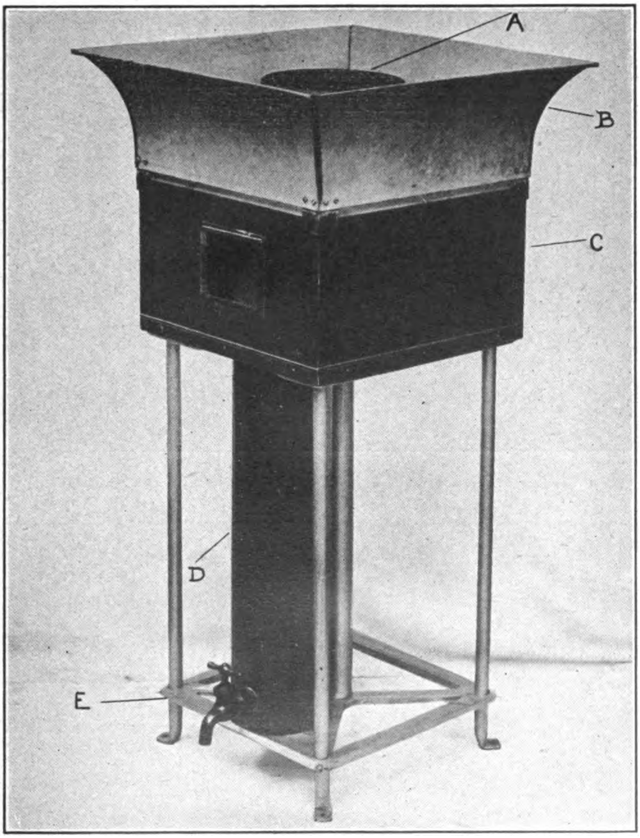

Fig. 7.—Weekly float-gauge.

float rises the chain is wound up by the pull of the counterweight suspended from a length of silk cord, also fastened to and wound up on the drum H. The chain and cord run in a shallow screw thread cut in the drum, and the chain winds up as the cord unwinds, and vice versa. The chain eliminates possibilities of variation of length, such as would be caused by moisture and stretching should a cord be used; moreover slipping is impossible.

The cam shaft I, carrying the drum H, turns once for each one-half inch of rainfall, and revolves a cylindrical cam K, made to turn with the shaft I but free to slide endwise at the same time. The pen and pen level are shown at S and L, respectively. The pen carrier T is mounted on the long screw N and guided by the rod

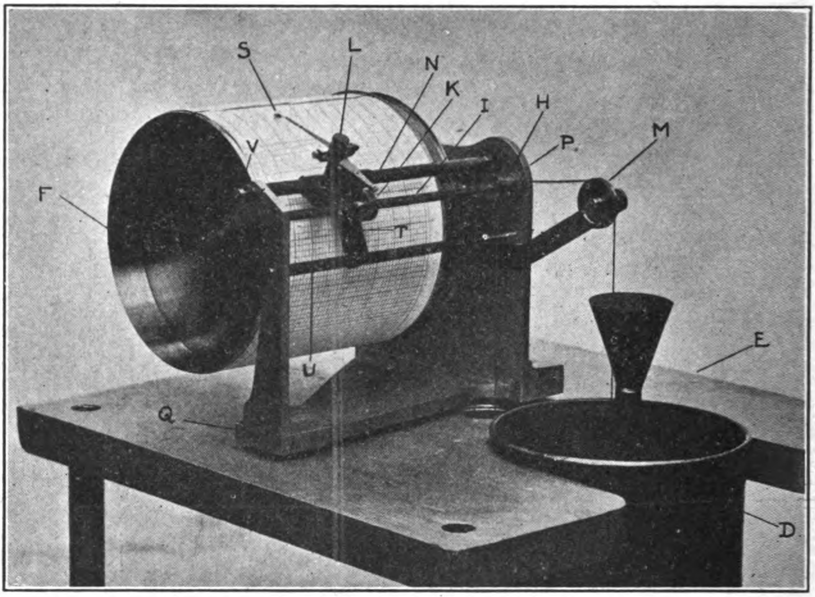

FIG. 8.—Recording mechanism of weekly float-gauge.

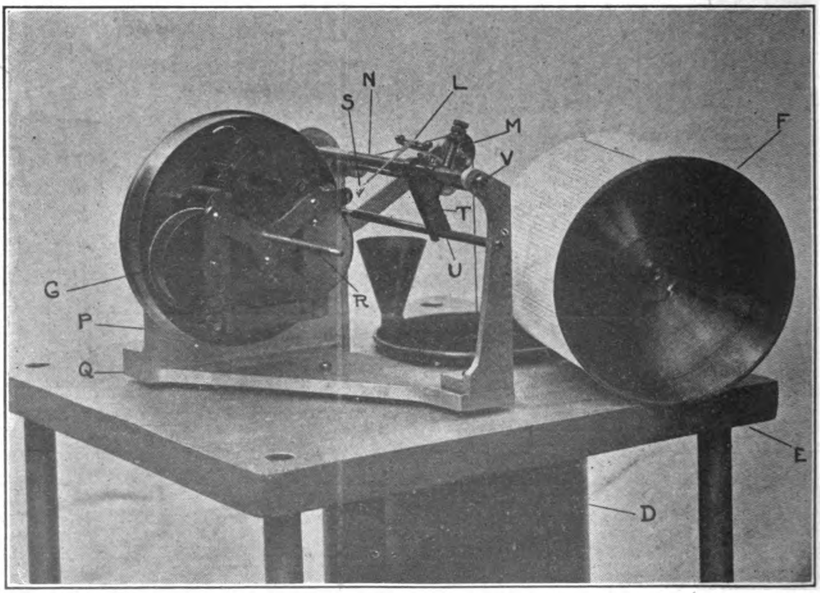

FIG. 9.—Clock and driving mechanism of weekly float-gauge.

U. The motion of the pen is somewhat complex, but the arrangement is one that affords the maximum of clearness of records of excessive rates of precipitation, and at the same time the minimum of size of record sheets. Nearly all other automatic gauges with records on a large scale require very large sheets that must be changed after a relatively moderate amount of rain has been recorded thereon. In this gauge the rise of the float in the manner already explained rotates the cam K, which in turn causes the pen to oscillate laterally over an extreme range of one-half inch on the record sheet. This amount of motion, over and back, represents one-half inch of rain. The one-tenth-inch rulings on the sheet represent 0.05 of an inch of rainfall and permit of very satisfactory estimates to hundredths of inches. The practical impossibility of any kind of accumulative error in this gauge makes its records more reliable than gauges of the tipping-bucket type.

