W. B. No. 811

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU.

INSTRUCTIONS FOR WIRING METEOROLOGICAL INSTRUMENTS.

APPENDIX 2, CIRCULAR D, INSTRUMENT DIVISION.

Prepared by Roy N. Covert, *Meteorologist.*

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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INSTRUCTIONS FOR WIRING METEOROLOGICAL INSTRUMENTS.

Appendix 2, Circular D.

INTRODUCTION.

1. The wiring at many Weather Bureau stations was installed years ago, the materials and methods employed at that time being in general satisfactory. But there has been a steady improvement in both materials and wiring methods as the electrical industries have grown, and the following is written with the purpose of bringing these matters more closely to the attention of station officials in order that when a station is moved to a new location or a new station is opened, or when for other good reasons it becomes desirable to overhaul the electrical installation the wiring of the instrumental equipment may be made to conform with modern standards. Sections V, VI, and VII of Circular D, Instrument Division, Fourth Revision, pertaining to wiring, batteries, etc., will be modified by this appendix.

2. In general there are three principal cases with which it is necessary to deal: First, the wiring of instruments, plans for which can be made before or during the construction of a new building; second, the wiring of instruments when first installed in a building already erected; third, the rewiring of instruments in their present location.

I. WIRING OF INSTRUMENTS IN A NEW BUILDING.

3. Whenever it is possible to install equipment in a building under construction an opportunity is afforded to wire the instruments to the best possible advantage. At such a time rigid metallic conduit with suitable outlets and pull boxes should be placed according to plans prepared in advance with the assistance of the Instrument Division. When the removal of a Weather Bureau office to a new building is contemplated, this advantage should not be lost sight of, and the plans for the interior wiring of the instruments included, so far as is possible, in the general plans for the building wiring, with provision for roof outlets. Following is an outline to follow for such work, to be modified according to the particular requirements:

4. *Parts of equipment to be wired.*—For the normal instrumental equipment the several parts interconnected are as follows: (1) Distributing box; (2) instrument stand; (3) battery; (4) wind instru-

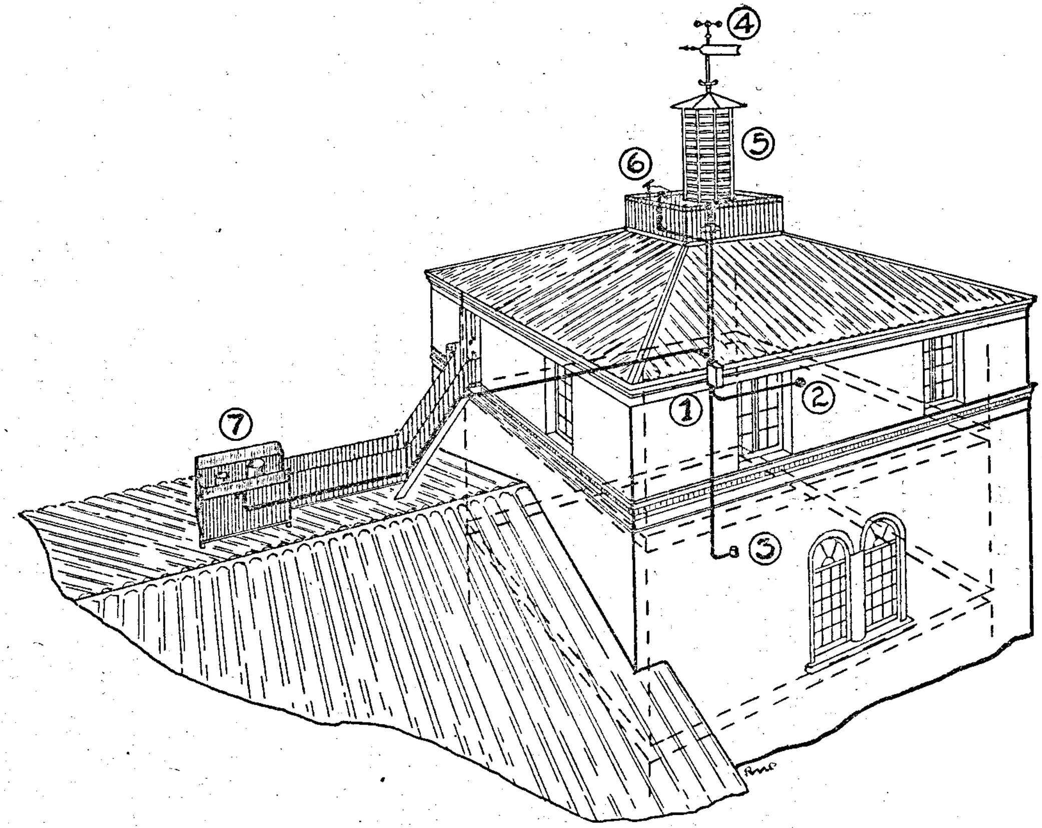

FIG. 1.—General arrangement of conduit connecting instrumental equipment, Federal Building, Honolulu, Territory of Hawaii.

ments; (5) instrument shelter; (6) sunshine recorder; (7) tipping-bucket rain-gage.

5. Figure 1 illustrates very well the general arrangement of the parts required, which are numbered according to the preceding paragraph. Each installation, however, will require special consideration because of the differences in architecture and the relative locations provided for the Weather Bureau offices and roof equipment.

6. *Conduit.*—Rigid metallic conduit is best for all interior wiring in a new building; black-enamelled conduit for the interior (except sheradized conduit at stations along the seacoasts, where corrosion of iron takes place readily), and sherardized conduit and fittings for locations exposed to the weather.

7. *Wire.*—No. 16 gage, heavy rubber-covered, single-braid, solid copper wire should be provided for all wiring, except as otherwise noted. A good-quality fixture wire serves admirably.

8. *General requirements of installation.*—All conduit will be run with as few turns as possible and with easily accessible pull boxes at all turns to permit of ready pulling of wires at any time. No traps must be left for the accumulation of water within the conduit.

9. All joints or splices in the *wiring* will be carefully soldered, the excess of flux washed off, and taped, and where necessary the wires formed into neat handmade cables such as are found in telephone-switchboard wiring. Wires projecting from lead-covered cables should also be taped, and then given two coats of a waterproof compound. See that the wires are tagged at the ends and in the distributing box or wherever splices are necessary. The numbering should conform to a diagram of circuits or to a written description, preferably the former. Small sheet-lead tags, lozenge-shaped, which can be easily wrapped around the wire, have been found to be satisfactory.

10. *Extra or spare wires* should be pulled into the conduits for emergency or future use. (See list in par. 16.)

11. *For circuit diagrams* see Figures 6 and 7 and the accompanying explanation. Also consult publications on telethermoscopes and water-stage registers. Figure 7 will be used for storage-battery installations; Figure 6 for primary batteries.

12. The parts of the equipment and the wiring will now be considered in detail, as follows:

(1) *Distributing box, location of.*—The distributing box, from which branch circuits are to run to the battery, the instrument stand, and to the roof equipment, should be located, if practicable, in some easily accessible place within the building. The location shown in Figure 1 is a very good one, a panel box closed with a door being employed. Its location is near the battery, and the conduit

runs are direct. When the roof equipment is located at a distance from the office the box should be placed beneath the roof and at a point underneath or near the foot of the wind-instrument tower or the support made of iron pipe. Occasionally the box will have to be placed above the roof, in which case a weather-proof type of box is required, which can be attached to the tower girts or to the pipe support.

13. When the distributing box must be located above the roof the box can be most advantageously attached to the tower or to the wind vane and anemometer support, since most of the wires are required for the wind-instrument circuits, but when an iron contact box forms part of the 18 or 26 foot support, this box will serve for distribution, as described in paragraph 26. Branch conduits will be run from the box direct to the several instruments, no intermediate condulets being required.

14. Iron clamps may be obtained from the central office for the attachment of the conduit to the girts of the tower, and the condulet distributing boxes or equivalent may also be secured likewise. Sheradized or black panel boxes may as a rule be readily obtained locally.

15. *Kinds of box.*—Panel boxes should be employed for wall installations where good appearance is also a factor. Sherardized PJX condulets or equal, as illustrated in Figure 2, make very good boxes for either inside or outside exposures where appearance is not so important.

16. *Conduit runs and sizes.*—For the particular installation and wires shown in Figure 1, the following-listed conduits and wires extend from the distributing box to the other parts of the equipment:

From box to—	Conduit size.	Total number of wires.	Spares.
	Inch.		
Instrument stand	1	20	7
Batteries	½	7	2
Wind instruments and instrument shelter	¾	14	4
Sunshine recorder	½	4	2
Rain-gage	½	4	2

17. The installation illustrated can be used as a model, but other arrangements of the parts of the equipment would require somewhat different treatment. For example, when the distributing box is located near the roof, or above, one run of 1-inch conduit should extend from the instrument stand to the box and ½-inch conduit from the battery to the instrument stand if the battery is not placed in the stand. Otherwise the arrangement would be the same as listed above.

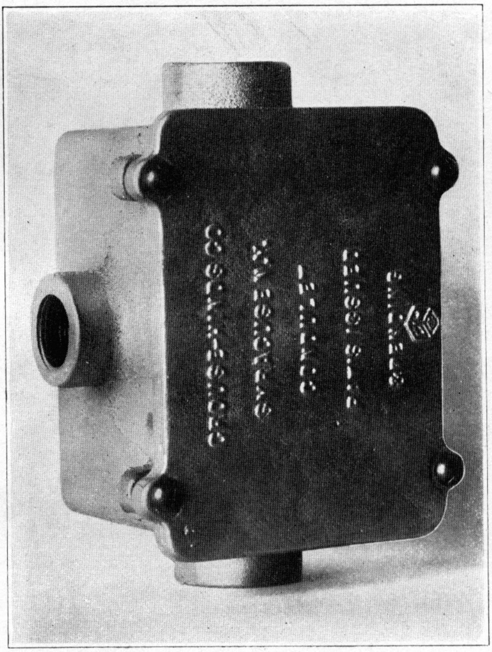

Fig. 2.—Condulet suitable for use as junction box. (Body of condulet $5\frac{1}{4}$ inches high by $3\frac{1}{4}$ inches deep, outside dimensions).

18. (2) *Instrument stand, outlet, and wiring.*—The outlet beneath the instrument stand can usually be made best with a sherardized Fullman floor box or equivalent. The wires leading to the instruments will be formed into a handmade cable, and fastened securely with leather straps to the woodwork of the stand.

Individual wires to the binding posts of the quadruple and telethermoscope registers will lead through holes about $\frac{3}{16}$-inch diameter drilled in the top of the stand directly beneath the binding posts,

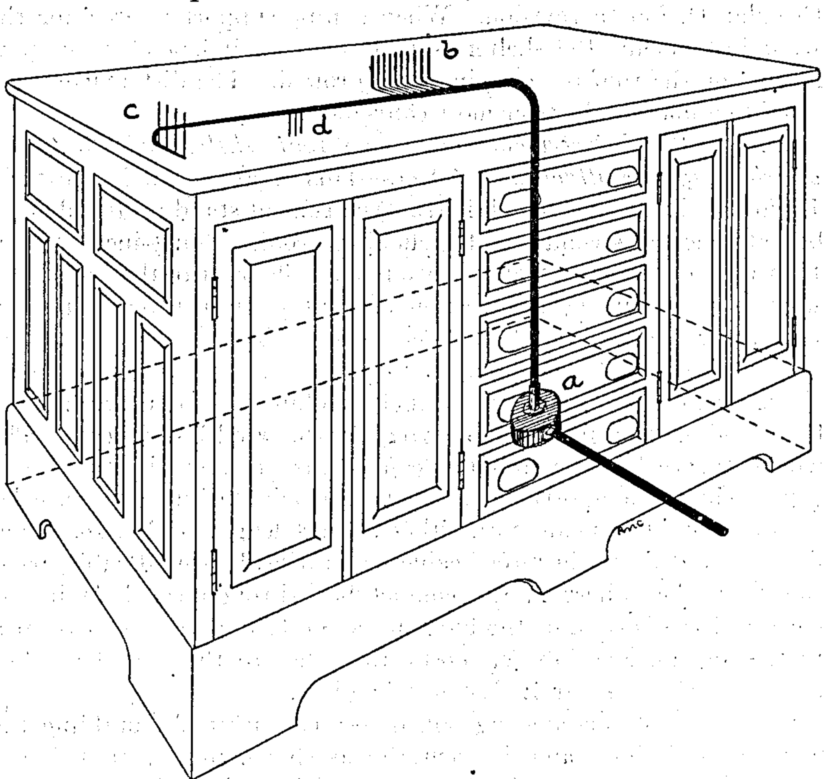

FIG. 3.—Wiring of instrument stand. "a" is floor box; "b," wires to triple register; "c," wires to telethermoscope; "d," spares.

the spacing of holes to correspond to the spacing of the posts. The location of the instruments on the stand should be such as will furnish the most convenient arrangement. Figure 3 serves as a wiring model to be modified to suit conditions.

