HOW TO MAKE LOW-PRESSURE TRANSFORMERS

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How to Make Low-Pressure Transformers

THIRD EDITION

WITH ADDITIONS

BY

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AUTHOR OF

"EXAMPLES IN ALTERNATING-CURRENTS"

"EXAMPLES IN MAGNETISM"

"DIRECTIONS FOR DESIGNING, MAKING AND OPERATING HIGH-PRESSURE TRANSFORMERS."

HANOVER, N. H.

PREFACE TO SECOND EDITION.

The hearty reception of the first edition of this small book has been very gratifying to the author who takes opportunity to answer, in the second edition, in the form of additional subject matter, a number of questions pertaining to fundamental principles, addressed to him by those interested in transformer construction; hoping by this method to aid many who desire to depart somewhat from the printed specifications and construct with similar material, transformers for a variety of application.

Pertaining to design it is probable there is no form of core that will effect so high operative efficiency as the form of discs recommended.

The numerous transformers made by amateurs according to the specifications and submitted to the writer for test, have all shown wonderfully high efficiencies for so small devices.

PREFACE TO THE THIRD EDITION.

The increasing popularity of "*How to Make Low-Pressure Transformers*", has rendered a *third edition* necessary. The wide spread sale of the book has been a pleasing feature. Copies have been sold in Alaska, the Panama Canal Zone, the Philippines, Norway, Italy, and throughout the United States, Canada and England. While in the third edition the book has been greatly enlarged, the price has not been increased.

In this edition a new and very simple form of core construction is described on page 14.

Due to the desire of many amateurs to make a small transformer without the use of discs for a core, a very simple type is described in this edition, beginning on page 16. A very novel utilization of discarded "tin cans" as transformer cores is also explained on page 20; being a lesson in the *conservation* of resources, and *the making of one transformer where none existed before.*

Introductory

Being constantly in receipt of inquiries regarding the design, construction, and operation of small transformers for experimental purposes, the following instructions have been put into the present form, to enable anyone to build a small transformer, at a small cost, without the use of expensive tools or machinery, that may be connected with any house circuit where the pressure is 110 volts or less, and the frequency about 60 cycles.

The particular shape adopted, while excellent as regards ease of construction, is also conducive to high operative efficiency; meaning that the meter bill will be a minimum. The high efficiency is due to the high permeability of the iron used and also to the fact there are no "magnetic joints" in the core of the transformer.

Many of these transformers have been made by students in our laboratories, with a variety of windings on the same size and shape of core, to produce a variety of pressures and out-puts.

The transformer here described, is a "step-down" transformer, to reduce the pressure from 110 volts, to about 8 volts as a minimum, for experimental purposes; such as operating low pressure tungsten lamps; ringing bells, operating small direct-current series motors, used with fans or small electric cars; operating sparking devices for gasolene engines; operating small arc-lights, and for a variety of other uses.

While the primary winding of this transformer is the same, regardless of the secondary or step-down pressure when connected with the 110 volt mains at 60 cycles, the secondary pressure may be varied at will by varying the number of turns in its secondary windings, when constructing the transformer.

The amateur is advised not to make a "step-up" transformer of the material here described, since this type of transformer is not designed for high pressures and the result of applying high pressures might be disastrous for the transformer, if not resulting in injury to the house wiring and experimenter.

If it is desired to build a high-pressure transformer for wireless experiments, information may be obtained from the book entitled "**Directions for Making and Operating a High Pressure Transformer**" by Prof F. E. Austin, mentioned in the last part of this book.

While the transformer to be described in the following outline, may be rated as a 100 watt transformer, when operating at its *maximum efficiency*, it will transform much more power without over heating. As may be seen from the efficiency curve, figure 6, page 12, which was drawn from actual experimental data obtained from testing one of the transformers made by students in our laboratories, the output *may be* 400 watts; and this without serious heating, if not too long continued. However the efficiency at this output is only slightly over 70%; while at 100 watts output the efficiency is over 90 per cent; a high efficiency for a small device.

The power input to the transformer is always greater than the power output because of the various losses within it. The power efficiency of the transformer at any output is always the *ratio* of the output, in watts, to the input, in watts, when the "load" connected with the secondary is "*non-inductive*"; that is not consisting of coils or motors, but of lamps, (incandescent) or a liquid rheostat.

The core of the transformer consists of 50 annular rings or washers 9 inches diameter over all with a 6 inch diameter central hole, punched from thin plates of so called "*electrical-steel*" about .015 of an inch in thickness.

The total thickness of the 50 rings, unvarnished, when tightly clamped together is about .744 inch. Since the width of the annular portion is $1\frac{1}{2}$ inch, the cross sectional area of the iron in the core is

$$1\tfrac{1}{2} \times \frac{744}{1000} = \frac{1500}{1000} \times \frac{744}{1000} = \frac{1.5 \times 7.44}{10} = 1.11 \text{ inch (approx.)}$$

The total weight of the 50 rings is about 6 pounds and 11 ounces.

It should be noted that the useful power output of this transformer is over $\frac{1}{2}$ horse-power.

