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W. B. No. 530.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU.

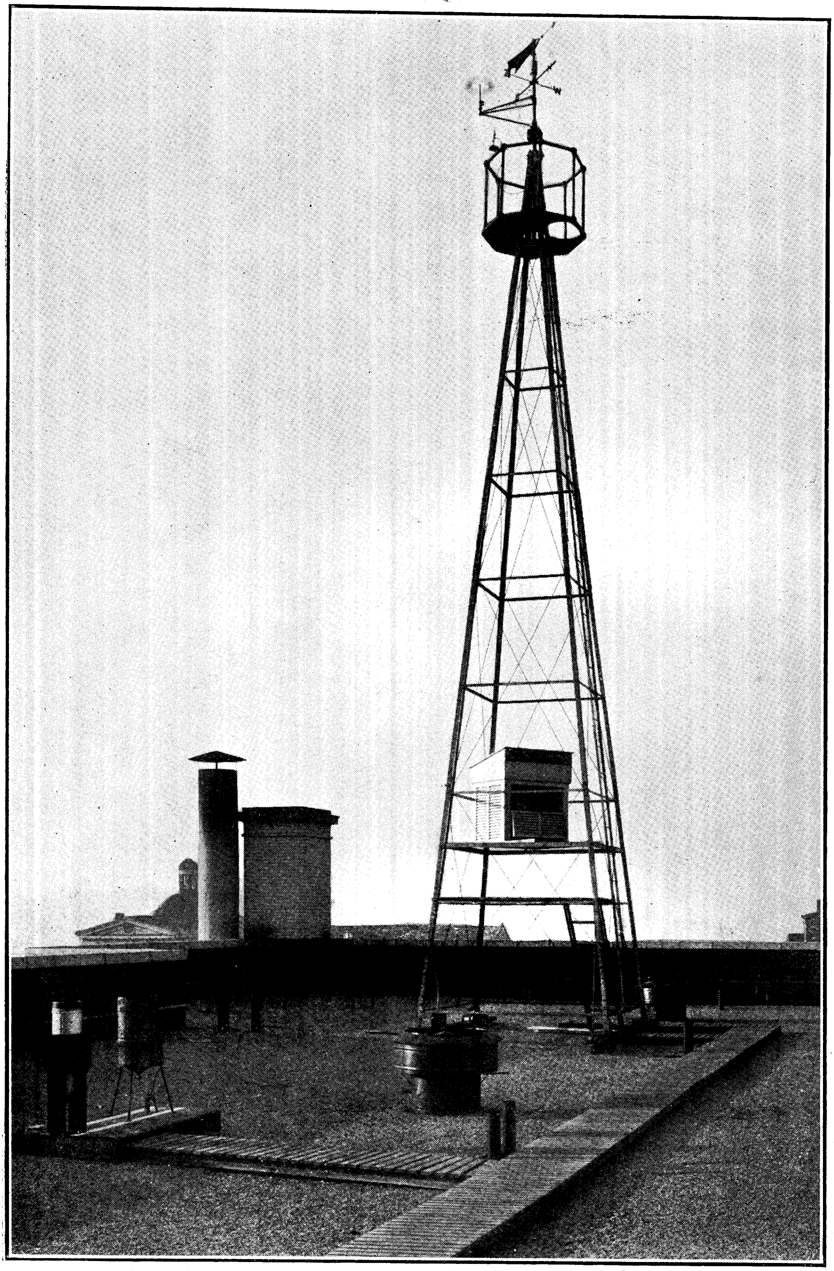
CHARLES F. MARVIN, Chief.

INSTRUCTIONS FOR THE INSTALLATION AND MAINTENANCE OF WIND MEASURING AND RECORDING APPARATUS.

CIRCULAR D, INSTRUMENT DIVISION.

FOURTH REVISION.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1914.



FORTY-FOOT STEEL WIND INSTRUMENT TOWER; TYPICAL INSTALLATION FOR HIGH OFFICE BUILDING. (LYNCHBURG, VA., JANUARY, 1914.)

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CIRCULAR D, INSTRUMENT DIVISION.

(Fourth Revision.)

INSTRUCTIONS FOR THE INSTALLATION AND MAINTENANCE OF WIND MEASURING AND RECORDING APPARATUS.

INTRODUCTION.

The third and last previous revision of "Circular D, Instrument Division" (1907), having become exhausted, a new (fourth) revision has been prepared. As will be noted, a change has been made in the title of this publication as heretofore issued, and the instructions herewith relate exclusively to the installation, care, and management of standard Weather Bureau instruments for the registration of wind velocity and direction, and the accessory apparatus required in connection therewith.

Accurate records of the velocity and direction of the wind are essential elements in all meteorological and climatological work, as well as of value to commercial and business interests. It is important, therefore, that the apparatus producing these records be given the utmost care and attention by observers, as outlined in this pamphlet of instructions.

I. ANEMOMETER.

1. *Type of anemometer.*—The anemometer that has always been used in the United States Weather Bureau is called the Robinson cup anemometer. Experience fully justifies the statement that this form is better adapted to general meteorological work than any other thus far available.

2. *Description of anemometer.*—The construction of the standard patterns of Weather Bureau anemometers is shown in figs. 1 and 2.

3. *Cups and arms.*—The hollow cups shown in fig. 1 are made of thin aluminum or copper, and are as nearly hemispherical as possible. These are securely fastened to small square steel arms set with their diagonals horizontal and vertical, respectively, so as to offer the greatest resistance to the bending action of the wind pressure upon the cups and as little resistance as possible to the wind itself. Copper cups should always be used for exposures where the aluminum does not well withstand the corrosive action of salt air or the acid fumes from smokestacks, etc. Such cups with reinforced arms are also supplied for seacoast stations where high wind velocities are likely to occur.

The cups are 4 inches in diameter and the arms 6.72 inches long from the axis to the center of the cups.

4. *Spindle and dial mechanisms.*—The spindle, *c*, figs. 1 and 2, which forms the axis of revolution of the cups, is made of steel, or of brass and steel together, and has a worm or endless screw, pitch $\frac{1}{16}$ inch, near the lower end. This worm engages a wheel, *m*, of fifty teeth,[1] upon the axis of which is another worm or endless screw similar to the first. This second worm imparts motion to the small pinion, *l*, which in turn gives motion to a pair of dial wheels having 100 and

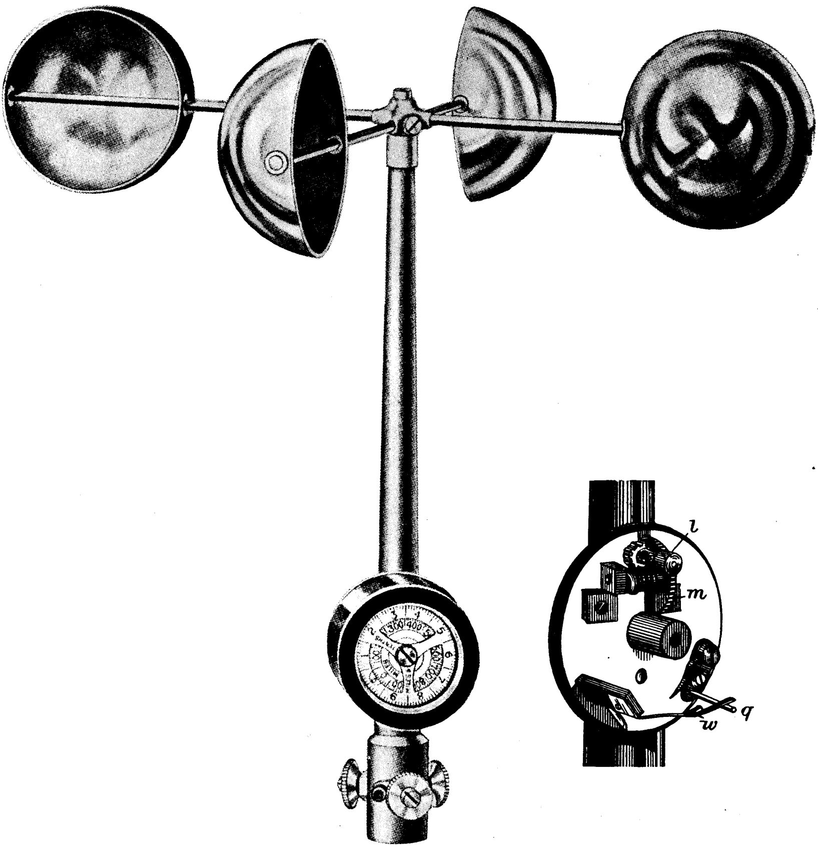


FIG. 1.—Standard anemometer.

99 teeth, respectively, and graduations to correspond. The dial wheels are shown mounted in figs. 2, 3, and 4. In accordance with a simple mechanical principle, the dial wheel having 99 teeth must go just one tooth more than a complete revolution for each complete turn of the upper dial, which has 100 teeth, for in any given movement both dials, being driven by the same pinion, each must move

[1] To cause the anemometer to indicate the movement of the wind in kilometers instead of miles it is necessary only to make 62 teeth in the wheel M and employ a double threaded worm on the spindle. The pitch in this case should be $\frac{1}{18}$ inch. These changes can be made without material alteration in the overall dimensions of the internal mechanisms. To be exact the cup arms in the kilo anemometer should be slightly less than 6.72 inches or 6.70 inches.

exactly the same number of teeth. This causes the lower wheel, for each revolution of the upper wheel, to move just one division of its graduations in reference to the latter, which motion may be observed by the aid of a zero or index mark arranged on the upper wheel to match the graduations below.

5. *Electrical registration.*—The dial wheel *e* is graduated into 100 spaces, and small contact pins *p* are set into the wheel at intervals of ten divisions. At *p′* two of the pins are joined together, forming what is generally called the *tenth-mile* pin or bridge-pin. At *w* is shown a small spring, generally called the contact spring, one end of which is free and tipped on one side with platinum. Near this stands a pin *q*, also tipped with platinum. This pin is insulated, so that it does not form electrical contact with any metal part of the anemometer. A small wire, protected by the metal tube *t*, connects *q* with the insulated binding post *u*, fig. 2. No part of the insulated wire is exposed, the connections being made within a closed cavity underneath the binding post, which is itself securely fixed to the base by two insulated screws.

A second binding post *v* is secured to the metal case, thus connecting electrically with the contact spring. The middle portion of the contact spring has a small brass piece attached that projects into the pathway of the dial pins, and these, as the dial moves, glide in turn over the projection on the spring, causing it to deflect and bring the two platinum surfaces, already mentioned, into close contact for a

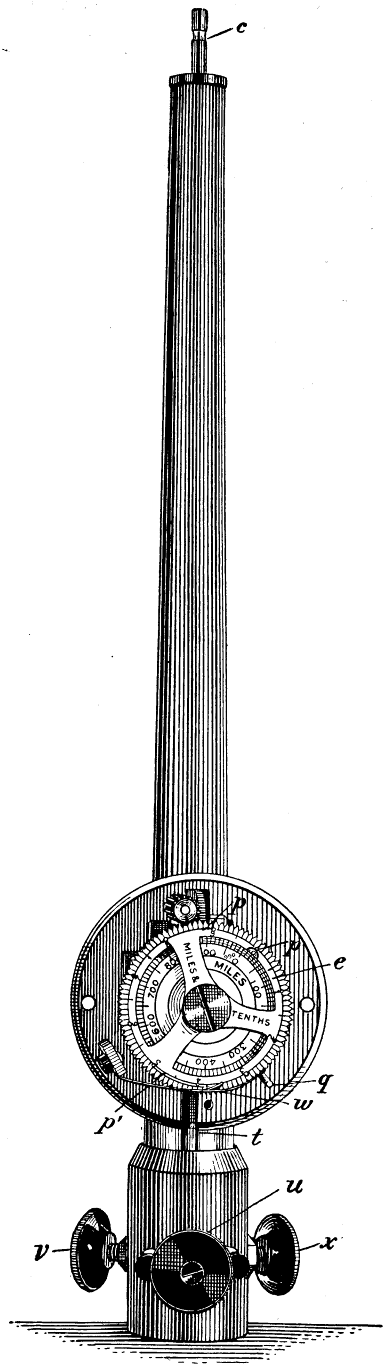


FIG. 2.—Standard anemometer, pattern of 1900.

short space of time. By these means the anemometer is made to close an electric circuit, and by the aid of recording mechanisms, more fully described hereafter, an electrical registration is made of the movement of the dials. The tenth-mile pin causes the electrical circuit to remain closed the entire time of its passage, giving rise to a record for this particular double pin of a different character than that for the other pins, as at *b*, fig. 19 (*a*), thus independently recording each revolution of the dial.

The thumbscrew at *x*, fig. 2, serves to clamp the anemometer to its support, as shown in fig. 7.

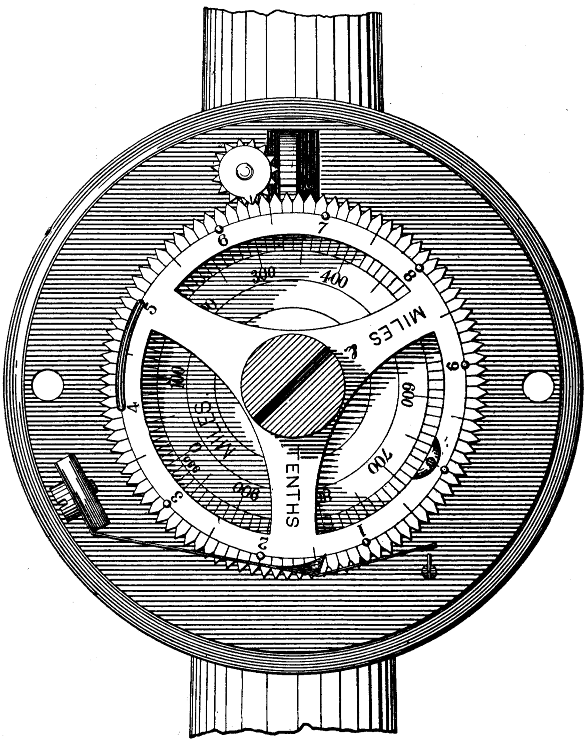


FIG. 3.—Anemometer dials.

6. *Nominal value of dial graduations.*—A little thought in connection with what has already been said about the train of gearing and the number of teeth in the various wheels will show that just 50 revolutions of the cups will be required to move the upper dial one tooth—that is, one division—and 500 turns will move it ten divisions. Since the arms of the anemometer are 6.72 inches long the cup centers will move just one-third of a mile in 500 turns, which, by Robinson's principle, represents an actual wind movement of just 1 mile, and the graduations of the dial are, therefore, designated miles and tenths of miles.

7. *Dial readings: how made.*—The reading of the anemometer dials, shown in fig. 3, is 666.3 miles. To read the dials seek out first the index mark upon the inner edge of the outer dial and observe the value of the graduation on the lower dial *next below the index mark.* In the present case this is 660. Next, read the graduation upon the outer dial opposite the index a little to the left at the top, or, in the absence of a special index, the graduation opposite the center of the small pinion which gives motion to the dials. In the figure this is 6.3, hence the dial reading is 660 + 6.3 = 666.3 miles. The dial reading in fig. 4 is 18.5 miles.

Attention is called to the fact that but three, instead of four, graduation marks should appear in the space on the lower dials between 950 and the next long line and the zero mark, that is, the highest possible count upon this system of dials is 990 miles, whereupon the dials return to their zero positions and the count begins over again. This is indicated by the small figures 990 near the zero mark.

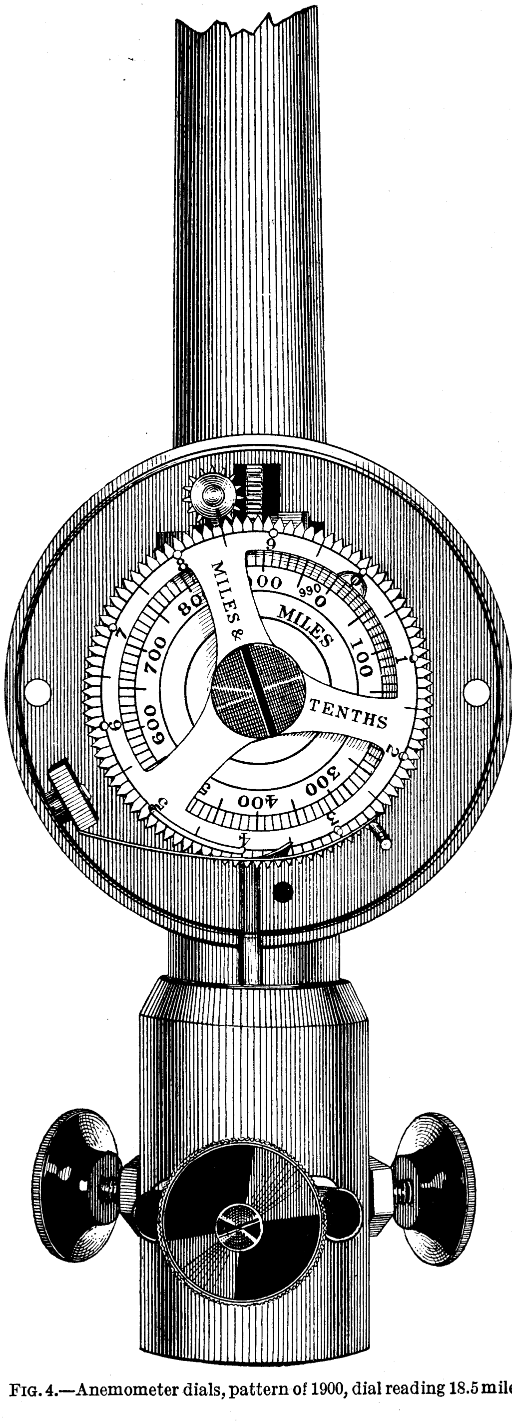


FIG. 4.—Anemometer dials, pattern of 1900, dial reading 18.5 miles

8. *Caution against mistakes.*—A mistake of 10 miles is sometimes easily made in dial readings by not being careful always to read from the lower dial the division *next below the index line.* For example: in fig. 3, the 670th line is almost opposite the index, still, strictly speaking, these can not come exactly opposite until the index line itself is opposite the driving pinion. We must, therefore, take the line below, namely, 660. Sometimes in loosely fitted gearing the index, in such a case as in the figure, may be even a little beyond the 670th line, still we must take the 660th line, since the reading of the outer dial, viz, 6.3, being so near 10, of itself indicates that the index line must be near to but not quite coincident with the 670th line.

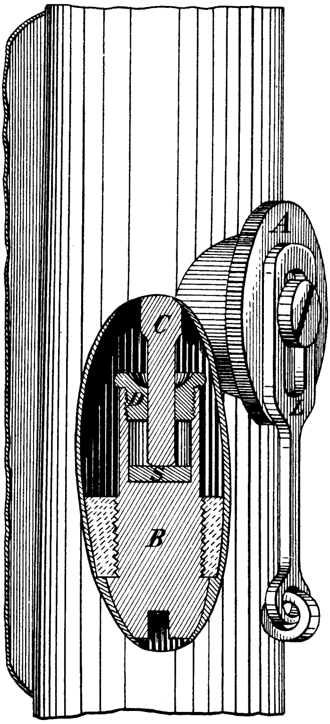


FIG. 5.—Pivot bearing of anemometer.

Observers should study this matter with the aid of the anemometer dials, placing the zero point of the outer dial in different positions, especially first a little to one side and then to the other of the pinion, and noting carefully the results. Study also the effects of looseness in the gearing.

9. *Essential characteristics of good anemometers.*—The weight of the cups and moving parts should be reduced to a minimum to avoid great momentum, and to reduce the pressure upon the lower end of the spindle. The pivot bearing at this point should be very small in diameter, slightly rounded and convex, and of very hard and highly polished steel. This should rest upon a small, flat, steel plate, also hardened, polished, and immersed in oil.

10. The construction of this portion of the anemometer is shown in fig. 5. A comparatively large opening is closed by the cap *A*, which is held by spring friction, but it is secured from being lost by the slotted link *L* attaching it to the anemometer. This opening gives convenient access to the worm and lower end of spindle for inspection and oiling. The pivot bearing for the end of the spindle *C* will be readily understood from the drawing. *S* is small flat disk of hardened and polished steel, resting loosely in the bottom of the cavity of the screw *B*, the annular space above being filled with oil.

11. The train of gears should be very freely moving, especially the worm wheel *m*, fig. 1, because frictional resistance in its movement is more prejudicial than in the other dial mechanisms, owing to its relatively rapid motion.

12. The most prejudicial resistance in any part of the anemometer, when in good condition, is that occurring in the top bearing of the spindle. This bearing should first be made very smooth and polished and afterwards kept clean and freely lubricated, if good results are to be expected. *When well made and properly cared for the anemometer will show only a very little wear after years of exposure, even with comparatively high winds.*

13. The small bright spot upon the lower end of the steel spindle, where it wears against the steel plate, should never be larger than a pin head. If this portion becomes dry of oil by neglect, as sometimes happens, it will quickly wear flat and introduce a very great amount of friction. The instrument can then be restored to good condition only by recutting and polishing the pivot end, also the small plate, so as to conform to the above specifications.