19. (3) *Batteries.*—As discussed in detail, beginning with paragraph 44, two types of batteries are employed—primary, and secondary or storage. In Figure 1 the batteries are shown located near the distributing box and connected thereto through $\frac{1}{2}$-inch conduit. When primary batteries are placed in the instrument stand, no separate battery conduit is needed, but connections to other parts

of the equipment are made through the conduit from instrument stand to distributing box. Occasionally it will be desirable to terminate the conduit run from distributing box to batteries in a floor box similar to the one used under the instrument stand.

20. (4) *Wind instruments.*—(5) *Shelter.*—Wind instruments are either mounted on (*a*) a wind instrument tower having a shelter within the tower, or on (*b*) a pipe support, the former usually 40 feet high from base to apex, the latter 18 feet, both as described in Circular D, fourth revision. When a pipe support is used for the wind instruments the shelter is placed on an independent support located on the roof or sometimes the ground. The distributing box should be placed wherever most convenient.

21. (*a*) *Wind instrument tower on roof, shelter within tower, distributing box attached to tower.*—This arrangement is shown in Figure 4. Run 1-inch conduit from instrument stand to distributing box attached to second set of girts above roof. Run ½-inch conduit thence to instrument shelter, through the floor near the back, and upward to a point near the center of the top, from which wires can be readily dropped to the telethermoscope bulb. This connection may be omitted if no telethermoscope is in use or contemplated.

22. From the box also run ¾-inch conduit to a point within the lower end of the 2-inch support carrying the wind instruments. The wiring thence to the wind-vane contacts is protected by the 2-inch pipe. The outside portions of the anemometer and sunshine recorder circuits should be made with either a short length of No. 16, 2-conductor braided weatherproof cable or with lead-covered cable, passing from the splices in the contact box through the hole in the corner of the bottom of the box, one connection along the cross arm to the anemometer binding posts, the other to the recorder. The cables should be securely fastened in place.

23. When the distributing box is located within the building the tower conduit is arranged essentially as shown in Figure 4, but a smaller box or condulet should be used, the number of outlets being two, three, or four as needed; three when the telethermoscope is wired and four when the rain-gage is also included, but only two are required for wind instruments and sunshine recorder.

24. (*b*) *Pipe support for wind instruments; shelter on separate support on roof; box beneath roof.*—In this case run ¾-inch conduit from the box to an outlet through the roof near or under the base plate of the wind-instrument support. Make a run of ½-inch conduit from the box to a similar outlet beneath the shelter. Do not expose any more conduit to the weather than is necessary.

25. At the shelter outlet place a C condulet about 1 foot above the roof to facilitate wiring. The balance of the wiring to the shelter will be similar to that above described.

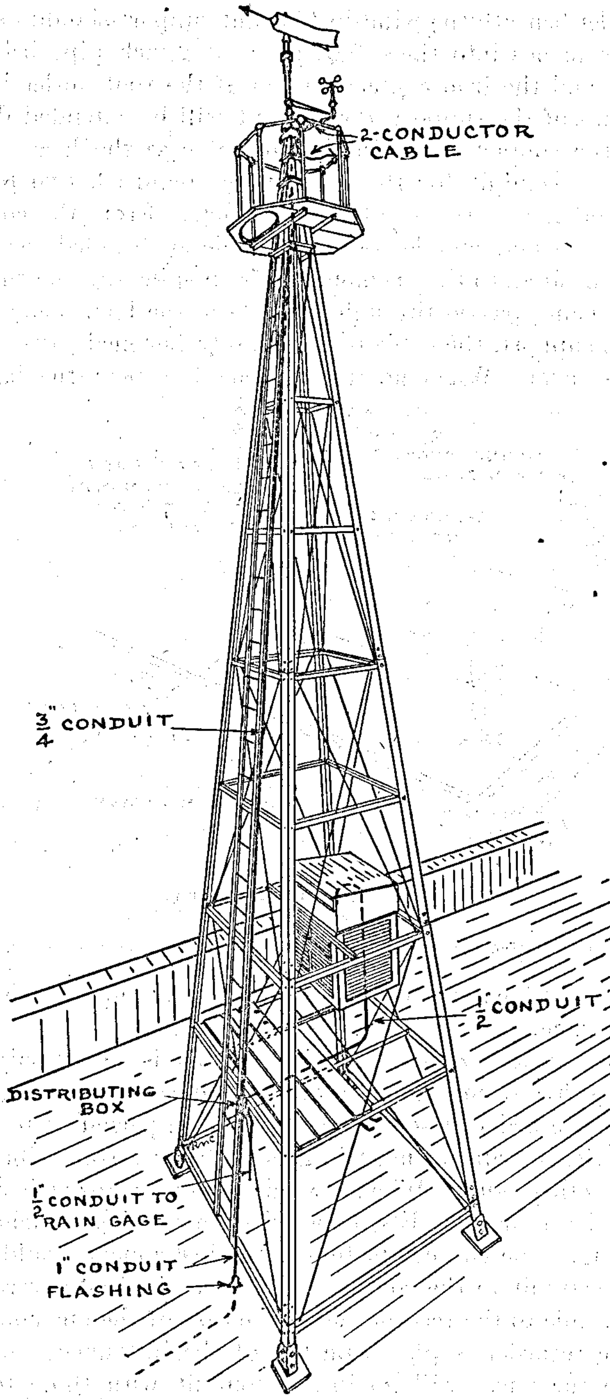

FIG. 4.—Wiring of wind-instrument tower.

26. The outlet beneath the wind-instrument support should extend upward a few inches into the 4-foot piece of 2-inch pipe between the base plate and the iron contact box, or if the roof outlet is not beneath the base of the support, the conduit will be extended direct to a hole in the contact box. In the former case the larger pipe then serves as a conduit for the seven wires required, two to the anemometer and five to the wind-vane contacts. From the contact box run No. 16, 2-conductor lead-covered cable, or braided weatherproof cable if desired, to the anemometer from splices in the contact box, the cable being passed through the hole in the box, thence outside along the support, the cable to be securely fastened to the support and cross arm. When no iron contact box near the base is

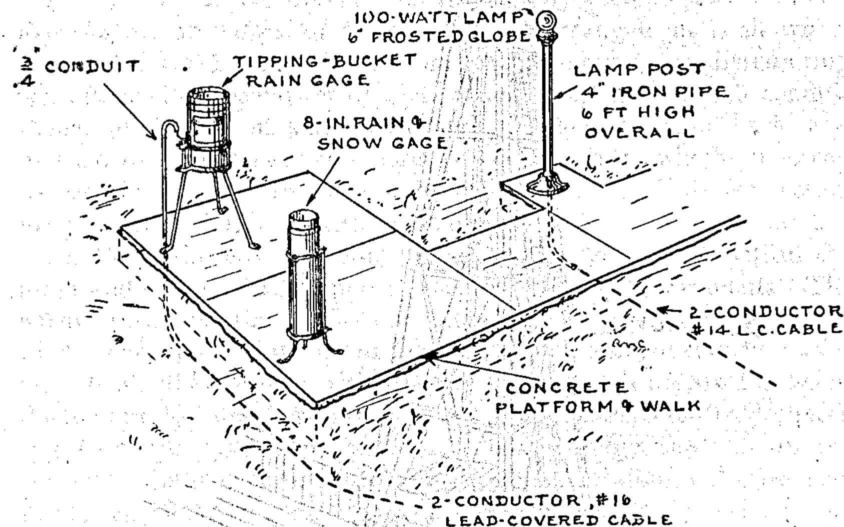

FIG. 5.—Rain-gage installation and wiring for tipping-bucket rain-gage and electric light.

used the wires will extend upward through the support to contacts near the vane.

27. (6) *Sunshine recorder.*—This instrument is necessarily exposed in a place free from shadows caused by objects coming between the sun and the recorder at some time during the period of possible sunshine, and the instrument must in general be free from vibration due to wind or other cause. When a wind-instrument tower is available the recorder is usually best exposed on a bracket attached to the hand railing. The two conductors to the instrument would then be carried in conduit to the contact box, thence in lead-covered or weatherproof cable to the recorder as in the case of the anemometer. Sometimes the recorder is placed on top of the instrument shelter, in which case the wires will go in the conduit with those to the telethermoscope, all as described above, and the last end of the cir-

cuit completed through a piece of 2-conductor lead-covered or weatherproof cable. Occasionally the recorder is placed on the coping of the building or other location rather remote from the other instruments. In this case a separate run of ½-inch conduit to the recorder is required, usually direct from the distributing box, although occasionally it will be more convenient to use a conduit branched from one serving other instruments, employing a condulet where needed.

28. (7) *Tipping-bucket rain-gage.*—From the distributing box run ½-inch conduit to the tipping-bucket rain-gage, forming the outer end into a gooseneck to prevent entrance of water, and from a point a few inches within the end of the conduit splice to a short length of No. 16, 2-conductor, lead-covered or weatherproof cable for the exposed connection to the rain-gage. (See fig. 5.) Where the conduit passes along the roof it should be separated from the latter by 2 or 3 inches to keep moist dirt from accumulating between conduit and roof, with the resulting corrosion of the conduit.

II. WIRING OF INSTRUMENTS WHEN FIRST INSTALLED IN A BUILDING ALREADY ERECTED.

29. In general the requirements are the same as covered in case I, preceding, and the roof wiring can be completed essentially as outlined, except that the distributing box can seldom be located beneath the roof. The interior wiring will usually have to be a compromise with that possible in a new building where the conduit work can be planned in advance. Occasionally conduit already in place can be employed, or ducts are available within which conduit can readily be run. Modern practice requires concealed wiring in conduit. This is desirable both from the standpoints of appearance and safety rather than to resort to open work, even if allowed, or to expensive lead-covered cables, although the latter will occasionally be found convenient to use. It is sometimes possible to install flexible conduit when ducts are not available, particularly in buildings of frame construction. The advantage of conduit wiring, whether rigid or flexible, should be sought, since it is possible when rightly installed to pull out or add to the conductors within the conduits, and the wiring is thoroughly protected from injury. All the possibilities should be investigated when preparing plans for the wiring in new quarters and the whole case submitted to the Instrument Division for such help as can be given.

III. REWIRING OF INSTRUMENTS.

30. The same general principles apply to this case as to the preceding, but there is added the difficulty of carrying on the work while maintaining a continuous operation of the instruments. This

can usually be accomplished, however, with proper planning, although a brief suspension of records is not objectionable. The wiring at quite a number of stations has been in service a considerable number of years and perhaps is giving occasional trouble. When such a condition occurs, an opportunity is afforded to improve the wiring and bring it up to the modern standard. This applies more especially to the roof wiring, where corrosion and other injury readily take place.