Directions

1. Carefully remove all sharp edges and burrs from the edges of the rings by means of a fine half-round file or sand paper.

2. Carefully count the rings, weigh them and measure their thickness and width.

3. Coat both sides and edges of each punching or disc with shellac varnish or some other good insulating varnish. Shellac varnish seems to give as good results as any varnish and can be easily made by any one; being simply gum-shellac dissolved in sufficient denatured alcohol to give the proper consistency to spread easily, with a brush. If too thick, it may be thinned by adding more alcohol. Do not use the *powdered* shellac if the orange flake shellac can be obtained.

4. As soon as each disc has been carefully varnished, hang it on a horizontal stick, to become thoroughly dried. This may require five to ten

hours in a warm room. The supporting stick may be long enough and of sufficient strength to support all 50 discs. Do not allow the varnished discs to come into contact with one another before they are dry. See figure 1, a. page 5.

5. Cut carefully from thin brown or white wrapping paper, 50 annular rings having the same size as the steel punchings, to be used to insulate each punching from its neighbor when assembled. A large sheet of the wrapping paper may be folded into a square somewhat larger than a punching then with a punching as a pattern, using a small sharp pen knife, a number of paper rings may be cut at one operation. These may be cut while the varnished discs are drying.

6. After the varnished discs are well dried, they should be assembled by placing one disc on a level board between three or more wooden pegs which are inserted in holes in the board so the pegs are perpendicular to the surface of the board, and at such distance from each other as to allow the disc to just touch them when placed between them. See figure 1, b. Apply a thin coat of varnish to the upper surface of the first disc and immediately place a paper ring on the newly varnished disc. Place another steel disc on top of the paper ring and apply a thin coating of varnish to its upper surface, upon which place another paper ring. Continue this process until all the steel discs have been used.

7. After the assembled pile of discs have been allowed to dry for several hours carefully remove the pile from the board and clamp together in a vice, and in two or more places by wooden hand screws. The vise is not necessary but serves to hold the assembled discs firmly in position for the next operation.

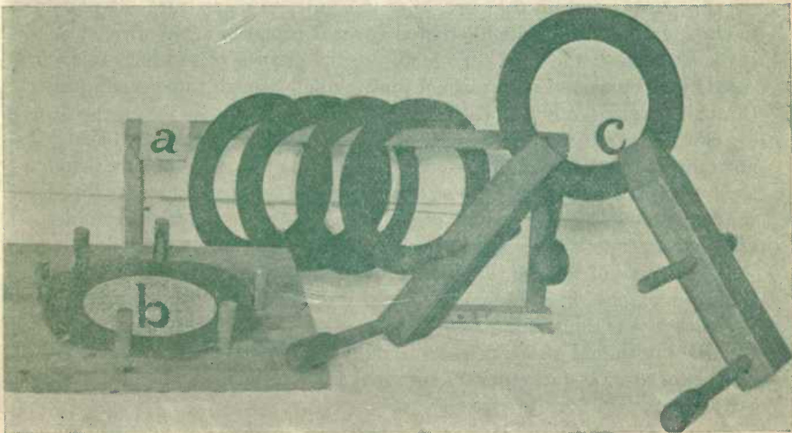
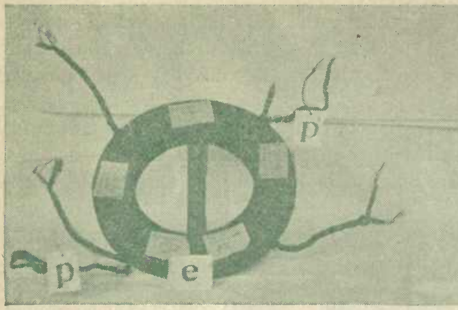


FIG. 1.



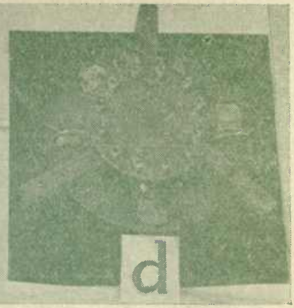


FIG. 2. **FIG. 3.**

8. Begin to wind ordinary electricans' sticky tape, about ¾ inch wide, around the assembled discs between two of the attached clamps, which should be placed about two inches apart. Lap the edges of tape about ⅛ inch.

After the tape has been wound tightly over this space, remove the clamp up to which the tape has been wound, and place it so as to again clamp the discs at a distance of about two inches from the point where the winding of the tape was stopped. Continue to tape over this space of two inches, up to the clamp. Proceed in this manner until the whole transformer core has been tightly taped. See figure 1, page 5.

If the adhesive tape is lapped ⅛ inch on the outer circumference of the core, it will of course lap *more* in passing around the inner circumference. Two layers of tape will be advisable.

9. Next wind on the core, over the tape, as many turns as possible in one layer, of No. 22 double cotton covered copper magnet wire, so as to cover one-half of the core. To facilitate the process of winding, this wire should first be wound onto a spool that is small enough to be easily passed through the circular hole of the transformer core.

