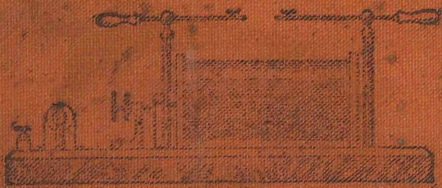
HOW TO MAKE AND USE

INDUCTION COILS.

By EDWARD TREVERT.



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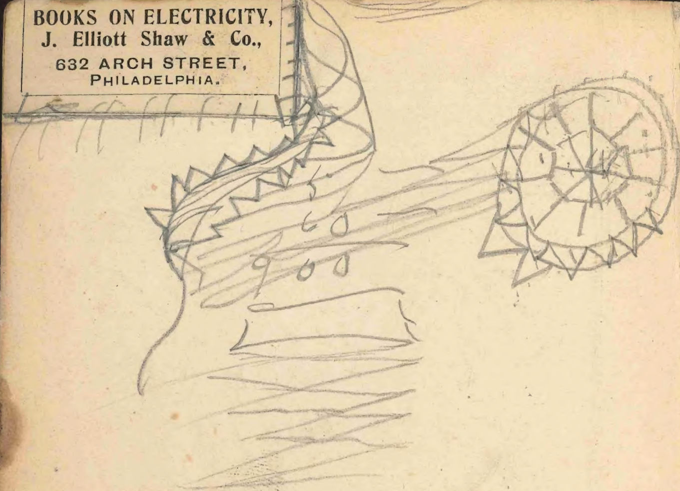

Robt. Starrett

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By EDWARD TREVERT.

AUTHOR:

EVERYBODY'S HANDBOOK OF ELECTRICITY.
EXPERIMENTAL ELECTRICITY.
ELECTRIC RAILWAY ENGINEERING, ETC.

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PREFACE.

The induction coil is one of the most important adjuncts of an electrical experimenter's apparatus. It is almost the first piece of electrical mechanism that the amateur attempts to build. For the especial benefit of this class of electricians, this little book has been prepared, containing directions how to construct the apparatus and perform some experiments. In the preparation of this volume I have also endeavored to give the reader some information concerning the batteries best suited to operate the coils.

EDWARD TREVERT.

LYNN, MASS., September 5, 1892.

CONTENTS.

INDUCTION COILS.

AN induction coil consists essentially of two coils, a primary and a secondary. To these is added, for the purpose of intensifying their action, a magnetic core, consisting generally of a bundle of iron wires.

An alternating or a pulsating current is passed through the primary coil, and produces (by the phenomenon known as induction) a current, likewise pulsating, in the secondary coil, although the two coils are entirely unconnected.

If the primary and secondary were alike, that is, had the same number of turns around the same portion of the core, and we were to neglect the losses caused by the resistance of the wire, the hysteresis of the core, etc., we should get a current from the secondary of the same number of volts and amperes as that in the primary.

Any change in the number of turns of either coil will produce a change in the relation of the volts and the amperes in the primary to that of the secondary, and in fact, this ratio is the same as the ratio of the number of turns in one coil to that of the other.

Thus, neglecting the losses above mentioned, if we have 10 turns of wire on the primary, and 50 turns on the secondary, we will have five times as many volts on the secondary as on the primary, but only one-fifth as many amperes. On reversing the above supposition, and giving 50 turns to the primary and 10 to the secondary, we should divide the volts and multiply the

amperes on the primary by 5, to get the volts and amperes on the secondary.

It is thus apparent that in order to obtain any current or potential we desire, we have only to arrange the ratio of the two coils to each other, so as to make it equal to the ratio of the potential or current at our disposal, to that which we desire to obtain, and the problem is solved.

Practically, however, difficulties are encountered which modify the above statement very materially.

In the first place, the output in volts and amperes is always somewhat less than the amount calculated by taking the ratio of the coils.

This is due to the losses above mentioned, of resistance and of hysteresis.

Secondly, mechanical difficulties prevent the construction of coils in which the ratio of the primary to the secondary is extremely large or small.

In order to get a high ratio and still keep the coil within the necessary limits of size, it is necessary to use a large quantity of extremely small wire. This is difficult to handle without kinking or breaking, and the insulation is necessarily so delicate that the least rough usage is sufficient to abrade it. Then, too, the fine wire coil is of course subjected to a higher potential than the coarse wire coil, or, rather, turns of wire at a great difference are closer together.

In coils with a large number of turns on the secondary, it is customary to wind the wire on in sections, carefully insulated from each other, and thus avoid the proximity of wires subjected to a greater difference of potential than the insulation will stand.

The term "induction coil" will, of course, include any combination of coils in which a pulsating current in one induces a current in another. The transformers used in the alternating system of lighting are, of course, induction coils, but nowadays the custom is, in general, to restrict the use of the term "induction coil" to that form which has what is known as an "open" magnetic circuit.

This use of the term will be adhered to in this article.

Transformers are generally used with an alternating primary current, that is, a current which periodically reverses the direction of its flow.

Induction coils are generally used on a current which simply fluctuates in strength from its maximum to zero.

A transformer may be used on a fluctuating current, or an induction coil may be used on an alternating current, but neither so effectively as the other way.

The reason for this is that the transformer has an iron core which is closed upon itself, or forms a complete ring around the coils of wire. When in this form and magnetized the magnetizing current may be entirely removed and the iron still retain a large portion of its magnetism. Now it is the variation of the magnetic force in the core which produces the current in the secondary, therefore in order to merely bring the core back to its zero state of magnetism, it is necessary to reverse the magnetizing current. Practically, the demagnetizing current is always as strong as the magnetizing current, and in place of simply bringing the iron to a zero state carries it on to the same strength of the opposite sign. Therefore when a closed magnetic circuit is used it should be in

connection with an alternating current.

The reason for employing a closed magnetic circuit is that it greatly increases the capacity of the transformer by reducing the resistance to the formation of lines of magnetic force.

On the other hand an induction coil has a core composed of a bundle of soft iron wires. Their magnetic retentiveness is small, and the instant the magnetizing current is off they lose the greater part of their magnetism.

This property it is which makes the fluctuating current a suitable one for use on an induction coil. An alternating current would, of course, work as well as a fluctuating current, but would work much better, as explained above, on a coil with a closed magnetic circuit.

We will now take up the making of the coil, leaving such points as have not yet

been made to be spoken of as they com
up in the description.

