the child. It is not necessary that these plants should grow only in the throat of the patient; the fact is, they may and often do grow wherever the skin or the mucous membrane has been either destroyed or seriously injured. Physicians have had diphtheritic sores occur even on the back of the hand or other parts of the body (remote from the nose or mouth) where the skin has been broken.

To remove the plants themselves which are producing this poison, and the consequent disease symptoms, may be, and often is, extremely difficult and well nigh impossible; and the disease runs its course, often with fatal results. If we can introduce into the system before much damage has been done some substance that will neutralize the action of the toxin or poison, we, of course, can prevent further extension of disease and save the patient; and such a substance we have in our antitoxin, which is dissolved in the serum administered. It may be that later we shall even separate the antitoxin from the serum produced in the blood of the horse or other animal and administer it in aqueous solution, but at present it is more practicable to not attempt such separation.

This treatment of the dread disease of diphtheria has been in use but very few years—not more than four, at most. In that time most encouraging results have been obtained. From all over the world reports have come testifying as to its efficacy, but it must be used early in the course of the disease to be of benefit; for if the toxin has been introduced in sufficient quantities and has acted long enough to destroy the tissues, the antitoxin has no power to restore or repair the latter. If we can administer it before the second or third day of the disease, great hopes are to be had of success. If its administration does not take place until after the fourth day, the chances are that its employment will be of no avail and that the results of the disease will be practically the same as if it had not been employed.

Not only have individual physicians given their testimony as to the efficacy, but the results obtained from large communities and the statistics that involve an immense number of cases show that there is no doubt, no matter what may be said to the contrary, of the great value of this discovery. The following statistics from the Philadelphia Medical Journal as to the deaths from this disease in Paris, Berlin, and other of the larger German cities prove this beyond a doubt:

Year.	Berlin's Diphtheria Deaths.	Paris' Diphtheria Deaths.	Absolute Number of Deaths from Diphtheria in German Towns of Over 15,000 Population.	Paris' Diphtheria Deaths per 1,000 Living.
1886	1,662	1,512	12,211	6.7
1887	1,392	1,585	10,970	7.0
1888	1,195	1,729	10,142	7.6
1889	1,210	1,706	11,919	7.5
1890	1,601	1,688	11,915	7.3
1891	1,006	1,361	10,484	5.6
1892	1,342	1,403	12,365	5.8
1893	1,637	1,206	16,557	5.1
1894	1,416	1,009	13,790	4.2
1895	987	435	7,611	1.8
1896	559	444	6,262	1.8
1897	546	300	5,208	1.2

You can see from the above table how, up to the end of 1894, there was not in Berlin (which is about the size of Philadelphia) or in Paris (which is larger) a year in which the deaths from diphtheria did not number more than a thousand. From then on they began to fall, although the population of the cities was increasing, until in 1897 in Berlin there were only 546 deaths, where four years before there were 1,416, and in Paris 300 deaths, as against 1,009 in 1894. The figures in the right hand column of the table give simply the deaths (from diphtheria) that occurred to every thousand people who lived in Paris, and refer to said city alone. This shows you that the rate in that city has fallen to about one-sixth of what it formerly was.

In addition to the above, a recent Medical News refers to the use of antitoxin in Chicago for the last twenty-seven months as reported by the Chicago Board of Health. About the first of October, 1896, there began to be a very serious epidemic of diphtheria in Chicago, now one of the largest cities of the world. The Board of Health soon became alarmed and took stringent measures for its suppression; that is, they instituted a thorough inspection of the city and began to inoculate every case reported with the antitoxin except where restrained by the action of foolish persons in families where the disease occurred. From October 5, 1896, until the last of December, 1898, there were reported to the board 5,739 cases of possible diphtheria. Not all cases reported to a Board of Health as diphtheria are diphtheria; and they have to be proved as to their identity by bacteriological test. Of these 5,739 cases, 3,956 were found to be true diphtheria, and all but 134 of these were treated with the antitoxin. Out of the 3,822 patients thus inoculated, 3,563 recovered and only 259 died, that is, only 6.7 per cent. Heretofore, for the entire period of the history of the Chicago Board of Health, they had never been able to keep the death rate from diphtheria in that city below 35 per cent. In fact, almost every text book on the practice of medicine published before 1895 will give the death rate from diphtheria, no matter what the treatment, as necessarily being from 30 to 40 per cent.