Fasten one end of the wire by clamping it, or by any method that will not injure it or the tape on the core, and passing the spool of wire through the central hole, wind the wire so the successive turns as they pass through the central hole, lie close to each other. The proper action of the completed transformer depends largely on the care observed in winding the coils.

The turns of wire as they pass around the outer circumference will be slightly separated from each other and this distance should be the same between each turn if possible.

Each terminal of the primary should be properly tagged to show the number of turns and whether the terminal is an inside one or an outside one. See figure 2, page 6.

The four terminals of the two primary sections are shown at P, P′; figure 2, page 6 the other eight terminals being those of the secondary coils.

The second half of the core should be wound with the same kind of wire, observing the same precautions as with the first half, and should be wound in the same **direction**.

The two coils should consist of about 484 turns, total, and constitute the "primary" of the transformer. See figure 2, P. P′, page 6.

There will be four free ends of wire, and when two adjacent ends are connected together and the two remaining free ends connected with a cricuit, the two coils will act *together*; or not in "*opposition*."

10. Apply two coats of varnish to the wire of the primary coils, allowing the first coat to dry during several hours before applying the second coat.

11. Carefully count the number of turns of wire on the primary, and record the number.

12. Cut two annular rings from thick card board, each ring having an over all diameter about $\frac{1}{8}$ inch greater than the overall diameter of the transformer as already constructed; that is, inclusive of the primary windings.

The diameter of the central hole in each cardboard disc should be about $\frac{1}{8}$ inch *less* than the diameter of the central hole in the transformer as wound.

13. These cardboard discs should be carefully varnished with at least two coats of shellac varnish and very thoroughly dried. Certain kinds of cardboard may need three or more coats.

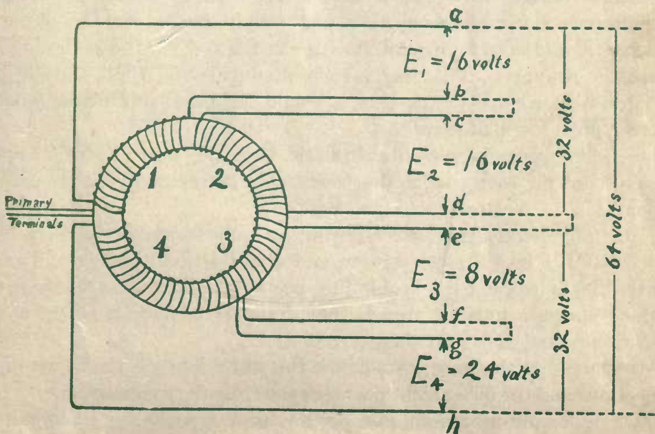


FIG. 4.

14. Cut strips from the same card-board material from which the cardboard discs are made, which have a width equal to the thickness of the transformer inclusive of the primary winding, and long enough to encircle the inner circumference of the transformer and also the outer circumference. Two strips may be used for the outer circumference if one strip cannot be obtained of sufficient length. These strips should be varnished like the card board discs.

15. Carefully wind each terminal P. P′, figure 2, page 6, of the primary coil with insulating tape to insulate the terminals as they pass out through the cardboard insulation that is placed between the primary and the secondary. Considerable care regarding this feature should be taken, that no short-circuit or ground can take place between the primary and secondary windings.

16. Place one of the cardboard discs on one side of the transformer against the primary wires, and the other disc on the opposite side. Fit the varnished cardboard strips around the edges of the transformer between the circumferences of the two cardboard discs and hold all in position, temporarily by means of string. The primary is now completely covered with varnished cardboard which serves to insulate the primary from the secondary windings.

17. Next wind carefully over the cardboard covering, No. 16 double cotton covered copper magnet wire in four sections. The first two sections occupy $\frac{1}{4}$ of the transformer per section; or $\frac{1}{2}$ of the transformer for *both* sections. Another section should occupy $\frac{2}{3}$ of the unwound half or $\frac{1}{3}$ of the whole transformer, while the last section occupies the remaining $\frac{1}{3}$ of $\frac{1}{2}$, or $\frac{1}{6}$ of the whole transformer.

The secondary is wound in one layer, with the turns on the inner circumference lying close together and evenly spaced on the outer circumference, and is to be wound always continuously in the same direction as was the primary. That is in such manner that if all the adjacent free ends were connected together it would form one continuous winding. Figure 4, page 7, will illustrate.

18. The secondary winding should be given two or three coats of varnish; allowing each coat to dry thoroughly before applying the succeeding coat.

19. For convenience the transformer may be mounted on a board base about 12½ or 13 inches square and about 1 inch thick, and the various terminals brought out to binding posts as indicated in figure 3, page 6, which shows a finished transformer, having 12 binding posts; one for each primary and each secondary terminal.

In the figure the four posts below the white line are the four primary connections and the other eight posts are the secondary connections.

The following tabulated data applies to a transformer made in our laboratory according to directions given in this book.

TRANSFORMER.