14. *Ball-bearing anemometers.*—Certain advantages result from the use of ball bearings in anemometers, chiefly in increasing the service to be obtained, and in reducing the attention necessary to maintain the bearings in proper lubrication. The reduction in friction is not such an important gain as might be supposed, unless the instrument is used in very slight wind. The slight friction in any good anemometer is quite inconsequential in light and fresh winds, such as usually prevail at practically every station most of the time.

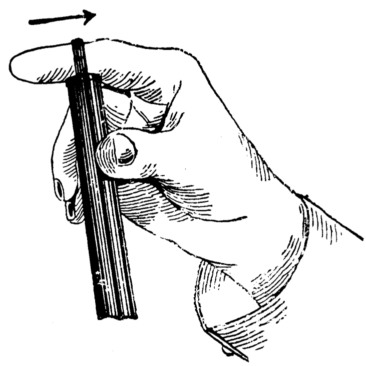


FIG. 6. Friction test.

15. *Simple tests as to the friction of anemometers.*—Whether or not the bearings of an anemometer are sufficiently frictionless can be told by the following simple tests: Remove the cups and holding the anemometer vertical, twirl the spindle smartly as you would spin a top, between the thumb and finger. If properly fitted and twirled the spindle should make many revolutions and not stop quickly, but spin freely after starting. This test succeeds best when there is only a little oil on the top bearing of the spindle.

16. A better test is to press the forefinger of the right hand *strongly* sidewise against the spindle above the bearing, see fig. 6, and slowly draw the finger across the spindle. The latter should always revolve in its bearing and not slide on the finger, as may sometimes happen.

17. These tests, however, may not always show the condition of the dial mechanisms. To determine this the spindle must be removed. Then, with the finger-tip or nail of the middle finger of the right hand, impart a quick impulse to the worm wheel *m*, fig. 1, thus setting the whole train of wheels in motion. Some practice is required

to give a good impulse. The force must be applied *exactly* in the plane of the wheel else the latter will be thrust sidewise in its bearings and revolve only sluggishly. If the gearing is in good order the worm wheel will run 40 or 50 revolutions before stopping, and four or five dial pins will glide over the contact spring.

18. Instruments are not in good condition that will not behave properly under these delicate tests. In many cases, however, it is only a little dust or finely ground metal, etc., in the bearings that causes the friction, and the instrument needs cleaning and new oil.

19. *Suggestions about oiling anemometers.*—The only oil suitable for use on these instruments is clock oil, such as is furnished by the central office of the bureau for the purpose. The oil should remain liquid at temperatures well below zero if possible. The train of gearing and dials need be oiled only at long intervals, and then but a very little oil should be applied to each point. A very small quantity should be placed upon the inclined face of the projection on the contact spring.

20. The bearings of the spindle and the worm require more frequent and copious lubrications. A greater supply than will remain in the bearing, however, is simply wasteful. One drop of oil, such as will generally adhere to a match or similar pointed stick, applied once a week, is, in most cases, sufficient for the parts of the spindle. The worm needs less than this. The cups must be removed to properly oil the upper bearing. The oil must be applied directly to the points at which it is needed. Anemometers, as now constructed, admit of doing this with very little trouble.

21. *Durability of anemometers.*—One of the official anemometers in use at this office was exposed continuously, except for short periods from time to time for cleaning and oiling, *for over 30 years*, and yet did not have a single part renewed, and showed scarcely any perceptible wear. This instrument was, in fact, exactly as good as new at any time during its service. In view of this fact, as well as the prolonged use of other instruments at this and other localities, observers should bear in mind that very great durability is reasonably expected of anemometers, and that any failure in this respect is a strong indication of neglect, either because of careless attention or lack of knowledge as to the proper manner of caring for the instrument.

22. *Neglected anemometers.*—If, in any event, by neglect or otherwise, the bearings of an anemometer become dry of oil, they will, in a few hours or less, in high winds, grind and wear themselves badly, becoming rough and seriously injuring the instrument. On such occasions the anemometer will nearly always emit a shrill squeaking or other very audible sound that is a sure indication of its imperfect condition, and trained and careful observers will always be on the alert for sounds of this kind. If this state of affairs continues, especially

in fresh winds, the abrasion of the spindle in the top bearing will presently cause it to lock tight, exactly as a carriage wheel becomes locked under the conditions so commonly known as a "hot box." Nothing but gross neglect and insufficient lubrication ever produce this condition, and the wind movement, especially if light, afterwards indicated by such an anemometer, will be largely deficient until the injured parts are renewed. Any such defective action must be carefully noted on Form 1017 and, if necessary, reported in detail to the central office by letter.

23. An anemometer heard squeaking should be immediately removed from the support and carefully examined. If not seriously injured, it should be thoroughly cleaned and freshly oiled before being used again; otherwise it should be returned to the central office, and a good instrument secured in its place.

24. *Suggestions about cleaning anemometers.*—While an instrument, if properly cared for, will run for many years and still remain in perfectly good condition, yet instruments should be critically examined as often as once each month, and if the bearings of the spindle and the oil about them appear to be in a very dusty and dirty condition, or the oil is thick or dry, the instrument should be replaced or removed and cleaned, having regard to the following points:

25. Generally the spindle and its bearings, both upper and lower, will be the parts that specially need cleaning. Only *clean* cotton (not cotton waste) or soft cloths should be used, and the parts should be rubbed quite dry and clean and all old oil removed thoroughly before any new oil is applied; a little kerosene or benzine is helpful in this connection. It often happens that under tests an anemometer newly cleaned will exhibit greater friction than before. This arises from the fact that in handling the parts, and perhaps in wiping the bearings with more or less dusty and dirty rags, small dust and other gritty particles make their way into the bearings and increase the friction. These points should, therefore, be had in mind always and guarded against in all manipulations.

26. If the anemometer has not suffered injury by running without oil, the top bearing of the spindle will be smooth and bright and the lower pivot still round and with only a small bright spot in its center, a corresponding bright spot being noticeable on the plate beneath. On the other hand, if neglected, or insufficiently and improperly oiled, the bearing will contain injurious scratches more or less serious, according to circumstances, and the lower pivot end will have a large flat spot and bad scratches, with corresponding injuries in the plate beneath. *Such an anemometer can not give accurate results.*

The top bearing is best cleaned by drawing a piece of clean cloth back and forth through it a few times, taking care to avoid leaving dust or lint behind when the cloth is withdrawn.

In general it is not necessary to remove the lower pivot bearing, but if the spindle is worn and flattened on the end, or, if from careless attention long exposure or the use of poor oil this bearing is gummed, it must be removed and thoroughly cleaned. The small screw-cap *D*, fig. 5, should be taken out, and after cleaning out the oil in the cup-like space the small steel plate at the bottom should be shaken out. This is loose in the cup, though sometimes the adhesion of the oil makes its removal difficult. When in good condition, the plate *S* appears *flat* and highly polished, and without a noticeable hollow worn in the center. In replacing this bearing it should be about half filled with good oil and screwed up tight into the anemometer socket.

In replacing the spindle a drop or two of clean oil is first applied to the inside of the top bearing, which may then be placed on the steel spindle after it also has been rubbed over with a few drops of oil. The pivot end and worm are then oiled and the spindle with the top bearing upon it is inserted within the tube of the anemometer and without rubbing the sides of the tube, if possible. The top bearing need be tightened only moderately.

There is generally less necessity for cleaning the dial mechanisms, but, if these are taken apart, great care should be exercised to avoid injury to the sharp points and teeth of wheels and the contact spring. Dipping the parts in a small dish containing benzine or gasoline serves to clean them well. The spring ought not be taken out at all, and should not be bent or displaced from its original form.

27. *Adjusting contact spring.*—In giving proper form to a contact spring that may by accident be in need of adjustment, it should be bent so that the advancing contact pins first strike the little projection on the spring about midway between its base and point. The outer portion of the spring may then be bent so that its platinum point is brought firmly into contact with the post *q*, figs. 2 and 3, *only during the last portion* of the movement of the pin across the spring. *Do not bend the contact spring so that the pins rub along the spring itself before reaching the projection.* Adjust the spring with the idea of producing perfect electrical contact with the least possible frictional resistance, and for a short duration of contact; but, on the other hand, care must be taken to have the break ample, or the circuit is liable to be closed for several minutes at a time between the 10-mile contacts. This results also in unnecessarily exhausting the batteries.

Always carefully brighten the platinum contact surfaces. A roughly scratched surface or one pitted and corroded because of the small electric arc formed when the circuit is being broken, is very bad for good contact; the surface should be bright and smooth.

28. *Exposure of anemometers and supports.*—The ideal anemometer exposure is secured when the instrument is placed where the movement of the wind is unobstructed from any direction, such for example as would be obtained in the center of a large open expanse or plain. Only an approximation to the ideal exposure is at present possible in most places, but every effort should be made to better anemometer exposures in order that the records from the several stations may be comparable.

Usually, with an anemometer exposed in a city or town, the great interference offered by buildings and other natural obstructions to the free movement of the wind causes the velocity to be much less in the vicinity of these obstructions than beyond such influence; therefore, in selecting the location for an anemometer preference should be given to the more elevated points in the vicinity of the station, and some rigid support should be used to raise the instrument as far as practicable above the immediate influence of the office building itself.

The most approved pattern of anemometer support is made up of wrought-iron pipe, in the same way as the wind-vane support shown in fig. 7, page 18. The top of the support is capped with a small brass pin fitted to carry the anemometer. Iron footsteps clamped to the pipe form a secure ladder by which the anemometer may be reached and examined, oiled, dial readings made, etc.

Very often the anemometer is exposed upon a cross arm fixed upon the wind-vane support, as shown at *B* in fig. 7, or *above* the wind vane, as shown in fig. 13.

The support must be set up so that the anemometer on top or on the cross arm is as nearly vertical as possible.

II. Wind Vane.

29. *Wind vane.*—The wind vane or anemoscope, for showing the direction of the wind, should be highly sensitive to variations in wind directions, but at the same time should possess a property of steadiness that will prevent the vane, when suddenly shifted in direction, from going altogether too far and thus giving erroneous indications as to the true character of changes in the wind direction. It is a very common mistake to imagine that large and heavy vanes are necessarily better and more steady than smaller ones. It is true they may often seem to vibrate and oscillate in the wind less than lighter vanes, but the seeming steadiness is really a defect, and is due to excessive friction, which prevents the vane from responding to any except very strong winds, and then its position of rest generally differs widely from the true wind direction.

If a vane is heavy and moves in *frictionless* bearings it will always oscillate more or less in adjusting itself to a new and steady wind direction. If friction is entirely absent such a vane would continue to oscillate indefinitely except for the dissipation of energy by the eddies produced in the air flowing around the tail. Such a vane once at rest will, however, take exactly the direction of the supposed steady wind. The energy of oscillation will be dissipated more quickly if there is some friction in the bearings, but in this case the friction may hold the vane at rest in a position more or less out of the true wind direction.

The ideal vane should be both *frictionless* and *without weight*. It would then follow perfectly every change in wind direction without exhibiting any oscillations except those of the wind itself.

Friction in the bearings would prevent even the weightless vane from taking the exact wind direction. In fact, under all circumstances, friction in the bearings of a vane is highly objectionable and must always be made as small as possible. A properly designed vane should, therefore, be as light as possible, relative to the extent of surface, and move in bearings with a minimum friction.

Such a vane will oscillate only a little more than the wind itself. Owing to the whirls and eddies of limited extent always found in air currents, a short vane, if well made, will show many sudden and great changes of wind direction that would produce little or no effect on a larger vane with a comparatively long tail. The latter is, therefore, much to be preferred for showing the average direction of the wind.

30. *Spread-tail vanes.*—When a perfectly straight, thin vane stands exactly in the direction of the wind, there is, strictly speaking, no lateral pressure upon it whatever, and even for slight deflections the pressures are very small. If, however, the tail be spread somewhat, a lateral pressure acts upon each side of the tail and tends, as it were, to hold the vane steadily in its position. Moreover, for slight deflections of the vane from the wind direction a spread tail presents a greater extent of surface to the wind than a straight-tail vane of the same dimensions.

The spreading of the tail also forms various angles and irregular, partly closed spaces, which produce many eddies and whirls in the air whenever the tail moves; this, as was mentioned above, absorbs energy, and is of sensible advantage in suppressing oscillations.

There is but one proper way to seek to suppress the oscillations of a vane; namely, by interposing some sort of frictionless obstruction to its *sudden* movements, such as the resistance of vanes or blades moving in oil. These oppose sudden shifts in the vane, but do not prevent the vane from slowly adjusting itself exactly in the direction of any steady current.

III. Wind Instrument Supports and Towers.

31. *Standard 6-foot vane and support.*—The standard vane of the Weather Bureau and its support with contact box and electrical contacts used prior to 1909 are shown in fig. 7. A more recent design is shown in fig. 10. The construction, as far as practicable, embodies the essential principles of the ideal vane mentioned above. Owing to the considerable dimensions and extremes of exposure to which wind vanes are subjected it has long been a difficult question as how best to avoid excessive friction in the mounting, and at the same time secure durability with little or no attention, and under the corroding effects of moisture, etc. For a long time the Weather Bureau has been using a form of vane supported and revolving upon a system of three wheels moving between two circular plates as shown in fig. 7. This bearing does not require lubrication at all, and in its improved form has been generally satisfactory. New installations, however, will embody the features shown in fig. 10, hereafter described.

The axis of the vane (fig. 7) is formed out of a solid iron rod, *a*, about five-eighths inch in diameter and about 42 inches long. The tail of the 6-foot vane is of thin wooden boards, spread apart about 9 inches at the end. These boards are bound together and reinforced by suitable iron bands, of which the two on the edge are prolonged to carry a small counterweight *w* and the arrow point *o*. The rod *a* is reduced at the top portion and squared at *f*, as shown in the enlarged section at *A*, where it fits closely into a corresponding hole in the lower iron-bound edge of the vane, the rod and vane being held together by the spearhead nut *g*. The entire weight of the vane with the moving parts connected thereto is supported upon the three antifriction rollers, seen enlarged at *A*. These are of hard brass and are mounted in the carrier or frame *h*, which fits loosely around the solid rod and yet centers and otherwise keeps the wheels in their proper positions. The bell cover *k* is made of hard brass, turned out true and smooth on the inside, and fitted with a cylindrical zinc projection, held in place by friction or small brass screws, and which can readily be lowered to permit of examining bearings. The cover *k* fits the solid rod a little loosely and rests against the shoulder *n*, formed on the rod *a*. The bell cover, by being fitted loosely in this manner, is able to center itself and distribute the weight equally over the three antifriction wheels. The cap *m* is made of hard brass, turned true and smooth, and forms one of the pair of surfaces between which the antifriction wheels roll, the other being the under surface of the bell cover. The axis of the vane is guided laterally by the cap *m* at the top and by the brass bushing of the coupling *b* at the bottom. The lateral pressures are, as a rule, very small, and no special provision is made for reducing friction in this respect, except to insure

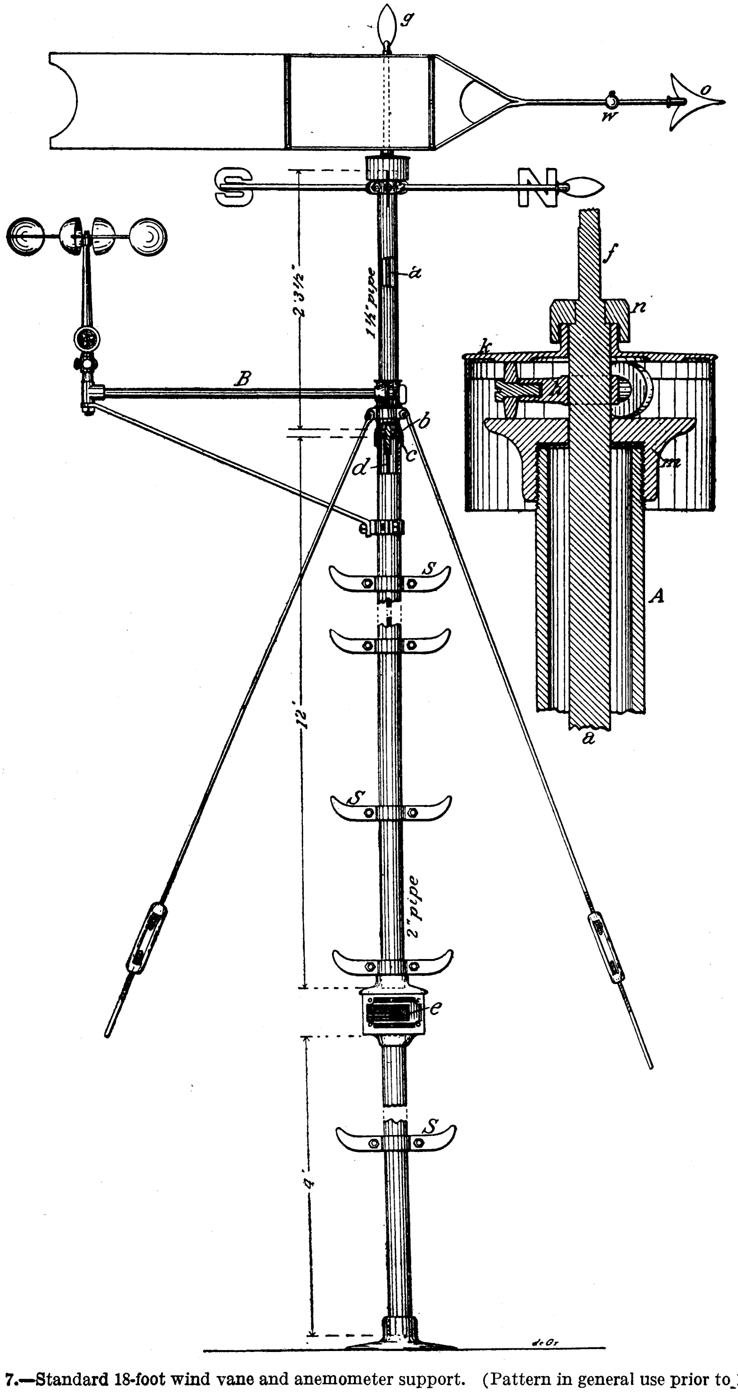


FIG. 7.—Standard 18-foot wind vane and anemometer support. (Pattern in general use prior to 1909.)

a loose fit and smooth holes. The cap *m* screws upon one end of a short piece of $1\frac{1}{2}$-inch wrought-iron pipe and the coupling *b*, with its bushing upon the other end.

32. *Improved construction of antifriction rollers.*—Antifriction-roller carriers of a later pattern were constructed in *two* parts, attached together by screws, to facilitate placing in position, when new rollers were required, and without the necessity for taking down or dismantling the support. New rollers can be promptly furnished by mail, whenever required to replace those that may become worn from long service, and these may be readily placed in postion by slipping down the zinc cylinder attached to the bell cover and blocking up the latter so as to lift the weight off the rollers.

33. The vane and short axis, as described above, including the short piece of $1\frac{1}{2}$-inch pipe, is a complete mechanism in itself; and the inside rod is short and straight, a condition necessary for perfectly free movement. This construction readily admits placing the vane upon any suitable support and at any convenient height. The standard support is made out of wrought-iron pipe, and becomes extremely secure and rigid when stayed with three guy rods, as partly seen in the figure. These latter are provided with turnbuckles for tightening, and are secured to the roof by iron shoes.

When electrical contacts are used the above described short axis of the vane is extended by the addition of a sufficient length of $\frac{1}{8}$-inch gas pipe, the outside diameter of which is about $\frac{5}{16}$ inch. One end of this pipe is screwed firmly into the lower end of the solid rod of the vane *a*, as at *d*. The inside rod thus extended will probably not be quite straight, but can be easily bent nearly so, and if slightly out of true the matter is not serious, since the long and very slender pipe is comparatively flexible and adapts itself to its constraints with only slight frictional resistance.

34. *Foot rests.*—To afford access to the top of the support, iron foot rests, shown at *S* in fig. 7, are clamped to the pipe at intervals of about 18 inches.

35. *Anemometer cross arms.*—A horizontal arm is often attached to the wind-vane support at a point about 3 feet below the vane. The outer end of this arm carries a brass pin upon which anemometers may be exposed. The anemometer cups are then about 18 inches below the level of the under edge of the vane and at a distance of about 30 inches from the support itself. This cross arm is shown in the figure at *B*.

36. *Contact box.*—The contact box, within which the devices for securing electrical registration are placed, is of cast iron, and, to be easy and convenient of access at any time, is usually inserted at about 5 feet from the base. Rain, etc., are perfectly excluded by close-fitting covers provided with lead gaskets.

37. The contact mechanisms are shown separately in figs. 8 and 11, and are partly seen in position within the contact box at *e*. These devices consist of two parts: First, the so-called cam collars, shown separately in fig. 8, and the contact plate and springs seen in fig. 11. The device in fig. 8 consists of four exactly similar cams, the acting portion of each embracing three-eighths of a circumference. These are arranged on a common axis in such a manner that the acting portion of the top cam overlaps the one below just one-eighth of a circumference. This cam similarly overlaps the one next below the same amount, and so on.

38. The contact plate is provided with proper bearings for the cam collars, and carries the four cam levers with the cam wheels *a a a a*, fig. 11, also the four insulated contact springs N E S W, the points of which approach closely the corresponding cam lever, but make contact only when the lever is pressed outward by one of the cams, thus closing an electric circuit through that particular spring. It will be remembered that adjacent cams overlap for a portion of their extent; this, in certain positions of the cams, brings *two* of the springs into contact—thus, N and E, for example, may both make contact at the same time, a condition that indicates the vane is pointing toward the northeast. By these devices, with four springs and circuits, a record of eight possible directions may be secured.