The coils are to be wound upon a tu
built up of cartridge paper, wrapped arou
a cylindrical stick ⅞ of an inch in diamet
The tube is to be 8 inches long and t
paper to be wound on until it is $\frac{1}{16}$ of
inch thick, making the tube 1 inch outsi
diameter. Each turn, or layer, of paper
to be glued down to the preceding one, s
that when dry you will have a good sti
foundation on which to begin work.

The ends of the reel upon which the wi
is wound are to be made of well-season
hard wood, thoroughly boiled in paraffin
of the shape and dimension indicated
the following sketch. (See Fig. 1.)

These pieces are placed upon the en
of the paper tube and glued to it solidly

Two holes are to be drilled in one of
end pieces, just below the tube, for

purpose of introducing the primary wire.

It will be well, if possible, to do the winding in a lathe, and for that purpose place the reel upon a snugly fitting wooden mandrel, with some sort of a dog to keep it

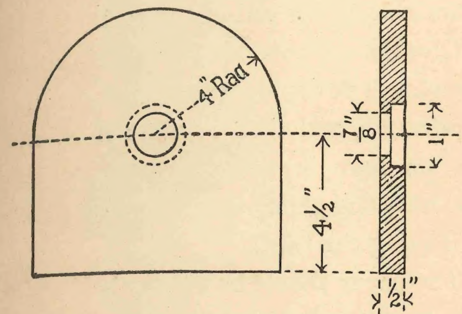

FIGURE 1.

from slipping. Then, having pushed a short length, say a foot, of the wire with which you are going to wind your primary, through one of the holes in the end of the reel, start your lathe to revolving slowly and feed the wire on evenly, taking care to have it tight and to keep the insulation unbroken.

Use No. 16 cotton covered copper wire on the primary and wind on two layers, bringing the finishing end out through the other hole in the end of the reel.

Give the coil several coats of thin shellac, allowing it to dry thoroughly between each application, and then insulate it by winding on four layers of cartridge paper smoothly and gluing them down as directed in making the tube.

The paper should be cut say half an inch broader than the distance between the inside faces of the reel, and ¼ inch slits cut along the edge at short intervals, so that when placed upon the coil these slits allow the paper to be turned up at the edges and pasted against the ends of the reel. (See Fig. 2.)

The paper insulation should be made to

fit as close to the ends of the reel as possible and whatever there may be in the way of interstices left between them should be carefully filled with as much shellac as they will soak up. It is also a good plan to fillet the corners with a mixture of resin

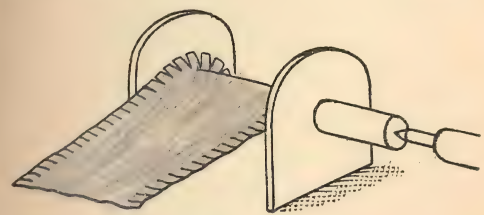

FIGURE 2.

and beeswax, five parts of the former to one of the latter.

The secondary wire is No. 36 silk covered.

On account of its liability to injury, the starting wire should not be brought outside the coil, but be soldered to a piece of

No. 18 gutta-percha covered wire, led in through a hole in the opposite end of the reel to that from which the primary wires issue. It is next to impossible to repair a break on the inside of the coil after it is once wound, and the greatest care should be taken while the winding is going on to make sure that everything is right before leaving it. On this account the gutta-percha covered lead wire should be wedged firmly into its exit hole, so that it cannot work around and break the joint inside.

Wind on the fine wire in the same way that you did the coarse, evenly and smoothly, and when one layer is finished it should be thoroughly soaked in thin shellac and then covered with three thicknesses of thin writing paper, laid on with shellac. This paper should be made, as directed above, a little wider than the distance between the inside faces of the ends

of the reel and slit to fit, and the interstices well filled with shellac before going on with the next layer.

This is wound on and insulated in the same manner as the first, and the process continued until the coil is about 3½ inches in diameter. The finishing end should then be soldered to another piece of gutta-percha wire passing out of the opposite end of the reel to that from which the starting end issues, and the coil then covered with eight or ten layers of writing paper and wound over with silk ribbon or cord.

The danger of breaking is so great with this fine wire that each layer should be tested after being wound, by connecting the starting end of the coil to one pole of a magneto and the other pole to a spot on the wire, which you can bare for the moment and then cover up again when you resume winding. Be sure that your magneto will ring through the coil before you cover up the layer last wound.

Another method of testing, if you happen to be without a magneto, is to have a tolerably strong battery and connect one of its poles to the tine of a file and the other to the starting end, then with a

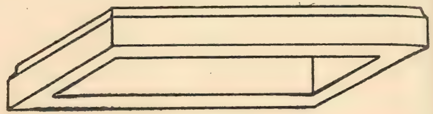

FIGURE 3.

piece of wire which touches a bare spot on the wire you are winding on, rub the roughened part of the file. If there is a good connection it will be shown by numerous sparks at the point of contact.

After winding, the coil may be mounted on its base.

This base is made of dry, well-seasoned

wood, 8 inches wide, 14 inches long and 2 inches high. (See Fig. 3.)

The bottom is to be hollow and the edges and top to be ¾ of an inch thick.

The core for the coil is to be made of iron wires, about No. 12 or No. 14, cut to the same length as the reel and bound together by fine brass wires into a cylindrical bundle. Its outside diameter should be such that it will just slip inside of the tube upon which the coil is wound.

One end of this tube is to be closed by a wooden plug projecting into the tube ¼ of an inch and this, of course, will cause the core to project a like distance from the other end of the tube.

The make and break device is to be mounted in front of this projecting end and is made according to the accompanying sketch. (See Fig. 4.)

It consists of a piece of ⅜ inch round

iron, ¼ of an inch long and soldered to the end of a piece of spring brass, whose other end is bent to a right angle and screwed to the base. To this spring is also soldered a small contact piece, preferably of platinum, but silver may be made to answer.

Opposite this contact piece and sup-

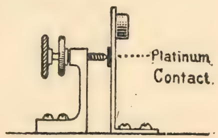

FIGURE 4.

ported by a brass standard, through which it passes, is the contact screw, whose point is tipped with platinum. This screw has a check nut on it to prevent its working loose when the vibrator is in action.

The iron armature on the end of the vibrator must, of course, be opposite the

end of the core and about ¼ of an inch away from it. After it is in place the spring can be bent backwards or forwards until the best adjustment is found.