Now suppose we should have 35 per cent. of these 3,822 patients who were sick and who were inoculated with antitoxin die. That would have made 1,337 deaths instead of 259 deaths from the disease in Chicago in the last twenty-seven months. There is another thing that is noticeable; if you inject this antitoxin serum into a person who has been exposed but a short time before to diphtheria, he will not get the disease; just as if you vaccinate a person who has been exposed to smallpox, he will be protected for a considerable time against that disease. Formerly, where people lived in the same house with diphtheria patients, or were directly exposed to diphtheria, it was found that almost one out of every two would get the disease; and especially this was true among children. The Chicago Board of Health not only inoculated the 3,822 sick persons mentioned, but they also inoculated 3,633 children and others who did not have the disease but who had been directly exposed to the infection; and of these,

instead of 1,800 getting sick, as would have probably happened in the old way, only thirty got sick and not a single one died. Under the old regime, if there had been 1,800 sick, 35 per cent. would have died and then we would have had to add 630 to the 1,337 others; in other words, in the twenty-seven months, through antitoxin, in Chicago, there were saved over 1,700 lives. This is one of the most remarkable evidences one could desire of the value of this discovery; and in cities of over a million inhabitants each, you can easily see what a great advance has been made in the caring for and wiping out of this one disease.

Certainly, there is nothing more brilliant, more hopeful for humanity, than this discovery of antitoxin; and as it is probable, as I have indicated, that similar discoveries regarding other diseases will shortly be made and be practically applied, with results as satisfactory as the above, we should be correspondingly hopeful for the future.

Certain it is that such a saving of human life ought to justify the sacrifice of the lives of many animals which had to be made to bring the discovery to its perfection and safety of application. I know that the statement has been made that the sacrifice of animal life has been of no value, has not saved human life; and the same people say that the deductions are false, and that these statistics are not of value; and yet there has been no change, as far as I know, in the treatment of diphtheria, other than in the use of antitoxin; and there is no other way of explaining the wonderful reduction in the death rate, from what has been one of our most dreadful diseases, than by the assumption that it was due to this discovery.

In regard to the diagnosis of diphtheria in the city of Philadelphia, we have in the City Hall a bacteriological laboratory which is doing a great deal of good work. Suppose a doctor is called in to see a case of diphtheria or probable diphtheria. There are not many doctors

and in that way a great many deaths may be prevented; whereas, a few years ago, we had to wait a few days to see how things developed, and often it was then too late to save the patient.

As far as we know, the antitoxin produces transient immunity, lasting several weeks. Vaccine immunity lasts a long time. We are finding out in regard to vaccination that it is not surely protective for a lifetime, in some cases only for eight or ten years. The wise man who is going to be subject to infection from smallpox will get vaccinated every time he is exposed to the disease. Every child ought to be vaccinated; and every young person ought to be revaccinated at the age of eighteen or twenty. We have so little smallpox in a city like Philadelphia (only one or two cases a year, or, sometimes, no cases in a year) that we are really running no very great danger if we are not vaccinated frequently after we are grown up, unless an epidemic occurs, when everybody should be revaccinated.

I trust that I have said enough in this talk this evening to make you all feel that little things are not to be despised and that we have possibly had too harsh an opinion of bacteria in the world at large. There is no doubt that we are just on the threshold of the science; and that, within a very short time, we shall have many discoveries which will heighten our appreciation of their uses and which will enable us to make our living more comfortable, more satisfactory, and more safe than it has been in the past.

THE CONSTRUCTION OF A VOLTMETER AND AMMETER SUITABLE FOR A SMALL SWITCHBOARD.

By NEVIL MONROE HOPKINS.

DYNAMO and motor tending, unaccompanied by suitable means for reading the voltage value, current

VOLTMETER.

that can diagnose diphtheria every time and surely, because, sometimes, mild cases may be overlooked and at other times cases of tonsillitis are erroneously diagnosed as diphtheria. The only way to secure an exact diagnosis is to make a bacteriological test. The bacteriological laboratory supplies a little box, containing a tube of sterilized culture medium (blood-serum) and a sterilized swab (in another tube) to any physician upon application; these boxes may also be had at any time at any of the police stations in the city.

When a doctor is called to a doubtful or suspected case of diphtheria, he accordingly sends for one of these outfits; but, if he is wise, he will probably inoculate the patient with a dose of the antitoxin serum while waiting for the box or, at least, before the test is completed.

When he gets the paraphernalia just described, he puts the swab into the patient's throat, touches the false membrane with it, and then moves the swab around over the surface of the culture medium, puts the soiled swab into its own tube, replaces the plugs in both tubes, and sends the box and its contents down to the laboratory or to the nearest police station, from which there is a collection made twice daily. Upon its arrival at the bacteriological laboratory, the culture tube is put at once into the incubator, which is kept at the body temperature. By the next morning, if there are any bacteria there, they will appear on the surface of the culture medium. The doctors who are there will take a little out, examine it, and determine by the microscope whether it is the true diphtheria plant or not. If it is, they will send at once to the physician in the case a notification of it or, if telephoned, they let him know by telephone; so that he knows positively within twenty-four hours whether it is a case of diphtheria or not and can act accordingly. If it is not, well and good; if it is, he has used the antitoxin in good time;

strength, and power, whether for commercial or experimental purposes, places the electrician in charge of a machine in an inefficient capacity, when not in an altogether impossible rôle. As an accompanying equipment for the numerous small motors and generators, the working drawings and designs of which are to be found in the columns of the various technical periodicals, the little indicating instruments described for construction in the following pages are primarily intended. With a sensitive voltmeter placed across the feeders of one of these small machines, the speed of its armature can be "observed" and held constant, and with a delicate ammeter included in its circuit, the very pulse of the machine can be "felt" at any instant of its performance.