45. The adoption of an oscillating motion of the pen enables a large amount of precipitation to be recorded in a narrow band one-half inch wide across the record sheet. The remainder of the sheet is made available for additional record simply by causing the pen carrier to move laterally by the action of the clock at the rate of one-half inch per revolution of the drum. Thus each day's record (one revolution of the drum) occupies only a transverse space on the record sheet one-half inch wide. Each sheet provides a record for eight days. The object of adopting an eight-day record is that four sheets will suffice for a full record for each and every month. Instruments using only seven-day or weekly record sheets require five sheets with little only on one of the sheets. The record cylinder F is 6 inches in diameter outside and 5$\frac{7}{16}$ inches in length over all, and it is made to revolve on the axis R by the clock, which is entirely inclosed and protected from dust and moisture when the cylinder is in place.

46. *Operation.*—The rainfall caught in the 8-inch collector A passes through a funnel and a small pipe to the bottom of the cylindrical receiver D, which has half the sectional area of the receiver A. The depth of rainfall is therefore only doubled for measurement. Receiver D has a capacity for nearly 10 inches of rainfall and may be conveniently emptied by the aid of the spigot provided. This has a siphon-like extension inside the receiver that permits the surplus water within to be drawn off to a certain zero level, but leaves remaining not only a small quantity of water but especially a surface layer of kerosene that is added to the receiver when the instrument is installed for the purpose of preventing evaporation. Changes in the level of the water are communicated through a float and auxiliary mechanism to the recording pen in the manner explained above.

47. Although the gauge may be continued in operation for eight days without requiring attention, yet occasional inspections during the period will avoid possible failure, as it can hardly be expected that

the instrument will invariably give satisfactory service without attention.

48. *Exposure and installation.*—The exposure of the gauge will conform to the instructions already outlined in paragraphs 3 and 4. When the gauge is installed some kind of a support is necessary, and either a small wooden platform or a surface of concrete will be used. The wooden platform permits fastening the feet of the gauge by wood screws. The gauge may be secured to the concrete by means of expansion bolts or other customary methods.

49. The gauges are sent out only after having been carefully inspected, tested, and the clock adjusted to keep correct time. When received, the float, counterweight, and clock key will be found wrapped in the bottom of the receiver. The float and counterweight will then be attached to the chain and cord, respectively, which are carefully cut to the proper lengths at the Central Office, so that when the cord is entirely wound up the float rests at the bottom of the receiver and a part of a turn of the chain still remains on the drum H. When these parts have been attached, water will be placed in the receiver to the depth of 4 or 5 inches and a layer of kerosene about one-fourth inch thick added to prevent evaporation. The spigot will then be opened, and closed when the flow of water has ceased.

50. The record sheet is arranged for use on the cylinder by first giving the sheet a cylindrical form, so that the punched holes in each end register over each other, then inserting the narrow metal strip through the holes so that the strip is on the outside of the sheet at only the center and ends. The strip must be inserted so that the top edge of the sheet will go next to the flange of the cylinder. Finally the sheet will be slipped endwise over the cylinder until the point of the metal strip is inserted in the slot in the flanged head of the cylinder. Of course, the overlapping ends of the rulings on the sheet should register with each other so that the diagonal lines come together.

51. When the record sheet has been put in place, the next step is to move the pen carriage T until it comes to rest against the stop or collar placed on the screw N. The record sheet is to be started or changed at or near noon, and this time should be adhered to, if possible, for the length of the float chain has been so adjusted with respect to the zero level of the water in the receiver that when the pen is set on the sheet and the pen carriage placed against the stop the oscillations of the pen will fall between the heavy diagonal lines on the record sheet. The last operation is to adjust the pen to the correct time by rotating the cylinder on its axis in the proper direction, similar to the manner customarily used in setting the hands of a clock. The backlash can be taken up by effecting the final

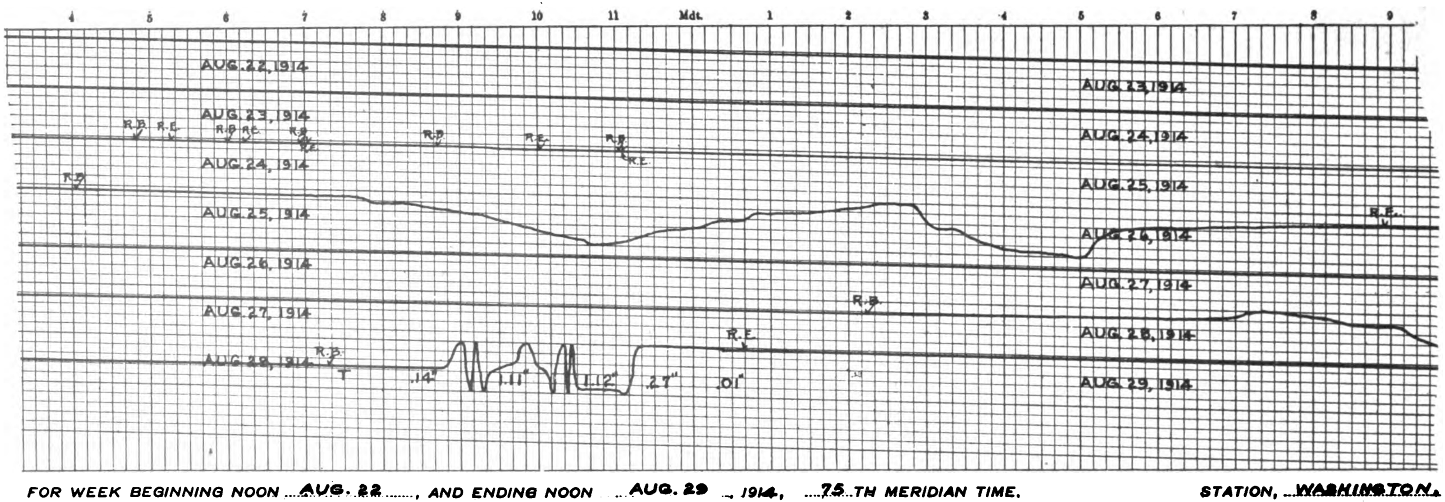

FIG. 10.—Sample record sheet from weekly float-gauge.

setting in a direction opposite to that in which the cylinder turns when moved by the clock.

52. *Explanation of record.*—Figure 10 shows a record sheet the actual size of which is about 20 by 5¼ inches over all when trimmed at the right-hand end ready to be placed on the cylinder. The vertical graduations on the sheet are spaced nearly 0.13 of an inch apart and correspond to 10 minutes of time; and the diagonal lines are spaced 0.10 of an inch apart and correspond to 0.05 on an inch of rainfall.