A commutator will be found a very useful addition to the coil, for, while it is not

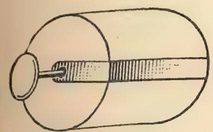

FIGURE 5.

FIGURE 6.

absolutely essential it will prevent the unequal heating of the electrodes of the vacuum tubes used in some experiments, and will also serve as a key to open and close the primary circuit.

It consists of a cylinder of hard wood or vulcanite, 1 inch long and 1 inch in diameter, to which are affixed two brass strips ¼ of an inch wide. These strips are L shaped and are set opposite each other, with their edges flush with the surface of the cylinder. See Figs. 5 and 6.

At the centre of each end of the cylinder is soldered a piece of brass wire to serve as

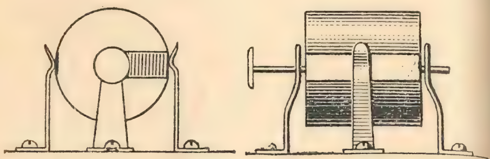

FIGURE 7.

an axis upon which the cylinder turns. The cylinder is mounted upon two supports made of sheet brass and on each side of it is a spring brass contact piece. (See Fig. 7.)

The discharging apparatus next claims our attention.

The supports are to be made of heavy

glass tubing, such as is used in the water gauges on steam boilers. They are to be firmly set in holes in the base, a little to one side of the central axis of the coil and to project about 4 inches above the top of the coil.

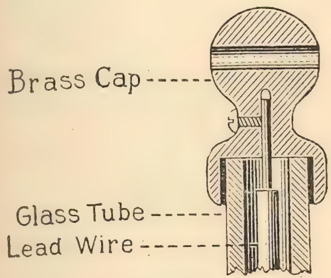

FIGURE 8.

On the top of each tube a brass cap is fastened by means of sealing wax, as shown in Figs. 8 and 9.

The leading wires from the ends of the secondary coils, which should both be gutta-percha covered, are to be taken by the nearest paths to the tubes, to the inside of them, through holes drilled for the purpose, and then up to the caps and fastened to them by screws, as shown in the sketches.

Holes may be drilled in glass with ordinary drills, whose points are kept wet with turpentine.

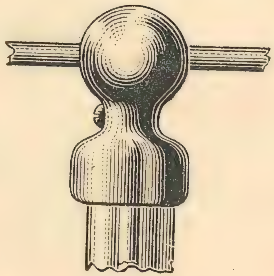

FIGURE 9.

A discharging rod must be made for each cap piece. It must fit the hole in the cap snugly but not tightly, and be long enough to reach half-way from one pillar

to the other, and have room left on the other end for a handle.

The inboard end of each rod must be drilled about an inch deep and have a small screw with a milled head, with which to clamp anything which it may be desirable to attach to the rod. (See Fig. 10).

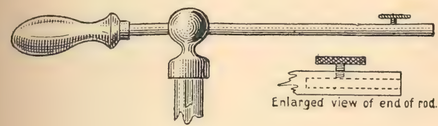

FIGURE 10.

The condenser for the coil may go into the hollow space in the base or may be placed in a separate box, but the first is preferable, as the instrument is in this way self-contained.

Prepare 50 sheets of tin foil 6 x 8 inches and cut off one corner of each, as shown in Fig. 11. You will also want

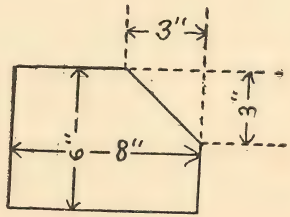

FIGURE 11.

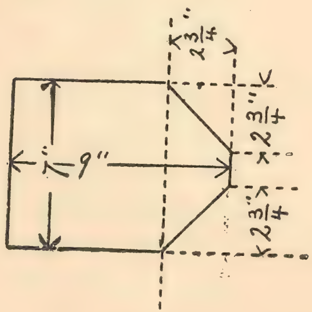

FIGURE 12.

60 sheets of thin writing paper, cut according to Figure 12.

The cutting of both tin foil and paper can, of course, be done by hand, but it is better to fold up a number of large sheets to about the right size and take them to a bookbinder to trim to the shape you want.

Each paper must be examined carefully in a darkened room, before a gas jet or flame, for pin holes, and if any are found the piece having them must be rejected.

The paper is to be paraffined by dipping it in the melted wax. The melting must be carefully done so as not to cause the wax to boil or burn. After dipping a sheet draw it out and if the paraffine is hot enough the bubbles will run off. It must then be hung, by wooden clips, on a line already stretched for the purpose and the wax allowed to harden. When all the papers have been prepared we are ready to build the condenser. A compartment should be made in the base for the coil, just large enough to contain the condenser, that is, 9 x 7 inches.

Place five sheets of the waxed paper in this receptacle and then lay on them a

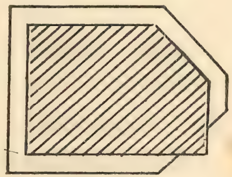

FIGURE 13.

sheet of tin foil, with its unclipped corner projecting over one of the clipped corners of the paper. (See Fig. 13). Then lay on a sheet of paper and on top of that another sheet of tin foil, this time with its unclipped corner over the *other* clipped corner of the paper. Then follows another sheet

of paper and then one of tin foil, laid on like the first, and so on, alternating the position of the unclipped corner with each sheet of tin foil. When the last piece of tin foil is in place put on the remaining sheets of paper and cover the whole with a small board of the same size as the com-

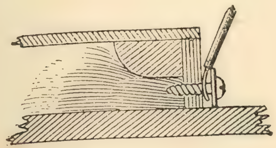

FIGURE 14.

partment in which the condenser is placed. On the side of the board cover which turns towards the condenser glue two blocks, one over each of the uncovered corners of the tin foil, and of such a thickness that when the cover is in place they will press the sheets of tin foil into compact bundles. (See Fig. 14).

Then through the side of the box holding the condenser screw two short round-head wood screws far enough in so that their points shall penetrate the foil and to these screws attach the wires to the condenser. The connections may now be made according to Fig. 15.

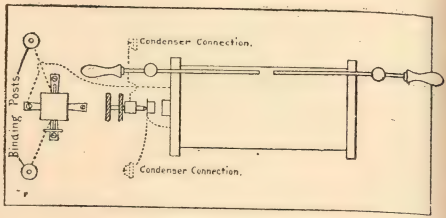

FIGURE 15.