It is with the wish of assisting those who have constructed electrical machinery on a small scale that the writer gives the following directions for making simple forms of indicating instruments, and gives instructions for their calibration and care. Instrument making requires considerable skill and nicety of workmanship, and the writer feels that he should impress upon those seeking sensitive and delicate action of their product to work with neatness and care, approaching the exactness of the watchmaker's art as far as possible, not only in turning and polishing the all-important pivots and their little conical seats, but in the entire assembling of all portions and their final adjustment. These instruments, carefully and accurately made, will fully repay one for the time and slight expense incurred. The voltmeter and ammeter are illustrated in Figs. 1 and 2 respectively, with plan and edge views which are the reproductions of working drawings.

The voltmeter, which we will first take up, embodies the well known principle of the old D'Arsonval galvanometer, which has won for itself such universal popularity in fine laboratory measurements. As will be seen,

the fields of this voltmeter are made from a pair of common horseshoe magnets, bolted together, and cored out on the lathe to receive the little moving coil of wire. The readings scales as given in the illustrations are of arbitrary character, and not the result of calibration, which will be discussed later. The most satisfactory way to commence the making of this instrument is the choosing and cutting out of the magnets. For the purpose we will require two 6-inch magnets, measuring from the tips of the poles to the outside curve at the top, chosen well mated, that is to say of the

the best portion of the steel at the poles, they must be separated through a distance of at least $\frac{3}{8}$ inch. This reason will be made clear by a glance at the figures illustrative of the cored-out magnet. This separating is easily accomplished by placing the magnets in a vise in the manner indicated in Fig. 3.

The poles are placed directly against one jaw of the vise, and an iron rod is slipped in between them in such a way that it rests against the second jaw. By holding this rod firmly, and keeping it in a vertical position, when screwing up the vise, the pole pieces can be

the lines of magnetic force to leak between. We can now remove the work from the lathe, but before taking the magnets apart, they must be marked with a file in order that they may be reassembled correctly after tempering and magnetizing. They are now placed separately in the fire for the second time, and raised in temperature to a full cherry-white color, and plunged immediately, poles downward, into a large pail of ice cold water. This most effectually replaces the temper, making the steel so hard that it is not possible to work it afterward, and it is for this reason that the holes for the bolts and scale screws must be very carefully and accurately located beforehand.

In order to replace the magnetism, it is only neces-

FIG. 1.—FRONT AND SIDE VIEW OF SMALL SWITCHBOARD VOLTMETER, MADE FROM HORSESHOE MAGNETS.

same shape as near as possible, in order that they will coincide at the poles when bolted together. Any slight overlapping, of course, is not serious, for the coring out on the lathe after the two magnets are firmly bolted together reduces all vital irregularity, cutting the cylindrical opening from the two thicknesses of steel absolutely true.

The magnets are now placed in a charcoal furnace one at a time, and are raised to a cherry red heat, and allowed to cool slowly in a less intense portion of the fire. This annealing is necessary in order to allow of the cutting out and drilling for the bolts and screws, as the magnets are made from excellent hard steel, and when tempered are worked with the greatest difficulty, if they can be worked at all. Having drawn the temper, and of course incidentally the magnetism, the coring and drilling of the steel is a very easy matter. It will be observed that the poles are separated by a very small gap, in some 6-inch magnets only about $\frac{1}{8}$ inch. In order to make a sufficiently large lathe cutting for the movable coil of wire without boring away

forced apart to almost any desired extent. Having spaced the poles just $\frac{3}{8}$ inch on each magnet, they are carefully placed together in a small hand vise, and firmly clamped for drilling. The position of the holes, which are just $\frac{1}{8}$ inch in diameter, with the exception of the two small ones, is shown in Fig. 4. The upper holes are just $1\frac{1}{2}$ inches from the pole tips, carefully measured, and the third hole is drilled through the center of the curving portion as shown. At an exact distance of $4\frac{5}{8}$ inches from the poles are drilled the two smaller holes which are to receive the screws of the scale plate.