The graduations are of such size as to permit the record to be easily read, as will be seen by examining the illustration, Figure 10. Take, for example, the rainfall recorded during the night of August 28, 1914. It will be noticed that "rain began" (RB) at 7:18 p. m., but from that time until 8:47 p. m. very little rain fell, as is evidenced by the line traced by the pen, which is very nearly parallel to the diagonal lines, but which still has an upward tendency. A trace (T), or an amount too small to measure, is therefore entered for the hour ending at 8 p. m. At 8:47 p. m., however, the record line makes a decided bend upward, passes across four-fifths of the space in which it is moving (amounting to 0.04 of an inch of rainfall), and thence across two additional diagonal lines; all of which totals to 0.14 of an inch of rain up to the point where the record line crosses the vertical 9 o'clock line. Between 9 and 10 o'clock the pen made four complete oscillations with an additional movement of slightly more than two divisions (corresponding to 0.11 inch), making a total of 1.11 inches for the hour. During the next hour another heavy downpour occurred, the gauge recording 1.12 inches within 32 minutes, after which time until 11:05 p. m. no appreciable amount fell. The storm terminated with an additional heavy fall amounting to 0.27 of an inch within a short period ending at 11:10 p. m., the rain finally ceasing altogether at 12:40 a. m. (RE), after recording 0.01 of an inch between 12:20 and 12:22 a. m. The total amount of rainfall for the entire storm is therefore 2.65 inches. The performance of the gauge in recording lighter rains is shown by the record for the period from 4:04 p. m., August 25, to 8:55 a. m., August 26.

53. The observer should be careful to record the times of beginning and ending of rain by eye observations, making a written memorandum of the actual time of occurrence to be transferred to the record sheet when removed from the cylinder. The beginning of rain should be indicated by the letters "RB" (rain began), the ending by "RE" (rain ended), and the actual time checked on the sheet.

Insuring good record.—After operation of the gauge has begun, there are several features to be considered in order that a good and continuous record may be insured, as follows:

The clock should be kept running to the exact time, as nearly as can be ascertained, and if adjustment becomes necessary it will be accomplished in the usual manner by moving the small rod passing through the slot in the mounting plate P to the side marked S or F, to cause the clock to go slower or faster, respectively. If there is a time error, it should be noted on the record sheet when it is removed and the corrections applied to the several beginnings and endings of rain.

If, for any reason, the pen has not made a complete record, the total amount may be determined by noting the number of lateral throws made by the pen while the water is being drawn out to its original or zero level preparatory to placing a new record sheet on the cylinder. The amount thus determined should be indicated on the sheet, together with a brief note of explanation giving the times of occurrence of rainfall if practicable.

To avoid needless friction, about every second week, and oftener in a dirty location, the horizontal bars and screws I, U, and N should be rubbed off with an oily rag, so that there remains a clean but *slightly* oiled surface over which the pen carriage slides. The long screw with the pin and carrier can easily be removed by backing off the pivot screw V, and all other parts should be thoroughly cleaned by use of kerosene or similar light oil. When cleaned these parts should be supplied with only the merest film of fine oil, and when replaced the pivot screw V should be set up so that there will be just a trifle of "end shake" to the screw N. Occasionally the pivot bearings in the mounting plate and post should be given a *little* clock oil. The clock, being inclosed, should need but little attention and will be cared for in the customary manner.

Under no circumstances will the gauge be left out in freezing weather, for if ice forms in the receiver or in the pipe leading thereto these parts are likely to be rendered unserviceable.

54. *The Fergusson weighing rain- and snow-gauge.*—The purpose of this gauge is to record at the particular spot chosen for its exposure the amount and time of occurrence of precipitation in any form, such as rain, snow, hail, sleet, etc. The action of the gauge is best explained by reference to Figure 11, in which the several parts of the gauge are shown. By means of a suitable collector C the precipitation is directed into the receiver R, which is a well-made cylindrical copper vessel resting upon the scale platform J. This platform is rigidly connected to a yoke Y, whose lower cross member is attached to a strong coiled spring. The upper end of this same spring is attached to a bracket E, the purpose of which is to provide a rigid point of suspension. This point of suspension may, however, be adjusted up or down to a slight degree by turning the screw O to permit setting the recording pen to the zero of the sheet when the gauge

is empty. The movement of the receiver-platform yoke assembly produced by the added weight of the precipitation in the receiver is transmitted through a series of multiplying levers to the recording pen. Ordinarily a system of this kind would provide for only one traverse of the pen across the record sheet; but in this instrument there has been introduced an ingenious balanced linkage by means of which continuous downward movement of the receiver-platform-yoke assembly causes the pen to make three traverses of the sheet; that is, from its zero position to the top of the sheet, back again to zero, and again to the top. Each traverse of the sheet represents 3 inches of precipitation, and the total capacity of the instrument is therefore 9 inches.

The clock cylinder is of the same size and style as the well-known thermograph clock, but its rate of speed is such as to provide a complete revolution in 24 hours. The right-hand margin of the record sheet is trimmed close to make the scale continuous when the sheet is on the cylinder, to which it is secured by means of rubber bands. The record may thus be repeated on the same time scale day after day, using the same record sheet until rain has fallen, when the sheet is removed for preservation. When abrasion and consequent spreading of the ink indicates that the pen has been running on the same line for too long time, the pen can be raised a little, say one-tenth of an inch, so that a record of precipitation will leave a clear, sharp line. The total in such case is to be measured from this new zero. The funnel F is designed to be attached to the lower portion of the collector C to prevent evaporation, and also to minimize the effects of gusts of wind, which by their impact may cause momentary oscillations of the pen. This funnel must be removed when snow is expected. Its removal is a simple process that will be readily apparent upon inspection of the bayonet joints that serve to hold it to the collector.

The effects of wind pressure are further minimized by the use of a dashpot or stilling device. This dashpot should be filled with glycerin just sufficient in amount to cover the bottom of the movable cup when the receiver is empty. When the glycerin is in place, kerosene should be added until there is a layer about one-half inch deep floating on top of the glycerin.

The inclosing case has been somewhat altered in form in the gauges recently purchased, but the purpose is the same, namely, to permit access to the instrument for changing sheets, inking pens, etc., and at the same time to keep out rain and snow.