Core: 50 annular discs of "electrical steel".
Total weight of 50 discs, 107 ozs. (6 lbs. 11 ozs.)
Weight of each disc, 2.14 ozs.
Total thickness of 50 discs not varnished, 0.744 inch.
Average thickness of each disc, $\frac{15}{.1000}$ inch.
Outside diameter of disc, 9 inches.
Diameter of central hole, 6 inches.
Width of annular portion, $1\frac{1}{2}$ inch.
Cross sectional area 1.11 square inch.

Primary: 485 turns, of No. 22 D. C. C. copper magnet wire.
Wound in two sections.
Total resistance of primary wire, at 70° F (or 21°C) 3.8 ohm.
Total length of primary wire, 204 feet.
Total weight of primary wire, 7 ozs.

Secondary: 287 turns, of No. 16 D. C. C. copper magnet wire.
Wound in four sections.
Total resistance of secondary at 70°F (or 21°C) is 0.63 ohm.
Total length of secondary 137 feet.
Total weight of secondary 24 ozs. or 1 lb. 8 oz.

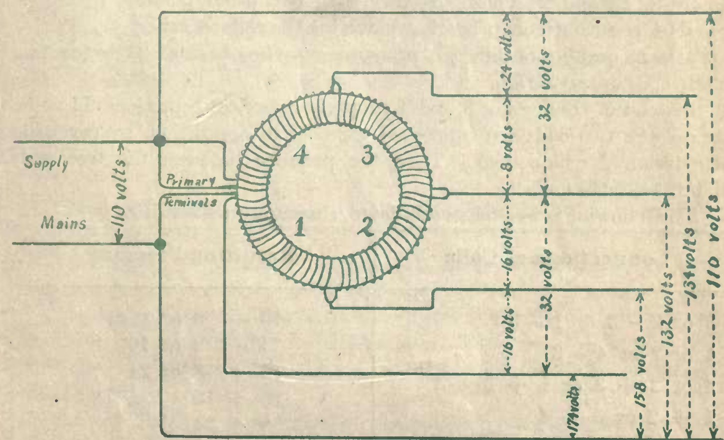


FIG. 5.

The reason for winding the secondary in unequal sections, is to obtain a wide variation in pressure.

Without direct reference to any particular transformer that has been built, suppose diagram figure 4, page 7 denotes a transformer with a secondary having four sections, two of which, 1 and 2 are equal to each other, and the pressure of each section is $\frac{1}{4}$ the total secondary pressure.

Let it be assumed the total no-load secondary pressure is 64 volts; that is with all the sections connected together in series so that their pressures are all *added* together.

The sum of the pressures of the two sections having the same number of turns will be 32 volts when they are connected together in series; see between a and d, figure 4, page 7.

Now suppose sections 1 and 2 are connected together in *opposition*, by changing their terminal connections; that is terminal d be connected with terminal b; then the pressure between a and c will be zero. Two equal pressures, numerically, being *opposed* to each other.

Next suppose terminals of coils 3 and 4 are connected as at f and g; then the pressure between e and h will be 8 + 24 = 32 volts. Therefore the two sections formed by coils 1 and 2 in series, and coils 3 and 4 in series, could be connected together in *parallel*, for heavier *current* output. Both sections thus formed could supply twice as much current to a load as could one section alone. Coil 4 having three times as many turns as coil 3.

Figure 4 indicates the pressure obtainable from *each* of the four coils; namely 8, 16 and 24 volts, together with two other possible pressures, 32 and 64, resulting from properly connecting the coils together.

A large number of different pressures may be obtained by connecting certain coils in *opposition*.

Instead of connecting 3 and 4 properly in series to produce 32 volts, suppose the two coils are connected together in opposition, by reversing their terminal connections. Then the pressure between the free ends will be 24–8 or 16 volts.

The following pressures as tabulated, show some possibilities.

Connections of Coils	**Resulting Pressure**
3 or 2 – 3 or 1 – 3	16 – 8 or 8 volts
1 or 2 or 4 – 3	24 – 8 or 16 "
4 or 2 + 3 or 1 + 3	16 + 8 or 24 "
1 + 2 or 3 + 4	16 + 16 } or 32 " 8 + 24 }
4 + 1 or 4 + 2	24 + 16 or 40 "
4 + 3 + 2 or 4 + 3 + 1	24 + 8 + 16 or 48 "
4 + 1 + 2	24 + 16 + 16 or 56 "

The negative or – sign denotes that the coils are connected together in opposition; while the positive or + sign denotes that the coils are so connected that their pressures are *added* together.

Figure 5, page 9, gives some idea of the application of the transformer as a "booster", or auto-transformer, if part of the primary is employed. The arrangement indicated in figure 5 is such that the pressure applied may be boosted, in steps, from 110 to 174 volts. In order not to over heat the transformer, no greater current should be taken from the device when used as booster, than the *primary* winding is designed for. Other pressures than those indicated, may be obtained; as between A D, is 48 volts; between A E, 64 volts. Also if secondary coil 4, figure 5, is connected in opposition to the primary pressure, then about 110–24 = 68 volts may be obtained, the transformer acting as a "crusher", or negative booster.

The primary pressure, less any of the other coil pressures, will give other possible values.