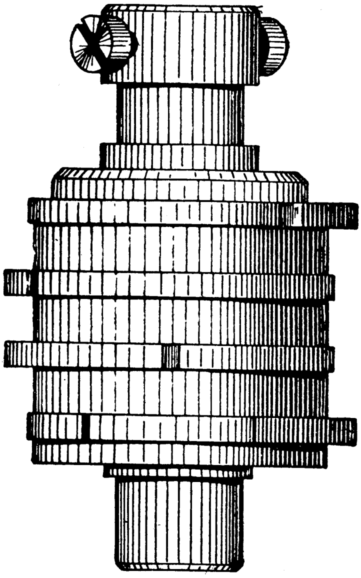


FIG. 8.—Cam collars.

39. When the contact mechanisms are placed in the contact box the inside ⅛-inch pipe passes centrally through the cam collars, which are securely clamped thereto by the set screws *b b*. The contact plate is not rigidly fixed in the contact box, but is simply prevented from turning by means of two screws passing through opposite sides of the box, and with their points entering loosely into appropriate slots in the ends of the contact plate, as shown at *g*, fig. 14. The whole mechanism simply hangs on the slender inside rod of the vane, and offers only the slightest resistance to rotation in the bearings of the cam collars and the cam levers.

The 6-foot vane, constructed as described above, and provided with contacts for electrical registration, will turn with very light winds.

40. *Description of 4-foot ball-bearing wind vane.*—The apparatus is shown in fig. 9 and consists of a brass casting, the lower portion of which fits loosely over a standard $1\frac{1}{2}$-inch iron pipe, such as ordinarily forms the top of the wind-vane supports now in use by the Weather Bureau. A set screw serves to secure the vane in the desired azimuth, as will be explained in paragraph 41. A copper sleeve *d*, shown at the bottom of the picture, slides up over the casting and is held in place by a pin fitting into a groove, as will be understood from inspection. This sleeve effectually protects the interior parts

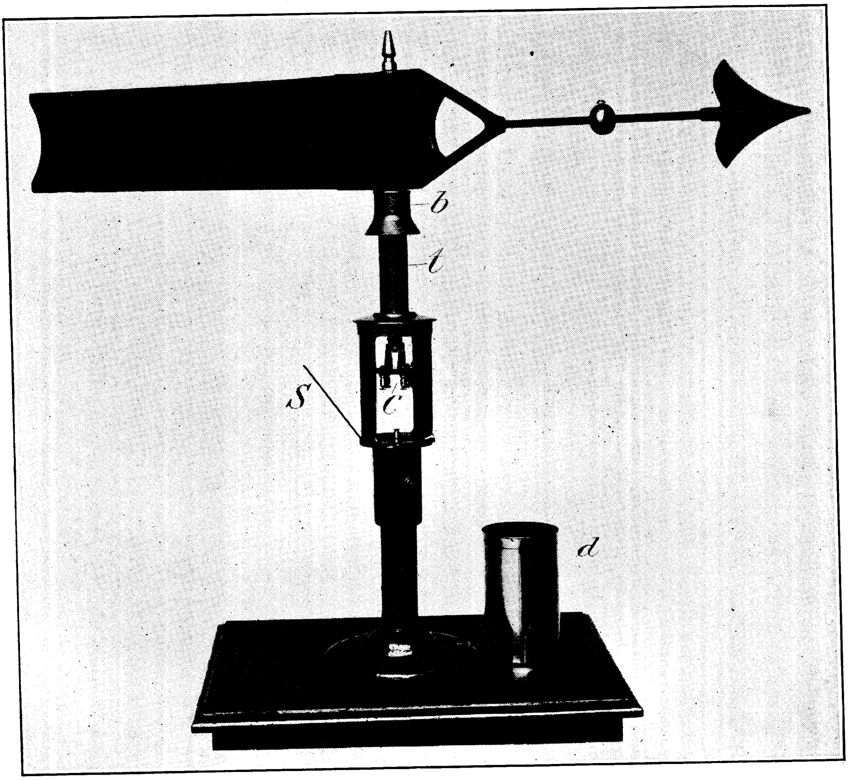


FIG. 9.—Standard 4-foot ball-bearing wind vane, with cast brass or "McAdamite" contact box, adopted 1907.

from the weather. The four contact springs, insulated from each other, are attached by a brass bracket *C* to the side of the contact box. The axis of the vane is carried on a pair of ball bearings in the ends of the short piece of brass tubing *t*, seen in the picture above the contacts. The whole is surmounted by a standard 4-foot wind vane which is clamped securely to the steel rod and the small, flanged, antifrost sleeve *b*. The apparatus weighs, complete with vane, about 17 pounds and has been designed in this portable shape to be handled independently of its support (after the manner of an anemometer), to facilitate repairs, cleaning, etc.

To enable the vane to be set accurately in the meridian, a small, hinged sighting staff *S* is fixed in the casting at one side. The use of this in adjusting the vane is fully explained in paragraph 41.

41. *To adjust the contact box to the meridian.*—When the vane is installed, and whenever removed for cleaning or repairs, special pains must be taken to secure proper adjustment to the meridian, and a sighting rod is provided for this purpose, and enables the observer to set the vane to the meridian by reference to the shadow cast by the sun in full sunshine at noontime.

The exact moment that the sun crosses the meridian at the station on the day the vane is adjusted will be determined in accordance with the instructions given in paragraphs 57 and 58. The sun must, of course, be shining at this time. The sighting staff *S* will be inclined outward from the contact box and the vane turned on the support so that the shadow cast by the sighting staff falls exactly on the heavily engraved line on the brass casting *at the moment of local solar noon; that is, at the moment the sun crosses the meridian, as previously determined.* The apparatus should then be secured in this position on the support, care being taken that it is not shifted in the process of clamping with the set screw provided for this purpose.

After an adjustment of this kind has once been made, the pipe may be marked in such a way that the contact box can always be returned to its correct position, but resettings of the vane should be carefully verified to make sure that correct records of wind direction are being obtained.

42. The contact springs and the single cam itself are of very simple construction, and when any spring becomes worn or defective it is easily and quickly replaced by a new one which will be furnished on application to the central office. In making requisitions for new parts of this kind, always give the official number of the contact box which will be found stamped thereon.

43. A considerable number of stations have replaced the 6-foot wind vanes formerly in use with this improved pattern 4-foot vane, but the 1913 pattern (see fig. 10) is considered most satisfactory and reliable, and new equipment and changes will be made according to this latest pattern. The present standard 18-foot supports for wind instruments are, as a rule, more durable than the vane itself, and the ball-bearing vane is designed to be installed on the old supports, as far as practicable. For this purpose it will not usually be necessary to take down the support completely when replacing the equipment. The 6-foot vane, inner solid rod, electrical contacts, the bell cover *k*, and the brass cap *m* (see fig. 7, p. 18, of this pamphlet) will be entirely removed, whereupon the new vane may readily be placed in position on top of the upper ($1\frac{1}{2}$-inch pipe) section of the support. This will give a slightly increased elevation to the vane,

the amount of which should be reported, with time and date new vane is placed in operation.

44. Where the cable is to be run up through the inside of the support it will be very desirable, if not necessary, to remove the brass bushing in the coupling *b* (fig. 7), unless the wires or cable to be run through are of such small diameter as to easily pass through said bushing. The removal of this brass bushing may present some little difficulty without taking off the top section and reducer. Perhaps the best way to remove the superfluous part is to provide a tapered, pointed, iron rod of some character, of suitable length, having a diameter slightly larger than the hole in the bushing, either roughened on the outside at the lower end, or perhaps 4-sided, with rather sharp edges. If such a rod as this is driven into the bushing slightly, after the point has entered the hole in the center, the bushing can easily be unscrewed by turning the rod in a clockwise direction, as viewed from the top end. When the bushing has completely unscrewed down into the 2-inch pipe, it can easily be forced off the tapered end of the rod used as a wrench by lifting the latter forcibly so as to cause the bushing to strike the contracted section of the opening in the reducer, and it will then fall into the space of the contact box. It will probably be advisable to cover the hole in the bottom of the contact box with waste, paper, a small piece of wood, or something, so that the bushing can be recovered.

45. Where new supports or any alterations to the present supports are required special instructions covering the case will be given from the instrument division of the central office.

46. *Cable connections.*—Five wires, only, are required for the electrical connections to the contact box. In the case of old supports, with old-style cast-iron contact box, the wires or cable may be run up through the inside of the iron pipe or pass up the outside, as preferred; the usual connections to the anemometer being suitably arranged.

47. *Wind vane and contact box, 1913 pattern.*—Whereas the ball-bearing wind vane and contacts described above and illustrated in fig. 9, constituted a compact and satisfactory equipment, difficulty was experienced because of the necessity of making the ball bearings part of the electrical circuit; and because the contact box could not be reached without climbing the support. This led to the design of the wind vane and anemometer support shown in fig. 10, which obviates the above difficulties by resorting again to the contact box near the base of the support, with the contacts joined by an inside $\frac{1}{8}$-inch pipe to the 4-foot wind vane mounted on ball bearings.

The instructions for installing the 6-foot vane and standard support are quite sufficient for this newer equipment, being practically the same, except for the substitution of the ball bearings in the latter for the roller bearings, and the simplification of the wind-vane mounting.

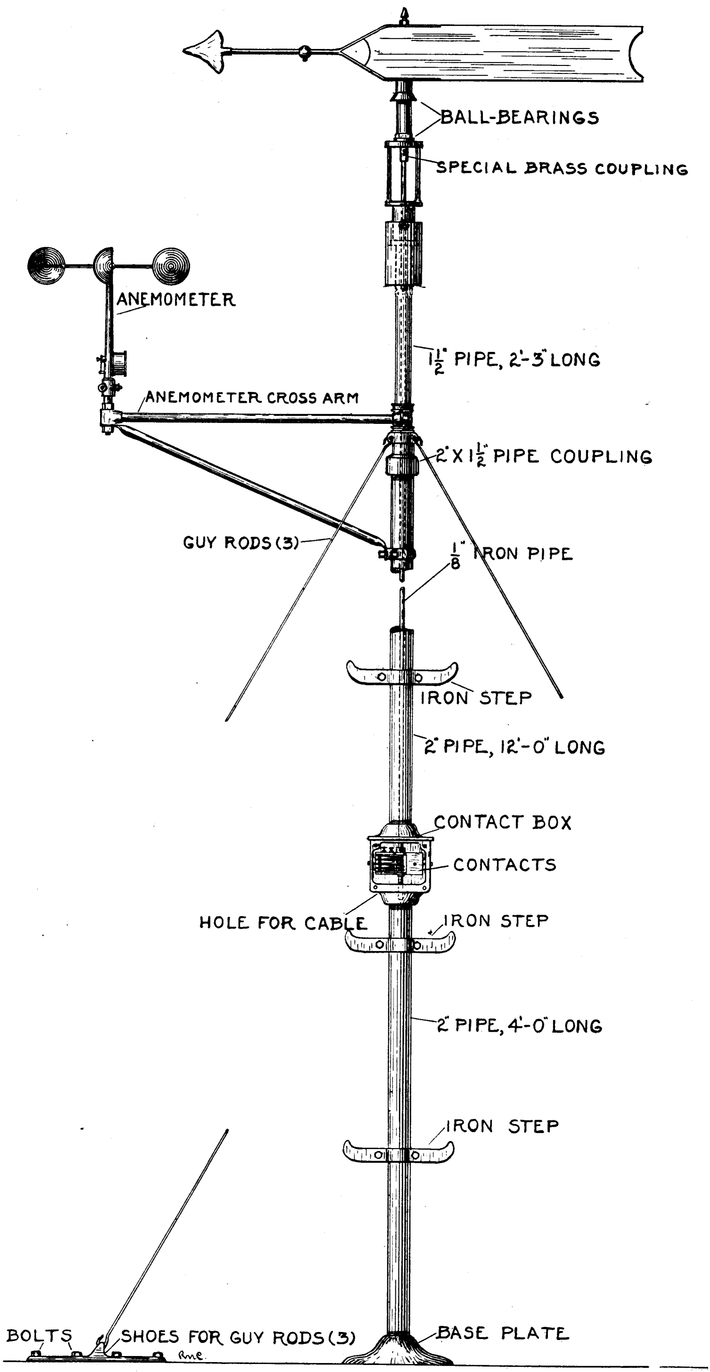


FIG. 10.—Wind vane and anemometer support, pattern 1913. (Showing 4-foot wind vane on ball bearings.)

48. When it is desired, however, to utilize an old-style support for this newer equipment, the questions involved in each installation will be taken up in detail with the central office. Attention is called to the fact that the 1913 pattern contacts are smaller and lighter than the old style, and require that the set screw for preventing the rotation of the contacts be placed thirteen thirty-seconds of an inch nearer the center of the box, to properly locate the contacts with respect to the axis of the support and to allow free rotation of the moving parts. This necessitates the drilling and tapping of new holes in the contact box.

49. *How to install a standard wind vane.*—The position selected for the exposure of the vane should be as unobstructed as possible by adjacent chimneys, domes, ventilators, towers, buildings, or other objects that may interfere with the free movement of the wind. In

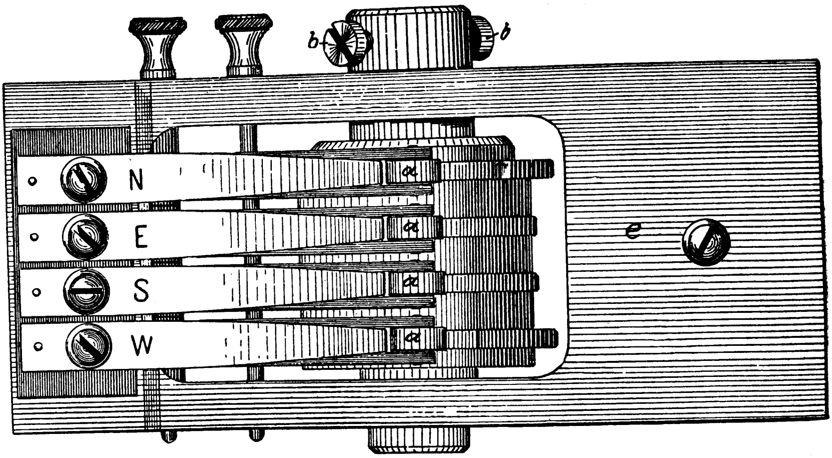


FIG. 11.—Electrical contacts for wind direction.

general the higher the support the better, but difficulties of construction, etc., limit the height of structures of this character to from 15 to 25 feet.

50. The standard 18-foot support, as shipped from the central office, is ready to be elevated in position when the base plate and lower section of pipe are screwed into the contact box and the guys, foot rests, and other extras are attached. Generally it will not be difficult to tilt the support into the vertical position.

When supports are built up at stations the sections must be screwed together as tightly as possible, and with the cast-iron contact box (when this is used) at from 4 to 5 feet from the base. The following additional details need attention.

51. When an inside rod is used to form the axis of the vane (see figs. 7 and 10) it should not be extended downward below the top section unless electrical contacts are to be used, in which case the exten-

sion should be made of ⅛-inch gas pipe. In joining this pipe together or to the solid rod *a* great care must be taken that the couplings are very tight and the sections as nearly as possible in line. The inside pipe should be placed in the support before the latter is erected, though it is possible to insert the pipe afterwards, if necessary.

52. *To straighten the inside rod.*—The inside pipe is generally straight in supports sent out from the central office, but observers may sometimes find the following suggestions helpful in straightening the rod in supports that are changed or reerected at stations.

Before placing the vane on the support or the contact plate in the box an assistant should climb to the top of the support and twirl the axis of the vane between the thumb and fingers. The movement of the inside pipe should be watched within the contact box. If it is not in proper alignment the portion passing through the contact box will describe a circular movement rather than revolve on a line through its center. To remedy this the pipe must be lifted up so as to bring the joint, marked *c*, above the top of the support, and be bent gently at that point until, by the twirling test, it is found the portion passing through the contact box does not describe a noticeable circle; that is, the rovolution is nearly or quite about a line through the center of the pipe itself. By this method a very accurate alignment of the pipe can be made.

53. In order that the support may be braced as securely as possible it is essential that the three guy rods be spread about equal distances from each other, or so that the points of attachment to the roof or platform will be about 120° apart, as measured from the base plate as a center.

In securing the guy rods to the roof or platform special attention must be given to insure a firm hold not only of the iron shoe but of the flooring or roofing itself, as if the latter is fastened only by nails, as is generally the case, it is a very easy matter when screwing up the turn-buckles of the guy rods to pull the boards loose from the floor or roof timbers.

54. *Oiling vane bearings.*—The bearings of the 6-foot vane are so designed that it makes very little difference whether they are oiled or not. In erecting a vane, however, a little oil should be put upon the iron axis along the portions passing through the guide just below the antifriction rollers and at *b*; also, a *very little* upon the *axes* of the antifriction rollers. *Oil must not be applied to the surfaces upon which the antifriction wheels roll or upon the wheels themselves,* as this causes dust to adhere and accumulate and finally block up the free rolling of the wheels. It is probable that *vaseline* is the best material to use for lubricating the ball bearings of the 4-foot vane, and one application should last a long time. As the bearings are lubricated when they leave the factory, additional lubrication should not be required for a

long time after they are first installed. Observers should, however, make certain that the bearings are never in need of lubrication, and they should be occasionally examined as to condition.

Two oil holes are provided in the bearings of the cam collars and these should be lubricated from the start, and from time to time afterwards as may appear necessary.

55. The inside rod having been straightened and oiled, as described above, the electrical contact plate is placed in the box and the inside rod lowered and passed through the hole in the cam collars. The points of the screws passing through opposite sides of the contact box are then caught into the slots in the ends of the contact plate. The vane itself is next placed upon the top of the rod. The cam collar is fastened to the inside rod at the time the vane is adjusted to the true meridian.

56. *To adjust vanes to true meridian.*—When vanes are provided with electrical contacts, the cam collars must be so clamped to the inside rod, that, for example, when the vane itself points truly north the center of the particular cam giving a north direction record will be exactly opposite the center of the wheel of the corresponding contact lever. To secure this adjustment it is necessary to hold the vane accurately in a north and south position, or such other principal direction as may be convenient, and adjust and clamp the cam collars on the inside rod so that the central line (engraved on each cam collar), on the particular collar corresponding to the direction of the vane, will be exactly opposite the center of the wheel of the corresponding contact lever. When in this position the contact plate should be free from both the bottom and the top of the contact box and be held by the two screws passing through opposite sides of the contact box and entering into the grooves or slots made in the edges of the contact plate. Special pains should be taken to fasten the set screws on the cam collars firmly to the inside rod. This should be done by alternately tightening and loosening the screw a little so as to cause its sharp point to enter, more or less, into the metal of the inside rod. Both clamping screws on the cam collars should be firmly tightened. After the screws are tightened careful comparison should be made to insure that the cam collars are fixed so that the center of the particular cam comes opposite, *exactly*, the contact lever when the vane is held fixed in its true direction.

When the four direction arms shown at N S, fig. 7, are furnished, they must be secured to the top of the support so as to indicate the true direction.

57. *True meridian: how determined.*—The accurate adjustment of the vane requires a knowledge of the meridian of the place in question, and, as many office buildings contain a great deal of iron, and as the

support is itself also of iron, a magnetic compass can not generally be relied upon. Where a true north and south line can not be established with certainty from other information, the following method may be employed.

The wind-vane support being adjusted as nearly as possible to a vertical position, the shadow cast by the support on a *horizontal* surface, at *true solar noon,* will be an exact north and south line. This line should be established across a portion of the instrument platform, but only true solar time can be used.