In starting a new instrument it is well for the observer to familiarize himself with its operation by gradually pouring water into the receiver, meanwhile observing the action of the pen upon the record sheet. A test for accuracy may be made at any time by placing a

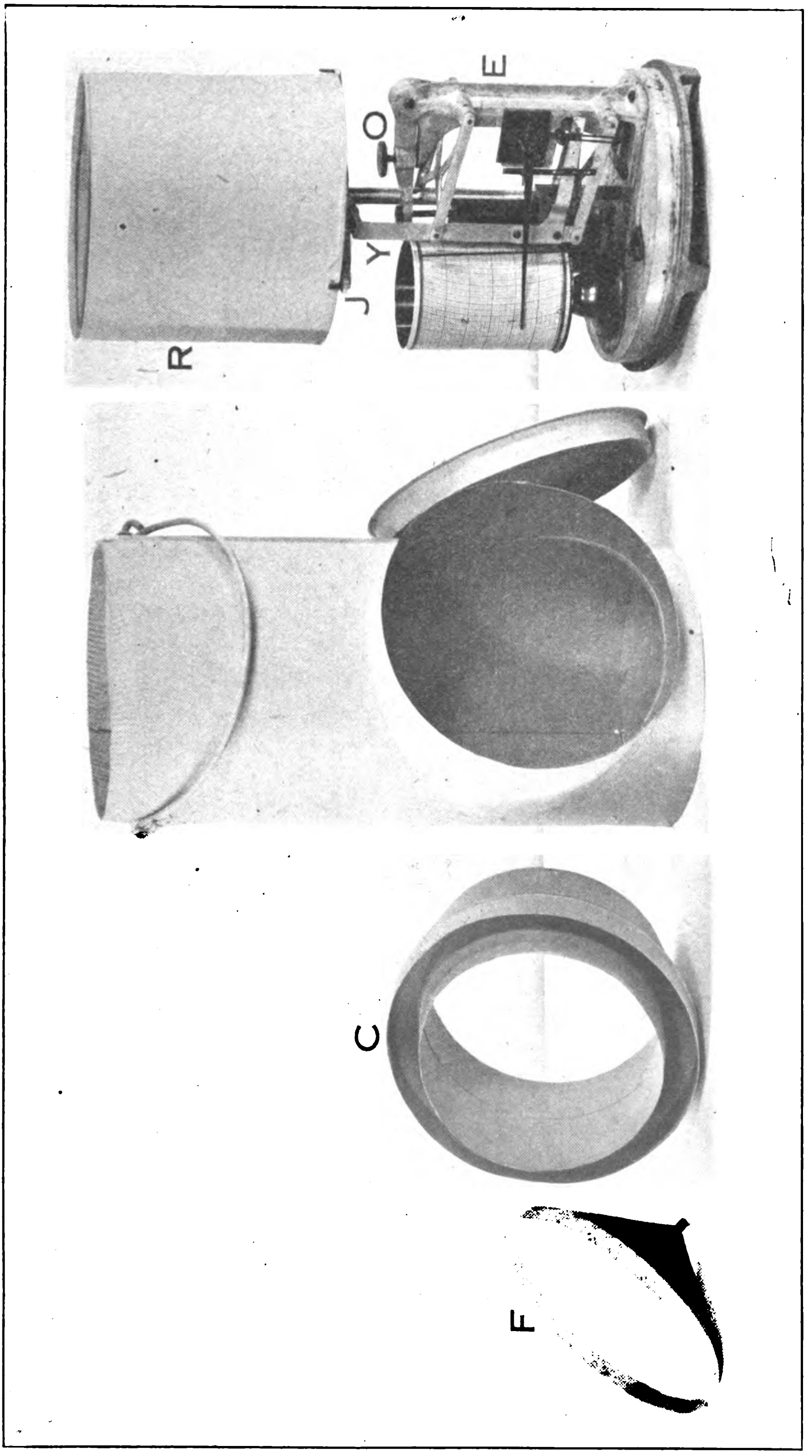

FIG. 11.—Fergusson weighing gauge, parts.

known weight of water, or for that matter of anything, in the receiver, when the displacement of the pen should correspond with the values given in paragraph 19, since the collector has a diameter of 8 inches. The measuring tube from the standard 8-inch gauge may also be used for testing this gauge.

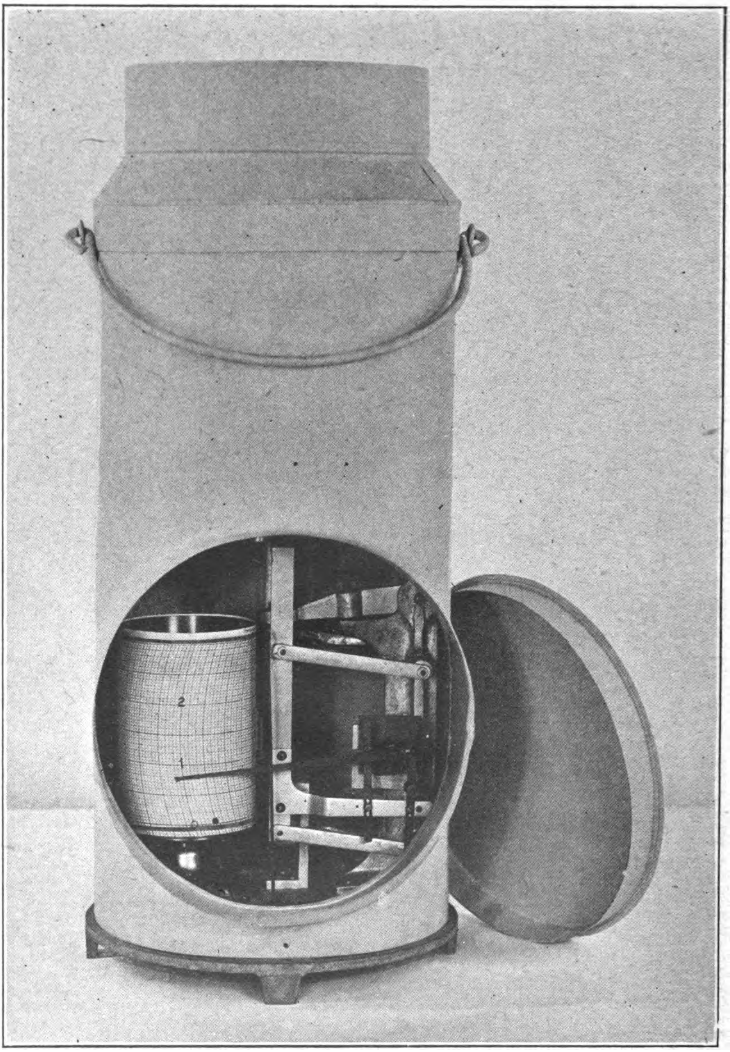

Fig. 12.—Fergusson weighing gauge, complete.

A more detailed description of the gauge may be found in the Monthly Weather Review, July, 1921, **49**: 379–384.