When wound according to the instructions given here, the input to the transformer at no load secondary, when primary is connected across service mains having a pressure of 110 volts at 60 cycles, is about 11 watts.

If the cost of electric power is 15 cts per kilo-watt hour, (1000 watt-hours) the cost per day of 24 hours of having the *unloaded* transformer connected with the mains, would be

$$\frac{11 \times 24 \times 15}{1000} = 3.9 \text{ cents; say four cents.}$$

This is about $\frac{1}{6}$ cent per hour.

According to the curve figure 6, page 12, when operating a load of 90 watts the input is 100 watts; and the cost *per hour* will be:—

$$\frac{100 \times 1 \times 15}{1000} = 1.5 \text{ cent.}$$

Compared with the expense of batteries to furnish the same amount of power, the expense is small.

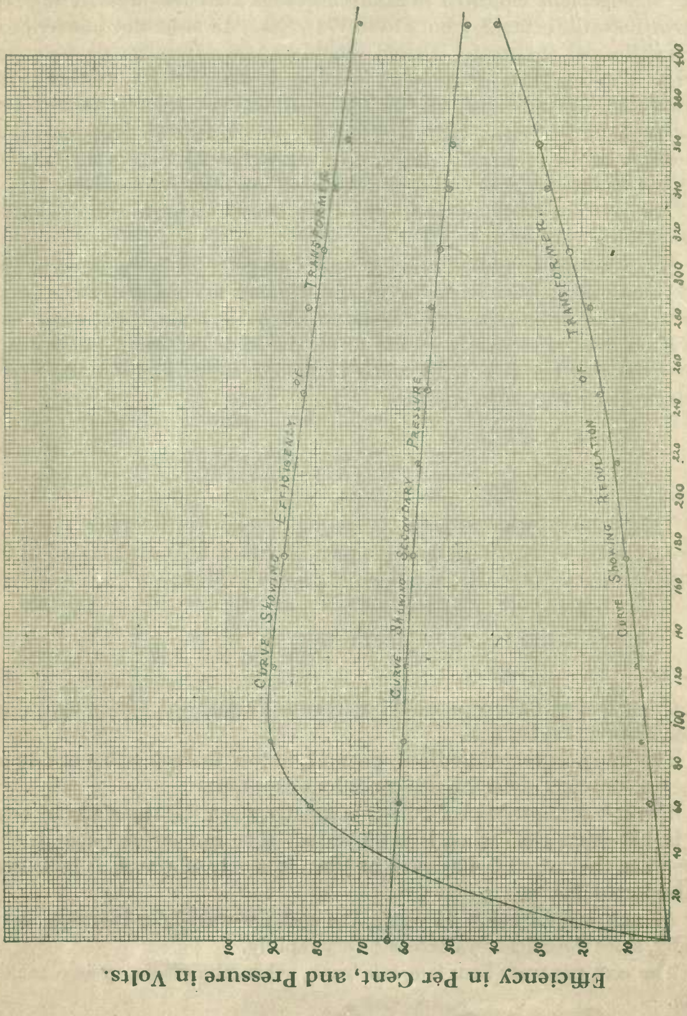
The upper curve of figure 6, page 12, shows the efficiency of one of these transformers under various conditions of output.

The *cost per-watt-hour* of output is greater when the transformer output is 400 watts than when it is 90 watts. The *cost per-watt-hour* is the same when the output is 400 watts as when it is only 46 watts, as indicated by the dotted line.

At any output below 44 watts, the cost per-watt-hour increases very rapidly, since the efficiency decreases very rapidly.

The cost per-watt-hour is a *minimum*, when the efficiency is a maximum.

The lower curve in figure 6, page 12, shows what is called the "*regulation*" of the transformer; which is the **ratio** of the *difference between the no-load secondary terminal pressure and the full-load secondary terminial pressure, to the full load secondary terminal pressure,* when the load connected with the secondary is non-inductive, such as incandescent lights. The primary applied pressure must be kept constant while finding the regulation.



Output in Watts.

Fig. 6.

REGULATION.

If E denotes the no-load secondary terminial pressure, in volts, and E_1 denotes the full-load secondary terminal pressure, in volts;

$$\text{then, } \textbf{regulation} = \frac{E - E_1}{E_1}$$

when the applied primary pressure is maintained constant and the load on secondary is non-inductive.

The middle curve in figure 6, page 12, shows the drop in the secondary terminal pressure as the load output increases.

At no load the secondary terminal pressure was 64 volts, with all secondary coils connected together in series and 110 volts 60 cycles applied to primary terminals.

At 100 watts output the secondary terminal pressure fell to about 60 volts; while at 400 watts output it fell to about 47 volts. The pressure applied to primary was kept constant at 110 volts.

The secondary of this transformer may be used as a "*choke-coil*" for currents up to about 10 amperes. By tapping in at different secondary binding-posts, various "*choking*" effects may be obtained. The primary of the transformer may also be used as a choke coil, but for very much smaller values of current; about 2 or 3 amperes.

RECAPITULATION.

The design and construction of the transformer just described, leads to the consideration of certain fundamental principles it is well to have in mind, if it is desired to vary the windings of the secondary to meet a variety of applications.