For this purpose the observer must ascertain the exact difference between the standard time in use at his station and the true local time. To this difference must then be added or subtracted, as the case may require, the so-called equation of time, which is the number of minutes before or after local noon at which the sun passes the meridian. The equation of time is given, approximately, in the accompanying diagram, fig. 12, and more exactly in the following table:

Equation of time for 1899.[1]

Days.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
1........	+ 3 53	+13 50	+12 29	+3 53	−3 01	−2 24	+3 36	+6 06	− 0 09	−10 23	−16 20	−10 45
2........	4 21	13 57	12 17	3 35	3 08	2 14	3 47	6 02	0 28	10 42	16 21	10 22
3........	4 49	14 04	12 04	3 17	3 15	2 05	3 59	5 58	0 47	11 01	16 20	9 58
4........	5 16	14 10	11 51	3 00	3 21	1 55	4 09	5 53	1 07	11 19	16 20	9 34
5........	5 43	14 14	11 37	2 42	3 26	1 44	4 20	5 47	1 26	11 37	16 18	9 09
6........	6 10	14 19	11 23	2 25	3 31	1 33	4 30	5 41	1 46	11 54	16 15	8 44
7........	6 36	14 22	11 09	2 08	3 45	1 22	4 40	5 34	2 07	12 11	16 12	8 18
8........	7 01	14 24	10 54	1 51	3 39	1 11	4 50	5 26	2 27	12 28	16 08	7 51
9........	7 26	14 26	10 39	1 34	3 42	0 59	4 59	5 18	2 47	12 44	16 03	7 25
10........	7 51	14 27	10 23	1 18	3 45	0 47	5 08	5 10	3 08	13 00	15 57	6 57
11........	8 15	14 27	10 07	1 02	3 47	0 35	5 16	5 00	3 29	13 16	15 50	6 30
12........	8 38	14 27	9 51	0 46	3 48	0 23	5 24	4 50	3 50	13 31	15 43	6 02
13........	9 01	14 25	9 35	0 30	3 49	−0 11	5 31	4 40	4 11	13 45	15 34	5 33
14........	9 23	14 23	9 18	0 15	3 49	+0 02	5 38	4 29	4 32	13 59	15 25	5 05
15........	9 44	14 20	9 01	0 00	3 49	0 15	5 44	4 18	4 53	14 12	15 15	4 36
16........	10 05	14 17	8 44	−0 14	3 48	0 27	5 50	4 06	5 15	14 25	15 04	4 07
17........	10 25	14 12	8 27	0 28	3 46	0 40	5 55	3 53	5 36	14 37	14 53	3 37
18........	10 44	14 07	8 09	0 42	3 44	0 53	6 00	3 40	5 57	14 49	14 40	3 08
19........	11 02	14 01	7 51	0 56	3 42	1 06	6 04	3 26	6 18	15 00	14 27	2 38
20........	11 20	13 55	7 33	1 09	3 39	1 19	6 08	3 12	6 40	15 10	14 13	2 08
21........	11 37	13 48	7 15	1 21	3 35	1 32	6 11	2 58	7 01	15 20	13 58	1 39
22........	11 53	13 40	6 57	1 33	3 31	1 45	6 13	2 43	7 22	15 29	13 42	1 09
23........	12 09	13 32	6 39	1 45	3 27	1 58	6 15	2 27	7 43	15 38	13 26	0 39
24........	12 23	13 23	6 20	1 56	3 22	2 10	6 16	2 11	8 04	15 45	13 08	− 0 09
25........	12 37	13 13	6 02	2 07	3 16	2 23	6 17	1 55	8 24	15 52	12 50	+ 0 21
26........	12 50	13 03	5 43	2 17	3 10	2 36	6 17	1 38	8 45	15 59	12 31	0 51
27........	13 02	12 52	5 25	2 27	3 04	2 48	6 17	1 21	9 05	16 04	12 11	1 21
28........	13 13	12 41	5 06	2 36	2 56	3 00	6 16	1 04	9 25	16 09	11 51	1 50
29........	13 24	....	4 48	2 45	2 49	3 12	6 14	0 46	9 45	16 13	11 30	2 20
30........	13 33	....	4 30	2 53	2 41	3 24	6 12	0 28	10 04	16 16	11 08	2 49
31........	13 42	....	4 11	....	2 33	....	6 09	+0 10	....	16 18	....	3 18

[1] The equation of time changes slightly from year to year, but the values given in the table may be taken as a fair average of those that ordinarily occur.

When the equation of time is +, the sun is slower than the clock and the specified number of minutes must be added to the true local noon to give the time at which the sun passes the meridian, and, similarly, when the sign is —, the number of minutes must be subtracted from local noon.

58. For example, suppose the north and south line is to be located at some station on October 3, and where the local time is 24 minutes faster than the standard time in use. Hence:

Difference between standard and local time........................ = −24 minutes.
(Use + when standard meridian is east of station and − when west.)
Equation of time, October 3.................................... = −11 minutes.

Total correction.. = −35 minutes.

Therefore the sun will be exactly on the meridian at 12 o'clock, minus 35 minutes = 11.25 a. m., and the shadow of the wind-vane support at

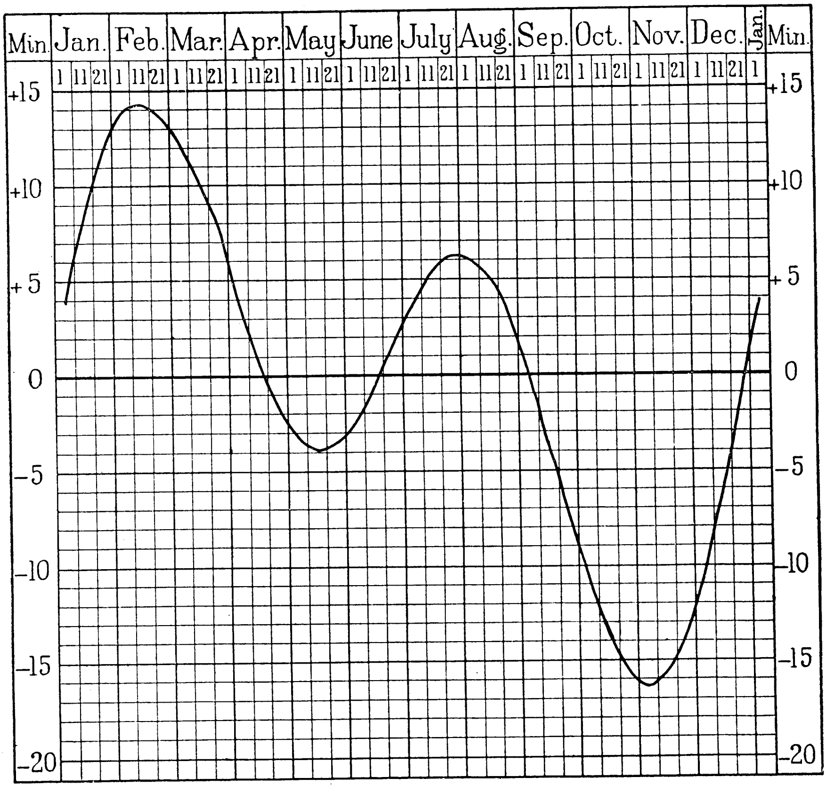


FIG. 12.—Diagram of equation of time.

this moment will be in a true north and south line, which should be permanently marked on the platform and will afterward serve to guide in adjusting the wind vane, and also the wind direction cross-arms of the support, to the true meridian.

This method can not be employed in a satisfactory manner where the support is erected on a sloping roof, as the shadow will be north and south, in general, only when cast on a horizontal surface.

59. *Top section: anemometer above wind vane.*—A modified form of the top section of the wind-vane support is shown in fig. 13, the object

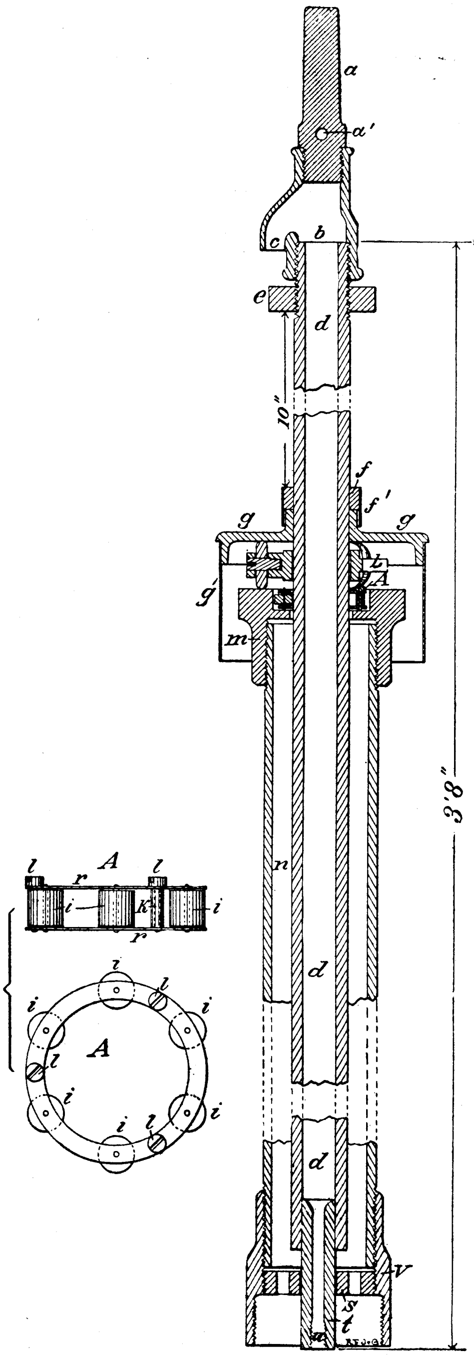


FIG. 13.—Top section of support with anemometer above wind vane.

of the arrangement being to provide a method of mounting the anemometer *above* the wind vane, thereby dispensing with the cross-arm attachment described in paragraph 35, and affording a better and freer exposure for the anemometer. This position of the anemometer necessitates carrying the electrical connection for the instrument down through the center of axis of rotation of the wind vane. For this purpose the top section of the axis of the vane is made hollow, and, in order to secure adequate strength, consists of a piece of turned iron pipe about an inch in diameter. To give freedom of motion a double system of roller bearings is provided at the top. One of these is similar to the ordinary kind, as shown at *L*, and the other, for taking up the lateral thrust of the axis, is shown enlarged in two views at *A*. The wooden vane is clamped on top of the hollow axis by a lock nut *e*, and above this is screwed a special fitting with the brass pin *a* for the anemometer. A complete support, of extra height, with this form of top section and provided, in addition, with storm-warning lanterns *a b*, is shown in fig. 15. When the height must exceed 26 or 28 feet, a form of tower such as shown in frontispiece has been adopted for the exposure of lanterns and wind instruments.

60. *Electrical connections for anemometers.*—In the combined support with the anemometer above the vane, it is necessary to pass an insulated copper wire down through the hollow axis of the vane. This is sometimes done before shipment, but if the support exceeds 18 feet in height, it is often not practicable to ship the parts in a sufficiently long section to permit of the introduction of the wire. Little trouble will be experienced in the insertion of the wire if pains be taken to keep the wire straight.

61. *Insertion of electrical connection for anemometer.*—If the height of the support exceeds 18 to 20 feet, it will generally be best to pass

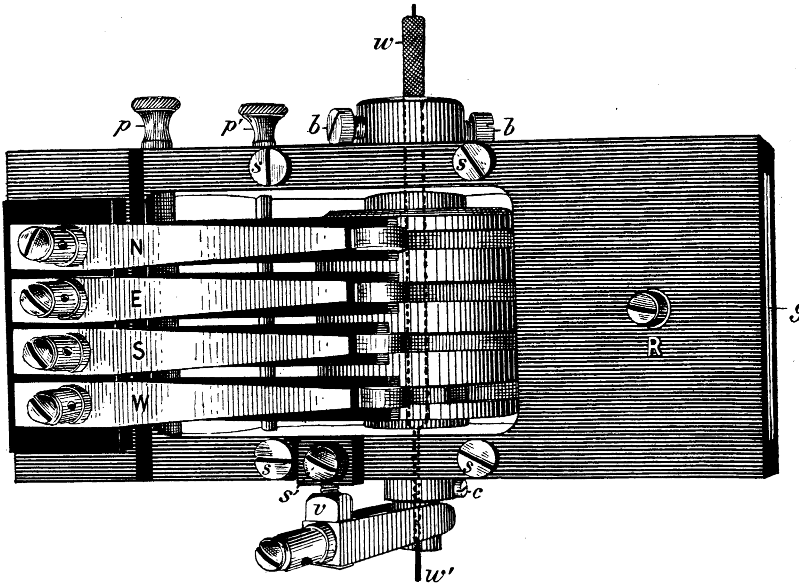


FIG. 14.—Electrical contacts for direction and velocity.

the wire through the $\frac{1}{8}$-inch pipe *before the tube d* (fig. 13) *is screwed on.* The wire should first be straightened out carefully and, if practicable, the rod and the wire laid out in line on the roof. The wire may then be passed into the pipe and little by little worked through a long length. The sticking of the wire and finally the failure to get the end through is generally due to the failure of the operator to keep the wire reasonably straight and pass successive portions *directly into the pipe.* He bends the wire more or less into a wavy configuration; each of these little waves rubs with more or less pressure against the walls of the pipe. The accumulating resistance thus introduced is sooner or later too great to overcome and the wire sticks and must be pulled out and straightened and the operation properly performed. The wire can be inserted in an 18-foot support even with the tube *d* in place, but a slight crimping of the wire is likely to take place inside the large tube *d* before the wire enters the $\frac{1}{8}$-inch tubing, so that special pains are necessary in feeding in the wire. In some cases a small naked wire may first be introduced and used to pull through the insulated wire.

62. *Disposition of the wire in contact box.*—An inch or so of the free end of the wire in the contact box should be stripped of insulation and brightened and the wire passed through the cam collars so that the naked end passes out, as shown at w', fig. 14. It is best to pull the wire down at w' as far as the insulation will permit it to come. This will prevent exposing a naked portion of the wire to the inside of the $\frac{1}{8}$-inch pipe, when this latter is afterwards passed down through the cam collars in the usual way as described in paragraph 39. The small set screw *c*, fig. 14, is for the purpose of clamping the naked wire w', but this should not be tightened at first. It is best, after having passed the wire through the cam collar, to sharply bend out the end w'. This will hold the wire in place and prevent it from being pulled out accidentally during subsequent manipulations. After all the adjustments have been made the screw *c* should be tightened, the wire w' should be straightened out, and the end cut off if necessary.

63. *Disposition of end of wire at anemometer pin.*—The wind vane having been secured on the rod *d* by the lock nut *e*, fig. 13, the cap *b* is screwed on after first unscrewing the anemometer pin *a* and passing the wire directly through *b*. The free end of the wire is then turned backward through the cap and passed out at *c*, all slack pulled up, and the pin *a* screwed in. A sufficient surplus of wire should be left and wound snugly around the cap. This inside wire must connect with the *insulated* binding post on the anemometer. The wire direct from the battery, or, in some cases, from the batteries feeding the anemometer and wind-direction circuits, must connect into the *uninsulated* post *R*, fig. 14, thus grounding the batteries on the metal of the support, and in general with the wire from the wind-velocity magnet on the register connects into the binding post *v*, fig. 14. The diagram of the circuits is shown in fig. 25.

64. *Caution.*—If the parts of the upper section are dismantled for any purpose, care must be taken to see that the set of side thrust anti-friction rollers *i* is properly seated in the brass bearing cap *m* with the screw head *l* *upward*, as shown enlarged at *A*. Also, never loosen the cam-collar set screws *b*, fig. 14, without also loosening the set screw *c*, otherwise the insulated wire to the anemometer may be twisted off and the circuit broken.

65. It will generally be best to completely assemble the support, except possibly the anemometer, and then tilt or elevate the whole structure to a vertical position.

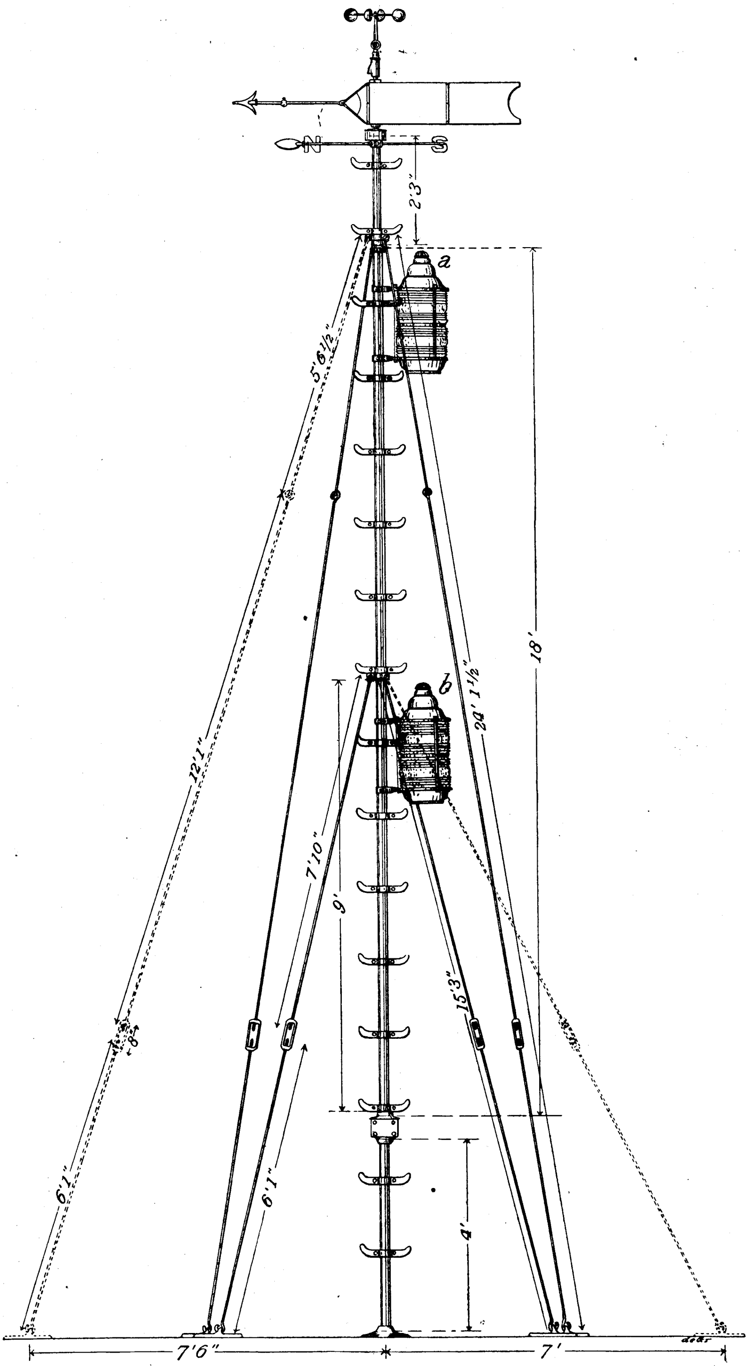


FIG. 15.—Combined 26-foot support for wind instruments, with storm-warning lanterns, *a* and *b*.

The foot rests near the top of the support should be disposed in such a manner as will afford convenient access to the anemometer for oiling and making the dial readings.

66. *Combined 26-foot support.*—The support shown in fig. 15 is adapted for use at stations where electric storm-warning lanterns are employed. It resembles closely the standard 18-foot support, except that two sets of guys are employed and the anemometer is exposed above the vane instead of on a cross arm. The instructions already given, paragraph 31, for the erection of the 18-foot support apply also for this support.

67. *Steel towers.*—When instruments and storm-warning lanterns must be elevated above 20 to 30 feet a form of steel tower, shown in frontispiece, answers best, and elevations exceeding 40 or 50 feet are practicable.

As designed for the use of this bureau the steel towers are made with a special view to their easy erection and the longest pieces scarcely exceed 10 feet, so that, as a rule, the parts can be carried up to the office roof through the building.

68. *Erection of steel towers.*—At some stations towers of this character may be erected on the ground adjacent to the office building, and observers will be guided in superintending the work by the following general instructions, which are framed for a 50-foot tower:

69. *Position of tower.*—If the tower is used for the display of storm-warning lanterns the side of the tower to which the ladder is attached must face squarely the harbor or water front, in order that the improved oil-burning lanterns, which will be displayed on this side of the tower, may be freely visible over the greatest possible extent of water front and best subserve the purpose intended. Even where electric lanterns are employed, the ladder should face the water front so that oil-burning lanterns may be employed if necessary. In other cases the ladder may be placed in the most convenient position.

70. *Anchorage: bottom section.*—Locate site for tower and lay out anchor holes 11 feet 6 inches from center to center. Dig holes 2 feet in diameter by 4 feet 6 inches deep, so that the bottom of each will be of common level. Bolt anchor plates to bottom of anchor posts and place in holes; bolt lower 10-foot sections of corner posts to upper end of anchor posts, and on the outside. Select the longest girts and the longest tie rods, passing the threaded end of the latter through slotted holes in the ends of the girts, then bolt girts to anchor posts. Pass tie rods through holes in center of second set of girts and bolt the latter to the corner posts; bolt the next, viz, the third set of girts to the corner posts, using the third hole from top end of post. Pass the threaded end of the tie rods through the slotted holes in the ends of these girts and put on the level washers and nuts. Tighten the tie rods to such an extent that this first section of the tower will be trued

up square and vertical, as shown by levels on the girts. Fill anchor holes with cobblestones and earth, tamping same down firmly. If the soil is very sandy and a secure anchorage for the tower can not be formed from the earth available, it may be necessary to make a footing for the anchor plates of concrete formed of one part of standard cement, three parts clean, sharp sand, and five parts clean broken stone. If necessary, this concrete mixture should also be used in filling in around the anchor posts after the first section of the tower has been carefully and accurately leveled. When concrete is to be used around the anchor posts the holes should not be more than 12 to 18 inches in diameter.

71. *Ladder.*—One girt of each set is drilled for attaching the ladder; place all these girts on the side where the ladder is desired, and secure the latter in place.

72. *Upper sections, etc.*—Proceed in the above-described manner with each section until apex is reached, bolt the tower cap in place at top, tighten the tie rods and square the tower, being sure that same is plumb. The tie rods should be tightened only enough to come under slight tension. If the rods are tightened unnecessarily an extra internal strain is produced upon the girts and corner posts and the tower is thereby weakened.

73. *Erection of the tower as a whole.*—When there is sufficient room, and men and tackle blocks handy, the tower may be assembled complete on the ground and erected to place by means of gin pole and ropes.

74. *Platform.*—The platform and railing are framed together and attached to the tower in a manner that is readily understood from a simple inspection of the parts in question.