55. *Other forms of gauge.*—While this pamphlet is limited to a description of the standard equipment of the Weather Bureau it may be remarked that many excellent forms of rain-gauge are in use

throughout the world. Practically all agree in the principles of construction, embodying the open-top cylinder; but there are variations in size and set-up, and particularly in the methods of determining the amount. An excellent historical and descriptive paper on this subject has been prepared by Mr. Robert E. Horton.[1]

56. *Measurements of snow.*—Measurements of snowfall by means of collecting gauges can be satisfactorily made only when the gauge is shielded from the wind. The real problem is to catch the snow. Its subsequent measurement is a simple matter. A glade in a forest is perhaps the best possible location for a snow-collecting gauge, and the presence of trees, shubbery, or fences is helpful. Mechanical shields, which are generally in the form of a trumpet made of sheet metal, with its flaring rim somewhat higher than the month of the collector, are a necessity in the absence of natural shields, and are desirable in any event, because there is always some wind movement, even under favorable conditions of natural shielding.

57. *Collector to be removed.*—It is also important that the collecting vessel be of considerable depth so that the snow that falls into it may not be whirled out again by the wind, and for this reason when the 8-inch gauge is used to catch snow the funnel and measuring tube should be removed and only the overflow attachment should be used.

58. *Evaporation lessened.*—When conditions are such that the gauge is exposed to direct sunshine for any considerable time it is well to provide some means of shading it, since otherwise there may be appreciable loss by evaporation. The box support in which the gauge is usually shipped serves this purpose well, but when the overflow attachment is exposed in the iron-tripod support some attention is required to guard against evaporation loss.

59. *Snow section.*—When the precipitation to be measured has been entirely in the form of snow and at the same time it is possible to identify the layer, then the determination of the water content of the snow as it lies is the best method known, particularly since an opportunity is afforded to select sheltered spots and to make a number of independent measurements the mean of which is of which is of acceptable accuracy. This method may be used to demonstrate the degree of accuracy of the catch made in the gauge. Almost any tube with rigid walls and of known cross section may be used to obtain the sample, provided proper allowance be made for its area, although at the majority of Weather Bureau stations it is most convenient to use the 8-inch overflow attachment. Recent improvements in special snow-sampling devices simplify the work greatly, and it is hoped to supply samplers of suitable length to all regular stations that need them when funds permit.

[1] Horton, Robert E.: The Measurement of Rainfall and Snow: *Journal of the New England Water Works Association,* Vol. XXXIII, No. 1.

60. *Measurement of depth of snowfall.*—Existing instructions, which require the observer to measure the depth of snowfall at one or more points representative of the normal depth, will continue in force. There are two general conditions under which measurements must be made, however, which call for consideration.

The measurement of snow which has fallen on bare ground—here it is necessary only to measure the depth to the surface of the ground. Under such circumstances observers will determine, with the aid of the measuring stick, the depth at one or more places in open fields or on level surfaces where the layer has not been seriously disturbed or modified by drifting.

61. *Snow upon snow.*—The measurement of snow that has fallen on a previous layer—under these more difficult conditions measurements can sometimes be made on surfaces from which the previous layer of snow has been removed before the second fall began. In other cases, especially in cities, it is often possible to distinguish the surface of the previous layer by its discoloration from soot or dirt, or the formation of a crust through sleeting or freezing. The line of demarkation between the old and the new snow is often apparent to the eye by slight differences of texture or density, and which are revealed by cutting down through the bed of snow so as to expose a definite vertical section. Under such circumstances measurements of the depth of newly-fallen snow may be made by ordinary methods that will readily suggest themselves to the observer.

Efforts to provide a floor or platform that shall be swept clear before a new fall of snow occurs can not be generally successful because of drifting, and its weight precludes supporting such a floor upon the snow itself. Further complications arise in the matter of temperature differences between the floor and snow in the sunshine.

62. *The snow mat.*—This simple device will often aid in marking the surface between the old and new snow. It consists of a small square, 28 inches by 28 inches, of white duck, medium weight, neatly hemmed, and provided with a small triangular pocket at each corner. Two slats of wood, 2¼ inches wide by one-fourth thick, forced into diagonally opposite corner pockets, serve to maintain the mat taut and flat. Short pegs, projecting downward from the slats, may be provided if necessary to better secure the mat against displacement by the wind. When snow is already on the ground, the mat is simply laid upon the surface in some favorable location. A few yards of small cord tied to the mat and to some slender stake nearby prevents the possible loss of the mat, and serves to indicate its location when covered with snow.

The lightness of such a mat permits the soft snow to support it, so as to remain even with the surface of the old snow. Its color and material favor equality of snow and mat temperatures under conditions of sunshine, and thus lessen the chances of partial melting. Since the surfaces of the mat and snow so nearly coincide, drifting is of slight consequence, except in very light snowfalls.

63. When a measurement is to be made, the position of the mat must first be located by the cord, and a little of the snow cleared so as to expose a small portion of the mat. The depth of the snow over the mat can then be accurately measured.

64. *Snow in remote regions.*—The collection of snow by means of gauges in remote regions seldom visited by observers has not thus far been satisfactorily accomplished. Need for such collection no doubt exists where the precipitation is partly in the form of rain, or where melting temperatures are experienced; but where the precipitation is in the form of snow throughout the winter, and particularly where cool northerly slopes retain it, the ground itself is a collector, and save for small evaporation losses, the seasonal fall may be determined when desired by the methods set forth in paragraphs 75–85.

65. The actual depth of the snow layer, in inches, is measured and recorded daily, generally about sunset, at regular observing stations. The rain-gauge measuring stick, or for that matter any rule graduated in inches and tenths, is inserted in the snow layer at several selected spots where experienced judgment indicates that a normal and representative depth is to be found, and the mean of such measurements is taken as the depth of the snow layer.

66. Measurements of the depth of snow in regions visited only occasionally, particularly those regions in which the layer of snow has an important bearing upon power and irrigation projects, require special preparation and devices in addition to those mentioned in the preceding paragraph.

67. *Snow stakes.*—These are upright sticks of wood either driven into the ground to hold them vertical, or held in a vertical position by guy wires, used in regions of deep snow, particularly in the Rockies and the Sierras, the depth being read directly from the stakes. They are graduated in inches, black triangles on a white background serving to increase visibility, and are permitted to remain in the same spot year after year. The length is varied according to the depth of snow expected. Earlier models were made of a board about 1 inch by 6 inches, but on account of the effects of reflected heat and wind eddies in creating spurious depths in the immediate vicinity of the stake, this board form has been replaced by stakes $1\frac{3}{4}$ inches square, one face of which bears the graduations, while the adjacent face bears a number for each 10 inches or mul-

tiple thereof. That is, "1" means 10 inches, "2" means 20 inches, "3" means 30 inches, and so on. (*Caution: These numbers have been mistakenly read as feet by persons unfamiliar with the scheme*). The standard type of snow stake is shown in Figure 13.