Having completed this drilling, temporary iron bolts must be put in, and their nuts turned firmly on, holding the magnets securely together for the coring out on the lathe. This coring or circular opening must be, as indicated, just $1\frac{1}{4}$ inches in diameter, and is cut with a regular boring tool, with the work bolted on a lathe face plate. The magnets must be so placed on the face plate that the limit of the circular cutting just reaches the poles, leaving no mass of metal there for

sary to draw the magnets separately over the poles of a powerfully excited electromagnet. The horseshoe magnet is allowed to strike the poles of the electromagnet with some little force about midway up, when it is drawn backward and pulled away. This process is repeated about a dozen times with each magnet, and the two are finally laid together, with their like poles, of course, in contact. The electromagnet is best made for and operated with an electric lighting current, and will prove a most useful addition to any experimental shop. The iron cores of this magnet should be at least one inch in diameter, and be provided with bobbins or spools sufficiently large to hold the proper length of wire of the right resistance to be connected direct with the electric circuit. As the most simple application of Ohm's law in combination with the carrying capacity of a given wire and its resistance suffices for making electromagnets of all sizes, it is not deemed necessary to give the space here to detailed directions for different wires and lighting pressures, because of the undoubted ability of the reader to design and make just what he needs in this line himself.

Having the magnets drilled, cored, tempered, and magnetized to such an extent that they will lift two or three times their weight, which is readily accomplished if the electromagnet used was powerfully excited, we can lay them aside for the present, and take up the work, which requires the greatest care and attention.

FIG. 3.—METHOD OF SEPARATING MAGNET POLES.

FIG. 2.—FRONT AND SIDE VIEW OF SMALL SWITCHBOARD AMMETER, SHOWING SIDE IN PARTIAL SECTION.

FIG. 4.—HORSESHOE MAGNET CORED OUT AND DRILLED.

This work consists in making and winding the little movable coil, and in providing it with its steel pivots. The frame of this coil must be light, and preferably of insulating material, in order to eliminate the danger of grounds and short circuits. The material chosen for

the purpose is cardboard, cut with a sharp knife in use with a steel straight edge, from a stiff visiting card. Fig. 5 illustrates the simplicity of making, the two little frames being cut out accurately to size, as shown at A, where the dimensions are marked on the diagram in fractions of inches. At B we have simply a little frame bent to shape, for gluing between the two cut-out frames, which give the whole stiffness and strength as soon as put in combination. At C we have the framing complete, looking at it from its upper edge. The gluing together must be very neatly done, and the work must be absolutely true when finished. Several coats of orange shellac must now be applied inside and out, and when hard, a tiny hole is drilled through the upper left hand corner as shown in the figure at A. The frame is now arranged for winding with its fine wire, which is conveniently mounted for revolving in the lathe as indicated in Fig. 6. Here we have an edge view of the little bobbin at D, mounted between the two nuts, E E, on the bolt, F, which is held in the chuck of the lathe.

We now come to the choice of wire and the winding, which must be governed by the voltage of the machine with which the voltmeter is to be associated. We have on this little frame a space available for wire, $\frac{1}{4}$ inch wide by a trifle less than $\frac{1}{8}$ inch in height, we will say $\frac{3}{8}$ of an inch, $\frac{1}{8}$ of an inch being subtracted because of the thickness of the inner cardboard framing which is glued against the two outer pieces, and encroaching upon their width to this extent. The voltage most frequently met with is 110, with a maximum rise to about 125. Therefore, the instrument described is best wound to indicate between 0 volts and 125, including, in the opinion of the writer, nearly all the small machines described for construction, whether for power, lighting,

FIG. 5.—PORTIONS OF FRAME FOR MOVABLE COIL.

or experimental work. As this voltmeter is intended for switchboard work, it must be capable of remaining across the feeders of a current differing in potential by 110 volts, constantly without heating up or absorbing any appreciable amount of the current.

In order that it may indicate without being wasteful, it must possess a very high resistance, allowing only about 0.02 ampere of current to pass through its coils as the maximum. We must, therefore, choose a very fine wire for the bobbin, putting as much on as possible without bulging out beyond the sides of the little frame, and wind in addition on a resistance spool sufficient wire to shut out all current flow with the exception of about 0.02 ampere. We will require for the purpose of winding both coil and stationary resistance spool $2\frac{1}{2}$ ounces of No. 40 single silk covered wire. This fine wire is constantly weighed out on coarse or large scales, the weight, and consequently the resistance, of the wire being only approximate. In addition, the purity of copper in wire varies, and in some instances the gage, so it is wise to connect the wire across the feeders of a 110 volt circuit before removing

FIG. 6.—METHOD OF MOUNTING FRAME IN LATHE FOR WINDING.

from the spool upon which it was bought. The wire should warm up very little; in fact, to a scarcely noticeable degree, and when placed in circuit with a delicate ammeter should allow only 0.02 ampere of current to flow, of course, at the maximum pressure with which it is to be used. If the current absorbed by the spool is too great, more wire must be obtained and wound on; if the current taken falls short of 0.02 ampere, some of the wire must be removed. By making this test one cannot go astray.