75. *Wind vane and anemometer.*—The top of the tower is provided with a short piece of 2-inch pipe, designed to pass through the cap and stepped into a suitable footing formed 5 feet below. The contact box and attached top section of support are screwed firmly to the projecting end of this pipe, and the vane and anemometer secured in the usual manner, either before or after attaching the contact box to the top of the tower.

76. Owing to the very short distance between the contact box and the top section of the axis of the vane in this construction, perfectly free motion of the wind-vane axis is generally not possible when the electrical contacts are held in position in the contact box by two screws, one at each side, and if both screws are in position when the parts are received from this office the observer will *remove or loosen the screw entering the slot on the RIGHT-hand side of the contact box.* That is, the contacts will be held in position in the box only by the pointed screw entering the slot *near the direction binding posts,* and will be left free at the other end.

77. *Towers on roofs: anchorage.*—Roof towers are furnished with foot plates for the corner posts instead of anchor posts. It is sufficient to say that a perfectly secure and safe anchorage for these parts must be obtained by the party erecting the tower. The nature of this anchorage varies so much, depending on the structure of the roof on which it is proposed to erect the tower that detailed instructions can not be given here. In general, it is necessary to design a suitable special arrangement of the anchorage for each particular installation.

78. *Care of steel wind instrument and storm-warning towers.*—All towers used for the exposure of wind instruments or storm-warning displays must be carefully inspected from time to time, loose nuts or bolts and guy rods tightened, and the whole kept in thoroughly serviceable and secure condition. New nuts, bolts, or parts that are needed to replace those worn, defective, or unserviceable from long exposure to the elements may be promptly obtained upon stores requisitions, always referring to or using if practicable a printed "bill of material," copies of which should be on file at stations or section centers where such towers are part of the station or substation equipment.

79. *Painting.*—Under ordinary conditions of exposure galvanized steel is probably the best and most inexpensive weather-resisting material known. Such a finish should last for many years. When painting becomes necessary, however, the work should be done in accordance with the following specifications:

(*a*) Carefully go over the tower, scrape the metal surfaces wherever required, or brush with a stiff wire brush, so as to remove any appreciable incrustations or foreign matter.

(*b*) All parts of the tower will then be thoroughly coated with two coats of any one of the following paints: Best quality red lead, ground in oil. (If this is used, the second coat must be of some gray-colored paint.) "Ferrubron" (silver-gray tint), manufactured by the Ferrubron Metal Paint Co., 349 West Broadway, New York, N. Y. "Galvanum" (gray tint), manufactured by the Goheen Manufacturing Co., Canton, Ohio. The first coat will be allowed to dry thoroughly before the second is applied. Bidders will state the *kind* and *color* of paint they propose to use, giving trade designation.

(*c*) If the flagstaff, wind vane, and any attached parts of storm-warning towers are also in need of painting, and the work can not be well done otherwise, the staff must be lowered and all parts painted and put in good condition, the wind vane being painted black, the arrowhead and counterweight gilded if practicable, or well painted in some distinguishable manner with material that may be available.

(*d*) In the case of towers having cast-iron signs, the letters thereof will be gilded or otherwise distinguished by paint of a different color.

(*e*) The frequent painting of galvanized steel towers is not to be encouraged, as heavy layers of paint will prove injurious to the galvanizing. Therefore these towers will not be authorized painted except where urgently needed and under special conditions of exposure, all of which must be set forth in detail.

80. *Surplus towers and parts.*—Whenever from any cause a tower or any part thereof becomes surplus a special report will be made in regard thereto, setting forth the actual condition and the number of the parts, as checked on printed bills of material. State whether, in the opinion of the official in charge of station or section center, the parts in question are serviceable, repairable, or usable, the number and weight of the packages, etc., with a view to possible shipment either to the central office or to the factory for repairs. All unserviceable parts, especially if badly bent, broken, or seriously defective, and clearly not worth cost of shipment to factory are to be discarded as of no further use or value to the bureau. In reporting on such material, state whether or not the same has ever been painted, as painted iron can not be regalvanized at the factory.

Old insulated wires and cables that have been in use at stations for many years are generally not worth shipment, and in reporting on such surplus material care must be taken to report only such lengths as are in perfect condition and not weather worn. All worn and defective lengths must be disposed of at stations.

IV. Automatic Registration of Wind Velocity and Direction, Rainfall, and Sunshine.

81. *Definition.*—The term *register* is used by the Weather Bureau to designate certain pieces of apparatus, of which there are several distinct types, each apparatus acting in connection with some regular instrument to produce, usually by electrical means, a continuous and automatic record from the instrument. Thus, there are (1) the anemometer register, formerly inaptly designated self-register, and called also Gibbon's self-register, single register, etc.; (2) the two magnet register; (3) double register; (4) triple register; (5) telethermograph register, etc. In each case the register serves to produce, at a more or less distant point, a record of the indications of the instrument to which it is attached.

82. *Single register.*—The single anemometer register is used for recording the velocity of the wind. A clock gives regular and uniform motion to a cylinder at the rate of one revolution in six hours; the cylinder at the same time is moved endwise on its axis by the steep screw. The surface of the cylinder is covered with a ruled sheet of paper adapted to receive the record, which is traced by means of a pen attached to the armature of an electromagnet. The

standard Weather Bureau pen is shown separately in fig. 16. The pen traces a spiral line on the sheet of paper, but by the action of the electromagnet short lateral strokes or offsets are made to one side of the line whenever an electric current is passed through the coils of the magnet. As soon as the circuit is broken the armature and pen are drawn back to the main line by a spring. This action ensues when an anemometer, properly exposed as described in paragraph 27, is joined with the register and a battery by means of insulated copper wires.

83. Under these circumstances the armature and pen on the register will be alternately drawn aside and released every time one of the dial pins on the anemometer passes the contact spring and closes the electric circuit, as explained in paragraph 5.

84. *Two-magnet* register.—The two-magnet register, shown in fig. 17, is used at those stations where an automatic record of wind direction is not essential. This register records wind velocity in the manner described above for the single register, and simultaneously, on the same record sheet, rainfall and duration of sunshine in the manner described in paragraph 89.

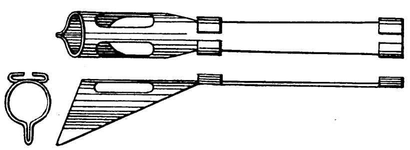


FIG. 16.—Register pen—enlarged view.

85. *Anemograph defined: double register.*—The apparatus described in paragraph 82 for recording wind velocity, when complete with anemometer, is sometimes called an anemograph, but this latter word more properly applies to an apparatus which also records the direction of the wind. The instrument in this case is more commonly known in the Weather Bureau as a double register; that is, one which records both direction and velocity of the wind. It is now rarely used, being displaced by the instrument described in the following paragraphs, which it closely resembles.

86. *Meteorograph: triple register-quadruple register.*—Instruments with which a continuous record of several meteorological phenomena are secured are often called meteorographs. The Weather Bureau instrument heretofore generally called the triple, or, more properly, quadruple register, is such an instrument and records four meteorological elements, namely: The direction and velocity of the wind, the rainfall, and the duration of sunshine. A general view of the instrument is shown in fig. 18. It embraces the essential mechanisms of the anemograph or double register mentioned in paragraph 85, but has in addition the rainfall and sunshine magnet *R* at the back. The drum *A* around which is wrapped the sheet of paper designed to receive the record, is revolved once in six hours by the clock movement shown. In each revolution the cylinder is shifted endwise nearly one-half of an inch by the action of the steep screw *C*

on the axis. The so-called wind-velocity magnet *V* actuates the pen *a* so as to trace upon the paper a complete record of the movement of the wind, in the manner explained more fully in paragraph 82.

87. *Wind direction.*—The direction of the wind is recorded by means of four magnets, of which two are seen at *W W*. These are often called the direction magnets, and are connected electrically with the wind direction contact springs, as described in paragraph 38, corresponding to the N., E., S., and W. points of wind direction. Each armature carries a long printing arm *P*, terminating in a downward projecting rounded point, which rests upon a small swinging ink pad *I* over the top of the cylinder. Whenever a current passes through a

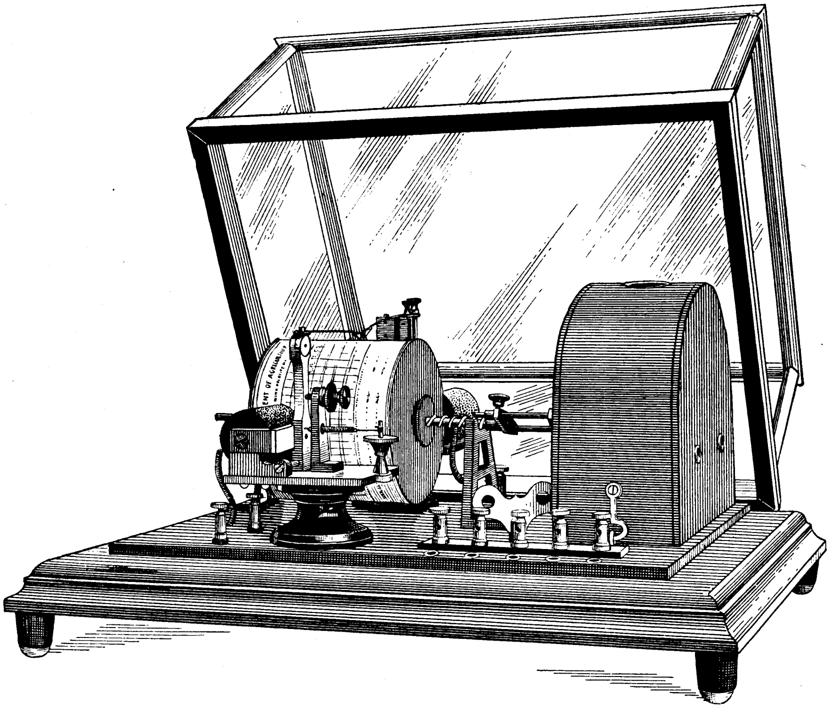


FIG. 17.—Two-magnet register. pattern of 1897.

magnet the armature is attracted and the printing point forced down on the cylinder, the ink pad being pushed aside at the same time. The imprint or dot made on the paper indicates a certain wind direction, which is shown by the position of the dot on the record (see fig. 19*a*). There being four magnets, four directions may thus be recorded by individual dots, but, as described in paragraph 38, the electrical contact mechanisms of the wind vane are so constructed that when the direction is intermediate between two principal points then *two* circuits will be closed; thus, for a northeast direction both the north and the east magnets will make a record upon the paper. In this way four magnets furnish eight possible directions.

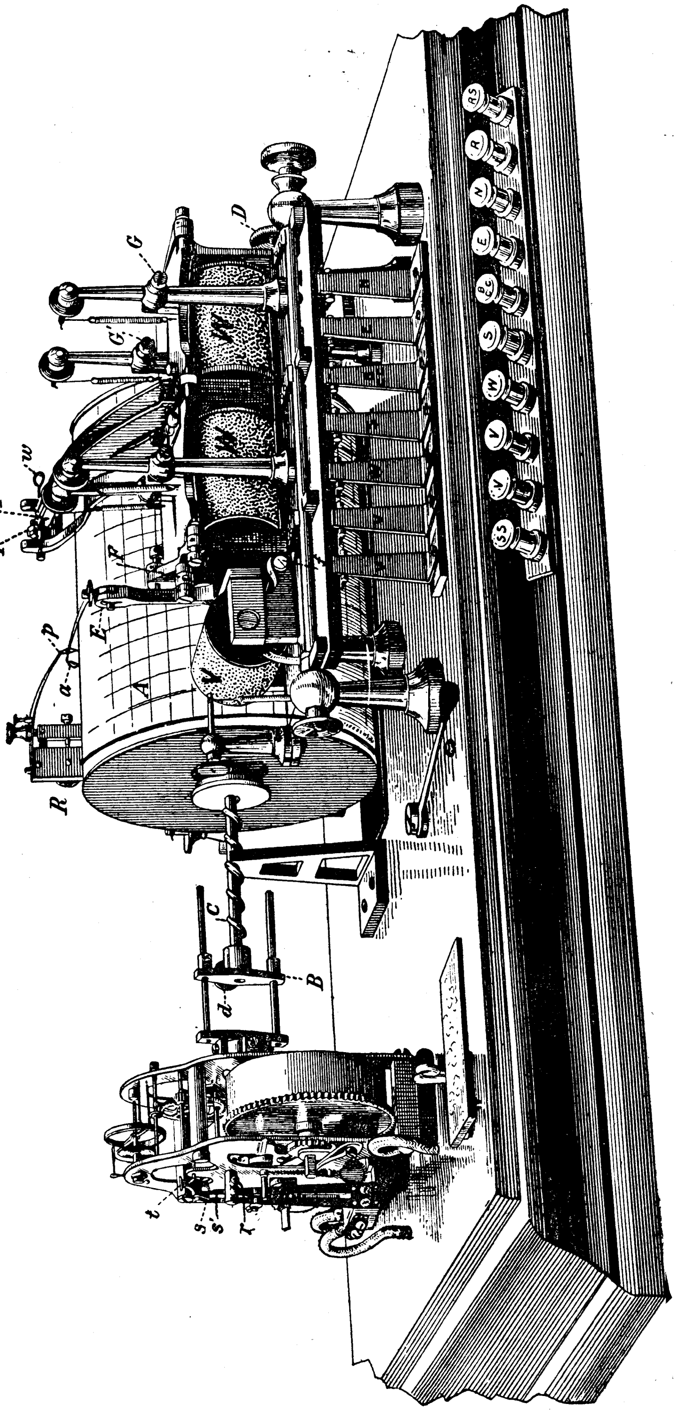


Fig. 18.—Station meteorograph.

88. *Renewal of printing points.*—The wind-direction printing points sometimes become corroded by the action of the ink and require to be renewed. New points are sent out from the central office, but the sizes of these parts are not exactly the same in all old registers, and it is often necessary to fit each set of points as received. For this purpose a small broach or reamer is sent with the new points. The points are generally held in the arms simply by friction and can be removed by driving them out from above, the arms, of course, being detached from the armatures. In rare cases the points may be held by solder, and it will then be necessary to gently heat the ends of the arms in a small alcohol or Bunsen flame until the solder is softened sufficiently to permit the point to be knocked out by gentle tapping.

If the new points will not fit, the holes must be enlarged by reaming out from the *underside*. This is a somewhat delicate mechanical operation for one not specially experienced. The reamer must not be forced too hard and must be frequently drawn out partly from the hole so as to free the metal chips. The desired size is secured when the reamer has been entered snugly up to the small brass collar thereon. When the new points have been fitted, the reamer will be promptly returned by mail to the central office in a package marked "Instrument Division."

89. *Rainfall and sunshine.*—As a record of rainfall is blank for a great portion of the time, and, as it rains but little during sunshine, one and the same magnet and pen may, without serious confusion, be employed to record both rainfall and sunshine. An electrical sunshine recorder and tipping-bucket rain gage, which may be used in this manner, are fully described in circulars G and E, respectively. The magnet and pen which produce the record are seen at the back in fig. 18. The electric circuit for the sunshine recorder passes through a clock contact described in paragraph 94. During sunshine the circuit is closed for an instant once each minute, and the recording pen is thereby caused to make a succession of short lateral strokes, which arrange themselves in a zigzag fashion by the action of the mechanism. The circuit from the rain gage passes directly through the same magnet, and during rainfall the pen makes, similarly, a succession of lateral strokes, likewise arranged in a zigzag fashion. A very little attention on the part of observers to the proper marking of records with marginal notes in doubtful cases will prevent any confusion of rain and sunshine records. Confusion, in fact, is much less liable to occur than would seem probable at first sight. The strokes of sunshine record occur with perfect regularity at uniform intervals and in fixed relation to the 5-minute lines ruled on the sheet at *c*, fig. 19 (*a*). The record of rainfall, however, is irregular, as shown at *d*, fig. 19 (*a*), and easily distinguished.

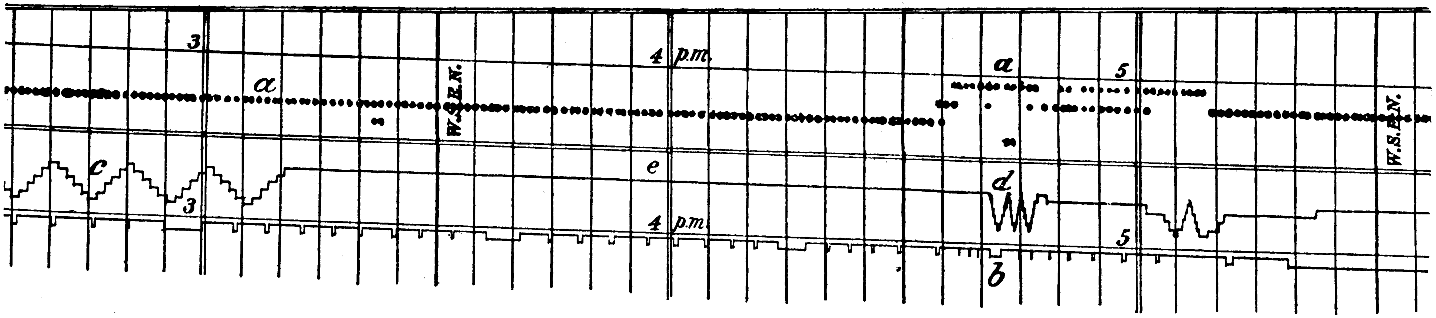


FIG. 19 (*a*).—Portion of actual record from meteorograph. For explanation see paragraph 90.

Minute Scale.

WIND VELOCITY SCALE.

(For determining velocities, as recorded on Form 1017.)

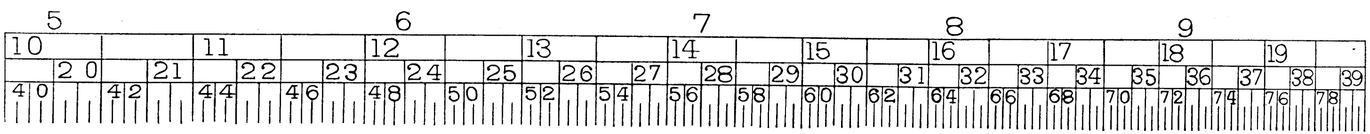


FIG. 19 (*b*)—Wind-velocity scale.

90. *Explanation of meteorograph record, fig. 19 (a).*—The record of wind direction appears at *a a*. The miles of wind movement are shown by the lateral dentations of velocity record as shown at *b*. Each 10 miles is marked by a relatively broad dentation. Duration of sunshine is shown by the regular zigzag trace as at *c;* rainfall, by the more irregular zigzag at *d*. The straight line, as at *e*, indicates cloudiness or the absence of either rainfall or sunshine.

91. *Mechanisms of the sunshine and rainfall magnet.*—Fig. 20 is an enlarged view of the magnet mechanisms employed in recording sun-

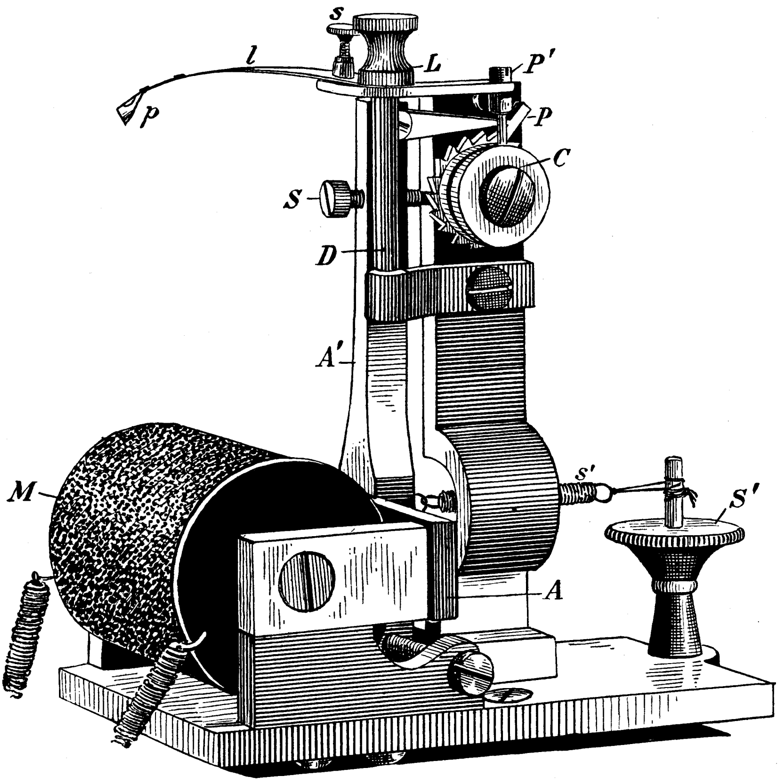


FIG. 20.—Magnet for recording sunshine and rainfall.

shine and rainfall. This magnet is placed on the meteorograph at the rear side of the recording cylinder, as shown in fig. 18, the pen, *p*, touching the record sheet on the same time line as the pen, *a*, and the wind-direction printing points.

92. The apparatus is operated on an open circuit, being actuated by closure of the clock contact, fig. 22, *for sunshine*, or by the contact of the tipping-bucket rain gauge, *for rainfall*. Any momentary closure of these circuits through the magnet *M* causes the attraction of the pivoted armature *A*, which carries at its top the pawl *P*, which

rotates the cam wheel *C*. The cam consists of a double right and left handed helical groove in *C*, which the pin *P′* of the pen lever *l*, fig. 21, engages. The cam *C* being turned one tooth with each successive to-and-fro movement of the armature, the pen, guided by the pin *P′*, traces on the moving record sheet a zigzag trace, as at *c*, fig. 19 (*a*), with five steps up and five steps back. The movement of the armature *A* can be adjusted slightly by the screw *S*, so that the pawl *P* properly engages the teeth of the cam *C*.