The stake is painted *white*, to minimize radiation effects, and to one face three enameled-iron scales will be attached by screws. These scales are each 30 inches long, with graduation marks to *inches*. The 10-inch marks are largest, while opposite each 10-inch mark on the adjacent face of the stake are large brass figures: "1" for 10 inches; "2" for 20 inches, etc., while the graduation marks at 5, 15, 25, etc., inches are of an intermediate and readily distinguishable size. *A considerable number of the snow stakes has been provided with the graduation marks stenciled in black paint on the wood direct, in lieu of the enameled-iron scales.* The stake with its scales and numbers is securely bolted to a piece of galvanized-steel angle, after the latter, which is sharpened at the lower end for that purpose, is driven into the ground to a proper depth, about 26 inches; all substantially as indicated in Figure 13.

68. *Assembly of scales and stakes.*—Attach the three 30-inch enameled-iron scales to *that face of the stake having two* countersunk one-fourth inch holes for bolts near one end. Set the bottom edge of the first 30-inch enameled scale exactly even with this end of the stake, then place the remaining sections one above the other and close together endwise, and secure them by means of the brass screws provided for the purpose. Attach the brass figures *opposite the 10-inch graduation marks*, on the smooth white surface of the stake to the left, as illustrated. The attachment of the scales and numbers to

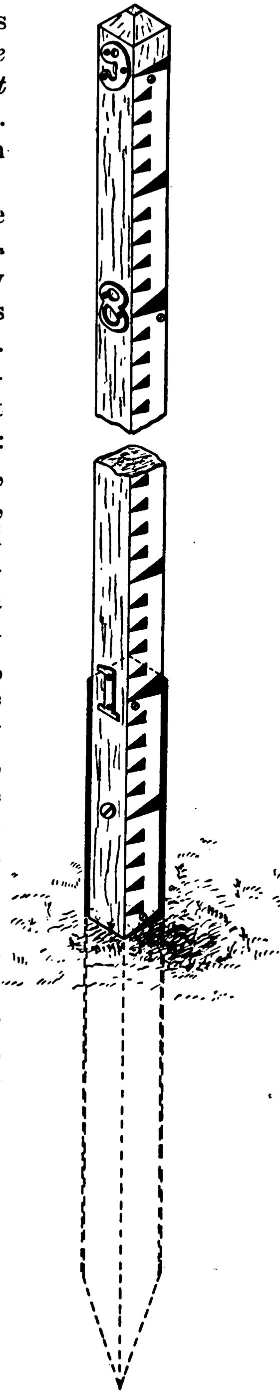

FIG. 13.—Snow stake (Weather Bureau pattern, 1913.)

the stake may be made at the office or otherwise as most convenient. Upon reaching the site selected for the scale, drive the anchor post into the ground as nearly vertical as possible, using a heavy mallet or equivalent means that will not batter or damage the iron at the top edge. The anchor post should project just 10 inches—that is, so that when the stick is bolted in place its lower end will just touch the surface of the ground. To secure the sticks in this fashion it may be necessary to remove or replace the lower section of the enameled scale.

69. *Guys.*—Under ordinary conditions of exposure it is not believed that any wire guys are required. Wherever needed, however, it will be necessary to procure a small quantity of annealed, galvanized-iron wire (about No. 14, B. & S. gauge); also a few galvanized-iron nails about 2½ inches long (8-penny); and, where guys are needed, attach three under the head of a nail driven part way down into the center of the top of the stake, the head of the nail projecting sufficiently to permit of securing the three guy wires thereunder, the outer ends of the guys being secured by any form of anchorage that may be most permanent and suitable. With the stake as a center, the wire guys should spread about 120° apart to afford the best stability.

70. *Method of reading snow depths.*—The depth of snow around the snow scales will be recorded to the nearest whole inch. The reading of the scale should not necessarily be the reading at the level of the snow immediately adjacent thereto, but a reading probably greater than the latter and one that represents the *level of the snow within a few feet of the stick.* Notwithstanding the small dimensions of the stick, it will probably often occur that, on account of wind eddies around it, and more particularly because of the melting and sinking of the snow close to the stick, due to the heating action of the sun thereon, a hollow will be made in the snow; and for a true reading of the depth, due allowance must be made for the presence of any irregularity in the snow surface in the immediate proximity of the stake.

71. *Location of stakes.*—Location of snow stakes is important. Bearing in mind the possible application of the reading at the stake to a considerable area, the ground in the immediate vicinity should correspond in direction and steepness of slope with the neighboring surroundings. The ground at the foot of the stake should be fairly smooth, and forest débris, sticks, brush, etc., should be cleared away in the fall.

72. *Slope effect.*—Slope of the ground, whether southerly toward the sun or northerly away from the sun, has an extremely important bearing upon snow melting. On steep south slopes exposed to sunshine the snow melts quickly so that such slopes are frequently bare of

snow during a winter. Hence the depth of snow measured on a slope of this kind is, in a sense, a result of fortuitous causes, and is poorly adapted to a comparison of one winter with another, or indeed of one large section with another.

73. *Northerly slopes preferable.*—Northerly slopes are conservers of snow, because they receive relatively little sunshine. Hence if any snow is present it will be found on such slopes, and it will remain there for a longer period in the spring. Such slopes afford excellent locations for snow stakes and should be preferred.

74. *Environment.*—It is of course important that the snow stake be accessible for readings. As to immediate surroundings, stakes should not be placed near to large trees, bluffs, or buildings, etc., since such objects, by intercepting falling snow or by reflecting heat, or by shading the stake, or by causing wind swirls, are likely to cause a spurious depth at the stake. Low shrubs, bushes, aspen, or other trees whose leaves drop before winter are beneficial, since they minimize drifting.

75. *Water content of snow layer.*—The water content of the layer of snow on the ground is determined by taking out and weighing a core or sample of known area. Almost any cylindrical tube may be used when the snow is not deep, but the work is greatly simplified by the use of special equipment, while in the deep snows of the mountain regions of the Western States special apparatus is imperative, and to meet this need the following-described snow sampler has been devised.

76. *The snow sampler.*—There are three parts to the device: The tube for holding the sample while it is being weighed, the cutter for bounding the area of the sample, and the spring balance for indicating directly the water equivalent of the snow layer.