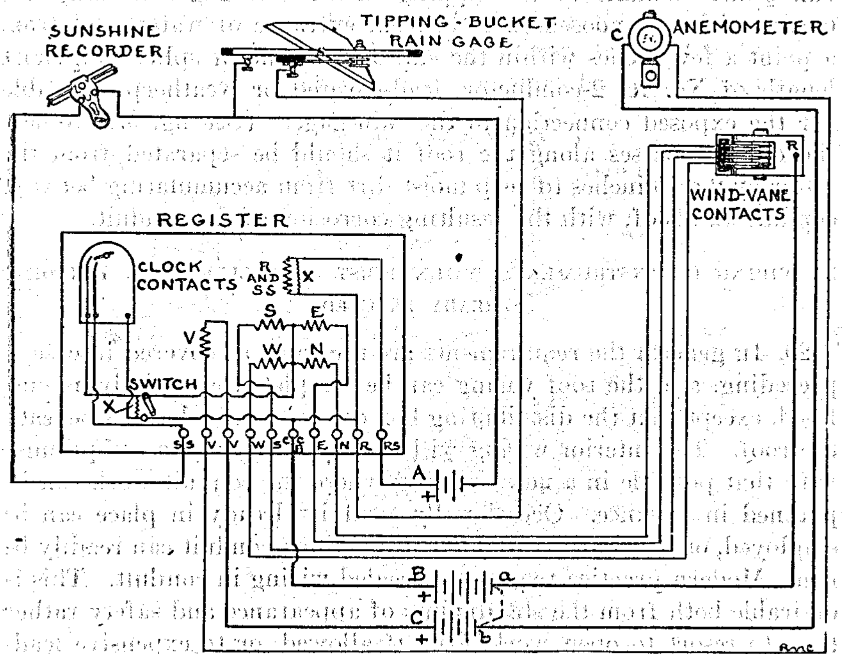

FIG. 6.—Diagram of circuits, quadruple register. "A," rain-gage and sunshine recorder battery; "B," and "C," wind vane and anemometer batteries, respectively. Primary batteries used.

To connect for a common-battery wire to wind vane and anemometer, join "a" and "b" and omit wire from "b" to "c." Current flows from "R," wind-vane contacts through frame of support to the uninsulated post of anemometer.

31. *Ground exposure of instruments—use of lead-covered cables.*—Except for short lengths of exposed wiring, ordinarily the only use for lead-covered cable is for wiring underground, when the shelter and rain-gages, and sometimes the wind instruments on a tower, have a "ground exposure." A good and reasonably safe installation can be made in this instance by wiring, as before described, in sherardized conduit above ground and extending the ends of the conduits to lead-covered cables laid without protection in narrow trenches about 30 inches deep, depending upon the character of the soil, except that where the cable passes under a roadway or other place where the cable might be subject to mechanical injury it

should be protected by threading the cable through a sufficient length of iron pipe. A good location for the distributing box for such an installation would be the basement of the Weather Bureau building. See Cincinnati Observatory specifications, paragraph 117 and following. The lead-covered cables should extend from the box to an opening in the basement wall, through the opening, diverging thence to the several instruments. The opening should, of course, be made water-tight by filling in around the cables with a lean cement mortar. Two-, three-, seven-, and thirteen-conductor lead-covered cable may be obtained from the Central Office on stores requisition.

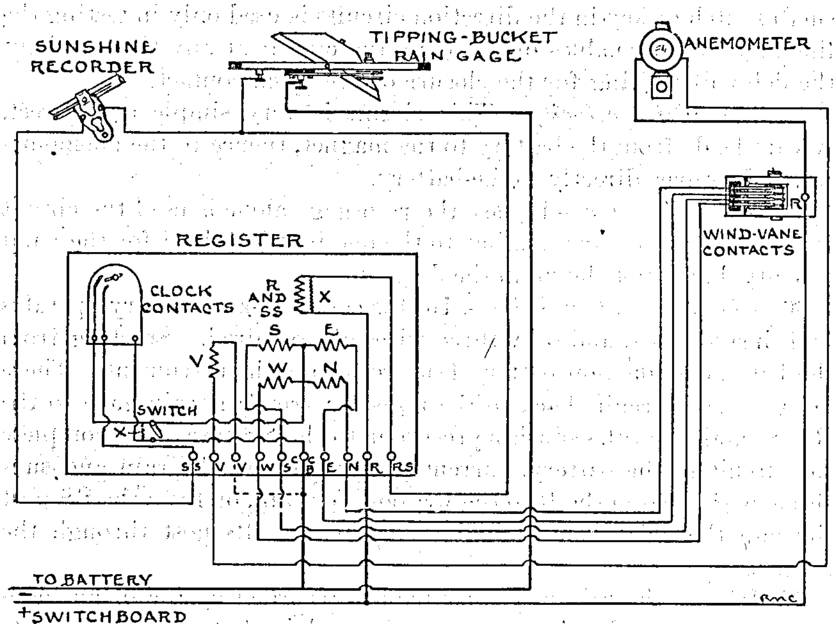

FIG. 7.—Diagram of circuits, quadruple register. Storage batteries.

Cables may be used to advantage for temporary installations or where the official in charge finds it practicable to wire the instruments without employing outside assistance.

IV. EXPLANATION OF CIRCUITS.

32. Figures 6 and 7 show the electrical circuits for the quadruple register, and likewise represent, in principle, the manner in which circuits of corresponding parts of the single and double registers are made.

33. (*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 register; next through the clock contact; from the clock to the four wind-direction magnets, one ter-

minal 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, and one or two circuits, therefore, completed through the corresponding magnets of the register at each closure of the circuit in the clock. 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 contact.

34. (*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.

35. (*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.

36. (*d*) *Rain and sunshine.*—In this case the same battery operates both instruments, and only three wires are required. Starting from the battery a common battery lead goes to each instrument. There are then two circuits back to the register; from the rain-gage to the R post and from the sunshine recorder to the SS post. To complete the circuit to the battery, current passes through the rain and sunshine magnet from the R to the RS post for rain, or from the SS post through the clock contact and thence to the RS post through the magnet.

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

38. (*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 the register. The two posts SS and R on the register are joined by a short piece of wire.

39. *Spark shunts.*—All Weather Bureau registers having minute-contact attachments for clocks are provided with specially wound shunt coils. These are inserted in the sunshine and wind-direction circuits, at points corresponding to those marked XX, Figures 6 and 7, 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 recently constructed registers the spark shunts have been wound on the magnets themselves and can not be seen.

V. BATTERIES AND SWITCHBOARDS.

40. *Character of battery required.*—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 some type of storage battery, described in detail below.

41. 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 or positive of one cell joins to the zinc or negative of the next, etc.

42. 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.

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

44. *Comparison of primary and secondary batteries.*—The electric current required for running the ordinary meteorological instruments may be 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.

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

46. *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, but in general this type of cell is more or less permanently impaired when the circuit remains closed for any considerable period of time, depending upon the quantity of current being taken from the cell. 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.

47. There are, on the other hand, what are often called closed-circuit batteries, which give out a current of practically constant or even increasing quantity 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.

48. 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.

49. *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 2 volts.

50. 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.

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

52. 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.

53. 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.

54. 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

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

55. *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 300 ampere-hours. This means in general that the cell will give a current of 1 ampere for 300 hours. But in practice it is found that the ampere-hour capacity of a battery varies considerably with the rate of discharge.

56. 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 many cases these cells on a triple register recording wind direction, wind velocity, sunshine, and rainfall have lasted from 12 to 18 months. A pronounced shortening of the life of a battery, either primary or storage, is indication either of a short circuit on the line or the improper setting up and handling of the battery, contrary to the instructions given. 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.'s, etc.

57. 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.

58. One of these cells is shown in Figure 8, and a set of recharging supplies in Figure 9.

59. *Description of cell used.*—The compressed copper-element battery is shown in Figures 8 and 9. The compressed cylindrical copper element, with projecting stem and winged nuts, is seen in Figure 9 (*b*). The zinc element is suspended from the lid by means of two projecting lugs, as shown in Figure 8 (*b*). At Figure 8 (*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.

60. *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 hereto-

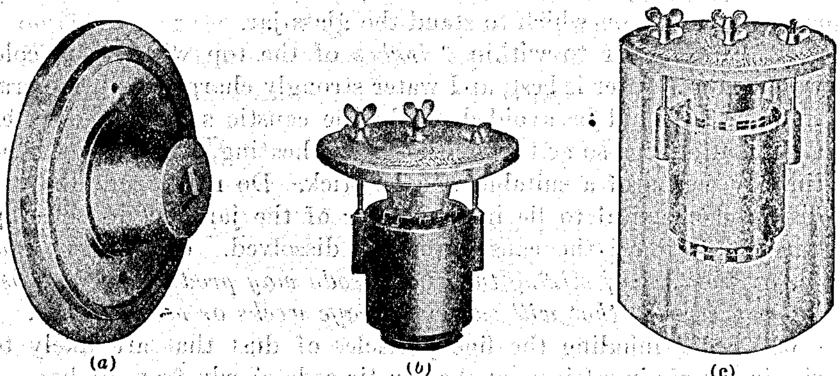

FIG. 8.—Waterbury battery, details and assembly.
(*a.* Solid porcelain top, under view; *b.* Same, with copper and zinc elements mounted; *c.* Battery complete with glass jar.)

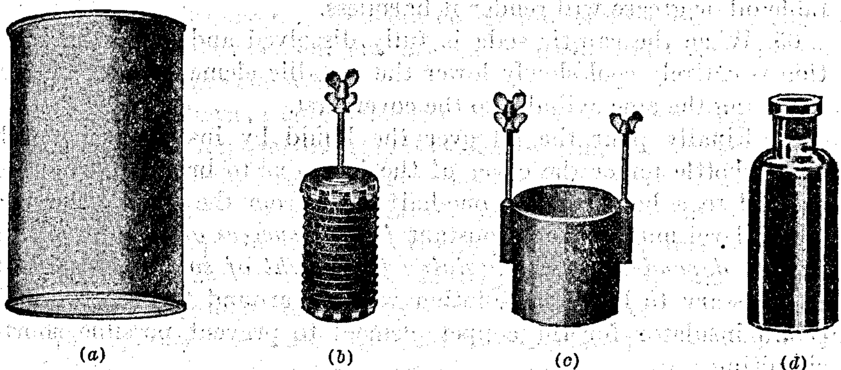

FIG. 9.—Set of recharges for Waterbury battery.
(*a.* Sodium element for making solution, furnished in air-tight metal can; *b.* Compressed copper (+) element, as mounted for use; *c.* Zinc (−) element, ditto; *d.* Bottle mineral oil.) Note: The winged thumb nuts shown in *b* and *c* are parts of the permanent fixtures of the cell, and are *not* supplied with the sets of recharges unless specified.

fore, 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.

61. *Instructions for setting up Waterbury cells.*[1]—Much 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 nonconduction 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.

62. 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 a little at a time, 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. *Overheating the jars at the time of mixing the caustic soda may produce in the glass internal stresses that will cause breakage weeks or months later.*

63. *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.

64. *Avoid* splashing the solution on the hands, or out of the jar in any way, but the immediate application of any animal or vegetable oil or grease will render it harmless.

65. When the caustic soda is fully dissolved and when the solution is entirely cool slowly lower the metallic elements into the jar, attaching the zinc cylinder to the cover first.

66. 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 about one-half inch from the top of the jar, which level must be kept constant *for the success or failure of this battery depends upon maintaining the height of solution level.* It is necessary to have the solution well up around the central porcelain insulator for the copper element to prevent possible short-circuiting.

67. *Caution.—The layer of special oil furnished for the purpose is absolutly 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.*

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

68. *Inspection.*—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 ascertaind by inspecting the zinc plate.

[1] Taken in part from instructions published by manufacturer, the Waterbury Battery Co.

When this has been eaten away to a considerable extent the cell can not last must longer and will need to be replaced.