The question is simply this: It requires at least this amount of wire to offer sufficient resistance to the high voltage current to shut out all but 0.02 ampere, which is the maximum carrying capacity of the wire itself. As much of this quantity as possible must be placed on the movable bobbin and the remainder must be wound on a spool and included in series. This wire is extremely fine and is to be handled with great care. In the first place do not, under any circumstances, allow the dealer to sell the wire wound on anything but a smooth wooden spool. Small wire is sometimes wound on a card or roll of paper for the purchaser, and should on no account be accepted in this condition. To attempt to handle wire of this size from anything but a spool will surely result in great delays, and the loss of the major portion of the material through kinking and tangling.

Having mounted the little framing on a bolt, as indicated, and placed the same in the lathe chuck, we are ready to fill it with the insulated wire. The reader

must expect to exercise much patience here, and give a good deal of time and attention to the smooth laying on of the layers. The winding commences from the small hole in the cardboard frame, and the lathe is run away from the operator, or clockwise when facing the chuck. This wire is so fine that it should not be made to pass out of the little hole unprotected, as it is sure to break off and necessitate rewinding just as the coil is finished. In order to give it proper protection, its

FIG. 7.—METHOD OF ATTACHING PIVOTS TO MOVABLE COIL AND SCHEME OF CONNECTIONS.

end is attached to the end of a short piece of No. 32 wire, which is brought out and wrapped around the bolt temporarily, prior to attaching to the upper pivot of the coil. In attaching this No. 40 wire to the No. 32, the two are twisted together, and solder is made to flow by means of a jeweler's soldering copper. Use no zinc chloride or other corrosive fluid on small wire, as it rapidly corrodes it away after completion. A little resin is safe, and should be applied finely pulverized. The No. 32 wire is wrapped around the bobbin once or twice in order to take all strain off the finer wire. We can now proceed slowly, putting as many layers on evenly as possible, that is, in perfect layers. It will not be possible to put them all on in layers, but as many as possible should be put on in this order before the lathe is run more rapidly, and wire simply fed on back and forth. A tiny hole should be made on the outer corner of the little frame when the coil is complete, and the wire drawn directly out. Should it break off here, it is not a serious matter, but should it break below, a repair is a very difficult thing to make.

We can now remove the work from the lathe, and provide the coil with little brass plates for the reception of the steel pivots. The scheme of attaching the pivots and their plates is illustrated in Fig. 7. The little coil is represented complete at G, with the top and bottom plates bound in place with silk thread. At H we have an end view with a single layer of wire wound on merely to show the connections, which are very simple, one end of the coil going to the upper plate, where it is soldered, and the other end going to the bottom, where it is attached in the same manner. At I we simply have the little plate drilled out to receive the pivot. The pivots are cut from steel rod $\frac{1}{8}$ inch in diameter and $\frac{1}{2}$ inch in total height. The little brass plates into which the pivots are to be soldered are $\frac{1}{8}$ inch thick, leaving the point of the pivot $\frac{1}{8}$ inch above the surface of the plate.

These pivots are drilled through with small holes as indicated, and turned to fine cones in the lathe by means of a very sharp and fine tool. The work on these must be perfect, and if the first attempt does not bring true and smooth cones, a second set must be made. They are now held in the flame of a Bunsen burner, and heated to bright redness, and plunged into a vessel of mercury, which makes them extremely hard. Two little brass plates are now cut from brass 1-16 inch in thickness, and filed to just cover the upper and lower edges of the little frame respectively, by resting upon them. Holes are drilled through exactly in the centers with a $\frac{1}{8}$ inch drill, and the little pivots pressed in. They must be absolutely in line before proceeding, which can only be expected as the result of accurate and skillful workmanship. Before soldering in position the little pivots should be polished by revolving in the lathe, and by applying the finest meal emery on cloth.

The little plates with their respective pivots are firmly bound on the framing with silk, as illustrated at G, the corners of the brass being filed smooth before winding on the silk to prevent its being cut. The ends of the coil are now securely soldered to the brass plates, and the whole given a good coat of orange shellac to keep out all moisture, which is liable to warp the coil in time, should this precaution be omitted. We are now ready for making the frame of brass which holds the little movable coil. This is cut out by means of a hack saw from a solid plate of brass $\frac{1}{4}$ inch thick, and has the dimensions and form as given in Fig. 8. This frame is neatly smoothed off with a fine flat file

FIG. 8.—DIMENSIONS OF PLAN OF BRASS FRAME FOR MOVABLE COIL.

after sawing out, and is provided with a hardened steel screw possessing a conical cavity at its end for the reception of one of the little pivots of the coil. This screw passes through the frame at J, and is securely locked in position by a couple of nuts as shown.