Of course the wires are to be run beneath the base board as much as possible and wherever they cross one another they should be carefully insulated.

Fig. 16 is an elevation of the coil complete.

For battery power use three or four large Grenet cells, which are to be connected to the binding posts.

When the battery is connected and the commutator turned so that the brushes are touching the metal strips start the vibrator

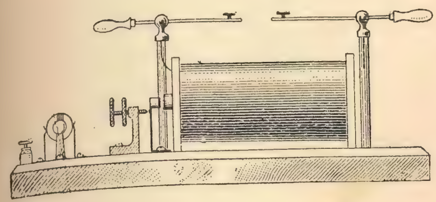

FIGURE 16.

to working and adjust the contact screw until the motion is uniform and smooth. Then bring the ends of the discharging rods (which have previously had short pieces of wire inserted in their ends for discharge points) together, when a shower of sparks will be observed to jump across the space between them. The closer the points are together the more intense the sparks.

Bend one of the wire discharge points so that its side is presented to the end of the other, and the spark will be observed to assume a brush-like form. A ball on the end of one of the discharging rods has the same effect of producing a brush-like discharge. Discharge points made of fine iron wire, when brought closely together, give a brilliant spark and cause one of the points to heat up and burn away.

Discharges through vessels which are partly exhausted of their air present a very different aspect from those in air at ordinary pressures. These effects are usually shown in a glass globe, into which electrodes connected with the coil project. (See Fig. 17.)

These electrodes have rounded ends and are sealed air-tight where they enter the

globe. An orifice with a stop cock is provided, by means of which the globe may be attached to an air pump for exhaustion. When the air is partly exhausted and the

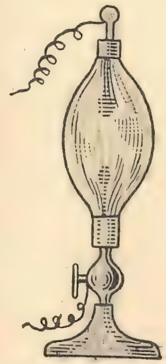

FIGURE 17.

current turned on, a stream of light takes the place of the spark.

A decided difference in the character of the discharge at the two electrodes can be observed now. At one electrode the light is a brilliant red and at the other a soft violet. The use of the commutator now appears, for the electrodes differ not only in appearance but also in temperature, and the temperature of the hot electrode will often get so high, in the case of Geissler tubes, as to destroy the platinum wire which leads the current into them.

By rotating the commutator so as to change the direction of the primary current, an excess of temperature at either electrode may be avoided.

The gas which fills the globe has a great effect upon the color, and sometimes the character of the discharge. When, after thorough exhaustion, a small amount of alcohol or naphtha vapor is introduced, the discharge, instead of appearing as a solid stream, will be divided transversely into a number of zones.

Hydrogen gas, under the same circumstances, gives a white light, nitrogen a

rose color, varying to orange, and carbonic acid a pale green.

If a piece of uranium glass be examined by ordinary light its color will appear to be a light yellow, but upon holding it between the eye and the discharge through a vacuum tube or globe it will show a bright green color.

Geissler tubes are simply hermetically-sealed glass tubes, arranged to show the same effects as those produced in the electric globe, and are generally constructed so that the discharge takes the form of some design. The variety of forms which they may take is limited only by the ingenuity of the glass worker, but inasmuch as their manufacture requires no inconsiderable skill, the attempt will not be made here to give directions for constructing them, and the amateur, if desirous of experimenting upon them, had best buy them ready-made.

They are necessarily extremely fragile and, moreover, great care must be exercised to have the primary current reversed frequently enough to prevent undue heating of either electrode, as noted above.

The Primary Spark.—When the coil and battery are connected, a small bright spark may be seen between the point of contact of the platinum tipped screw and contact breaker. When the coil and battery is large, it has the appearance of a flame.

The Secondary Spark.—When the battery circuit is completed and two wires are attached to the binding post of the secondary coil with their free ends brought near together, a stream of sparks will pass

between them. This is caused by the induced or secondary current.

The Static Spark.—If you bring the knuckle, a piece of wire, or any other conductor near either binding post of the secondary coil, sparks of feeble brilliancy will pass from one to the other. These sparks are a manifestation of a static condition of the current.

Calorific Dynamic Spark.—Diminish the distance between the two wires from the secondary coil and the spark will become brighter and more intense, assuming a fiery red color, a condition suitable for ignitions and all calorific effects.

A spark may be made to diverge towards a flame by first arranging the electrodes so as to obtain a spark of average length. Then, while the current is passing from one electrode to the other of the discharger, bring the flame of a small candle near the stream of sparks. Instantly the character of the spark will change, its luminosity will be greatly diminished and it will be attracted by the flame. This is probably caused by the heated atmosphere around the flame and the particles of unburnt carbon in the flame form a better conductor than the ordinary atmosphere.

A spark may be elongated by simply placing a lighted candle below the discharging electrodes. The spark becomes blue and it will be found that the electrodes can be separated much farther than before, thus producing a spark three or four times longer than by ordinary means.

A very pretty experiment is to sprinkle some very fine copper and iron filings upon a piece of hard rubber, then bring the two electrodes in contact with the filings,

when sparks will be seen in all directions and of various colors.

Place an ordinary Edison incandescent lamp upon the table and bring one of the wires from the secondary coil in contact with either the glass globe or socket and it will glow with a static discharge resembling the aurora.. By bringing the hand near the glass its brilliancy may be greatly increased.

A Leyden jar may be charged from the coil in the following manner: Place the jar upon a piece of hard rubber, thus insulating it, and attach one electrode to the ball of the jar. Place the other electrode at a short distance from the outside coating of the jar. As soon as the coil is set in action the jar will begin to charge and can be discharged by the ordinary methods. Phosphorus may be ignited by placing a small piece the size of a pea upon a glass or earthern plate and allowing the spark to pass through it.

Ether may be ignited by wetting a small piece of cotton wool with sulphuric ether and holding it between the discharging electrodes while a current is passing. Hydrogen gas may be ignited by simply sending the sparks through a stream of it from an ordinary gas burner.

Many other interesting experiments may be performed but the space in this little book will not allow for their description. We will now consider the construction of the shocking or medical coil.

THE MEDICAL COIL.

An induction coil for medical purposes is the analogue of the one just described, excepting in general dimensions and details of winding. Not being intended for such high voltages it need not be so large, nor must the secondary wire be so fine.