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

70. 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:

Instruments.	For recording.	Number of cells required.
Single register	Wind velocity	2
Two-magnet register	do	2
	Sunshine	2
Do	Wind velocity	2
	Sunshine and rainfall on same battery	3
Quadruple register	Wind velocity	2
	Wind direction	4
	Sunshine and rainfall on same battery	3

71. *Storage batteries.*—Storage batteries are usually issued to stations for the operation of automatic instruments when direct current of approximately 110 volts is available. It is possible also to use 220-volt current. In a few cases, however, rectifiers to convert alternating to direct current are being used, and, when properly cared for, serve very well.

72. The extensive employment of small storage batteries for automobile starting and lighting, besides assisting in the development of reliable, low-priced rectifiers, has resulted in the establishment of numerous battery service stations where portable batteries can be rented and kept in first-class condition for a reasonable cost. A few stations have solved their battery problem by this method, a contract being made for battery service by the year.

73. *Operation.*—When two relatively inactive plates or electrodes of metal or metallic compounds are immersed in a suitable electrolyte to form a cell, and a direct current of proper voltage and strength is passed through the cell to charge it, the chemical relations of the elements of the cell are changed, and when the cell is connected to an external circuit, current will be forced through the circuit. Usually several plates are connected together to form one positive electrode and several others to form one negative electrode. During the period of discharge the electrodes tend to revert to their original composition. When the cell is 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.

74. *Composition.*—A number of chemical substances are capable of forming a storage cell, but those used commercially have as active materials peroxide of lead and sponge lead immersed in an electrolyte of dilute sulphuric acid; or of nickel hydrate and iron oxide in an electrolyte consisting mostly of a solution of potassium hydrate. The active materials do not possess in themselves 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 are pressed into recesses, or otherwise secured to suitably formed "grids," which serve the double purpose of properly supporting the active materials in the electrolyte and of conducting the electric current to or from the active material. The substance of the grid is itself chemically inert toward the other elements in the cell. The type of cell first mentioned is called the "lead cell," the second the "Edison cell."

75. *Chemical actions.*—In the lead cell, which is used almost exclusively in Weather Bureau work, the peroxide of lead, the active material of the positive electrode, presents a rich chocolate-brown appearance when the cell is charged, while the sponge lead of the negative electrode is grayish-white in color. This sponge lead is an allotropic form of ordinary metallic lead.

76. The chemical transformations in a storage cell are not, perhaps, perfectly understood. Without attempting to give the complete chemical reactions so far as they are understood, 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. Complete instructions regarding the installation and operation of lead storage batteries are given below. Information about the Edison battery will be furnished when required.

77. *Weather Bureau storage batteries.*—The batteries issued to Weather Bureau stations usually consist of four cells of the PT type manufactured by the Electric Storage Battery Co. These must be set up in two batteries of two cells each, but for long circuits 3-cell batteries are required. (See figs. 10 and 11.) There are other reliable lead cells on the market which may be employed.

78. *Location of batteries and switchboard.*—A well-ventilated, dry, and moderately warm, closed room (50° to 80° F.) located off the instrument room provides the best location for both battery and switchboards. In general the batteries, and more especially the switchboard, should be located with a view to convenience of access,

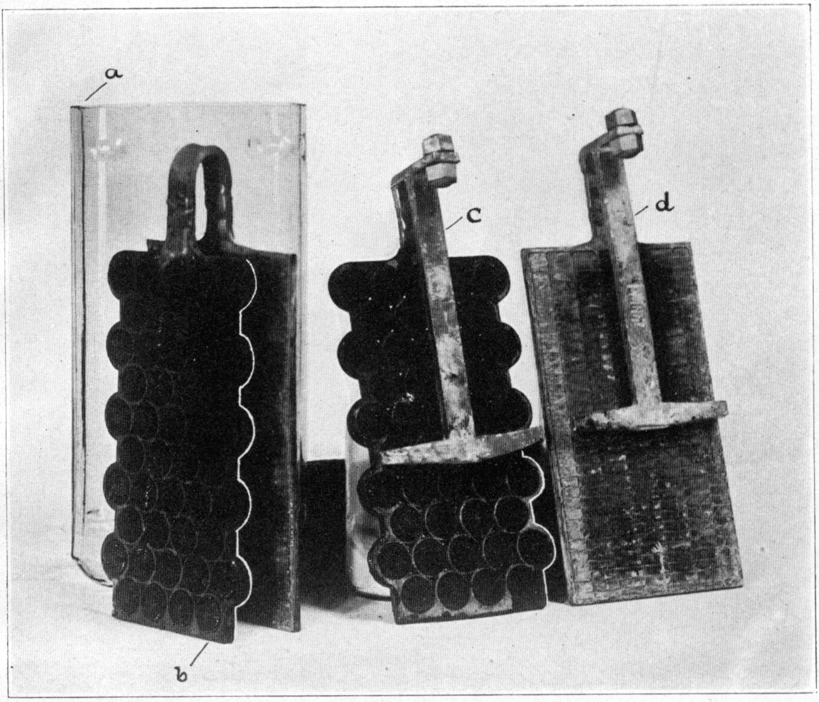

FIG 10.—Parts of PT storage-battery cell: (*a*) Glass jar; (*b*) couple; (*c*) positive plate; (*d*) negative plate.

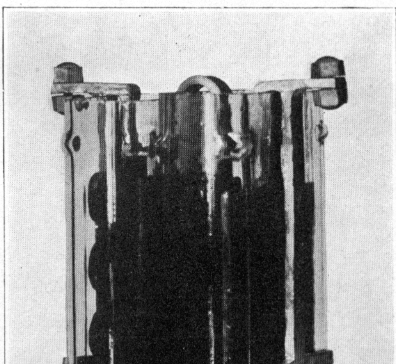

FIG. 11.—PT type storage battery of two cells.

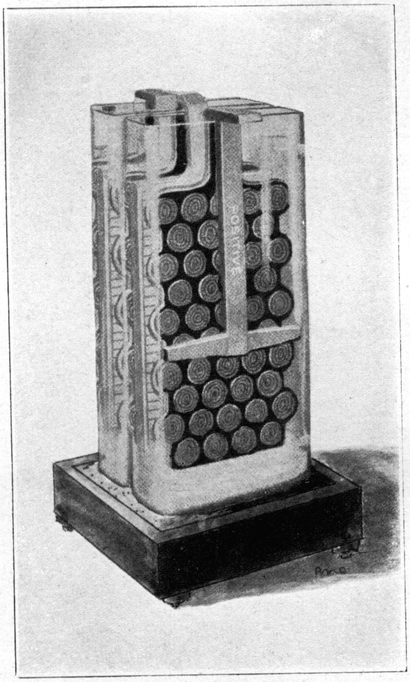

FIG. 12.—Battery tray for PT storage cell.

facility for installation and care, wiring, etc. It is not advisable to place the battery in one of the workrooms because of the fumes given off. If a special battery closet is not available, they may be located in a storeroom, or perhaps the attic or basement or some relatively remote closet, the switchboard being placed in the instrument room. This battery compartment should, if possible, be arranged for in advance of the completion of a building to be occupied as quarters. The ventilation must be good or the gases, largely composed of hydrogen, given off during charge may possibly cause an explosion. An exposed flame should never be brought near a gassing battery.

79. *Battery trays.*—The cells should be placed in one or more of the standard battery trays, such as are generally used in storage-battery work (see fig. 12), 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 vaseline or 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 vaseline or 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.

80. *Use of panel box for switchboard.*—The switchboard can readily be installed in a pressed-steel panel box of suitable size provided with lock and key. The use of a box obviously prevents tampering, keeps the board cleaner, and makes a more sightly installation when the board occupies a conspicuous location. Otherwise it is not needed. The provision for a panel box can be included in the bid for the wiring of instruments and batteries.

81. *Attachment of board to wall.*—The board as shipped is meant to be mounted direct on the wall by means of expansion bolts, if the wall is constructed of brick or tile; or by large wood screws if the wall is framed of wood. When the board is placed in a panel box, the iron mounting strips should be removed and the board attached direct to the back of the box by means of machine screws.

82. *Description.*—The board and its wiring is illustrated in Figure 13. It is similar in its essential details to the wooden board heretofore illustrated in Circular D, the principal difference being the substitution of a rheostat for incandescent lamps to secure a charging current of the proper strength or ampereage; and the addition of an ammeter to measure and adjust this charging current. The rheostat

and ammeter are merely connected in series with the 110-volt lighting circuit, the 6-ampere plug fuses in the upper right-hand corner of the board and the battery being charged. When the lighting current is alternating, and a rectifier is used, connection is made to the latter.

83. *Wiring.*—When the board and batteries are close together the connection between them may be made by two pieces of 2-conductor lead-covered cable, No. 12 wire. The wires at the board are secured to the binding posts at the bottom. When the board and batteries are a considerable distance apart, however, the wires should be run in one-half-inch conduit. It is best not to place the board directly over the batteries, because the acid fumes will corrode the copper on the board. In general, however, the circuits to the board should be run in conduits, connections to the instruments and to the charging circuit being made at the board to studs at the back, as indicated in Figure 13. It will be noticed that the charging circuit is protected with 6-ampere plug fuses, the discharge with 3-ampere fuses. Also, that a battery is being charged when the controlling switch is thrown to the right and discharged when thrown to the left, the rheostat being adjusted to provide current of the proper strength, as shown by the ammeter.

84. *Operation.*—The PT type of storage cell requires a normal charging rate of 3 amperes, and it is the intention, when using the board shown in Figure 13, to charge at this rate and only about once a week. Each week, say Monday, for example, connections to the batteries will be interchanged; i. e., the battery charged the previous Monday connected with the instruments, and the other with the charging circuit. The latter battery will then be charged according to the detailed instructions given below, and thus made ready for use the next Monday or in case of emergency.

85. A record of the voltage and specific gravity of each cell should be kept. Thus, for any single cell, its voltage and specific gravity should be measured just before being connected to the charging circuit, and the same data secured after the battery is charged and disconnected from the charging circuit.

VI. INSTRUCTIONS FOR INSTALLING AND OPERATING THE PT TYPE STORAGE BATTERY.

86. The following instructions are taken in part from those published by the manufacturers of the PT cells, but they apply largely to any lead-cell battery.

87. *Installing battery.*—Place the jars, after they have been cleaned, in position on the sand trays (see fig. 12) which should previously be filled evenly with the top with fine dry sand. The trays, which should be separated by an air gap, rest on glass in-

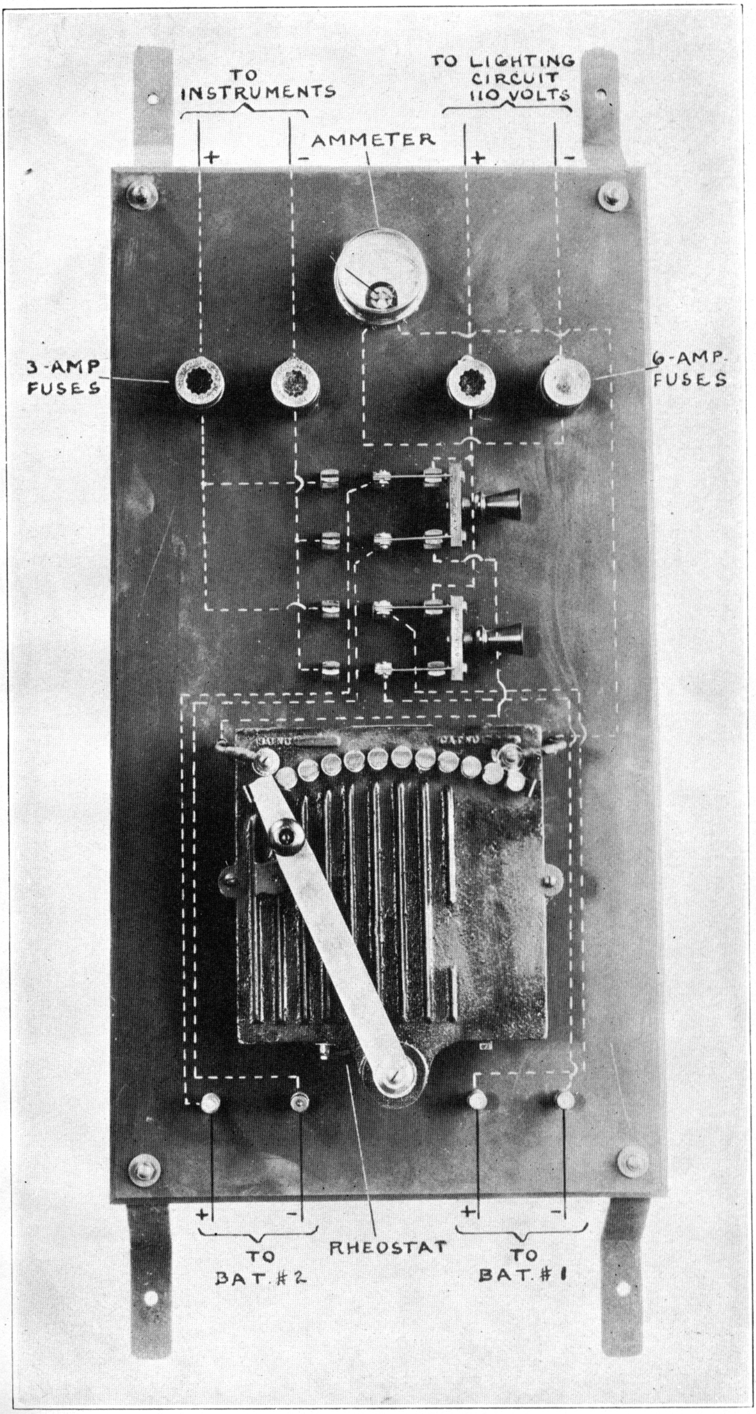

FIG. 13.—Storage-battery switchboard.