93. These mechanisms are adjusted with special care before shipment to stations, and observers must not, as has sometimes been done, attempt to file or alter the shape of parts, without authority from the central office. Any parts worn or becoming defective can generally be promptly replaced by mail, upon application.

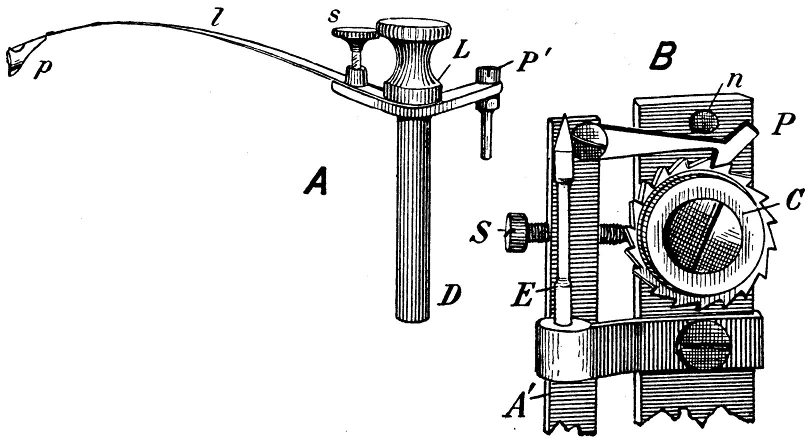


FIG. 21.—Zigzag mechanisms, sunshine and rainfall magnet.

94. *Clock contacts.*—Extended experience has shown that the most satisfactory results are obtained with contacts which close the electric circuits for wind direction and sunshine once each minute. The construction for closing two circuits is shown in fig. 22.

A small platinum-tipped hand *a* is fixed upon the secondhand staff of the clock, and its point rubs against the platinum-tipped contact springs *s s′*, closing the circuit first through one and then through the other. The hand itself is made a part of the electric circuit in the manner more fully shown in the diagram of electric circuits, described in paragraph 101.

V. WIRES, CABLES, AND ELECTRICAL CIRCUITS.

95. *Suggestions relative to running wires and cables for registers.*—When a number of electric circuits are required, it is always best to use a cable containing a sufficient number of conductors, each insulated from the other, and much time can be saved in connecting up

the several instruments operated over such a cable if the separate wires are each plainly marked or tagged at the ends, so that any particular wire may be utilized at any time. This is sometimes done by the use of different colored threads in the insulation, but such marking is often obscure and of little value. Nevertheless, at least one of the wires of almost every cable is marked by the manufacturer by some peculiarity of the insulation, such, for example, as double wrapping, or by use of one or more fine white threads loosely twined around the insulation. When practicable the wires of a cable not already marked should be identified before placing the cable in position. For this purpose the two ends of the cable are picked out of

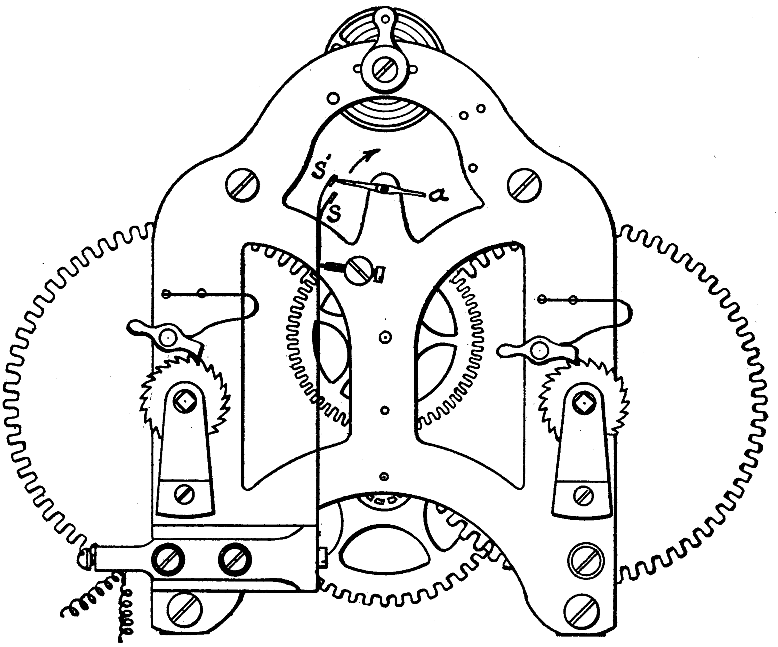


FIG. 22.—Minute contact for wind direction and sunshine circuits.

the coil and the outer wrapping laid back several inches, at the same time stripping the insulation from the ends of the wires themselves. All the wires at one end of the cable should then be numbered consecutively, either by a small but substantial tag, preferably metal, or, if the insulation is of rubber, or similar material, by cutting small V-shaped gashes in the insulation according to the number desired. A battery, or some other source of electricity, and an ordinary electric bell or buzzer, a galvanometer or telegraphic sounder, must then be brought into requisition. A telephone call bell answers admirably. A battery can even be used alone. One of the wires of the cable is joined to one pole, and the other end of the cable and a wire from the other pole of the battery brought up in a position convenient to be touched to the tongue, which is very sensitive to electric currents. The single wire from the battery is held against the tongue, while one after the other of those in the cable are touched in turn until the one is found through which the current flows. This is thereupon marked or numbered to correspond with the mark or number on the other end of the wire. The tests are proceeded with in this manner until all the wires are identified. It is also necessary to see that there are no crosses in the cable; i. e., no point in the cable where a circuit can be completed from one wire to another by the breaking down of the insulation. Moreover, none of the wires must be in electrical contact with the lead when a lead-covered cable is used.

In case the cable is already in position the services of an assistant will be needed to shift connections and to mark the wires identified. All the wires at one end, preferably the battery end of the cable, should be numbered consecutively, as explained above, and one pole of the testing battery joined permanently during the test to the wire of the cable already identified by the manufacturer. One after the other of the remaining wires of the cable being then joined in turn to the other pole of the battery, the assistant must make connection between the marked wire of the cable and the unknown wires in turn until he gets a flow of current in each case and all wires are identified and numbered. No difficulty from wrong connections will ever occur if this work is carefully and properly done. Failures in getting new instruments in operation are far more often due to insufficient care and attention in making all the connections correctly than to any other cause.

96. *Insulated wires and cables.*—Only the best quality insulated copper wires should be used to connect up meteorological instruments and apparatus. The cables regularly employed by the Weather Bureau are composed of copper wires of No. 16 or 18 A. W. G., in the form of 1, 2, 3, 6, and 9 conductor cables, as required for the different instruments. The 9-conductor cable serves to connect up the triple or quadruple register, and should be run by the most direct practical route, where it will be protected from the weather as much as possible, and where it will be undisturbed by the wind or other causes and not subject to abrasion.

97. In Government buildings special conduits are often provided for cable of this kind, as also for wires for electric light in instrument shelter, storm-warning lanterns, etc., as may be needed. Under no circumstances will electric-light wires be placed in the same conduits with the wires for the instrument circuits.

The cable must be supported at frequent intervals by suitable hooks or otherwise when necessary. Unsupported lengths greater than 10 feet are to be avoided.

98. In all cases the cable must be neatly run and secured in place, and untidy lengths or ends in battery or instrument stands or around the base of wind-vane support can not be permitted.

99. In general, the connections for anemometer, electrical sunshine recorder, and recording rain gage, are made by short lengths of single wires or 2-conductor cables connecting with the end of the 9-conductor cable in the vicinity of the contact box of the wind-vane support. All joints of a permanent nature should be *soldered*, the splice thoroughly cleaned of all acid, and then carefully wrapped and protected by insulating tape. Ends of cables exposed to the weather should be taped and given several coats of a waterproof compound to exclude moisture.

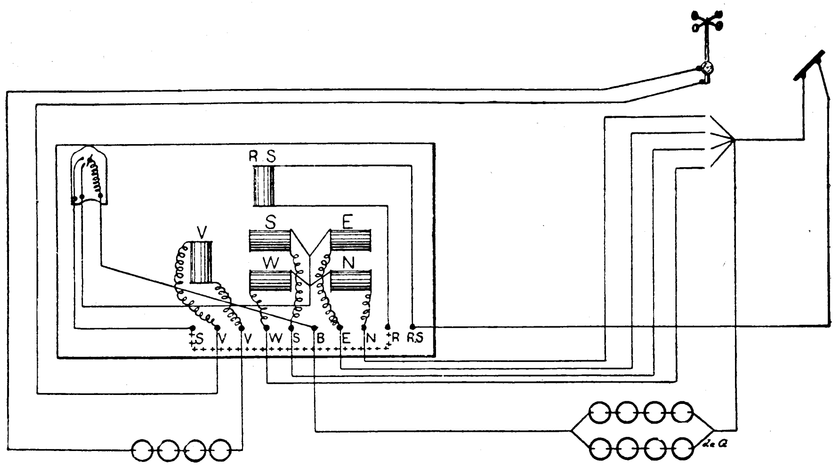


FIG. 23.—Diagram *A*, circuits of station meteorograph. Sunshine and wind on same battery.

100. *Inside wiring.*—No. 18 office wire is generally most suitable for inside connections with battery and registers, and all connections from wire to wire will be soldered and taped, thus insuring a permanent and durable job.

These inside conductors should be formed into neat handmade cables, such as are found in telephone switchboards, and every wire *carefully tagged.* It has also been found highly desirable to have a wiring diagram showing the course of the several conductors through the building; and the drawing should be made up in pen and ink and filed away for future reference.

101. *Explanation of circuits.*—Diagram *A*, fig. 23, shows the electrical circuits for the triple register, including sunshine circuit, and likewise represents, in principle, the manner in which circuits of corresponding parts of the single and double registers are made.

(*a*) *Wind direction.*—The circuit provided for registering wind direction is made up as follows: First, from one pole of the battery to binding post B on the triple register; next through the clock contact; from the clock to the four wind-direction magnets, one terminal of each of the magnets being joined to this clock connection; from the other terminals of the magnets by separate connections to the binding posts N, E, S, and W on the register; thence by four conductors to the four corresponding insulated binding posts in the contact box; through the wind-vane contacts, and finally by a single conductor or common return wire from "the contact box" to the other pole of the battery, thus completing the circuit. Either one or two of the contact points in the box are always closed, as explained in paragraph 38, and one or two circuits, therefore, completed through the corresponding magnets of the register at each closure of the circuit in the clock, thus producing the record described in paragraph 87. The small switch or key in the direction circuits is used only in testing the line, and simply enables one to close the circuit at any time without the delay of waiting for the closure of the clock.

(*b*) *Wind velocity.*—This circuit is very simple and direct. A wire leads from the battery to the magnet, thence to the anemometer, and returns directly to the battery.

Experience has shown that it is desirable to keep the anemometer insulated from its metal support in order to avoid short circuits, and in the new installations insulated anemometer pins will be furnished. This necessitates the running of copper-wire conductors to both posts of the anemometer, one from the meteorograph direct, the other a continuation of the battery connection to the R post on the wind-vane contacts (see fig. 25); or a connection to the anemometer battery is made when independent batteries are used, as shown in fig. 24. It is also expected to gradually replace the uninsulated pins used in the older equipment with those which are insulated. These pins will be furnished on requisition from the stock maintained at the central office.

(*c*) *Rain gage.*—In case the rain gage alone is used the circuit is made up in a manner similar to the one just described for the wind velocity, but is not shown in the diagram.

(*d*) *Rain and sunshine.*—In this case the same battery serves on both circuits and only three wires are required. Starting from the battery a wire connects directly to one end of the magnet coil at *R S*, fig. 24, diagram *B*. The other end of the coil divides into two circuits, one passing to a binding post *R*, thence direct to the insulated post on rain gage; the other circuit passes first through the clock contact, thence to the binding post *S S*, and finally to the sunshine recorder. This circuit and the one from the rain gage unite again after leaving their respective instruments, and pass thence direct to the battery by a common return.

In case the rain and sunshine are recorded by use of an independent battery, in the manner just explained, the binding posts *B R* are joined with a short piece of wire marked + + + + on the diagram *B*, fig. 24.

(*e*) *Sunshine on wind direction battery.*—This arrangement lessens the battery required and presents no complications, since the sunshine circuit and the wind-direction circuit are never closed at the same time. It can not, however, be used when rainfall is also recorded by this register. These circuits are shown in diagram *A*, fig. 23. The two posts *S R* on the register are joined by a short piece of wire. This is indicated by the line + + + +.

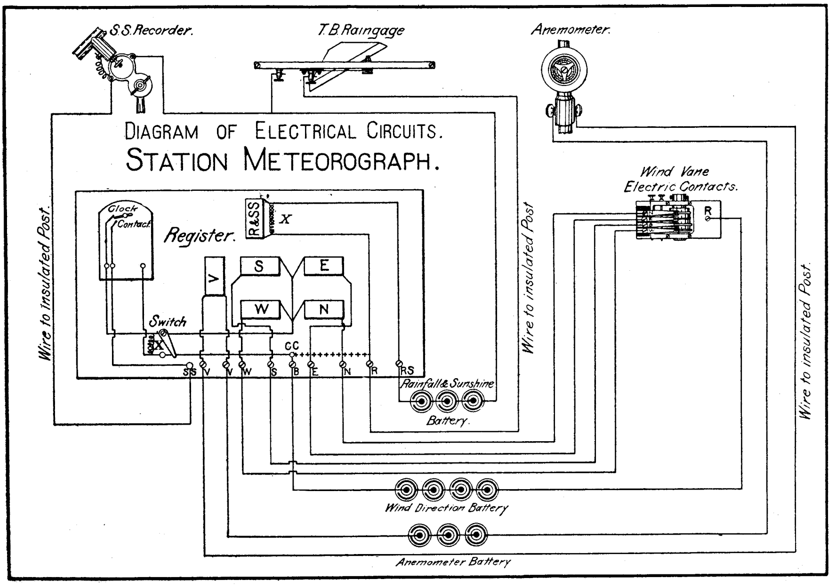


FIG. 24.—Diagram *B*, circuits of station meteorograph. Common battery for rainfall and sunshine; separate batteries for wind velocity and direction.

102. *Spark shunts.*—All Weather Bureau registers having minute-contact attachments for clocks are provided with specially wound shunt coils. These are inserted in sunshine and wind-direction circuits, at points corresponding to those marked *X X*, figs 24 and 25, for the purpose of diminishing sparking at the platinum contact points. These are made of insulated German silver wire, with a resistance of about 90 ohms and are usually placed on the underside of the base of the register. Their use largely prevents the contact points from becoming rough and corroded by the action of the spark, and, while they shunt off a small portion of the current that would otherwise flow through the magnet, they are essential to the nice working of the register and must not be disturbed by observers or electricians when seeking for defects that may exist in circuits.

In certain cases the spark coils have been wound on the magnets themselves and can not be seen. In these instruments they do not appear at the points X X.

103. *Lost motion and adjustment of record sheets.*—The record cylinders of the registers, described in the preceding pages, revolve once in six hours, so that the sheet makes just four revolutions in twenty-four hours.

104. It is of great importance that the record sheets of registers be adjusted so that their readings indicate correct time. Large errors are sometimes unnecessarily made in consequence of unavoidable looseness in the clockwork. The lost motion should always be taken up when the cylinder is set. This is accomplished by drawing the

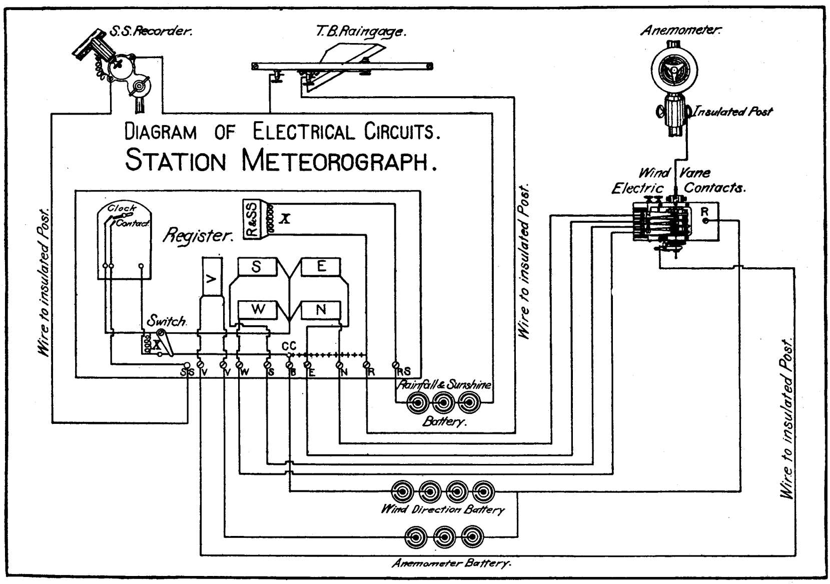


FIG. 25.—Diagram C, circuits of station meteorograph.

finger tip lightly across the edge of the cylinder *in a direction opposite that in which the cylinder revolves.* The friction brings the cylinder very nearly to the normal condition in respect to time that it will have when running undisturbed. When so adjusted the recording pen should indicate exactly the correct time.

105. In all instruments of recent design the recording cylinders are mounted adjustably on their axis, so that without loosening screws or clamps the cylinder can be turned upon its axis under gentle friction and easily and accurately set at any moment desired, in much the same manner as the hands of a clock are set.

106. A steady and constant current is required for operating automatic meteorological instruments, and the batteries which give the best results are, in general, those of the so-called closed-circuit type,

such as the Waterbury or preferably some type of storage battery, described in detail below.

107. For a single circuit, such as that of an anemometer, for example, two or three cells of battery are sufficient, unless the line is very long. The cells should be arranged *in series;* that is, the copper of one cell joins to the zinc of the next, etc.

108. In the case of wind direction it will be seen that when two contact springs are closed the current from the battery divides in passing through the two coils, so that each coil gets only half as much current as if only one contact spring was closed. Strictly speaking, the divided current is a little greater than half the current for a single circuit, because the line resistance is less with two coils in parallel than with one, and the current from the battery will be slightly stronger. The advantage on this account is most pronounced when the batteries have a low internal resistance, as is the case with the Waterbury and storage cells.

VI. Batteries.

The following statements of a few general principles concerning batteries may be helpful to some observers who are not already familiar with them:

109. The electric current required for running the ordinary meteorological instruments is generally derived from some of the many forms of *primary* batteries, that is, batteries in which the current is developed directly as the result of certain chemical changes. When the chemicals have been completely changed the battery is exhausted and no longer useful. Storage batteries or accumulators, on the contrary, differ from the so-called *primary* batteries in this interesting respect, namely, that the chemical changes are of such a nature that a cell, seemingly exhausted, can be restored to full activity again by passing a certain current of electricity through it for a proper length of time. This restoration or charging of a cell can be repeated a great many times, although ultimately the cell becomes inert.

110. Accumulators are being employed more and more generally for operating automatic instruments, and where practicable it is desired to use them, since they provide a sufficiently strong, steady current, and in general require less care than do primary cells.

111. *Open and closed circuit batteries.*—Some forms of batteries such as those made up of "dry" cells, so called, give off a satisfactory electric current only for a few minutes just after the circuit is closed. If the circuit continues closed, the strength of the current, unless originally very feeble, falls off and in a short time becomes very weak. In some cases the battery will partly recuperate if rested and the circuit opened, but in general this type of cell is more or less permanently impaired when the circuit remains closed for more than a

moment or two at a time. A battery of this character is often called an open-circuit battery, but obviously it is not well suited for use with meteorological instruments in which the circuit, though generally open, is sometimes likely to be closed for considerable periods of time.

There are, on the other hand, what are often called closed-circuit batteries, which give out a current of practically constant or even increasing force over prolonged periods, and until the chemicals of the cell are practically consumed. A cell of this type answers best for operating meteorological instruments, especially if it combines another desirable quality, namely, that it does not deteriorate and waste the chemicals when the circuit is open.

112. *Qualities of high-grade batteries.*—A high-grade battery should respond to the following requirements, viz:

(1) It should deliver a steady and constant current, even if the current is strong and the circuit continues closed. Some batteries can deliver a nearly constant *feeble* current, but fail if called upon to deliver a *strong* current.

(2) It should not be seriously influenced by ordinary extremes of temperature.

(3) There should be no local action, that is, there should be no appreciable consumption of the chemicals when the circuit is open. If the battery is set up and the circuit is kept open, the cells should maintain their original strength indefinitely.

(4) Each cell should be capable of yielding a strong current if required, that is, the voltage should be high and the internal resistance should be low.

(5) It should be generally inexpensive, free from offensive and noxious chemicals, fumes, etc., and be convenient to set up and maintain.

113. *Strength of current.*—The strength of current that can be drawn from a given cell depends upon the electromotive force and the resistance. The former is determined, in general, by the particular metals and chemicals employed in the construction of the cell; the latter is subject to great variation, depending upon the size of the metallic surfaces, the conductivity of the liquids or other substances in the cell, and the length, size, and material of the outside circuit. The electromotive force of the ordinary primary cells ranges from about one-half volt to less than two volts.