Make the tube on which the primary is to be wound of cartridge paper. This is to be wound upon a ⅝ inch cylindrical stick and enough paper put on to make the outside diameter of the tube ¾ inch. The tube is to be 6 inches long and to have upon each end a rim made of fiber, vulcanite or hard wood. (See Fig. 18.)

These ends are to be glued firmly to the

tube and two holes are to be drilled in o[n]
of them, to take out the starting and fi[n]
ishing wires.

The primary is to be No. 18 cotton-co[v]
ered wire, of which there are two layer[s]
Leaving an end hanging free through o[ne]

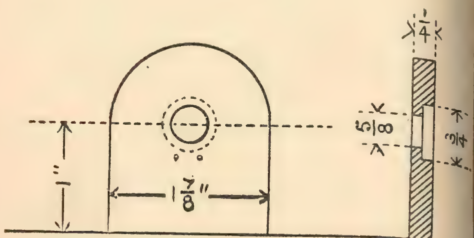

FIGURE 18.

of the holes above mentioned, wind on th[e]
wire tightly and smoothly, shellacing th[e]
first layer when wound and covering i[t]
with a piece of writing paper. The secon[d]
layer is then wound on and its finishin[g]
end pushed through the other hole an[d]

secured. The whole is now shellaced and carefully covered with four or five layers of thin writing paper stuck on with shellac. The paper should be cut a little longer than the distance between the ends of the spool and slightly slit along the edges, so as to allow them to be turned up and pasted against the ends.

All interstices, especially those at the ends of the spool where the paper joins them, should be filled with as much thin shellac as they will soak up.

Drill a hole for the starting wire of the secondary at the opposite end to that from which the primary wires issue, and as close to the paper covering on the primary as possible without injuring it.

The secondary wire should be attached to a piece of No. 18 wire, which is passed out through the hole, leaving the joint inside. And, by the way, any soldered joint made with chloride of zinc must be carefully washed, preferably with alcohol before being taped, as the acid, if left on would in time eat away the insulation and cause much mischief.

The secondary should be about No. 34 silk-covered wire. Each layer must be shellaced as soon as done and then covered with a sheet of thin writing paper, whose edges are turned up where they touch the faces of the end pieces and stuck fast to them. This prevents the wires of any layer sinking down into the one beneath.

There is much virtue in shellac about any electrical instruments and it can scarcely be too freely used, especially where the currents are high tension.

Wind on wire until the outside diameter of the coil is 1¾ inches and cover the whole neatly, first with paper and then with ribbon, velvet, or whatever suits the fancy of

the maker. The finishing wire should be soldered to a thicker piece when it leaves the coil, on account of its liability to injury from rough handling.

The coil should be mounted upon a base board ¾ inch thick and sufficiently large to have room for the contact breaker and four binding posts, besides the coil.

FIGURE 19.

The coil must be provided with a core composed of iron wires bound tightly into a bundle by fine brass wires at each end and the middle.

This core should be about a quarter of an inch longer than the coil and three or four of the middle wires should be allowed to project far enough to attach a handle to them. (See Fig. 19.)

The core must be just large enough to slip easily into the tube.

These wires do not have to be clean and bright, in fact, the rustier they are the better it is for preventing "Foucault" currents among themselves.

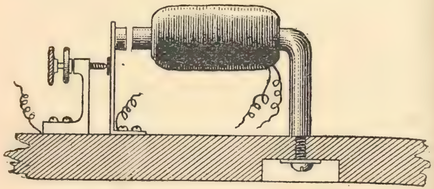

FIGURE 20.

The magnet for the contact breaker may be made of a piece of ¼ inch round soft iron, bent at right angles and fastened to the base board. (See Fig. 20.)

Before it is the vibrator, consisting of a spring with a piece of quarter inch iron fastened to the end, and a little below and on the other side a piece of platinum for a

"contact." Opposite this is the adjusting screw, also with a small platinum contact point.

The magnet is to be wound for about two inches of its length with two layers of No. 18 cotton-covered wire after being insulated with paper.

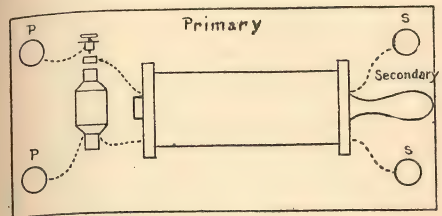

FIGURE 21.

The binding posts may be of any design to suit the maker and the whole thing is to be connected up in accordance with the accompanying diagram. (See Fig. 21.)

The binding posts *P P* are to be connected with the battery (one or two bi-

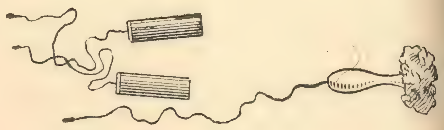

FIGURE 22.

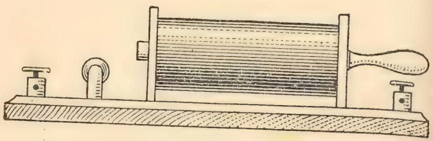

FIGURE 23.

chromate cells), and the posts *S S* to whatever apparatus you may have arranged for taking the shock from.

This usually consists of two tin handles attached to flexible conductors. For some purposes a moist sponge mounted upon a wooden handle, with a wire attached to a metal plate near its centre, is used. (See Fig. 22.)

The batteries having been connected to the primary wires and the vibrator adjusted to a uniform buzz, the core is pulled out and the handles grasped. Then insert the core until you get the intensity of current you desire. Figure 23 is an elevation of the coil complete.

Another small coil will now be described, suitable for shocking, and a few of the experiments on high tension currents. Take a brass tube ten inches long and one inch in diameter, and slit it on one side the full length of the tube. This is to prevent wasteful currents in it, which would greatly lower the efficiency of the apparatus. On each end of the tube slip a piece of fiber or vulcanite cut in the

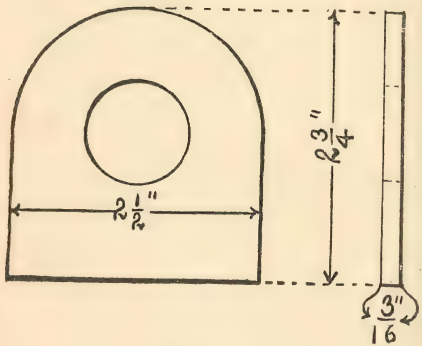

FIGURE 24.

shape shown in Fig. 24. These pieces must fit on tightly. Carefully insulate the brass tube by winding several thicknesses of writing paper on it and shellacing them down, and drill a $\frac{1}{16}$ inch hole in one of the

washers near the tube to let the starting wire through. The primary which is to be wound first is of No. 18 double cotton-covered copper wire. Push about ten inches of the wire through the hole from the inside and wind in four layers, placing between each layer a piece of paper. The finishing end should be taken out through a hole in the washer, where it stops. Shellac what you have wound on and cover it with six or eight thicknesses of writing paper well shellaced on.