Consulting page 9 it will be observed that the primary winding consists of 485 turns. If the pressure applied to the terminals of the primary is 110 volts, the pressure *per turn* of primary winding is $\frac{110}{485} = 0.22$ volts. One turn of secondary winding will have *very nearly* the same pressure. So that if a secondary pressure of 55 volts is desired, *one half* the number of primary turns (that is 243) should be wound on the secondary. If one fourth the number of primary turns are wound on for the secondary, then the secondary pressure will be some less than $\frac{110}{4}$ or about 27 volts.

Considering the matter from another standpoint, it will be necessary to wind on about 4.5 turns in order to obtain a secondary pressure of one volt. All of the foregoing considerations are based on a frequency of 60 cycles per second.

SPECIAL CORE CONSTRUCTION.

A special type of core may be constructed from the ordinary stove-pipe iron obtainable at any hardware store, as follows: First construct a form on which to build up the core, by fastening a circular wooden disc, 6 inches in diameter and $\frac{3}{4}$ inch (or even $\frac{7}{8}$ inch) thick to a larger board as illustrated by **D** in figure 7.

The stove-pipe iron should be cut from the large sheets, in strips $\frac{3}{4}$ inch wide, carefully varnished all over with shellac varnish and wound over the form in a spiral as shown in figure 8, so that the finished core will be wound to a depth of $1\frac{1}{2}$ inch. In other words the cross section of this core is to be the same as the cross section of the core made of the circular discs, and its weight will also be the same. That is, the amount of stove-pipe iron required will be about 6 lbs. and 11 oz. Pieces of string or tape **T** and **T′** figures 7 and 8, may be laid on the form before the strips are wound on, and used to hold the wound core together until it can be covered with tape as directed on page 6, section 8. The winding of the primary and of the secondary will be exactly the same with this spiral form of core as with the discs. This form of core will enable many to construct transformers of $\frac{1}{2}$ horse-power output, who find it inconvenient and expensive to obtain the proper *discs*.

Fig. 7.

Fig. 8.

A TRANSFORMER FOR 220 VOLTS 60 CYCLES.

By using *twice* as many discs as specified on page 9, or iron strip twice as wide as out-lined on page 14, and using the same size of primary and and same number of turns as specified on page 9, a transformer may be made, adapted for 220 volts, 60 cycles primary pressure. If the primary winding is wound in two equal sections (same number of turns in each section) each section may be connected with 110 volts 60 cycles; or the two equal sections may be *properly* connected together in parallel and the arrangement connected with 110 volt 60 cycle mains, giving a transformer with a continuous full load output of over one horse power. If the transformer is connected with 220 volt 60 cycle mains, the two sections of primary winding should be connected together in *series*; in which case the continuous full load working output will be some over one horse power. No. 10 double covered cotton wound magnet wire should be used on such a transformer for a secondary winding; being wound as closely as possible in *one layer*.

The same reasoning as regards pressures applies in the case of a 220 volt transformer, as given above for a 110 volt transformer. With the same number of secondary turns on the 220 volt, as on the 110 volt transformer, and with 220 volt 60 cycle primary pressure, the secondary pressure will be about twice as great as on the 110 volt transformer.

Great care should be exercised in winding the insulating tape around the iron core. If a cheap grade of electrician's sticky tape is used it will be advisable to wind *two* layers, one over the other.

Instead of using this class of insulating tape, ordinary cloth tape $\frac{3}{4}$ inch wide may be wound over the iron core, making a $\frac{1}{8}$ inch lap along the edges of the windings, carefully coating the finished winding with shellac varnish. After the varnish is thoroughly dry, wind another layer of the cloth tape over the first and shellac this layer.

In winding the primary wire on the taped core, do not pull the wire too tightly in winding over the corners of the core. If wound too tightly the sharp edges of the discs may cut through the insulation, causing "*shorts*"; that is *short circuits*.

SPECIAL TYPE OF CONSTRUCTION.

The following working directions for making a different form of low-pressure transformers may appeal to those who desire to *experiment* with different coil windings; the arrangement being such as to allow the forms or spools, on which the coils are wound, to be quickly and easily removed from the core, and others substituted, or the same rewound by being readily slipped on to a specially designed winding device, shown in figure 15, page 18.

No lengthy explanation is necessary, because of the insertion of the working diagram on pages 16, 17, 18 and 19, with the dimensions clearly indicated thereon.

The core consists of 124 pieces of transformer steel each $6\frac{1}{2}$ inches long by 1 inch wide, and 124 pieces of the same material $3\frac{1}{4}$ inches long by 1 inch wide; the material being about .015 inch in thickness. If thicker material, such as ordinary stove-pipe iron, is used, enough plates should be employed to build the core up to 1 inch in thickness. The cross section of the finished core is 1 square inch. The core weighs about $4\frac{1}{2}$ pounds. The longer strips constitute the "*legs*" of the transformer core, over which are slipped the forms or spools on which are wound the primary and secondary coils. The shorter strips constitute the end "*yokes*" connecting the "*legs*" and forming a *closed* core; or a closed magnetic circuit. Figures 9 and 10 show how to assemble the core and clamp the iron strips in position. By removing one end block and its clamping strip, as shown in figure 10, the coil bobbins or forms may be slipped on over the "legs" of the transformer core.