114. A given high grade cell yields the strongest current of which it is capable, when the terminals are connected by short heavy wires. In this case the total resistance in the circuit is the least possible, and consists principally of the internal resistance of the cell itself; a short, heavy copper wire has very little or no resistance.

The strength of the current from such a cell becomes less and less, the longer and finer the wire joining the poles is made.

115. A large cell, that is one having large sheets of metal or several of them, etc., will generally give, under the same circumstances, a stronger current than a small cell of the same type. When the like metals of two or more cells are coupled together the effect is obviously very much the same as if the contents of the several cells were all merged into one larger cell. In this case the *electromotive force* remains the same as for a single cell, but the surfaces exposed to the action of the liquid are doubled or multiplied, so that the internal resistance of the battery is lessened, and this always tends to increase the current.

116. When the unlike metals of two or more cells are joined in series, that is, copper to zinc—copper to zinc, etc., the *electromotive force* is doubled, tripled, or multiplied, but so also is the internal resistance of the whole battery. This will noticeably increase the current in the external circuit, provided the line resistance is large as compared with that of the individual cells. If the line resistance is small as compared with the cell resistance, joining the cells in series will only slightly increase the strength of the current. In this case, to increase the current the cells should be joined parallel, that is, zinc to zinc and copper to copper.

117. The strength of current I, that may be obtained in any given case, is shown by the following simple formula:

$$I=\frac{E}{R+B}$$

in which E=electromotive force, R=resistance of the line, and B=internal resistance of the battery. Suppose, for example, a given cell has an electromotive force of 1 volt, and the internal resistance is 0.1 ohm. The current such a cell will produce through a line having 5 ohms resistance is given by the following equation:

$$I=\frac{1}{5+0.1}=\frac{1}{5.1}=0.196 \text{ amperes.}$$

Five such cells joined in series will give a current of

$$I=\frac{5}{5+0.5}=\frac{5}{5.5}=0.909 \text{ amperes.}$$

118. *Life of a cell.*—It is obvious that a certain cell containing a given weight of chemicals can produce electricity only while the supply of chemicals is kept up. When these are exhausted the cell is inert. A strong current necessarily requires a more rapid consumption of chemicals than a weak current, hence the life of the cell will depend upon both the supply of chemicals present and the strength of current drawn from it. It is sometimes stated, for example, that a cell has a life of three hundred ampere hours. This means simply that the cell will give a current of one ampere for three hundred hours, or one-half an ampere for six hundred hours, etc.

119. After extended experience the Weather Bureau has found the type of primary battery made up of copper oxide and zinc in a strong solution of caustic soda, to answer all requirements for meteorological work in a satisfactory manner. The cell needs little attention and gives a constant and uniform current during its life, and is unaffected by considerable variations of temperature. In some cases these cells on a triple register recording wind direction, wind velocity, sunshine, and rainfall have lasted from twelve to eighteen months. The cell is put on the market under a variety of names, such as the Gordon Primary, the Waterbury, the Edison, the National Carbon Co., etc.

The electromotive force of each of these cells is about 0.67 volt, and the internal resistance is from 0.04 to 0.06 ohm.

One of these cells is shown in fig. 27, and a set of recharging supplies in fig. 26.

120. *Description of cell used.*—The compressed copper-element battery is shown in figs. 26 and 27. The compressed cylindrical copper element, with projecting stem and winged nuts, is seen in fig. 26 (b). The zinc element is suspended from the lid by means of two projecting lugs, as shown in fig. 27 (b). At fig. 27 (c) is a cell assembled complete, with the copper element in place in center. It will be noted that there are *two* projecting binding posts for the zinc element. These are necessary to give proper support for the zinc, and, of course, *either* may be used for making the necessary wire connection to the next cell or line of circuit.

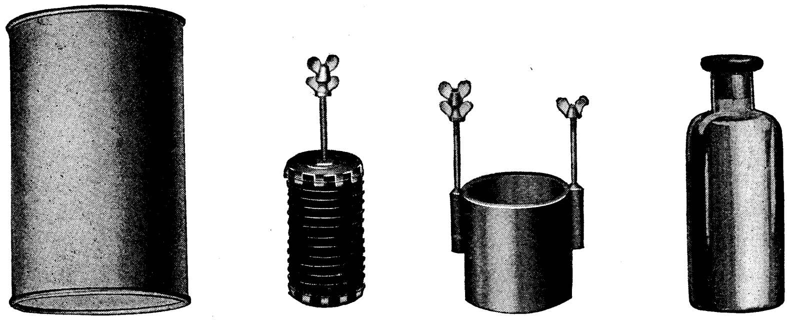
Recharges: The copper element is made in this compressed form from the loose, copper oxide flakes, so as to avoid the necessity for perforated basket and other parts, such as have been used heretofore, and facilitate the recharging of the cells. It must be borne in mind that although this compressed element may still retain its form and appearance when the zinc is completely consumed, the value of the compressed copper element as a positive pole is also gone and the cell is said to be completely exhausted. *New* compressed elements must therefore always be used in recharging old cells, and they should be carefully washed in clean water to remove any fine particles of copper that might otherwise float to the top of the solution and tend to produce a "short circuit" with the zinc element, thereby lessening the life of the cell.

121. *Instructions for setting up Waterbury cells.*—Very great heat is developed in preparing the liquid element, and to lessen the danger of cracking the glass jar the latter should be placed on wooden strips or some good nonconducting support. New cells are shipped with a piece of corrugated packing paper, which serves admirably as a protection, on which to stand the glass jar.

122. Fill the jar to within *2 inches* of the top with clean, cold water. Rain water is best and water strongly charged with mineral

substances should be avoided. Add the caustic soda to the water *slowly*, so as to avoid excessive heating, stirring it all the time by means of a suitable wooden stick. Do not permit the undissolved chemical to lie in the center of the jar, and do not stop stirring until all the caustic soda is dissolved.

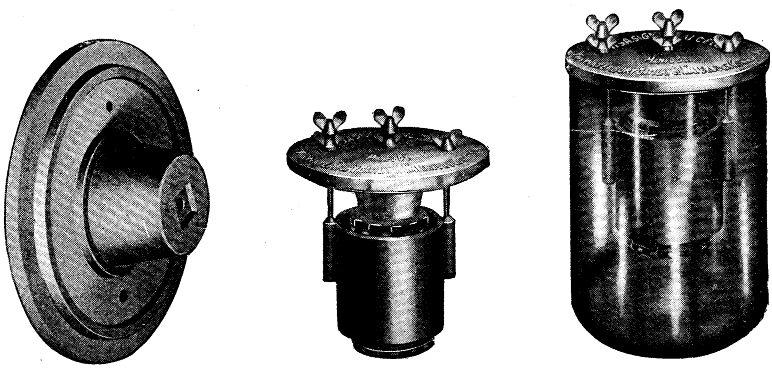
BATTERIES.



(*a*) (*b*) (*c*) (*d*)

FIG. 26.—Recharges (set), as used with the Schoenmehl compressed-copper element battery.

(*a*. Sodium element for making solution, furnished in air-tight metal can; *b*. Compressed copper (+) element, as mounted for use; *c*. Zinc (−) element, ditto; *d*. Bottle mineral oil.) Note: The winged thumb nuts shown in *b* and *c* are parts of the permanent fixtures of the cell, and are *not* supplied with the sets of recharges unless specified.



(*a*) (*b*) (*c*)

FIG. 27.—Compressed-copper element battery.

(*a*. Solid porcelain top, underside view; *b*. Same, with copper and zinc elements mounted *c*. Battery complete with glass jar.)

123. *Avoid* inhaling the fine particles of dust that are likely to rise in the air in sifting out the caustic soda slowly from its box.

Avoid splashing the solution on the hands, or out of the jar in any way.

124. When the caustic soda is fully dissolved, and when the solution is entirely cool, slowly lower the metallic elements into the jar.

Finally pour the oil over the liquid by inserting the neck of the bottle under the cover of the jar so as to bring the solution and oil to a height of about one-half inch from the top of the jar. It is necessary to have the solution well up around the central porcelain insulator for the copper element to prevent possible short-circuiting.

125. *Caution.—The layer of special oil furnished for the purpose is absolutely essential for retaining the volatile elements of the cell and for preventing action of the air on the solution, and this oil must be put on just as soon as the solution is cool.*

126. It is suggested each cell be tagged showing the date it was set up.

127. When in use, the batteries should be periodically inspected and their condition noted. All connecting screws, clamps, etc., should be tested to make sure that they remain tight, and the metallic circuits complete throughout. The condition, and the probable life of the cell, may be ascertained by inspecting the zinc plate. When this has been eaten away to a considerable extent, the cell can not last much longer and will need to be replaced.

128. As may be seen from the foregoing, the only *permanent* parts of these cells are: The glass cell, the porcelain cover, and the brass thumbscrews for binding posts. Requisitions for recharges, or for new cells complete, should be made accordingly.

129. The electrically recording instruments of the Weather Bureau on circuits of the ordinary length may be operated satisfactorily by Waterbury cells connected *in series*, as follows:

Instrument.	For recording.	No. cells required.
Single register	Wind velocity	2 cells.
Two-magnet register	Wind velocity	2 cells.
	Sunshine	2 cells.
Two-magnet register	Wind velocity	2 cells.
	Sunshine and rainfall on same battery	3 cells.
Quadruple register	Wind velocity	2 cells.
	Wind direction	4 cells.
	Sunshine and rainfall on same battery	3 cells.

130. *Storage batteries.*—Storage batteries are usually issued to stations for the operation of automatic instruments only when the offices are lighted on a low voltage (100 to 120) direct-current system of electric circuits, connection with such a circuit being necessary for charging the batteries. In a few cases, however, rectifiers to convert alternating to direct current are being used.

131. *Operation.*—Storage cells depend for their action upon the peculiar properties of particular chemicals, by virtue of which the constituents undergo a certain transformation and decomposition when subjected to the action of a suitable electric current. The cell is said to be "charged" by this action. Whereupon, the charging current being cut off and the terminals of the cell joined through an electric circuit, the chemical substances in their altered condition will react upon each other and themselves generate an electric current.

During the generation of this current the chemicals revert to their original composition and the cell is said to "discharge," and may thereupon be again "charged." The transformations which take place in a cell are purely electrochemical in character, and there is no real *storage* of electricity in the strict sense of such a term.

132. *Composition.*—A number of chemical substances are capable of forming a storage cell, but thus far couples consisting of peroxide of lead and sponge lead immersed in an electrolyte of dilute sulphuric acid have been used. Neither the peroxide of lead nor the sponge lead possesses in itself the requisite strength, rigidity, and electrical conductivity to be formed directly into the terminals of an electric element, but means have been devised whereby these active materials can be pressed into recesses, or otherwise secured to suitably formed lead plates called "grids," which serve the double purpose of properly supporting the chemicals in the electrolyte and of conducting the electric current to or from the active material. The substance of the grid is itself chemically inert. This type of cell is called the "lead cell."

133. *Chemical actions.*—The peroxide of lead is the positive pole and presents a rich chocolate-brown appearance. The sponge lead, which is an allotropic form of ordinary metallic lead, forms the negative pole, and is a grayish white in color.

The chemical transformations in a storage cell are not, perhaps, perfectly understood. Without attempting to give all the details, we may state simply that when the battery is discharging it is generally accepted that sulphate of lead is formed at both poles of the battery; that is, the peroxide and the sponge lead are both converted into sulphate of lead. Conversely, when being charged, the sulphate of lead at the positive pole is converted back into peroxide of lead, while the lead sulphate at the negative pole is transformed back to sponge lead.

134. *Caution against overdischarging.*—Complete discharge of the cell would imply complete change of the active materials to lead sulphate at both poles and consequent electrical neutrality. It is important, however, to prevent excessive discharge of a cell, as it is thereby seriously impaired or rendered worthless, since lead sulphate in a pure form or in excess on the plates can not be easily changed by the charging current back to either the peroxide or the sponge lead; hence, overdischarging of storage cells must be carefully guarded against. The normal discharge involves the chemical transformation of only a small percentage of the active material present. For a lead cell, 1.8 volts is considered the lower limit to which the voltage may be allowed to fall during discharge.

135. *Weather Bureau storage batteries.*—The batteries issued to Weather Bureau stations consist of six cells, which must be set up

in two batteries of three cells each. The switchboard sent with the batteries provides a convenient means by which to connect them with the instrument circuit and the lighting circuit, and is so arranged that one battery operates the instruments while the other is being charged, and *vice versa,* as more fully explained below. *One battery alone of this character suffices in all cases to operate all the recording instruments at a station,* excepting the tele-thermoscope and tele-thermograph. It has been found that three cells give a stronger current than desirable when the triple register only is used, and at stations which record only wind, sunshine, and rainfall *two* cells of the storage batteries are ample.

136. *Location.*—(*a*) The batteries may be located in a compartment of the instrument stand, but it is greatly preferred they be installed elsewhere, as on a shelf in a storeroom, closet, or other less confined place, where the fumes and acid are less likely to prove of serious consequence. A small closet specially designed for the purpose, and provided with means for ventilation makes the most satisfactory installation. The cells should be placed in one or more of the standard battery trays, such as are generally used in storage-battery work, and care should be taken to provide insulation for the cells, and protection of the brass and copper in the closet from corrosion due to the acid fumes and spray. If these metals are carefully painted with hot paraffin after the installation is completed, this trouble may be mostly avoided. In this connection, considerable trouble has been experienced in the past in having the copper wires at the battery terminals almost or entirely eaten away by the acid. Besides covering the parts with paraffin, it is best to lengthen the terminals by means of strips of lead $\frac{3}{4}$ by $\frac{1}{8}$ inch, and about a foot long, one end being bolted to the lug on the cell and the outer end provided with one of the special lead bolts for connection to the copper wires. This places the copper wires practically out of reach of the acid spray.

(*b*) The switchboard should be located with a view to convenience of access for shifting switches, facility of installation, wiring, etc., as hereafter fully explained.

137. *Switchboard.*—The switchboard completely wired is shown in fig. 28. The insulated leads, marked 1 and 2, are each 2-conductor cables, which at the distant ends are joined, respectively, to the two terminals of the two batteries, which should be plainly tagged or numbered 1 and 2. At the switchboard the two cables connect, respectively, with the *hinge joints* of two double-pole, double-throw switches. These are likewise plainly marked 1 and 2, but in such a manner that the number shows only for the particular battery being charged. Thus, the picture shows the position of the switches when the No. 1 battery is being charged.

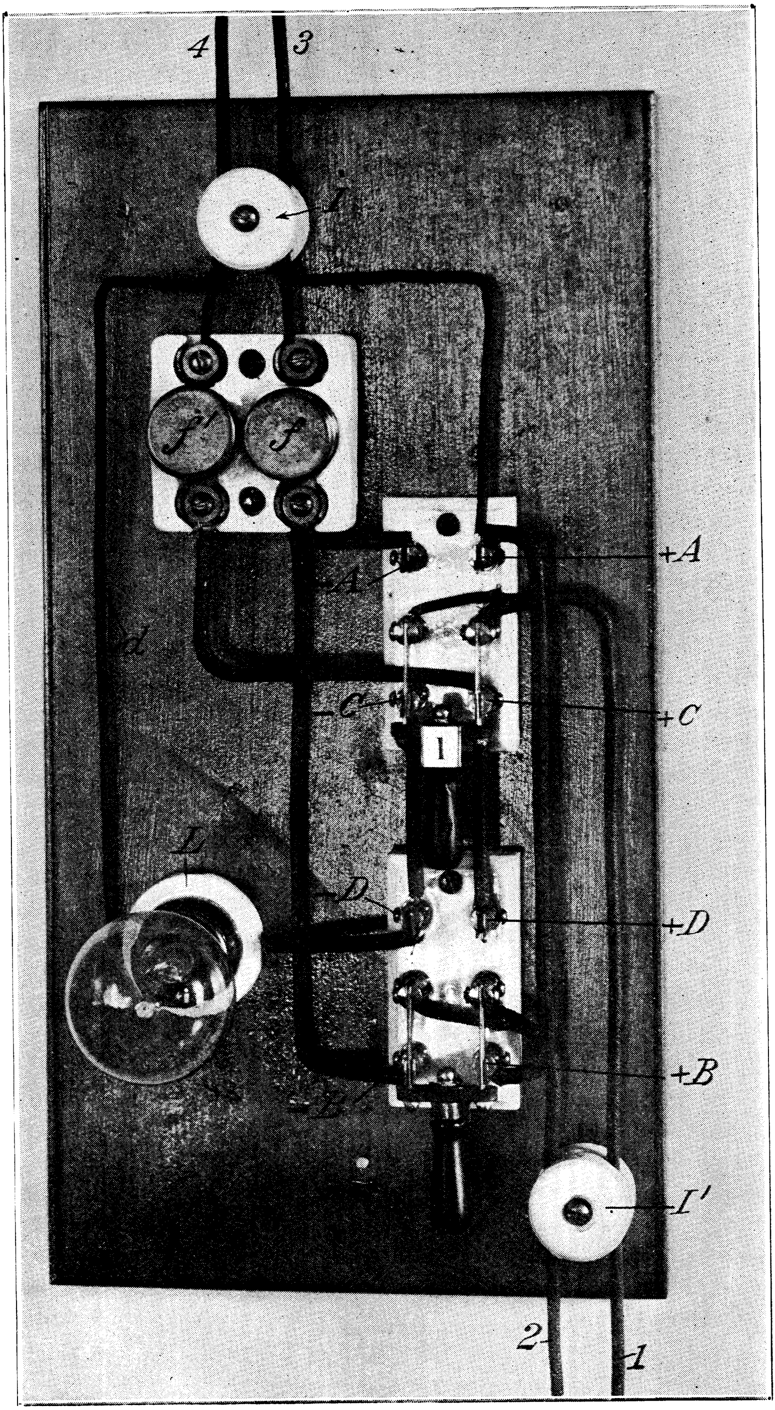


Fig. 28.—Storage battery switchboard

The line shown at 3, fig. 28, is likewise a 2-conductor cable and forms the main battery wires to all instruments. After passing the split insulator *I* the wires of this cable are separated; one passes directly to the upper right-hand pole + *A* of the No. 1 knife switch. This pole is also permanently connected by a short wire with the lowermost right-hand pole + *B* of switch No. 2. The remaining wire of the No. 3 cable is led through the 3-ampere fuse plug *f*, whence it branches in the manner clearly seen so as to connect to the upper and lower left-hand poles −*A* and −*B* of the two switches.

138. The charging current is brought in on the 2-conductor cable, No. 4, which is cut in on the regular lighting circuit at the nearest point practicable. This cable is likewise held in the insulator *I* and is separated just beyond, one wire connecting through the 3-ampere fuse plug *f′*; thence to the lower pole +*C* of switch No. 1. This pole, in turn, is permanently joined by a short wire to pole +*D* of switch No. 2. Finally, the remaining wire of cable No. 4 passes directly to one terminal of a plain, *keyless* socket and lamp *L*; thence from the other terminal direct to the switch poles −*C* and −*D*, which are permanently joined together by a short wire.

139. These switchboards are sent out complete, excepting for the lamp, which will be obtained locally. A 25-watt lamp will usually provide a sufficient charging current. All that needs to be done is to place the switchboard and connect it to the proper wires of the several circuits.

140. Special care must be taken in connecting the leads Nos. 1, 2, and 4 to have the positive and negative poles of the charging current connected with the positive and negative poles of the batteries, each to each, as indicated by the + and − designations of the switch terminals. If a change of polarity does occur, in all probability the batteries will be ruined.

Where there is any doubt about the matter, inquiry should be made of the proper parties as to whether or not the polarity of the office lighting circuit is ever changed for any cause.

141. It results from the arrangement thus described that +*A* and −*A* and +*B* and −*B* are two pairs of terminals in the 2-conductor cable carrying current to the instruments; also, that +*C* and −*C* and +*D* and −*D* are similarly two pairs of terminals of the office lighting circuit with the high resistance of the incandescent lamp *L* connected in series in it. Hence, in the position shown, current from the lighting circuit passes through switch No. 1 to No. 1 battery. At the same time battery No. 2 discharges through poles +*B* and −*B* to operate the instruments.

142. To shift batteries in any case the numbered knife (No. 1 in the present case) must be thrown first and closed in its opposite poles (+*A* and −*A* in this instance). Both batteries are now connected in

parallel on the instrument circuit and neither of the numbers shows on the switches. The No. 2 knife is next thrown and closed in the poles $+D$ and $-D$, completing the shift.

In shifting batteries the knife showing the number must always be thrown *first.* If this is done the instrument circuit is never opened and possible faults in the records on this account are avoided.

143. *Batteries shifted daily.*—When in regular operation the batteries should be shifted by throwing the switches, in the manner explained above, at or about the same hour daily. For example, the switches should be thrown each day at about the hour sheets are changed on the triple register.

144. *Interference with switchboard.*—If the switchboard occupies a conspicuous location where the burning of the lamp L at unusual hours is likely to attract the attention of janitors, watchmen, etc., precautions must be taken against the lamp being unscrewed, or the switches on the board otherwise tampered with. With this object in view it may even be of advantage to locate the lamp in the battery closet or elsewhere, inaccessible to interference. In such cases the wire—d will be joined direct to the pole—D and the lamp *must be cut in "in series"* on cable No. 4; that is, where the lamp is joined in *one wire of the cable must be cut in two and the two ends connected to the lamp terminals, respectively.* The lamp must not be attached to the No. 4 cable in the ordinary way, which will short-circuit the lighting circuit through the battery.