The conical cavity in the end of this screw is conven-

iently made by drilling into the end with a small twist drill, before hardening in mercury as in the case of the conical pivots. The angle at the apex of the sunken cone, or conical cutting, should be a trifle larger than the angle at the apex of the cone on the pivot to prevent friction. In other words, the angle of the cutters on the drill must be more obtuse than the angle at the apex of the little pivot. In this manner we will have the movable coil supported simply by hardened points in tiny hardened seats. At the left of the frame, at K, we have a little hardened block of cast steel, also provided with a little conical cutting for the reception of the other pivot. This steel block is forced into a groove, cut in a piece of vulcanite, L, which in turn is forced into a cutting in the brass frame. A little shellac applied before forcing in place insures a permanent hold.

The exact size of the steel block and vulcanite insulation, of course, does not matter so long as the distance of the conical seat from the back is $\frac{3}{8}$ inch. The space denoted by X is variable because of the screw, serving for the adjustment. The portion, M, is an edge view of a soft iron cylindrical core, held in place from a bolt at the back. The little hollow coil moves about this core without contact with it. This core is shown in position at O in the plan view of the completed voltmeter, Fig. 1. We must now provide a second piece of vulcanite, N, Fig. 8, which is screwed against the brass framing, and which carries a small binding screw. Small brass screw bolts with tiny nuts may be had which make these attachments very easy. The coil can now be placed in position in the frame, the screw being turned until a most gentle adjustment is established when the nuts are locked. Care should be taken, in locking the nuts, not to turn the screw further, thus damaging the points by undue strain.

FIG. 9.—DESIGN OF SPOOL FOR AMMETER SOLENOID.

The frame is now to be bolted to a brass base plate, $3\frac{1}{2}$ inches wide, $6\frac{1}{4}$ inches long, and $\frac{1}{8}$ inch in thickness. The bolts are shown at the left in Fig. 8, the exact distance separating them being marked on the brass plate before drilling holes for them. The distance from the top of the brass plate to the top of the coil-supporting frame must be just $\frac{1}{2}$ inch. The careful drilling of these holes and the adjustment of the frame and magnets cannot be too strongly impressed upon the reader. It is not the easiest stage in the making of this instrument. The height adjustment of the magnets, regarding the brass base plate, is most conveniently accomplished by using bolts and three running nuts, as illustrated at P P' in Fig. 1.

The pointer consists of a thin, tapering strip of sheet brass to which is soldered at the top a slender brass wire carrying a little sliding weight as shown in the first figure at Q, both in the plan and edge view. It is the weight of this little brass cylinder which resists the turning of the coil, and must be adjusted to each instrument by the maker, when calibrating. It must obviously be placed at such angle that the index will point at O when the weight is vertical. The scale is

FIG. 10.—POSITION OF MOVABLE TONGUE IN RELATION TO SPOOL.

best made from cardboard glued to a brass pattern which is screwed to the magnets as indicated. The scale is struck off with a pair of compasses set for a $4\frac{1}{2}$ inch radius for the center line of the reading portion, which is the length of the pointer. The actual width of the scale is $\frac{1}{2}$ inch, and the maximum angular measurement between the position of the pointer when at the extreme right and left is 60° , giving us a reading arc $4\frac{1}{2}$ inches in length.

The resistance spool, which is included in series with the wire on the movable coil, is shown in position at R in both views of the finished instrument. Connections are made between the pivots of the movable coil and the binding screws on the frame by little spiral pieces of No. 40 bare copper wire, as indicated at S S, which are firmly held in the holes of the pivots by a little wedge and the end of the pointer respectively. These tiny wires should have an easy bend of considerable radius, and should not be touched after the instrument is once adjusted, for, although they are of the finest character, they exert a little spring force on the moving of the pointer, and if they are not touched or bent after the first setting, their effort on the moving coil will be constant. The instrument is now ready for testing and calibration, and can be made to read true volts direct or to indicate any arbitrary potential values. For this it is only necessary to divide the scale into equal parts. For true volts, however, it is necessary to compare the instrument with a standard voltmeter.

It is assumed that the reader wishes a complete instrument for direct volt values, and that he can have the use of a standard instrument for the purpose of comparing the readings. Both the standard and the instrument we are making are placed across the terminals of a dynamo and the machine started, its armature being driven until the observer knows that both voltmeters are properly connected and observes the indicators moving over their respective scales. The dynamo is now speeded up until the standard indicates 125 volts, when the little brass weight on our instrument is so adjusted that our instrument also indicates 125 volts. The weight of the little brass cylinder can here be determined by actual experiment in connection with its own individual instrument, which is far more accurate than written directions can be which are based upon another instrument.