For the secondary we will use No. 30 double cotton or silk-covered copper wire. Make another hole in one of the washers for the beginning of the secondary to pass through. It would be well to use a larger wire to go out through the hole, say some of your No. 18, as the finer wire is likely to be broken off, which would necessitate unwinding the whole coil to repair it. So solder on a piece of the larger wire to your No. 30 and tape the joint well and push the larger wire through the hole and wind on as before. Shellac each layer as you finish it and cover it with a layer of paper. Wind the spool full. Now make a couple

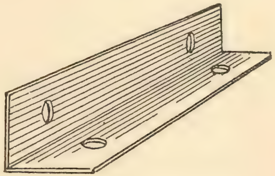

FIGURE 25.

of little brass angles 2½ inches long and a ½ inch in each leg (see Fig. 25).

Drill them for screws and use them at the ends of the coil you have wound to screw it to a board you have selected for a base. The core for our coil should be made of soft iron wires. These can be simply slipped inside the brass tube and

left there permanently, or can be made movable by attaching them to a handle. In the latter case a great variation in the secondary E. M. F., can be produced by sliding the core in and out. The wires should be rusty to avoid "Foucault" currents as far as possible. Cut the wire off in 10 inch lengths until you have enough to fill the tube snugly. Bind each end and the middle of the bundle with a few turns of fine brass wire and fit a wooden handle to one end.

A contact breaker must be provided to introduce into the primary circuit. This can be made by taking a piece of ¼ inch square wrought iron and bending it into a

 shape. The piece should be originally 4 inches long, and when bent make each leg one inch long. Wind the middle part ½ inch deep with the same kind of wire you used on the primary, of course

insulating the iron beforehand where the wire will touch it. A hole should be tapped in the end of one of the legs for ⅛ inch machine screw. Cut a strip of sheet brass ¼ of an inch wide and 2¼ inches long for a spring for a vibrator. If the brass is not already springy enough, it can be made so by pounding it a little. Solder to one end of this strip a piece of wrought iron such as you used for your magnet core, ¼ inch square and ⅛ inch thick. Also at the middle of the spring, on the opposite side to which you fastened the iron, solder a small piece of sheet platinum for a contact. If platinum cannot be procured, silver is the next best thing. Through the other end of the spring drill an ⅛ inch hole and screw it by this to the leg of the magnet you tapped, bringing the loaded end of the spring opposite the other leg.

Now fasten the magnet down to the

baseboard of your coil by a cleat, so that the spring will be perpendicular and the loaded end in the air. The spring should be bent back as shown in Fig. 26, so that the iron armature shall be about $\frac{3}{32}$ of an

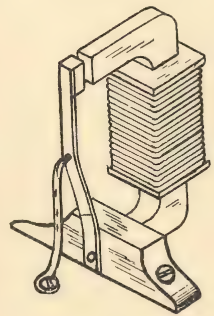

FIGURE 26.

inch from the pole of the magnet. Now bend up a piece of brass wire as shown in the same figure with a slotted eye in one end by which it can be screwed to the board and the other end of such a height that it will touch the platinum contact piece soldered to the spring. The end of the wire should also have a platinum contact soldered to it. Screw the wire down to the board so that its free end will just touch the spring and make a firm contact.

Four binding posts should be provided, two for the primary and two for the secondary. A diagram of the connections is given in Fig. 27. The wires should be run underneath the baseboard in grooves cut in its bottom and carefully insulated from each other wherever they cross. The current is taken from one of the binding posts to one of the primary wires and from thence to the winding on the circuit breaker, then attached to the circuit breaker spring. The other binding post and the brass wire of the circuit breaker are connected. Each of the secondary wires is connected to one of the other

remaining binding posts. We are now ready to operate the machine.

Connect two or three cells of the battery (the bichromate is the best for this purpose) to the primary binding posts. As soon as the current is turned on, the magnet of the circuit breaker should draw the

FIGURE 27.

iron on the spring to it and break the circuit between the spring and the brass wire. This of course allows the spring to fly back and again complete the circuit and then break it again, and thus keep up a steady vibration. The brass wire must be adjusted by means of the slot until the breaker works well and constantly. Now

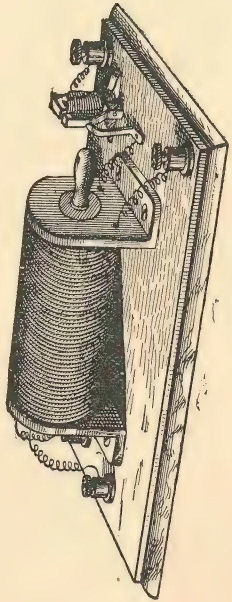

FIGURE. 28.

draw out the core of the coil and place your fingers on the two secondary binding posts and gradually push in the core, when you will feel the well-known tingling of a pulsating current of electricity. When the core is pushed in, the current becomes stronger, and when it is pulled out the current weakens. By this method quite a range of electro-motive force can be secured. Of course, the more batteries you use the stronger will be the secondary current. Figure 28 shows coil complete.

ELECTRIC BATTERIES.

A battery to be used with an induction coil should give a strong and steady current, therefore none but closed circuit batteries should be used. Of these the "Grove," "Bunsen" and "Grenet" are the best. The author prefers the Grenet, as it is the cleanest and easiest to care for, besides it does not throw off any noxious fumes. Also the exciting solution is easily obtained or made. Particularly noticeable among the solutions prepared for this battery is "*Bubier's Battery Compound*," which comes in the form of a salt, put up in neat boxes, which can be sent through the mails. All that is necessary in using it is to mix it with water.

Enough to make a quart of solution costs only fifteen cents. It is manufactured by the "Bubier Publishing Co., Lynn, Mass."