145. The switchboard and batteries must be fully installed and wired up, except connecting the No. 3 cable to the instrument circuit, before filling the batteries with the electrolyte.

146. *Electrolyte procured at stations.*—Full details for setting up and filling the cells are given on the leaflet sent by the manufacturer with the batteries. It has not been advisable to ship to stations the small quantity of electrolyte required, and this must be procured by observers, but its purity is a matter of the first importance. The cost of the electrolyte should be included with other slight expenses incident to the installation. It should be procured from the local office or agent of the "Electric Storage Battery Company," if there be one, or from a responsible dealer in battery supplies. The six cells will require 27 pounds of electrolyte, which must satisfy the specifications given in the manufacturers' leaflet.

147. The dilute acid should be supplied of standard density ready for use in a jug or demijohn, and after the cells are filled the jug should be refilled with distilled water *free from iron.* A supply of this must be kept on station and used for filling up losses by evaporation.

148. *Initial charge.*—The cells sent to stations are known to the trade as "Type PT" of the Electric Storage Battery Company. The

normal capacity of the cell is 24 ampere hours, and the strength of the current under normal rates of charge and discharge is 3 amperes. This capacity and rate of discharge are vastly in excess of the demands made by the instruments and a much slower rate of charge and discharge is adopted in the Weather Bureau usage.

Both batteries should not be filled with electrolyte the same day. It is best to set up and charge one battery, then the other one on the following day. On the initial charge the current may be stronger, and for this purpose the lamp *L* should be of, say, 100 watts, which

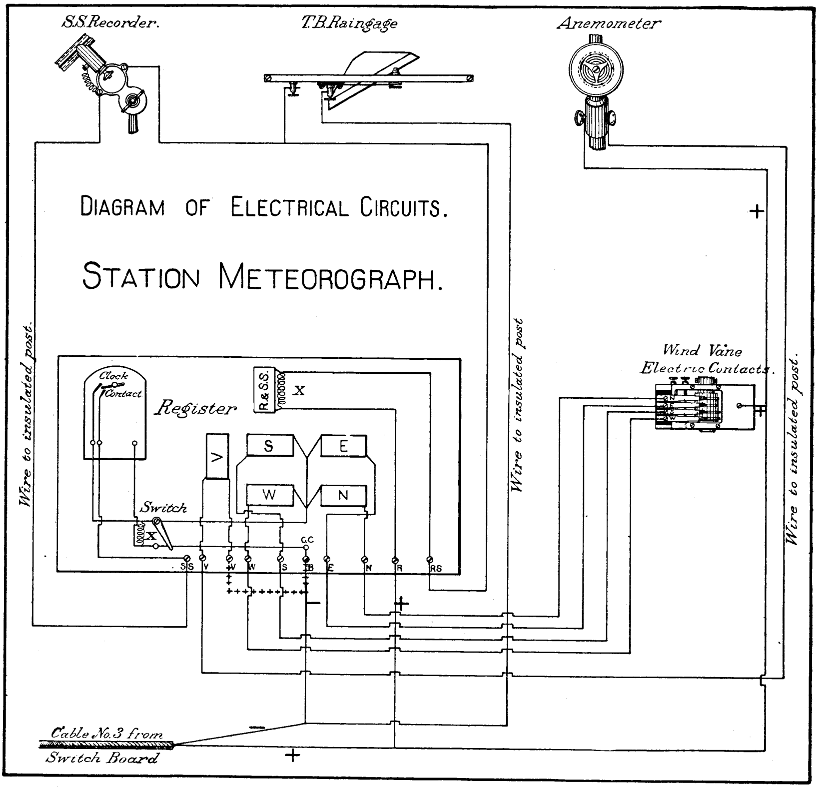


FIG. 29.—Diagram of circuits—storage battery equipment.

gives a charging current of nearly 1 ampere. This charge should be continued for at least 24 hours, or possibly longer if the lighting current is much interrupted.

One set of the storage cells having been charged ready for use, the necessary connections of the No. 3 cable can be made to the instrument circuits in accordance with the diagram of circuits, fig. 29.

149. *Charging while in regular use.*—Under ordinary working conditions nothing larger than a 50-watt lamp should be used at *L*, and at those stations where the lighting service is practically continuous,

day and night, a small 25-watt lamp should be used at *L*. This latter lamp gives a charging current of nearly one-quarter ampere.

There is, in practically all cases of usage in Weather Bureau work, a tendency to overcharge the cells, but the charging current is relatively very feeble and its effects are not objectionable. The type of battery used is one of great power and capacity compared with the instrumental demands.

150. While the daily shifting of batteries as explained in paragraph 143 is the rule, yet the capacity of a battery is ample in emergencies to operate the instruments for several days without charging.

151. *Fuses.*—The fuse block on the switchboard is considered ample for the voltage and class of circuits to which it is applied; nevertheless only one side of each circuit of No. 3 and 4 is fused. If there is any question as to the sufficiency of such a fuse in the case of the charging current, this line may be separately fused at the point where the No. 4 cable cuts in on the main lighting circuit.

The fuse block is fitted with 3-ampere plug fuses. In case these are blown, new plugs should be procured at the local electric supply stores.

152. *Testing lead storage batteries.*—The electrochemical transformations which take place in the cells of these storage batteries during the process of charging and discharging cause a corresponding change in the density of the electrolyte, so that a reading of the hydrometer is, in a certain sense, an index of the condition of a cell. Under the action of the charging current sulphuric acid is liberated in the solution, causing an increase in the density of the electrolyte, which reaches its maximum point when the cell is completely charged, and under normal conditions the hydrometer should then read about 1.300. From this as a starting point, as the cell is put into service and continues to deliver current the sulphuric acid previously liberated is withdrawn from the electrolyte, the density of which thereupon diminishes and finally reaches a minimum point when the cell is completely discharged. As pointed out in paragraph 134, overdischarging a cell is not advisable, and, under ordinary conditions, the density of the solution ought not to fall below 1.170 or 1.180, on the hydrometer scale, at which time the voltage of the battery is about 1.8 volts per cell. The voltage readings of a battery should also be freely used for determining its condition both during charge and discharge. A cell is fully charged when the voltage has reached a maximum and has been gassing freely for at least five hours. The specific gravity should then be at a maximum also. Moreover, the temperature of the electrolyte should not be allowed to exceed 100° F. but slightly. With the rate of charge used in Weather Bureau work but little difficulty will probably be experienced in maintaining the battery in proper condition. By giving careful regard

to these considerations, and by reading the hydrometer and the voltage, a very good watch can be kept on the condition of the cells, as regards their state of charge or discharge. Further details covering the care of the type of storage battery in use will be obtained from the pamphlet of instructions provided by the manufacturer. Electrical handbooks may also be referred to.

153. *Unequal densities of cells and possible short circuits.*—Special care must be observed to avoid possible contact between the two plates in the same cell, either by the twisting of the plates themselves or the possible bridging across between the plates at a narrow place by means of the sediment that sometimes accumulates in the cell. A short circuit of this character will cause the cell in question to be more or less completely discharged, even though the remainder of the battery is in good condition. This will be indicated by a falling off in the density of the electrolyte of this particular cell. Cases of this character should be immediately corrected, either by separating the plates or dislodging the sediment by means of a glass or vulcanite rod. *Metal rods for removing defects of this kind, or stirring the liquid, must, under no circumstances, be introduced into these cells.* The sediment which gradually accumulates in the bottom of the jars should be removed before it reaches the bottom of the plates; otherwise much harm will result. When such removal of sediment becomes necessary, which occurs usually about every year with lead cells, the electrolyte will be siphoned off into a glass vessel, the plates carefully removed, and the sediment cleaned out. Then the cells will be restored to their original condition.

154. After the internal defects of a cell have been removed it should be thoroughly charged again, even at the expense of overcharging the other cells of the battery, and, for this purpose, the charging current should be made stronger, or kept on the battery for two or three days. The other battery, if in good condition, is abundantly able to run the instruments during the interval.

155. In case a deficient density is not brought up to a standard by this process, or, in case the cell shows an excess of density, it is advisable to restore the density to a normal condition. In the case of an excess of density, some of the electrolyte should be withdrawn and replaced by distilled water. If the density is deficient, it should be made up by the addition of concentrated sulphuric acid, chemically pure. The acid should be added carefully so as not to flow directly against the plates, and the electrolyte should be stirred in the meantime by means of a glass or hard-rubber rod.

156. *The removal of water lost through evaporation.*—Since the surface of the electrolyte in the cells is usually open to the atmosphere, evaporation consequently takes place. It is necessary, therefore, to replenish the water thus lost by adding from time to time sufficient

distilled or pure filtered rain water to keep the level of the electrolyte at least one-quarter of an inch above the top of the plates. When using the lead cell it is particularly necessary that the water be free from iron.

157. *Instructions for using voltmeters.*—Voltmeters are sometimes furnished for use at stations in testing electric batteries in order to maintain them in good serviceable condition. Such instruments are necessarily of delicate construction, and it is essential that they be handled with corresponding care.

158. When tests are made the voltmeter may best be placed on some convenient surface nearby and connected to the cell or battery by short lengths of wire. The zinc, or negative, side of the battery or cell must be connected to the binding post of the voltmeter marked N, and the copper, or positive, pole to the post marked P. The scale reading of the needle, when it has come to rest, shows approximately the voltage of the electromotive force in circuit.

159. The voltmeter should never be connected to an electric-light circuit, or to a battery of many cells, the voltage of which is likely to exceed the capacity of the instrument; that is, *10 volts.* Batteries of numerous cells must be tested by going over a few cells at a time.

160. Observers should not break the inner seals or attempt to repair an instrument that becomes defective by excessive current or otherwise, but should report the matter to the central office for action.

U. S. Department of Agriculture,
Weather Bureau,
Washington, D. C., April 15, 1914.

The following summary of special instructions is segregated from the descriptive matter preceding, for the greater convenience of observers seeking guidance in the care of the instruments described. This pamphlet of instructions will replace and take precedence of the previous editions of Circular D, and observers will fully inform themselves concerning all points of instructions contained therein.

Charles F. Marvin,
Chief of Weather Bureau.

VII. Summary of Special Instructions.

ANEMOMETER.

161. *Exposure.*—The exposure of anemometers will be selected with a view to satisfying, as far as possible, the general principles discussed in paragraph 28.

162. *Anemometers oiled.*—An anemometer will never be exposed without first thoroughly oiling the top bearing and filling the cup-like bearing at the bottom of the spindle. The remaining parts will be oiled if necessary.

163. Before a new anemometer is exposed the observer will assure himself, by the test described in paragraphs 15, 16, and 17, that the instrument is in good condition.

164. *Anemometers oiled once a week.*—When in use anemometers will be given the necessary attention and oiled *once a week*, at the time the official dial reading is made. Only the clock oil furnished from the central office will be used, and the observer will be guided therein by the provisions of paragraphs 19 and 20.

165. *Anemometers exchanged.*—As far as practicable each station recording wind velocity will be supplied with two anemometers. Observers will always keep both of them carefully lubricated and in good condition.

166. *Anemometers cleaned.*—It is desired that the extra anemometer be not used except when necessary; but it will be exchanged with the station instrument once each month, or as often as may be required, for a period not to exceed 24 hours, during which time the station instrument must be cleaned and put in thoroughly good order, according to the provisions of paragraphs 25 and 26. The dial readings of both anemometers, with their official numbers, together with marginal notes stating the circumstances, will be entered in the appropriate space on the anemometer sheet, Form 1015 or 1017. When instruments are exchanged the anemometer newly exposed will not be set to read the same as the one removed.

167. Thorough cleaning as frequently as once a month is not necessary, if the anemometer is properly oiled each week, but this statement will not, in any case, serve as an excuse in the event of injury to an anemometer from neglect, either of weekly oiling or monthly cleaning, and observers are informed that the most extended experience and severe tests made at this office demonstrate the *impossibility*, if the instructions herein are conscientiously observed, of anemometer bearings becoming scratched, worn, and abraded, and spindles becoming fast in the bearings.

168. This office, therefore, finds but one explanation for injuries of this kind, namely, *neglect*. As the consequence of such neglect is always loss of valuable record, in some cases insiduous and extending over a long time, it is of a very serious nature and should be strenuously avoided.

169. *Defective anemometers.*—When, upon examination, the bearings of an anemometer are found to be in a bad condition, as described in paragraphs 13 and 22, or the instrument is otherwise defective and can not be repaired by the observer, request should be made for another instrument, and special care will be taken to preserve intact and unmodified the defective condition of the anemometer, which, as a whole, will be called in to this office for inspection.

A careful observance of the spirit of this instruction often aids the office in locating obscure defects and the inspection of the instrument often suggests helpful instructions to the observer who possibly failed to fully understand the difficulties.

170. *Requisition for anemometers.*—Whenever requisition is made for a new anemometer, to replace an unserviceable or defective instrument, the letter accompanying the requisition must give all particulars possible as to *how* the anemometer became unserviceable; the nature of the defects observed; how long the instrument has been in constant operation; and also the *official* number of the instrument.

WIND VANE.

171. *Exposure and erection.*—The general principles stated in paragraph 49 will guide observers in selecting exposures for wind vanes, and, if placed near the anemometer support, the one must be not less than 1½ to 2 feet higher than the other.

172. The middle and upper section of wind-vane supports, when sent out from the central office, are generally assembled complete, with the inside rod and contact box in place. The support should be erected without taking these sections apart. In any case, however, observers will be held responsible for the erection of the support and vane to the extent of supervising the mechanics employed to do the work, and will see (1) that the sections of pipe screw together firmly and straight; (2) that the inside rod is straight and moves freely in its bearings throughout each entire revolution; (3) when possible the vane rod will be oiled where it passes through its bearings, fig. 7, and the rod straightened, if necessary, by the method described in paragraph 52; (4) the electrical contacts must be properly adjusted so that the plate is perfectly free from all sides of the contact box; (5) the shoes for the guy rods must be securely fastened and in such positions as to allow plenty of space in the turnbuckles for tightening. The guy rods must be disposed around the support at equal angular distances from each other, and the observer must assure himself that the boards of the flooring are themselves securely fastened to the roof timbers.

173. *Adjustment to true meridian.*—The cam collars or direction cross arms will be adjusted to the true meridian with regard to the provisions of paragraphs 56 and 57, unless such a course is impracticable, in which case the best possible adjustment will be made and the circumstances reported.

174. *Oiling contact mechanisms.*—The only parts of the electrical contacts needing oil are the *axes* of the small rollers on the contact levers, also the top and bottom bearings of the cam collars. Contact plates of the newest construction are provided with two oil holes,

one at the top and one at the bottom bearing of cam collars. These parts will be examined from time to time and oiled, as may be required.

175. *Vane examined.*—The vane and parts must be examined from time to time and its behavior in light winds noticed to see that it moves with the usual freedom in its bearings.

176. A slender stick one to two feet long, with a light thread attached to one end, may be tacked to the side of the vane and project above it, the thread showing true wind directions.

REGISTERS.

177. *Cables and electrical conductors.*—The wires and cable connecting recording instruments, batteries, etc., will be run over the shortest practicable route, carefully placed, and well supported at all points so as to escape accidental or unnecessary injury or interruption of circuit by abrasion of insulation, breaking of wire, etc. A break in the wire, particularly if the insulation is intact, is often difficult to locate. If the break is in the anemometer circuit, the first indication will probably be a frequent opening and closing of the circuit at the time the contact is made in the anemometer, especially noticeable on the tenth-mile contact. Subsequently the ends of the broken wire will become completely separated and permanently open the circuit. A thorough inspection, particularly at exposed points, may be necessary to locate the break. Numerous joints are to be avoided, but when a joint is made the wires must be brightened and very firmly twisted together or soldered if practicable, covering the wire afterwards with insulating tape.

178. *Adjusting record cylinders to correct time.*—Special care must be observed to prevent erroneous records in respect to time, and the principle pointed out in paragraph 104 will be followed in setting records and every effort made to regulate clocks carefully.

179. The magnet on single registers must not be allowed to work loose from the base of the instrument; and, in general, undue looseness in any of the joints or bearings of the recording mechanisms must be avoided in order that the record may present an even and regular appearance.

180. *Ink and pens.*—The ink should be replenished daily and only enough applied to insure a supply during the next 24 hours. Avoid smearing the ink upon the outside of the pen and over the nibs by which the pen is secured to the arm. These precautions will, in a measure, prevent an accumulation of dried ink and dust about the sides of the pen. Only the *special ink* provided for registering instruments should be used.

181. *Colored inks.*—The use of *colored* inks for the different records is permissible and adds to the appearance of the record sheets (Forms

No. 1017–Met'l). A *green* ink of special quality can now be furnished on requisition. By using the green ink for sunshine and rainfall records, the standard *purple* ink for wind velocity, and a bright *red* ink for wind direction, very handsome records may be produced.

182. The adjustment of the pen should be such as to insure the lightest possible contact at all parts of the sheet. It is found that observers in many cases press the pen entirely too hard against the cylinder, thereby wearing away the point much more rapidly than is necessary and at the same time clogging it with particles of paper. *Be careful to avoid this fault.* The best way to judge of the amount of pressure between the pen and cylinder is to catch a pencil point under the end of the arm near the pen, so as to lift the latter slightly a few times from the paper, thus ascertaining the amount of pressure to the spring arm.

183. The pen arms of single registers should be curved so as to cause the extreme point of the pen only to come into contact with the paper. It is also an advantage to bend the pen itself a little just back of the rounded portion, thus causing the point to touch the paper at a high angle.

184. *To start the flow of ink* in a new or freshly filled pen, draw a piece of writing paper carefully between the points so as to wet the faces, but in a manner that will not bend or deform the points or spring them too far apart.

185. The lateral movement or stroke of the pen should be about one thirty-second of an inch. A long stroke has a tendency to throw ink from the pen when too much has been added and cause bad blotches upon the records.

186. *Pens cleaned.*—The pens should be removed from the instrument from time to time and thoroughly washed in water, scraping the parts of the pen a little with a knife blade to remove dried sediment from the ink that is not washed off by the water.

187. In cleaning the pens care must be exercised not to spread or otherwise injure the points. In order to give satisfactory results, these points must be quite sharp and must very nearly touch each other. Otherwise too wide a mark will be made on the form and records of high wind velocities will be indistinct. If after cleaning the flow of ink does not start, draw the edge of a thin sheet of paper between the points of the pen.

188. *Pens renewed.*—Whenever the pen becomes worn so that a neat and distinct record can not be obtained, replace it by the extra pen kept at station, and return the old one immediately to the central office by mail, in a package marked "Instrument Division." The pen must be fully protected from injury; use the regulation mailing case, if possible. When received the pen will be repaired and returned,

or a new one supplied, as occasion may require. In case an extra serviceable pen is not at station, requisition should be made for one.

189. *Wind-direction ink pads.*—These should be carefully inked, and in such a manner as to avoid smearing the ink over all the adjacent parts of the instrument. The quantity should be sufficient to carry the record for 24 hours, but not enough to cause bad blurs and blotches. The pad should be removed from the instrument by withdrawing the pin holding it in place, and the ink then worked into the pad, applying it with slight pressure by a small stick or flattened wire to both the top and underside of the felt, so that the latter will be moistened with ink through and through thus leading to a uniform strength in the record obtained.

190. *Felt ink pads renewed.*—Occasionally the felt of the pad will need to be lowered and the end cut off, or a new piece of cloth inserted. This is easily done by removing the small metal plate covering and holding the pad. New felt will be furnished upon requisition.

191. *Points of direction arms cleaned.*—The points of the direction arms also need occasionally to be cleaned from the accumulations of dust, dried ink, fibers from pad, etc. A brush such as used in cleaning the typewriter can be employed with advantage, the magnet plate being turned back on its hinge and the ink pad removed, so as to give free access to the points of the direction arms.

192. Observers can not be too strongly impressed with the importance of keeping recording instruments in a neat and clean condition. The whole question of clean and legible records is simply one of daily neatness and a little intelligent care and attention.

193. Whenever the points on the wind-direction printing arms become worn, so that the imprints made by the successive closures of the circuit are indistinct, or have a tendency to run together, requisition should be made for new points.

194. Observers will consult Circular A, Instrument Division, for instructions relative to obtaining and tabulating records from recording instruments, and Circulars E and G, for fuller details relative to rain gages and the sunshine recorder.

BATTERIES.

195. Observers will give such frequent attention to batteries as will prevent loss of record and failure of instruments, and particular attention should be given to the connections of the copper wires to the terminals of storage batteries to see if corrosion is occurring that would ultimately break the circuit.

196. Storage batteries are usually supplied only to stations at which *direct* current at 110 volts is available during at least half of the 24 hours. However, installations have been made where alternating

current only was available on the local lighting circuit, and the use of rectifiers has been permitted in these cases.

197. When wind, rain, and sunshine are recorded, *two* cells of the storage battery will be used. If additional instruments are maintained, such as the telethermograph, weighing gage, etc., three cells are required. Two or three dry cells of the ordinary type are sufficient for operating the telethermoscope, the number depending on the length of circuit required between the bulb and recorder. These cells are secured as emergency purchase from some local dealer.

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