The fields of the dynamo are now gradually weakened by turning the resistance of rheostats in, and the

FIG. 11.—METHOD OF DRAWING PATTERN FOR MOVABLE TONGUE.

scale of the voltmeter is marked off to agree with the readings on the standard as the voltage gradually falls. The voltage will not fall to 0 with this method, of course, but will drop below the readings at which the instrument will prove most useful on the switchboard. To get the lower readings, the machine is started up, from a state of rest, with both voltmeters connected across its terminals and the rise in potential closely noted on the standard and marked on the scale of the instrument undergoing calibration. The processes should be repeated a number of times, going backward and forward, upward and downward on the scale until the values are fixed beyond doubt and the readings of our instrument agree with the readings of the standard at every point. A carefully and skillfully constructed instrument as described, when adjusted and calibrated in this manner, will indicate very slight differences in potential from 0 to 125 volts.

It now remains to case the instrument to keep out dust and dirt, and to screw it to a heavy, firm back board, together with the necessary switches, lamps and cut-outs, leaving room to the right for its sister indicator, the ammeter, which we will now take up for construction. The ammeter, which is illustrated in its completed state in Fig. 2, is much simpler in construction and operation than the voltmeter, and with the first instrument complete, the work on the ammeter can be carried on with comparative ease. The foundation of the ammeter consists of a brass plate $\frac{1}{2}$ inch thick by $4\frac{1}{2}$ inches in width and $6\frac{3}{4}$ inches in height. To this firm bed-plate is attached the solenoid, *T*, and the movable iron tongue, *U*, supported by pivots in the

FIG. 12.—DIMENSIONS OF FRAME FOR SUSPENSION OF MOVING PARTS.

brass frame, *V*. The solenoid is made by winding insulated wire of large gage on a brass spool, which is attached to the back plate by means of bolts soldered to the top and bottom of the flanges. Fig. 9 will make the method of attaching clear, which gives also the dimensions of the spool. The center portion simply consists of a thin brass tube, upon which are soldered two turned rings of the same material, giving us a spool with $\frac{1}{4}$ inch flanges.

It is to these rings or flanges that the little bolts are soldered, furnishing a most convenient way of holding the spool rigidly against the back plate, indicated in dotted lines at *W*. The soft iron tongue must now be made, which, with its pointer, constitutes the movable portion of the instrument. Fig. 10 illustrates the exact form of this tongue, and its relation to the inside of the spool, which is drawn in section, the two extreme positions of the tongue being shown at *X* and *Y* respectively.

This tongue must be built up from several thicknesses of soft Russian iron, thoroughly annealed. Before describing the method of making, a few words regarding the exact pattern of the tongue are necessary. This tongue must enter the solenoid as illustrated in the figure, and occupy its center when at the extreme position as indicated in dotted lines at *Y*.

In order to get this movement without the tongue and spool coming in contact, the tongue must be of peculiar shape, and Fig. 11 has been prepared to enable the reader to exactly reproduce it. Here we have simply two centers, one on the horizontal line, *A B*, about which a circle is described with a $1\frac{1}{2}$ inch radius, and one on the oblique line, *C D*, about which a second circle is described, but with a $2\frac{1}{6}$ inch radius. The angle formed at the intersection of the two lines is 14° , and the distance apart of the two centers on the oblique line is $\frac{3}{8}$ of an inch. By following these measurements with care, one cannot go astray in cutting a pattern for the tongue. A sufficient number of thin iron sheets must be cut accurately to the pattern with shears, to make a tongue about $\frac{1}{4}$ inch thick when laid together.

The different thicknesses are held firmly packed by tiny bolts and nuts, as shown in the edge view in Fig. 2, and in the plan view, at *Z*, is to be seen a little bolt head answering the double purpose of clamping the ends together and of affording means for balancing the tongue and pointer. It will be readily seen that a small mass of lead can be attached here without making contact with the spool when the tongue is drawn into it. The little bolt must be of iron in this case, to replace the iron which has been removed from the tongue in drilling the hole, in order that the gradually increasing mass of the metal shall not be diminished slightly at this point. The head of the bolt must be thinned down with a file, and the screw end must be provided with a brass nut, in order not to increase the mass of iron at this point. In this way we have drilled out a portion of the tongue and replaced the iron very accurately, affording means for clamping under the nut little lead washers.

The pivots in the ammeter consist simply of a piece of the steel as used for the pivots of the voltmeter, cut to length and turned off with a little cone at each end.

the electrical side of the question, which consists in choosing and winding on the spool the proper amount of wire. This is a very simple problem, and should be worked out experimentally after the wire is chosen. Let us take for example the case where the ammeter is wished to indicate between 0 and 15 amperes. We must consult a wire table, and learn the sized wire possessing this carrying capacity. No. 10 has a capacity of 16 amperes, and consequently is able to remain in circuit continuously with 15 amperes flowing. The brass spool is wound with an even layer of this wire, experimentally, and the ends brought out for connection with a standard ammeter, which of course is included directly in series. The free ends are now run to the current supply, and included in series with that too, but through rheostats or water boxes.