sulators, also shown in Figure 12, which, in turn, rests on stands or shelves. The cells should be so located in the room that they will be easily accessible. If sand trays are not provided the jars may rest directly on a board or plank, the plank being insulated from the stand or shelf by glass insulators, and an air gap left between the section rests.

88. Plates of opposite polarity, except the terminal plates, are burned together by a connecting strap and are placed in adjoining jars; the positive plates are of a brownish color, the negatives of a light gray. Before placing the couples in the jars the straps should be bent over a piece of wood ¾ inch thick, the top edge of which is rounded. After removing from the form the straps should be still further bent until the lower edges of the plates touch, then by gently springing them apart when putting into the jars the plates of adjacent couples will not have a tendency to get together and short circuit. In bending, care should be taken that only the connecting strap is bent, as the burned joints must not be subjected to undue strain. The plates must be placed in the jars, so that in each there will be both a positive and a negative plate. *If couples are installed in the wrong direction the plates will be seriously injured.* The appearance of a battery when set up is shown in Figure 11, and the parts of a dissembled cell are shown in Figure 10.

89. *Connecting up the charging circuit.*—Before putting the electrolyte into the cells the circuits connecting the battery with the charging source must be complete, care being taken to have the *positive pole of the charging source connected with the positive end of the battery.* If a suitable voltmeter is not at hand, the polarity may be determined by dipping two wires from the charging terminals into a glass of water to which a teaspoonful of table salt has been added, care being taken to keep the ends at least 1 inch apart to avoid danger of short circuits. Fine bubbles of gas will be given off from the *negative* pole.

90. It has not been advisable to ship to stations the small quantity of electrolyte required, and this must be procured locally, but its purity is a matter of the first importance. The cost of the electrolyte should be included with other expenses incident to the installation. It should be procured from some reputable storage-battery service station, or from a responsible dealer in battery supplies. Six cells will require 27 pounds of electrolyte, which must satisfy the specifications following:

91. *Electrolyte.* The electrolyte is dilute sulphuric acid of a specific gravity of 1.170 or 21° B., as shown on the hydrometer at a temperature of 70° F. If it is not convenient or possible to procure this already mixed and ready for use, it may be prepared by

diluting suitable commercial sulphuric acid with *pure* water. The acid, as well as the water, must be free from impurities, such as iron, arsenic, nitric or hydrochloric acid; this is absolutely essential. Then diluting, *the acid must be poured into the water, not the water into the acid;* the proportions of acid (of 1.840 specific gravity, or 66° B.) and water are 1 part acid to 6 of water (by volume). The acid must be added to the water slowly and with great caution, on account of the heat generated; the final density of the solution (1.170 specific gravity) must be read when the solution has cooled. An earthenware crock or a lead-lined tank may be used for mixing; a wooden vessel which has not been used for other purposes, such as a new washtub, is also suitable. *The electrolyte must be cool when poured into the cells.*

92. The switchboard and batteries must be fully installed and wired up, except connecting to the instrument circuit before filling the batteries with the electrolyte. Cover the plates to a depth of one-half inch.

93. *Initial charge.*—The charge should be started at the normal rate, 3 amperes, as soon as the electrolyte is in the cells, and continued at the same rate, provided the temperature of the electrolyte is well below 100° F., until there is no further rise or increase in either the voltage or specific gravity and gas is being freely given off from all the plates; also the color of the positive plates should be a dark brown or chocolate, and the negatives a light slate or gray. The temperature of the electrolyte should be closely watched, and if it approaches 100° F. the charging rate must be reduced or the charge stopped entirely until the temperature stops rising. From 30 to 40 hours at the normal rate will be required to complete the charge, but if the rate is less the time will be proportionately increased. The specific gravity will fall somewhat after the electrolyte is added to the cells, and will then gradually rise as the charge progresses, until it is up to 1.210 or thereabouts. The voltage for each cell at the end of charge will be between 2.5 and 2.7 volts, and for this reason a fixed or definite voltage should not be aimed for. *It is of the utmost importance that the initial charge be complete in every respect.*

94. After the completion of a charge (initial or with the battery in regular service) and the current off, the voltage will quite rapidly fall to about 2.05 volts per cell and there remain while on open circuit, falling to 2 volts when the discharge is started.

95. *Operation—Battery in service.—Excessive charging must be avoided, nor must a battery be undercharged, overdischarged, or allowed to stand completely discharged.*

96. The battery should be preferably charged at the normal rate. *It is important that it should be sufficiently charged, but the charge should not be continued beyond that point.* Both from the standpoint of efficiency and life of the plates, the best practice is the method which embraces what may be called a *regular charge*, to be given when the battery is from one-half to two-thirds discharged; that is, charge at the normal rate until the number of ampere hours charged exceeds the preceding discharge by from 5 to 15 per cent.

97. Once in a while an overcharge should be given, the charge being continued until no rise in the voltage across the battery is shown for five successive 15-minute readings (thus indicating that it is at a maximum) and all cells are gassing freely.

98. On *discharge* the voltage should not be allowed to fall below 1.75 volts per cell, with current at normal rate; the limiting voltage, however, is higher if the rate is less than normal, and lower if the rate is more than normal.

99. *Inspection.*—Once every week before charging a specific gravity reading of all cells should be taken, and likewise all cells should be carefully examined to see that the plates are not touching each other or otherwise short-circuited and have normal color. The terminals should also be watched for corrosion of the copper and vaseline applied occasionally; also the cells should be kept reasonably free from sediment and the level of the electrolyte maintained sufficiently high. The correction of faults is discussed below.

100. *"Low" cells—Indications and treatment.—Falling off in specific gravity or voltage* relative to the other cells. *Lack or deficiency of gassing* on overcharge as compared with surrounding cells. *Color of plates* markedly lighter or darker than in surrounding cells.

101. In case of any of the above symptoms being noted, inspect the cell carefully for the cause and remove at once. Short circuits are to be removed with a thin strip of hard rubber or wood; *never use metal.*

102. If, after the cause of the trouble has been removed, the readings do not come up at the end of overcharge, the battery as a whole, or preferably the low cell or cells, should receive a separate or extra charge.

103. *Impurities* in the electrolyte will also cause a cell to work irregularly. Should it be known that any impurity has gotten into a cell, the impurity should be removed at once. In case removal is delayed and any considerable amount of foreign matter becomes dissolved in the electrolyte, this solution should be replaced immediately, thoroughly flushing the cell with water and putting in new electrolyte. The change should be made when the battery is discharged and just before charging. If in doubt as to whether the electrolyte

contains impurities, a half pint sample, taken at the end of discharge, should be submitted for test. The Electric Storage Battery Co. will analyze and report on, free of charge, samples received at the works, with transportation charges prepaid.

104. *Sediment.*—The accumulation of sediment in the bottom of the jars must be watched and not allowed under any circumstances *to get up to the plates,* as, if this occurs, rapid deterioration will result. To remove the sediment, the simplest method is to lift the couples out of the jars after the battery has been fully charged, draw or pour off the electrolyte and then dump the sediment, clean the jars and get the couples back and covered with electrolyte again as quickly as possible, so that there will be no chance of the plates drying out. Electrolyte, not water, will be required to complete the filling of the cells, the specific gravity being adjusted to standard (1.205 to 1.215 at the end of charge) at the same time.

105. *Evaporation.—Do not allow the surface of the electrolyte to get down to the top of the plates;* keep it at its proper level (one-half inch above the top of the plates) by the addition of *distilled water*, which should be added at the beginning of a charge.

106. *Restoring lowered specific gravity.—It will not be necessary to add new electrolyte, except at long intervals*, or when cleaning out sediment. When the specific gravity with the cells in good condition and at full charge and normal temperature (70° F.) has fallen to 1.190, it should be restored to standard (1.205 to 1.215) by the addition of new electrolyte instead of water when replacing evaporation. To correct to normal temperature, subtract one point (0.001 specific gravity) for each 3° F. below 70° and add one point for each 3° F. above 70°; for instance, electrolyte which is 1.213 at 61° and 1.207 at 79° will be 1.210 at 70°.

107. *Instructions for using voltmeters.*—Voltmeters of the type shown in Figure 14, are furnished for use at stations in testing 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.

108. When tests are made the voltmeter may be best placed on some convenient surface near by and connected to the cell or battery by short lengths of wire. The negative side of the battery or cell must be connected to the binding post of the voltmeter marked N and the positive pole to the post marked P. The scale reading of the needle, when it has come to rest, shows difference of potential across the terminals of the battery and approximately the value of the electromotive force impressed on the circuit.

109. The voltmeter should never be connected to an electric light circuit, or to a battery of many cells, the voltage of which is likely

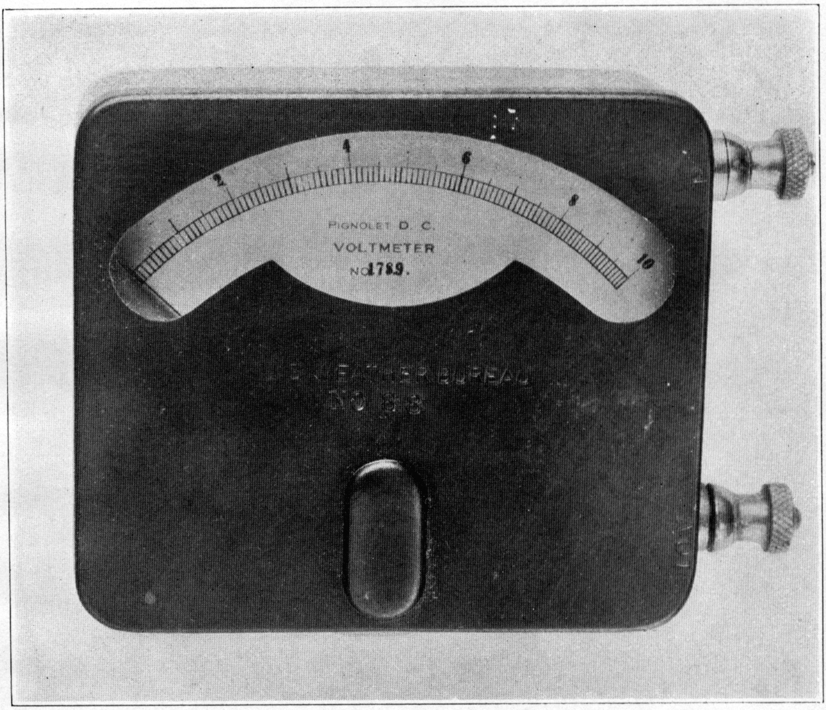

FIG. 14.—Battery voltmeter.