Voltaic Cell.—The simplest electric battery made is the Voltaic Cell. This is made by placing in a glass jar some water having a little sulphuric acid or any other oxidizing acid added to it. Then place in it separately two clean strips, one of zinc Z, and one of copper C. This cell is capable of supplying a continuous flow of electricity through a wire whose ends are brought into connection with the two strips. When the current flows the zinc strip is observed to waste away; its consumption, in fact, furnishes the energy required to drive the current through the cell and the connecting wire. The cell may, therefore, be regarded as a sort of chemical furnace in which the fuel is zinc. Before the strips are connected by a wire no appreciable difference of potential between the copper and the zinc will be observed by an electrometer; because the electrometer only measures the potential at a point in the air or oxidizing medium

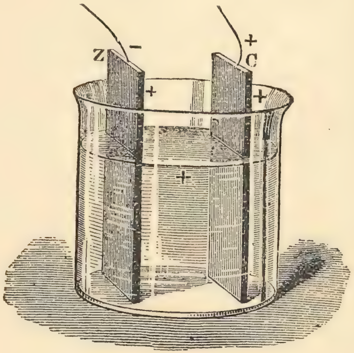

FIGURE 29.

outside the zinc or the copper, not the potentials of the metals themselves. The zinc itself is at about 1.86 volts lower potential than the surrounding oxidizing media; while the copper is at only about

.81 volts lower, having a less tendency to become oxidized. There is then a latent difference of potential of about 1.05 volts between the copper and the zinc; but this produces no current as long as there is no metallic contact. If the strips are made to touch, or are joined by a pair of metal wires, immediately there is a rush of electricity through the metal from the copper to the zinc, and a small portion of the zinc is at the same time dissolved away; the zinc parting with its latent energy as its atoms combine with the acid. This energy is expended in forcing a discharge of electricity through the acid to the copper strip, and thence through the wire circuit back to the zinc strip. The copper strip, whence the current starts on its journey through the external circuit, is called the positive pole, and the zinc strip is called the negative pole. (See Fig. 29).

The Grenet Battery, shown in Figure 30, consists of a glass jar or bottle. A well amalgamated zinc plate forms one pole and a pair of carbon plates, one on each side of the zinc, joined at the hard rubber top, forms the other pole. The zinc plate is fixed to the glass rod, by which it can be drawn up out of the solution when not in use. To charge this battery proceed as follows:

To three pints of cold water add five fluid ounces of sulphuric acid. When this becomes cold add six ounces (or as much as the solution will dissolve) of finely pulverized bichromate of potash. Mix well.

Pour the above solution into the glass cell until it nearly reaches the top of the spherical part; then draw up the zinc and place the element in the cell. The fluid should not quite reach the zinc when it is drawn up. "*Bubier's Battery Compound*"

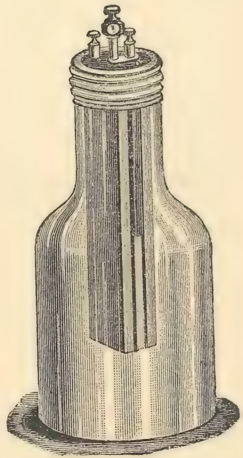

FIGURE 30.

can also be used with good advantage in this cell.

The Grove Cell consists of a glass jar containing the amalgamated zinc cylinder and dilute sulphuric acid. In the inner porous cup a piece of platinum foil dips into concentrated nitric acid. There is no

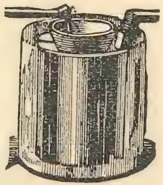

FIGURE 31.

polarization, for the hydrogen liberated at the zinc plate, in passing through the nitric acid on its way to the platinum pole, decomposes the nitric acid, and is itself oxidized, producing water and the red fumes of nitric peroxide gas. This gas does not produce polarization, as it is

FIGURE 32.

readily soluble in nitric acid. The battery has both a large amount of electro-motive force and a low internal resistance. It will furnish continuously for three or four hours a strong current. (See Fig. 31).

The Bunsen Cell is a modification of the Grove, the difference being in this cell that the platinum foil is replaced by a plate of hard carbon. (See Fig. 32).

The Taylor Battery.—This battery was invented by Mr. Theodore F. Taylor, the well-known electrician and expert in the branch of electrical science relating to batteries. This new battery possesses some admirable features which deserve more than a passing notice. It was gotten up to meet the demand for a constant, clean and cheap battery that would maintain a large current, and the result seems to have been attained to a large degree. There is no local action when the cell is standing

idle, and the zinc is thoroughly amalgamated by a process of Mr. Taylor's own invention. The battery is of the zinc-carbon element, and is constructed on a scientific basis, with the object of giving a large, powerful and steady current at a minimum cost. It is the result of twenty-eight years of experience in telegraph and electrical work. The best material is used and special care taken to insure low internal resistance.

One feature of this battery is that the zinc element is wholly immersed in the solution. The active zinc surface in the No. 2 cell is twenty-seven and one-half square inches. By the total immersion of the zinc, about thirty per cent of the outlay for that material is saved. The solution around the zinc remains clear and there are no creeping salts.

A No. 2 cell (6 x 8 inches in size) gives

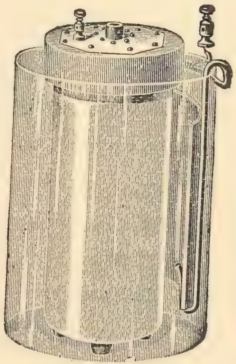

FIGURE 33.

1.80 volts in open circuit work, and delivers a current of 22.5 amperes on short circuit. The internal resistance of the cell is only .077 ohms. The porous cup holds one pint of the depolarizing solution, which is good for seventy ampere-hours at a cost of six cents. The cell can be set up with a saturated solution of common salt around the zinc. Some idea may be had of the power of this battery, when it is stated that one No. 2 cell will run an Edison phonograph twenty-three hours. It replaces thirty gravity cells. Two No. 2 cells and a good series wound motor will run a light sewing machine.

These cells are admirably adapted to intensity coils. A No. 1 cell (12 x 7 inches) has a capacity of 350 ampere-hours, and a No 2 cell (8 x 6 inches) of 70 ampere-hours. (See Fig. 33).

Gravity Batteries are two fluid cells.