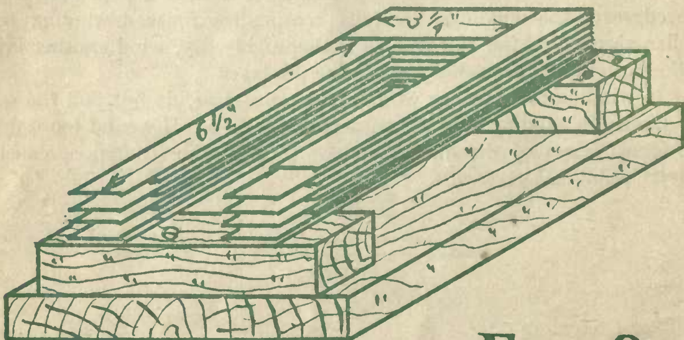


Fig. 9.

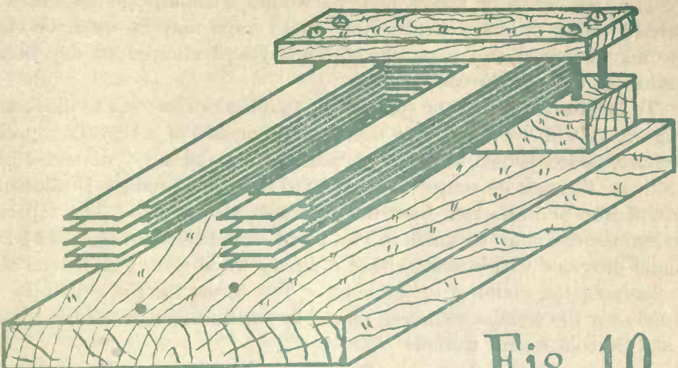


Fig. 10.

It will be advisable to carefully remove all sharp edges from the strips by using a file, and to carefully varnish both sides and edges of each strip with shellac varnish, allowing the varnish to thoroughly dry before beginning the assembling of the core.

The ends of the spools or bobbins are made of wood, figure 11, which are glued to the cardboard tube made of a single piece, and folded into shape as indicated in figure 12. By cutting partly through the cardboard with a sharp pen knife as indicated in figure 12, the cardboard may be more readily formed into the required shape.

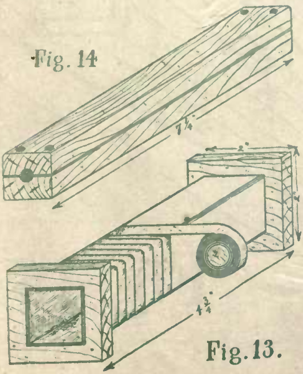


Fig. 13.

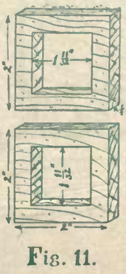


Fig. 11.

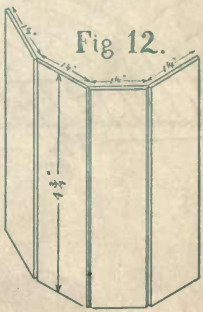


Fig 12.

The two forms or spools may be wound with tape as indicated in figure 13; either ordinary electricians' sticky tape may be used, or cloth tape may be used and carefully shellacked and allowed to dry before winding the wires on the spools.

To facilitate winding the coils on the spools a device such as illustrated in figure 15, will be found very useful, and consists of a slightly tapering wooden mandrel shown in figure 14, page 17, having a $\frac{1}{4}$ " diameter hole lengthwise through its center to allow it to be slipped onto a $\frac{1}{4}$" diameter shaft of iron or brass rod, bent into a crank at one end. The tapering wooden mandrel may be made in two parts as indicated in figures 14 and 15, and provided with screws, either ordinary wood screws or stove bolts, for clamping the mandrel to the shaft. The forms for the coils may be slipped over the wooden mandrel, placed in position as indicated in figure 15, and the coils readily wound.

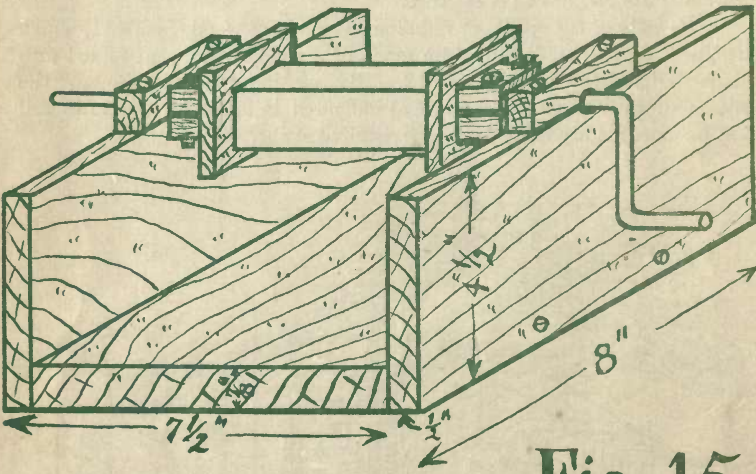


Fig. 15.