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.

110. 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.

VII. ELECTRIC LIGHTS FOR INSTRUMENTS.

111. *Electric lights are required* for convenience at the instrument shelter and at a point near the rain and snow gages. Special attention, also, should be given to the lighting of the barometers. Wiring for the same should in general be in conduit; one-half-inch conduit is sufficient for two No. 14 wires. Good installations may be made in accordance with the sample specifications given below, but a simpler and cheaper lamp support at the rain-gage can be made from conduit as shown in Figure 5.

112. *Conformity to National Electrical Code.*—The electric light and instrument wiring should conform to the rules and regulations of the city in which the station is located, and in general to the National Electrical Code. Under no circumstances are electric light and instrument wires to be run in the same conduit.

VIII. PROTECTION AGAINST LIGHTNING.

113. *Grounding of instrument towers.*—It is advisable to ground wind-instrument towers, and wind-vane and anemometer supports, to protect the wiring thereon and more especially the connected instruments located in the office. When the tower has a ground exposure, a piece of one-half-inch copper cable may be used for the earth connection, the upper end of the cable fastened to the tower by means of a solderless connector which should be bolted to one of the corner posts near the foot plate. The lower end of the cable must reach soil which is permanently moist.

114. For detailed description of methods used in lightning protection see Farmers' Bulletin No. 842.

115. *Grounding of roof equipment.*—Towers and supports when located on the roof should be grounded to some part of the roof or building that is itself well grounded, or in some cases it may be necessary to run a cable direct from the tower down the outside of the building to a suitable ground at some convenient point.

116. Following are specifications, somewhat modified from the original, for the wiring at one of the observatory stations where the wind instruments and the sunshine recorder alone were given a roof exposure, the balance a ground exposure, which necessitated the use of lead-covered cable for the latter.

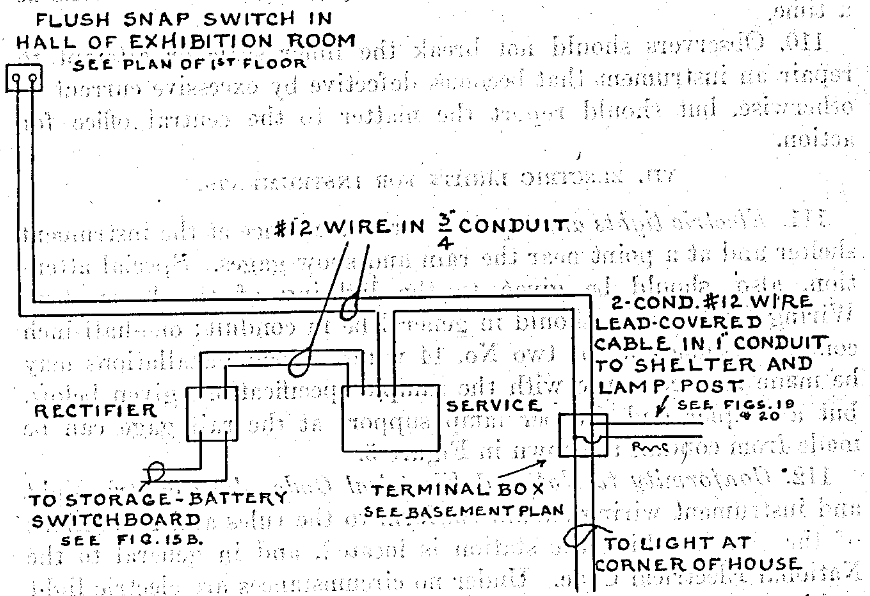

FIG. 15A.—Electric-light circuits for instruments and rectifier, Observatory, Cincinnati, Ohio.

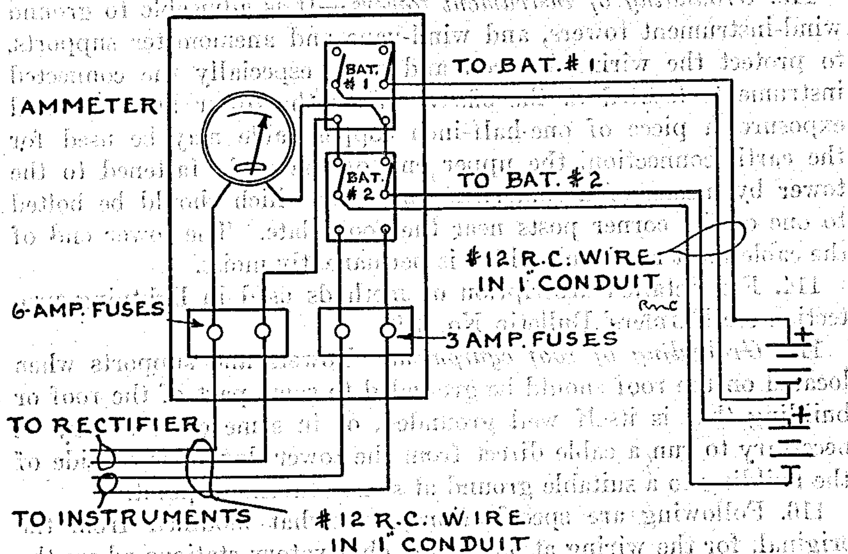

FIG. 15B.—Battery, switchboard and circuits, Observatory, Cincinnati, Ohio.

IX. SPECIFICATIONS FOR CONDUIT, ELECTRIC WIRING, ETC., FOR INSTRUMENTS AT WEATHER BUREAU OBSERVATORY BUILDING, CINCINNATI, OHIO.

117. *Conduit for instrument wiring.*—All conduit for interior work will be black; for exterior work sheradized.

118. Run 1-inch conduit from instrument stand to basement; 1-inch from basement to penthouse, terminating the same in the foot of the wind vane and anemometer support; ¾-inch conduits from switchboard near rectifier to end of first-mentioned 1-inch conduit, and from same switchboard to battery; all as indicated in wiring diagram and plans. All conduit shall be so installed as to permit of rewiring or such future changes as may be necessary. All conduit joints will be carefully leaded to make water-tight and no traps for water permitted.

119. *Wiring.*—Run nine conductors from the instrument stand without break through the 1-inch conduit to the contact box in the wind-vane support; a second nine wires from the stand to the basement, where two battery leads extend to the switchboard, and connection is made to a 7-conductor lead-covered cable extending across basement to walls and thence to rain gage and telethermoscope in instrument shelter. Run four conductors through 1-inch conduit from rectifier switch to end of 1-inch conduit in basement; also four conductors from batteries to rectifier switch; all as shown in Figures 15 to 19, inclusive, wiring diagrams. No. 16-gage heavy rubber-covered fixture wire will be used for all drawn wires in conduits and No. 16 lead-covered cables.

120. *Wind instruments and sunshine recorder.*—Connect the five wires to the wind-vane contacts, and from the box run 2-conductor lead-covered cables to the anemometer on the cross arm and to the sunshine recorder, also placed on a cross arm attached to the wind-vane support.

121. *Telethermoscope and rain-gage.*—From a short distance within the basement wall of the building extend the 7-conductor lead-covered cable in a trench 30 inches deep to a point beneath the instrument shelter. From the bottom of the trench inclose the cable in 1¼-inch conduit, terminating same in a PJX condulet placed about 20 inches below the bottom of the shelter. Wire thence in ½-inch conduit to the telethermoscope in the shelter, using three No. 16 single-braid rubber-covered wires, the end of the conduit to be about 12 inches below the center of the shelter roof, all conduit and wiring so disposed as not to interfere with the instruments. Form the wires into a neat handmade cable, carefully soldering the three connections to the telethermoscope as described in separate leaflet.

122. Wire with 2-conductor lead-covered cable to the tipping-bucket rain-gage; in ¾-inch conduit from the PJX condulet beneath the shelter to bottom of 30-inch trench, thence without conduit to end of walk, about 16 feet distant, (see fig. 19). Continue cable upward from trench through ¾-inch conduit upright with gooseneck at top, the conduit securely embedded at its lower end in the concrete walk.

123. The distance from the basement wall to the foot of the instrument-shelter support is about 56 feet; from the bend of the conduit below ground at the foot of the shelter support to the floor of the shelter, 13 feet.

124. *Conduit and fittings for electric lights.*—Run 1-inch sherardized iron conduit with water-tight fittings throughout, from the basement through openings already provided, to the foot of the instrument-shelter support in the yard. Provide at this point a sherardized T condulet or equivalent, securely fastened to the shelter support. Continue ¾-inch conduit up the leg of the

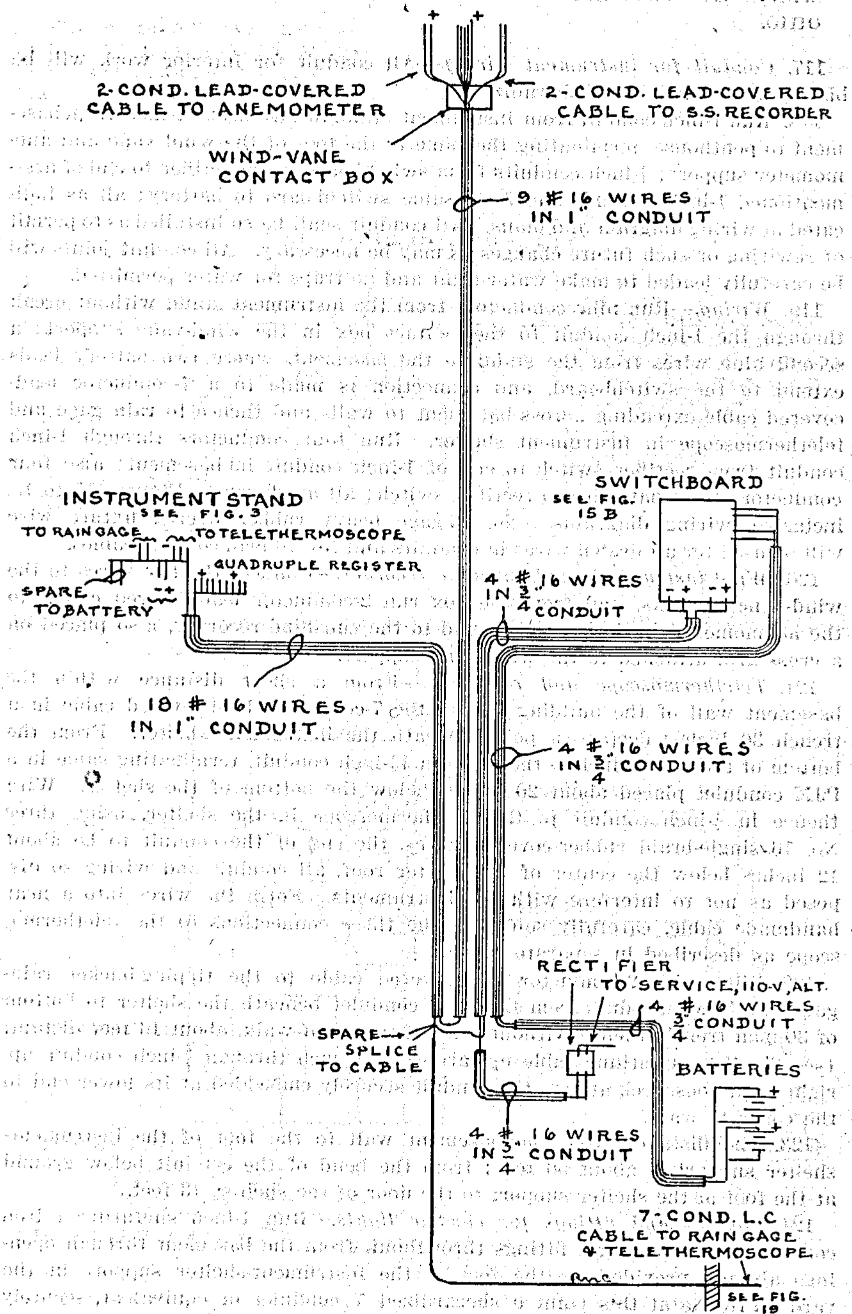

FIG. 16.—Wiring diagram, instrument circuits, Observatory, Cincinnati, Ohio.