The instruments are mounted together, and the pointer on our ammeter is balanced to the 0 reading. The current is admitted slowly by immersing the plate into the salt water of the rheostat, until the standard indicates 15 amperes. Where will the pointer on our instrument be? If we happen to have too many turns of wire on the brass spool, the pointer will go off the scale; if we have not enough turns wound on, the pointer will not reach the end mark. It will now be readily seen that it remains to take wire off, or to put more on, according to the behavior of the pointer regarding the range of the scale with which it is intended to work. By a little experimentation, we can get just enough wire on the spool to hold the pointer at the scale limit, or 15 amperes, for which we are designing the instrument, when the standard, which is in direct series, and consequently receiving the same current flow, also indicates 15 amperes.

It will also be readily seen that the ammeter can be made to indicate higher values by simply winding the spool with heavier wire and running through the same experiment. Of course, if a water rheostat is not at hand, the two instruments can be simply included in series with a feeder supplying incandescent lamps, and the instruments "loaded with current" by turning on lamps until the standard indicates the maximum amperes for which we are adapting our ammeter. For the points intermediate on the scale it is a very simple matter to gradually cut out lamps and make readings on

DISTANT INSTRUMENT FOR FINDING POSITION AND RANGE.

The pivot shank is forced into a hole drilled for it in the tongue, and securely soldered in place, exercising the greatest care to get it in perpendicular to the plane of the surface of the tongue. This of course is greatly simplified if the hole in the tongue has been drilled in with the drill perpendicular to begin with. We can now devote our attention to the brass frame, which is illustrated in Fig. 12, together with the dimensions. This is sawn from plate brass similar to that used for the frame of the voltmeter, being simpler to make, as the hardened steel block, *B*, is soldered in a cutting in the brass of the frame direct, as there is no need of insulating the pivot in the present case. We have at the right a screw, *F*, locked in place by the same kind of nuts. All the precautions of turning the cones with a smaller angle at the apex than the angle formed at the apex of the sunken cone by the cutters of the twist drill, in cutting the seat in the little steel block, must be exercised here again, and equal attention must be given to the most careful adjustment.

Before winding the spool with its wire, we must put the instrument together, and provide it with its scale and pointer, and the insulating blocks of hard rubber for the binding screws as illustrated. The scale, which is exactly like that of the voltmeter, is mounted upon a couple of little brass columns $1\frac{3}{4}$ inches in height, in order that the plane of the scale and pointer shall be the same in both instruments, which adapts them to similar cases with the same sized scale openings. The upper portion of the brass frame, *V*, in Fig. 2 must be placed $\frac{1}{2}$ inch from the top of the brass back plate, as in the case of the voltmeter, and the pointer of the movable tongue must sweep with a $4\frac{1}{2}$ inch radius, measuring of course from the points of the pivot. This measurement immediately regulates the scale adjustment, which will be found to match the scale of the voltmeter nicely when the instruments are placed in cases.

Having placed the brass frame carefully on the center line, and bolted it with its movable tongue securely to the brass back plate, the spool must be mounted accurately in the relative position to the tongue, as given in Fig. 10. This will put everything in working order, mechanically speaking, requiring now our attention to

the scale under calibration, when the standard indicates even ampere values between the limits. The current should be increased and decreased a number of times and the pointers caused to travel back and forth over the scales as in the case of the voltmeter. Both ammeter and voltmeter should now be provided with little stops for the pointers to prevent them from getting off the scale when they are ready for casing. The cases, for appearances, should be exactly similar and be provided with little lock doors and glass over the scale openings. The bottom portion of the cases should mount additional pairs of binding posts, which are intended for connection with the switchboard, taking all strain from the little screws within the instrument. Both instruments will be found extremely useful for switchboard use, their delicacy, sensitiveness, and accuracy depending, of course, upon the skill of the maker.

A HORIZONTAL-BASE RANGE AND POSITION FINDER FOR COAST ARTILLERY.

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In December, 1896, the Board of Ordnance and Fortification made an allotment for the development of a horizontal-base range and position finder for coast artillery. This instrument was completed and installed at Fort Monroe, Virginia, in May, 1896, and has been in use by the artillery troops since that time. The description which follows is a brief account of the development of this instrument.

The desirable and essential features of a good range and position finder might be stated generally as follows: It should be simple, accurate, and reliable, and, as will be pointed out later, should be capable of receiving protection against the fire of the enemy.

The instrument now referred to possesses the following features:

a. No electrical parts except a single protected telephone line between the base ends.