The main body of the sampler (Fig. 14) is of 3-inch drawn-steel tubing, 0.032-inch wall, in integral lengths varying from 2 feet to 6 feet, according to the depth of snow prevailing in the vicinity, several lengths being advantageous at some stations. The instrument is intended for surveying such snow layers as are found over wide areas, rather than for the deep drifts of the timber-line region. The tubes have inch graduations and appropriate numbers to show snow depth, and after having been made up they are finished by sherardizing, a process resembling galvanizing, but leaving a smooth finish that does not destroy the etched graduations as would galvanizing, and, furthermore, offers less resistance to the free movement of the snow core through the tube, because it is smooth. Observers report that oil or lacquer applied to the inner surface is an additional help. Tinners' down spouting, 3-inch by 24-gauge, with a graduated metal tape riveted in place longitudinally, is sometimes used in place of the special tubing.

The cutter (Figs. 15 and 16), with its special shape, constitutes an extremely important part of the device. The inside diameter is

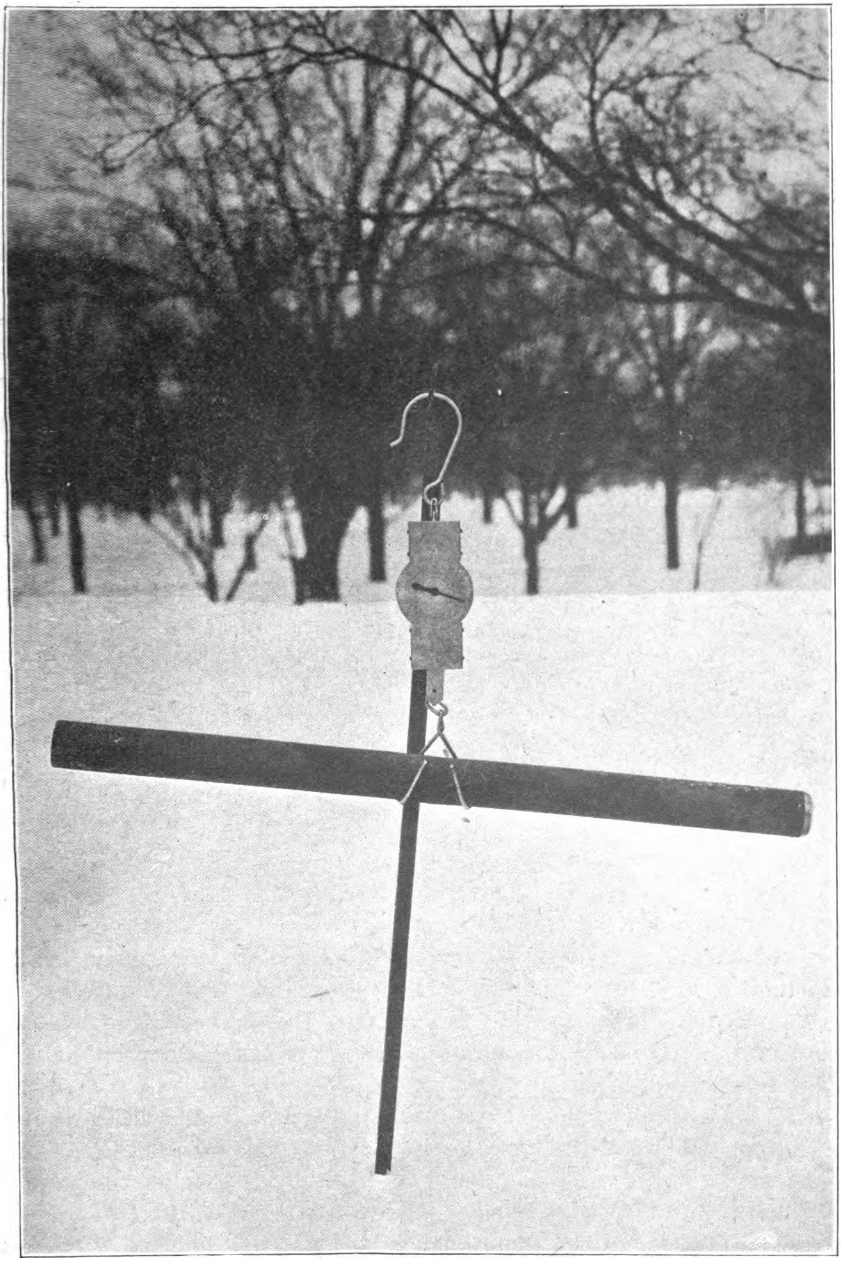

FIG 14. Snow sampler, with balance and alpenstock.

turned true to 2.655 inches, which makes one-fifth of a pound of snow equal to 1 inch water equivalent. The diameter selected is the result of a number of carefully made experiments in the field, which showed that cutters of too small diameter take up a sample that is too small to be representative of the layer from which it is cut, while samplers of larger diameter are too large and clumsy for use, particularly when they must be transported on snowshoes, although they possess the advantage of giving precise results. An examination of the illustrations will show that the cutter is sharply shouldered off at a point of ½-inch above its cutting edge. This shoulder is found in practice to wedge the snow so that in the great majority of cases the entire core can be withdrawn without losing the sample, although in some instances of extremely light dry snow it is necessary to tamp the snow into the bottom of the tube by means of a long slender stick in order that it may be somewhat packed before the tube is withdrawn. The cutters have smooth edges and are made interchangeable, so that in case of damage a new one can be easily attached.

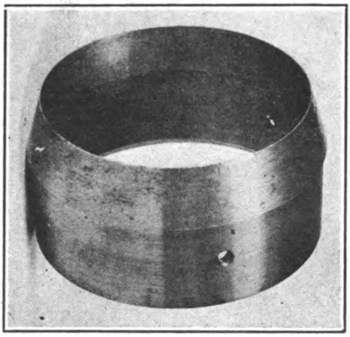

FIG. 15.—Snow cutter.

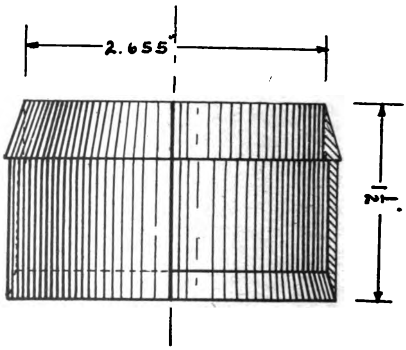

FIG. 16.—Snow cutter, line drawing.