The one shown in Fig. 34, is the Crowfoot Battery. Instead of employing a porous cell to keep the two liquids separate, it is possible, where one of the liquids is heavier than the other, to keep the latter on the bottom, and have the lighter floating upon it; this separation, however, is never perfect, the heavy liquid slowly diffusing upward.

To set up this battery proceed as follows: Open out the copper, so as to present all of its surface to the action of the solution, place it in the bottom of the jar, run the insulated wire out of the top of the jar for connecting up. Suspend the zinc above the copper by hanging the hooked neck on the rim of the glass. Pour clean soft water into the jar until it covers the zinc, then drop in six or eight ounces of copper sulphate (blue vitrol) in small crystals.

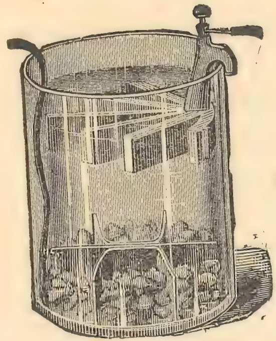

FIGURE 34.

Connect the battery (for ordinary purposes) zinc of one cell to copper of the next and so on, and connect the two electrodes of the series and let them so remain for a few hours, until the separation of the two solutions, which will be known by the blue observed in bottom of copper solution. This "blue line" should be maintained midway between the zinc and copper; when it is too low, drop a few crystals of copper sulphate, when too high, connect the battery in short circuit as before described until it goes down.

While the battery remains in action there is an increase in quantity of zinc sulphate solution in the upper part of the jar.

When zinc oxide forms on the surfaces of the zinc, it must be taken out and washed in clean water with a brush. This battery will be found very useful for use

with medical coils when a mild current is wanted.

Plunge Bichromate Battery. — One of the simplest, best and most inexpensive batteries to make where a strong current is wanted for an intensity coil is a Plunge Battery. This can be made in the following manner:

Take 4, 6, 10, or any even number of common tumblers, and arrange them in two rows parallel to each other, the tumblers to be held in place by an apertured board supported a short distance above the base-board by round standards. To these fit a board which is split from the standards outward, and provide it with two bolts with wing nuts, by which the board may be clamped at the desired height. Now take as many plates of carbon, about 1½ inches wide, ¼ inch thick, and six inches long, as you have tumblers, and saturate one end of them with a little melted wax or paraffine to keep the salts from creeping. When they are cool, fasten the paraffine ends to the opposite edges of the movable board, interposing between the carbon plate and the edge of the board

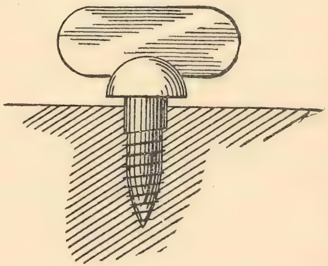

FIGURE 35.

a copper wire. The wooden, strips by which the carbons are clamped should be about one-half of an inch thick. Take as many zinc plates as you have carbon plates, taking care to have them the same size as the carbon plates, and amalgamate

them. This can be done in the following manner:

Take a little diluted sulphuric acid and give your zinc plates a bath in it, then rub a little mercury into the pores of the zinc with a small tooth brush. Having done this the zincs are ready for use.

Secure the zinc plates to the outside of the wooden strips by which the carbons are clamped. This can be done by ordinary one-half inch screws, passing them through holes in the zinc into the wood. Connect the copper wire of one carbon plate to the zinc of the next, and so on throughout the series. The terminal plates to be connected to two bindings posts, which can be made by soldering flat pieces of brass into the heads of round-head wood screws, and screwing them into the wood with the wire under the head. (See Fig. 35).

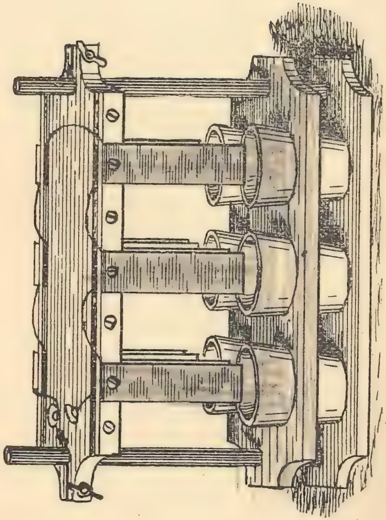

FIGURE 36.

Fill the tumblers about two-thirds full of bichromate solution. To make this solution proceed as follows:

To three pints of cold water add five fluid ounces of sulphuric acid. When this becomes cold add six ounces (or as much as the solution will dissolve) of finely pulverized bichromate of potash. Mix well. Always pull your plate out of your solution when your battery is not in use, as the zinc is continually being eaten away when it is in the solution. Each cell will give an electro-motive force of about two volts. Fig. 36 shows Plunge battery complete.

This battery can be used for running a small incandescent lamp or motor. A battery of six cells will run a small five or six-volt incandescent lamp quite a little while A much stronger battery can be made by using larger tumblers, or fruit jars and proportionately larger zincs and carbons.

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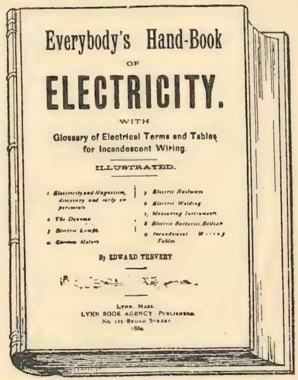

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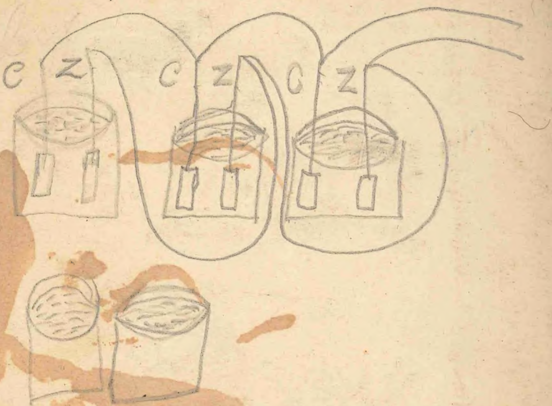

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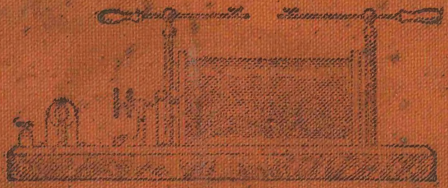

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