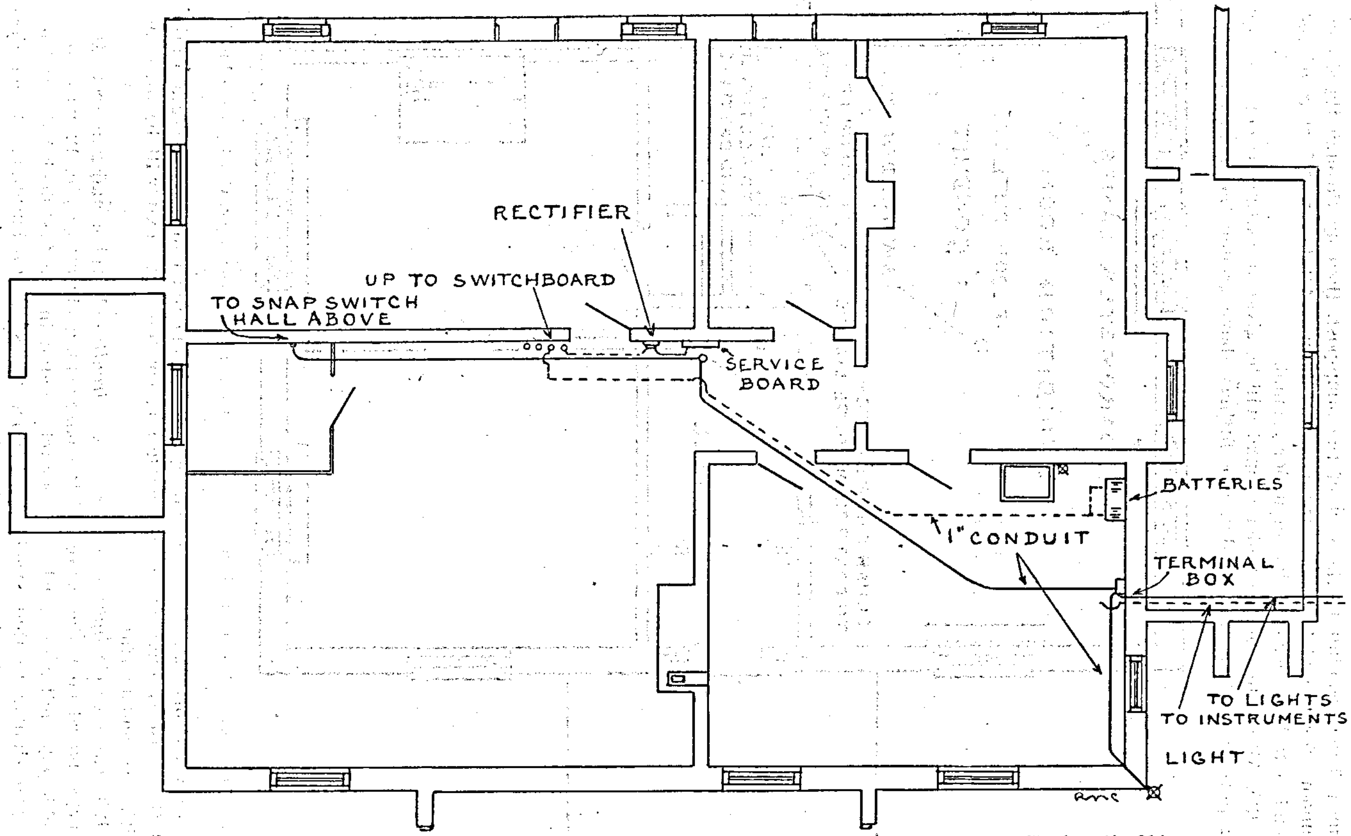

FIG. 17.—Basement plan showing electric-light and instrument conduits, Observatory, Cincinnati, Ohio.

shelter support to the inside of the shelter, and provide conduit fittings for the snap switch and lamp receptacles (see fig. 20). From the condulet also run a 1-inch conduit to the foot of the lamp-post, then up through the 4-inch support for the globe to the incandescent lamp. All horizontal runs of the conduit to be at least 30 inches under ground.

125. All conduit placed under ground will be given a coating of hot coal tar or pure asphaltum, and conduit and fittings above ground thoroughly painted

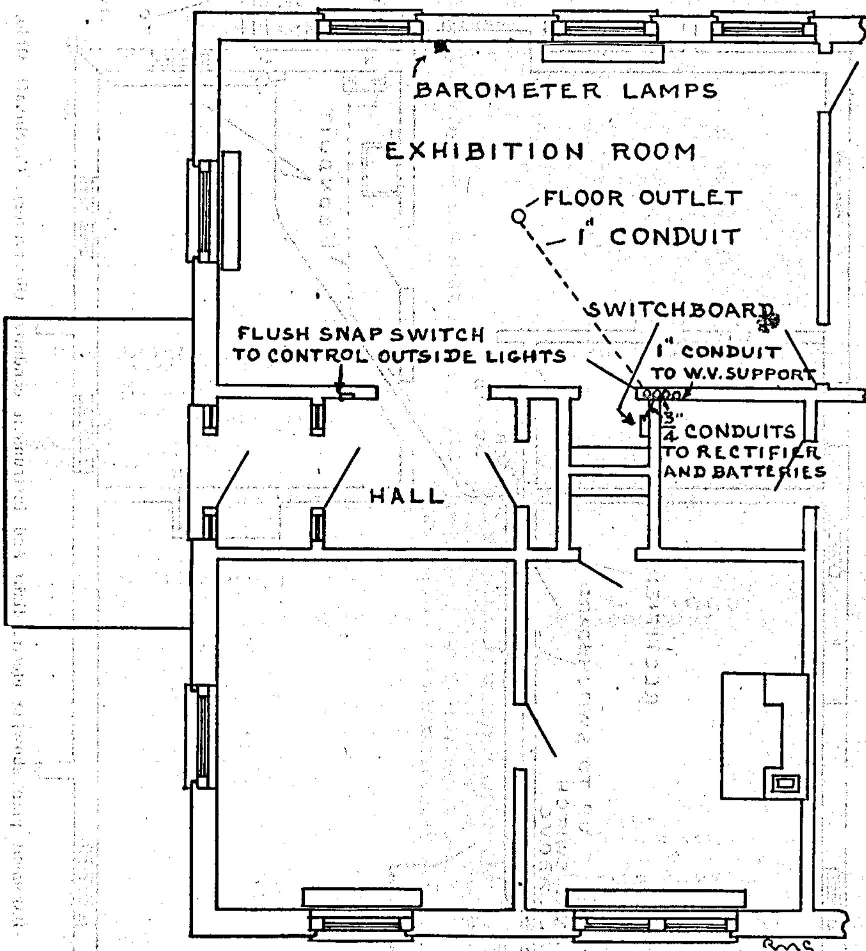

FIG. 18.—First-floor plan showing instrument circuits, Observatory, Cincinnati, Ohio.

to prevent corrosion. The 5-inch by 10-inch openings in the concrete walls of the house through which the cable and conduit have exit will be filled in with a cement mortar.

126. *The electric lighting and rectifier circuits.*—Furnish and run from the service board near the center of the basement a circuit of No. 12 wire to a double-pole indicating flush snap switch located in the first-floor hall, and of a type similar to that specified in other parts of the building. From the switch run the circuit to a terminal box at the beginning of the conduit in

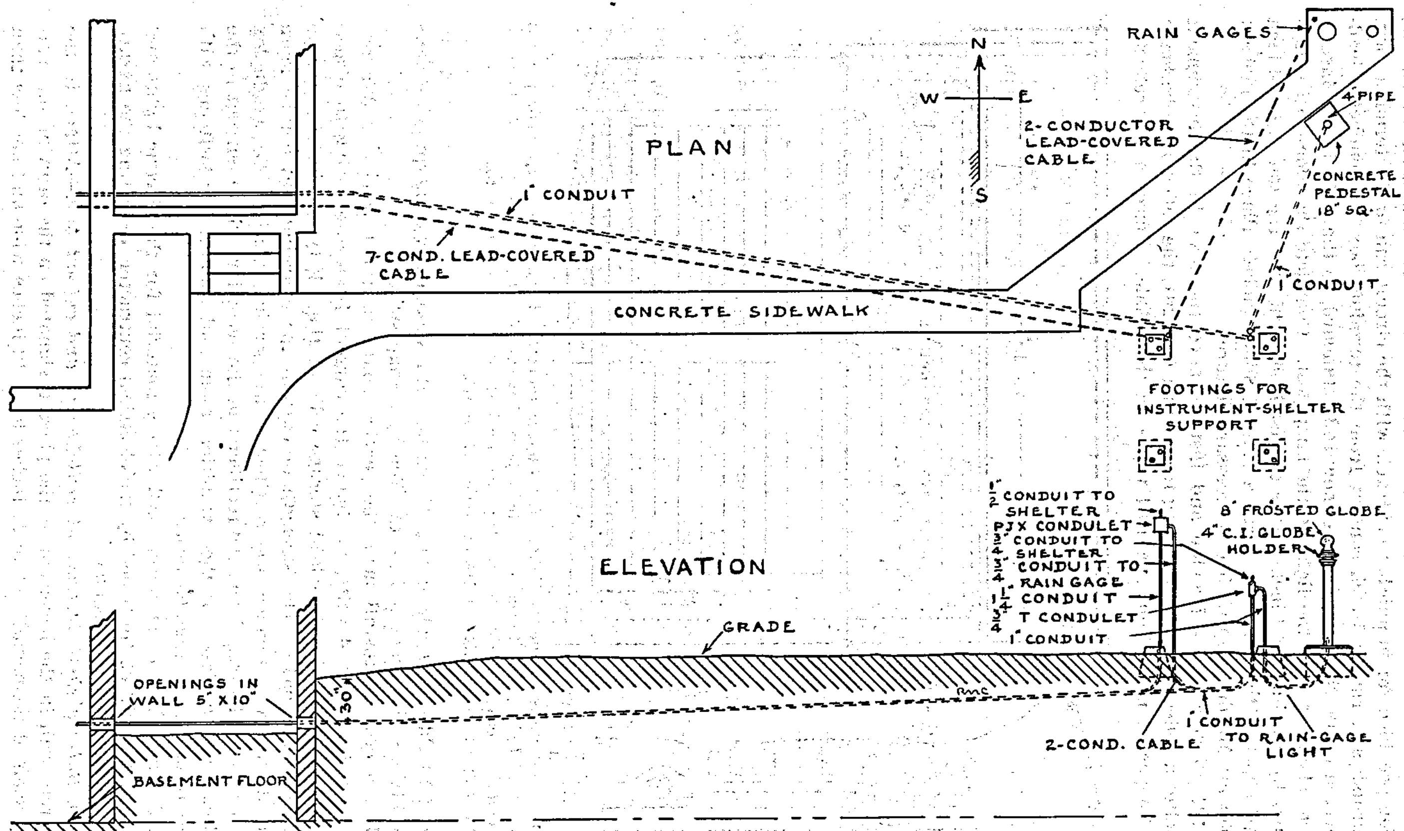

FIG. 19.—Conduits and wiring from Observatory to instrument shelter and rain gages, Cincinnati, Ohio.

the basement. Connect the light on the corner of the building, which has been provided for in another contract, with the circuit run to the terminal box. Furnish and run in 1-inch conduit from the terminal box a 2-conductor lead-covered cable, No. 12 solid wire, new code standard, to the light in the instrument shelter and to the light on the lamp-post. Complete the lamp-post equipment by providing a 4-inch holder of cast iron to fit over the top of the 4-inch pipe support, the holder to carry a frosted 8-inch globe. Place in the globe a 100-watt Mazda lamp with the necessary fixtures.