77. *Weighing device.*—The spring balance (Fig. 17) as shown in the illustration has grown out of experience. The graduations, which are engraved directly upon the case of the spring balance, give inches and tenths of water equivalent direct. The indicating hand is rigidly pinned to its arbor, thus eliminating the chance of accidental displacement. The bent aluminum wires are intended to hold the filled tube in a horizontal position for weighing, while the hook at the top is intended to be placed across a limb of a tree or other means of support. The entire balance is built largely of aluminum for lightness. In using the sampler, it is necessary to weigh the empty tube, then the snow-filled tube, the difference between the two giving the water content of the snow in inches and tenths.

78. *Alpenstocks.*—Alpenstocks are helpful in furnishing a steady support on which to hang the balance, although they are not required when other forms of support, such as limbs of trees, are at hand.

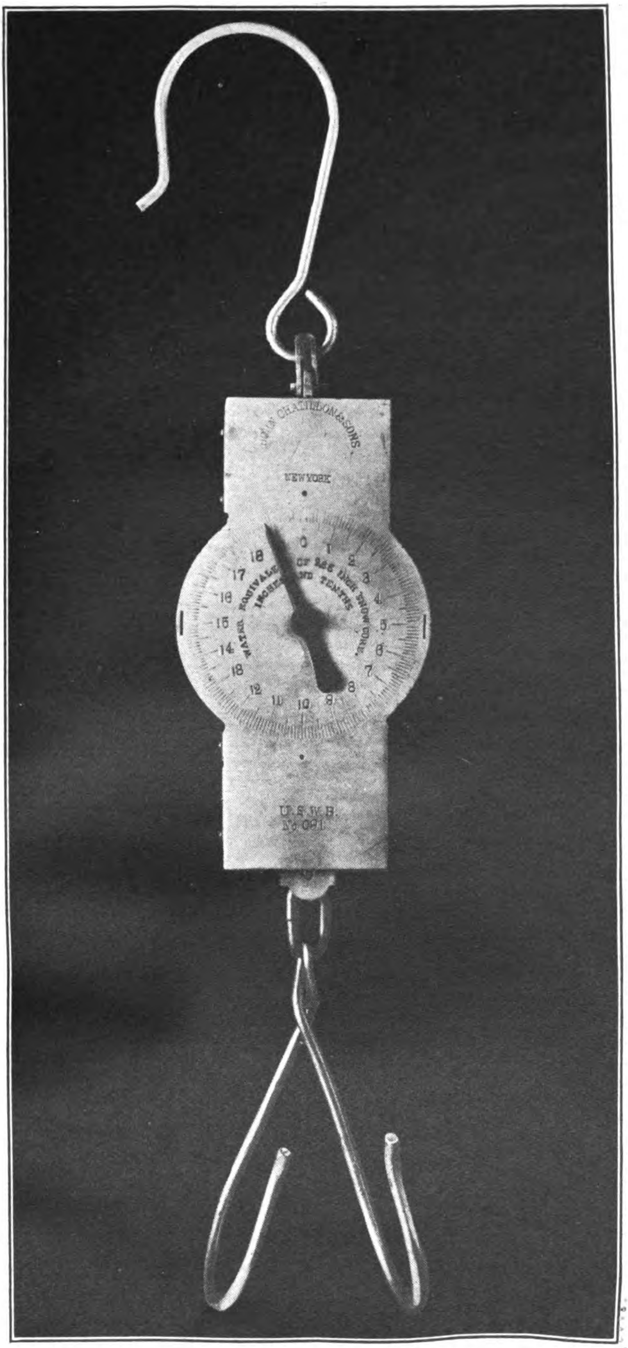

FIG. 17.—Weighing balance for snow sampler.

79. *Graduations.*—The sampling tubes are graduated in inches, so that the depth of the snow layer from which the sample is taken may be read directly from the side of the tube. Now, since we can determine the water content by the weight of the sample, and the depth from the scale on the tube, we may easily determine the density of the snow by dividing the water content by the depth. The quotient thus obtained gives the density or specific gravity of the snow as compared with water.

80. *Example.*—

	Inches.
Scale reading, with snow sample included	7.6
Scale reading, with tube empty	4.3
Water equivalent of snow	3.3
Depth of snow	22

Density of snow$=\frac{3.30}{22}=$15 per cent.

81. *Extended application of measurements.*—Experience has shown that the density of a snow layer is fairly uniform over a considerable area of similar slope, but that marked differences in density may be expected according to whether the slope is toward the sun or away from it. Therefore if we have, say 100 acres of fairly uniform slope, we may determine the depth from the mean readings of a considerable number of stakes, which require only to be read, while to the depth so obtained may be applied the density values determined at only a few points. Hence a few measurements may suffice to give a working value of the snow cover over an area of considerable size. Due regard must be had for marked differences in altitude.

82. *Sample normal to slope.*—Density measurements on a steep slope generally require the sample to be taken normal (at a right angle) to the slope, since an effort to take out a vertical sample on a hillside will often fail to take up a small portion of the snow next to the ground. The depth normal to the slope should be used only for the purpose of obtaining density.

83. *Depth measured vertically.*—Depth of snow on a slope should always be measured vertically. The reason will be apparent when it is remembered that land surveys are made on the basis of horizontal distances. Hence we have the relation: Depth multiplied by density multiplied by area equals water content.

84. *Large drifts.*—Deep drifts of the timber-line region present a special problem whose solution has been accomplished only in part. Such drifts are, however, fairly constant from year to year as to locality, and their extent depends upon the general depth of the snowfall. Furthermore their total area is relatively small so that

their real importance to the flow of streams is not great. In Bulletin 55 of the Agricultural Experiment Station of Colorado, page 9, Mr. L. G. Carpenter says: "As snow is most evident on high peaks, undue importance is attached to high elevations. I have had occasion to examine the watershed tributary to the Rio Grande. While this has an area of 4,611 square miles above 8,000 feet elevation, there is less than 200 square miles of it above 12,000 feet, although this watershed has a large number of the highest peaks in the State. In this case over 90 per cent of the watershed is below timber line and above 8,000 feet."

85. *Survey method.*—The testimony of those who have actually engaged upon snow surveys agrees as to the uniform fall [2] [3] over large areas, while agreement in depth and density under similar conditions of slope and elevation has been established by a number of years survey at Wagon Wheel Gap, Colo. Therefore we have at hand a method that with discretion may be applied to an entire drainage area.

[2] Church, J. E., Jr., Snow surveying for the forecasting of stream flow, Engineering News-Record, Feb. 10 and 17 ,1921, vol. 86, Nos. 6 and 7.

[3] Cole, Harvey S., Snow survey in the Walker drainage basin, Nevada, MONTHLY WEATHER REVIEW, March, 1913, 41: 448–9.

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