127. *Shelter light.*—Provide and install above the door in the instrument shelter a reflector made according to drawing (fig. 20), the reflector to be made of copper 31 inches long, painted white on the inside. Place in the reflector

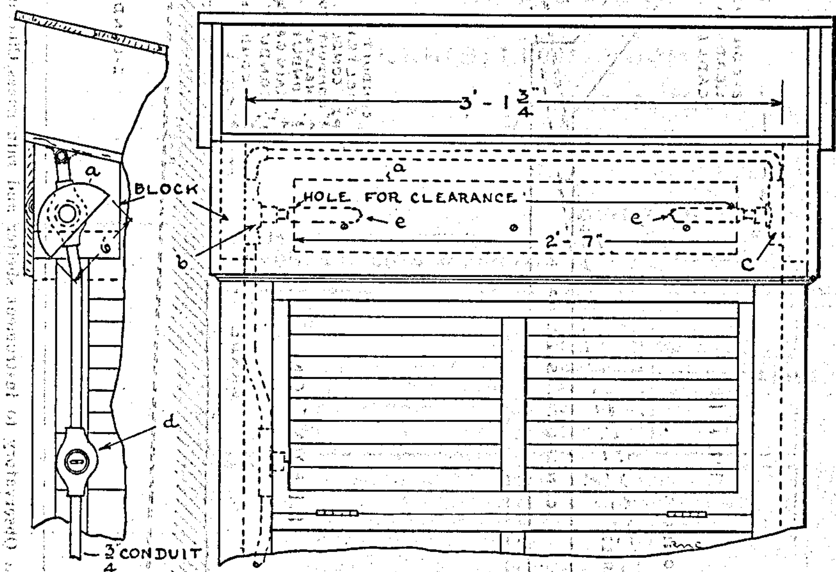

FIG. 20.—Details of shelter lights: (*a*) Copper reflector, 14-ounce copper, inside painted white; (*b*) type G, Form 5, condulet body, keyless receptacle; (*c*) type H, Form 5, condulet body, keyless receptacle; (*d*) type G, Form 5, condulet body, with snap-switch; (*e*) T-10 Edison Mazda lamp, 25 watts.

two T-10 Edison Mazda lights, 25 watts, with standard weatherproof sockets and fittings, the lamps to be controlled by a snap switch.

128. *Rectifier.*—Install near the service board in the basement a Wagner rectifier, type 5 B, 4 volts, to change the current from alternating to direct, suitable for charging two lead storage cells of the PT type, Electric Storage Battery Co.'s make. The strength of current for charging will not be more than 3 amperes. Connect the rectifier to the service board by No. 12 duplex rubber-covered wire. From the rectifier run the secondary direct current to the switchboard in closet off the exhibition room and connect the switches with their respective storage batteries.

129. *Furnishing of material.*—All wiring material for the electric lights and instruments will be furnished by the electrical contractor, excepting the fixture wire and lead-covered cables.

130. *Battery shelf, instrument switchboard and cut-out box.*—Attach to the concrete wall in the basement at the place designated on the drawing one battery shelf of nonmetallic slate 24 inches long, 12 inches wide and not less than

three-fourths inch thick, the shelf to be fastened to the wall by suitable brackets. Provide two light wooden sand trays 1½ inches deep and 7 inches square, inside measurements, one for each storage battery.

131. Provide and install in the closet connected with the exhibition room two 15-ampere, double-pole, double-throw baby knife switches, Bryant or equivalent, two Edison standard porcelain plug-fuse cut-outs with covers and fuses, and one ammeter of the type used with the Wagner rectifier, all mounted on a slate base and placed in a metal cut-out box, the box to be at least 18 inches wide, essentially as indicated in the wiring diagram of instrument circuits.

132. *Barometer lamps.*—Provide two outlets for barometer lamps one above the other in a vertical line and spaced 30 inches apart, the lower one of the two to be placed 26 inches above the finished floor, and at a point designated by the Weather Bureau. Use "Bossert" boxes No. 174 (3¼ inches diameter by 1⅝ inches deep), to fit Faries wall brackets No. 3112, the latter to be altered if necessary by cutting off the horizontal tubing to bring the vertical axis of the lamp 5 inches from the wall. Place fixtures so that the tip end of lamp is up.

133. Each lamp will be 25-watt tungsten and shaded with a paw-shaped shade with 2¼-inch holder. The finish will be the same as other fixtures in the room.

134. Provide one flush wall switch of the style specified for the remainder of the building, the switch to control both lamps, and placed midway between the two brackets.

135. *Inspection.*—The wiring must be first-class in every respect and subject to the inspection of the local Weather Bureau official before acceptance, and done in conformity with the Cincinnati Fire Prevention Bureau regulations. The contractor will be responsible for any damage done to the property through the carelessness of workmen engaged on the job.

136. *Concrete work.*—Construct, where shown on plans, four concrete plinths to support the instrument shelter. These plinths shall be 12 by 12 inches on the top and 18 by 18 inches at the bottom, the top surfaces level with the surface of the adjoining sidewalk, and they shall extend 18 inches into the ground, or farther if necessary, to secure a solid foundation. Set in the top of each post where directed two ½-inch galvanized bolts with cast-iron washers, with head down, and with the nut end 2 inches above the finished surface of the post.

137. Construct a concrete foundation, as shown on drawing, for the electric lamp-post, 12 by 12 by 18 inches deep, with the top surface set level with the surface of the adjoining sidewalk. In the center of the foundation embed a 4-inch galvanized, standard wrought-iron pipe, so that the top of the vertical pipe is 4 feet above the ground.

138. All concrete to be made up of 1 part Portland cement, 3 parts clean sharp sand, and 5 parts clean broken stone or gravel.

GLOSSARY.

Ampere. The practical unit of electric current flow; one coulomb per second; the unvarying current which when passed through a solution of nitrate of silver in water, according to certain specifications, deposits silver at the rate of 0.001118 grams per second.

Battery. A combination of cells.

Box, distributing. Any box from which branch circuits are run.

Box, floor. A metal box with cover used as an outlet for conductors run in conduit beneath the floor.

Box, junction. A box where connections are made from one circuit to another. A distributing box is usually a junction box.

Box, panel. A rectangular-shaped box usually of pressed steel fitted with a door, which is set in a recess in a wall so that the door is nearly flush with the surface.

Box, pull. Pressed-steel boxes of rectangular or circular cross section placed in conduit systems to facilitate the drawing or pulling through of wires.

Cable, handmade. A cable of wire formed into shape to fit certain connections or to make possible more ready handling. Moderately heavy waxed linen cord is employed in making the cable.

Cable, lead-covered. Two or more insulated wires protected by a continuous coating of lead usually about one-sixteenth of an inch thick.

Cable, Okonite. Two or more wires protected by an armor or sheathing of tape and insulated with Okonite, a trade name for an insulation made by the Okonite Co.

Cable, weatherproof. Two or more insulated wires covered with braid and all saturated with a dense, moisture-proof compound.

Cell, primary or voltaic. A combination of two different conducting materials immersed in a liquid or electrolyte which acts chemically on one of the materials more readily than on the other, and which produces a current of electricity when the two materials are connected outside of the liquid by a conductor.

Cell, storage, *or* **secondary.** A combination of two relatively inactive plates or electrodes of metals or metallic compounds immersed in an electrolyte which will not act on the plates until an electric current has been forced through the electrolyte from one plate to the other.

After the plates have been altered by this so-called charging current, upon completion of an external circuit the cell acts as a source of electrical energy until the plates approximately return to their original chemical condition.

Circuit, open, *or* **broken.** A circuit the conductors of which become separated at some point or points either intentionally or accidentally, with a resultant interruption of the current flow.

Circuit, closed. A circuit through which electric current is flowing continuously.

Conduit, black *or* **enamelled.** Rigid metallic conduit protected against corrosion by black-enamel paint, oven-baked.

Conduit, flexible. Conduit formed of spirally wound strip steel to secure flexibility, galvanized for protection against corrosion, the joints of the spiral made in such a manner as to be nearly waterproof (use only for interior wiring).

Conduit, rigid metallic. Standard steel pipe in lengths of 10 feet threaded at both ends, the interior free of any obstruction to the drawing of wires and protected against corrosion by enamel paint or by galvanizing or sheradizing.

Conduit, sheradized. A form of rigid metallic conduit, coated with zinc by inclosing in a retort with powdered zinc dust, heating to a suitable temperature, and then cooling gradually.

Compound, waterproof. A liquid for painting wires or taped joints to protect against moisture.

Condulets. A trade name for iron fittings, usually cast, of a large variety of forms, employed in connection with rigid conduit for electric wiring.

Coulomb. The quantity of electricity, transferred by a current of one international ampere in one second.

Couples. A pair of lead storage-battery plates, one positive and one negative, permanently joined together by a lead strap forming the electrical connection from one plate to the other when the plates are immersed in the electrolyte.

Current. The adjustment, or effects of a continuous attempt at readjustment, of potential difference by a conductor. Potential difference is measured in volts; rate of flow of current in amperes; quantity by coulombs.

Electrodes. The terminal of an open electric circuit. The terminals of the metallic or solid conductors of an electric circuit, immersed in an electrolytic solution.

Electrolyte. A liquid susceptible of decomposition by the electric current and capable of electrolytic conduction.

Electromotive-force. The cause which produces electric current. The practical unit is the volt.

Fuse. A wire bar or strip of fusible metal inserted for safety in an electrical circuit. When the current increases beyond a certain safe strength, the fuse melts, interrupting the circuit and thereby preventing possibility of damage.

Fuse, plug. A fuse made part of a plug to be screwed into a receptacle in a manner similar to an electric lamp.

National Electrical Code. Regulations of the National Board of Fire Underwriters governing electrical installations as regards both methods and apparatus. The code, or modifications of it, has been adopted as law to a large extent.

Ohm. Unit of electrical resistance, represented by the resistance, offered to an unvarying electric current by a column of mercury at the temperature of melting ice, 14.4521 grams in mass, of a constant cross-sectional area, and of the length of 106.3 centimeters.

Plate, negative. That plate of a storage battery which is connected with the negative terminal of a charging source, and which is therefore the negative pole of the battery on discharging.

Plate, positive. That plate of a storage battery which is connected with the positive terminal of a charging source, and which is therefore the positive pole of the battery on discharging.

Plate, terminal. The positive or negative plates of a storage battery to which connections are made to an external circuit.

Shunt, spark. A coil of wire wound noninductively, connected across a circuit in parallel with an electromagnet to prevent sparking of the contact points of an interrupter in the circuit.

Tape. A form of insulation for covering electric wires, especially at joints. The material can be plain rubber, cotton, or cotton impregnated with adhesive rubber preparations, or cotton treated with varnishes.

Volt. The unit of electromotive force or potential difference.

Wire, fixture. A rubber-insulated copper wire ordinarily used for wiring fixtures, solid or stranded, No. 16 or 18 A. W. G., and covered with braid at least 1/64 of an inch thick.

Wire, gage of. The size of all copper wire is given in the American or Brown & Sharpe wire gage.

Wire, rubber-covered. The grade of insulated wire commonly used in interior conduits. The rubber covering is ordinarily held in place with one or two layers of cotton braided on.

Wire, slow-burning. An insulated wire especially designed for use in hot, dry places. The insulation consists of three braids of cotton, all the interstices filled with material having fire-resisting and insulating properties.

Wire, solid *or* flexible. An insulated copper conductor, either made with one wire or, if flexible, of several smaller wires of equivalent cross section.

Wiring, concealed. Wires drawn through conduits within the walls or floors of a building as distinguished from wiring in molding or open work.

Wire, weatherproof. For use outdoors where moisture is certain and where fireproof qualities are not necessary. The insulation consists of at least three braids of cotton, all of which must be thoroughly saturated with a dense moisture-proof compound.

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