The primary winding on each spool consists of 260 turns of No. 25 copper magnet wire, double cotten covered, wound in two layers. After giving the primary windings two or three coats of shellac varnish, the secondary may be wound directly over the primary. The secondary consists of two layers of No. 14, double cotton covered copper magnet wire; 50 turns per layer. The primary may be wound in two sections per spool, bringing out four terminals. The secondary should be wound in two sections, bringing out four terminals.

For 110 volts 60 cycles primary, connect all the primary sections together in series. The pressure between the terminals of each section of the secondary will be about 5 volts; or all connected together in series about 20 volts.

If a tap is brought out from the middle of a secondary section (or layer) the pressure of 2½ volts per half section may be obtained. If desired an extra layer of 25 turns may be wound over the secondary to obtain 2½ volts.

From 10 to 15 ampers may be obtained from the secondary of this transformer. Even 20 to 25 ampers may be taken for short intervals.

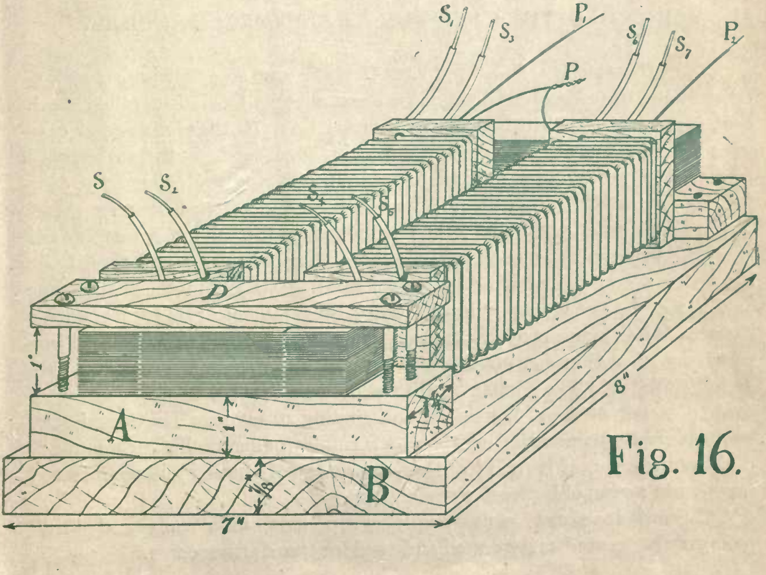


Fig. 16.

Figure 16, page 19, will serve to give an idea of the appearance of the finished transformer. If constructed as outlined and the primary connected in series as at P_1 P and P_2, and P_1 and P_2 connected across 110 volt, 60 cycle mains, the pressure between S and S_1
" S_2 and S_3
" S_4 and S_6
" S_5 and S_7 } will be about 5 volts

If S and S_2, S_3 and S_6, S_4 and S_5 are connected together, the pressure between S_1 and S_7 will be about 20 volts.

An important fact regarding the relation between the number of turns in the windings of coils and the current in the coils may serve as a guide in experimenting with different windings.

If the number of turns are doubled, the current will be reduced in value very nearly *one-fourth*; assuming the same frequency and applied pressure.

For example in the transformer last described, *with one end yoke removed*, if 110 volts at 60 cycles be applied to one primary coil of 260 turns about $3\frac{1}{2}$ ampers result in the coil, while with the two primary coils in *series*, making a total of 520 turns, with the same pressure and frequency only a trifle less than 1 ampere results.

USING OLD TIN CANS FOR TRANSFORMER CORES.

The ordinary so-called "tin" cans that are now so extensively employed in the distribution of canned goods, are really made of thin rolled steel, coated over with a thin layer of the metal tin. If these discarded cans are placed on top of a hot coal fire, the tin, together with the solder used to make the joints tight, may be melted off, allowing the ends of the cans to be knocked off. After the tin has been melted off and the thin metal of the cans kept at a red heat for a few moments, the cans may be removed from the fire and allowed to cool *slowly*. The slower they are cooled the better the metal will be annealed or softened. After the metal has become cold it may be cut into any desired shape by means of ordinary tinsmith's shears. After being properly treated as outlined above, the metal will be covered with a thin coating of *oxide* that is very desirable, since it serves as an insulator. The shellac varnish should be applied to this coating of oxide. Never attempt to remove the coating of oxide. The metal may be flattened by hammering gently with a small wooden mallet, or a number of the cut pieces may be laid together, one on top of another and compressed together in a vise; or between screw clamps.

Discarded varnish cans, maple syrup cans, milk cans and "tin" pails may be treated as suggested and used for transformer cores.

It may be noted that in all the types of transformers described, the primary and the secondary are always wound on the same limb of the core; or over one another. This construction is much more efficient than placing the primary on one limb or section of the core and the secondary on another section, as is sometimes advised.

NOTE FOR EXPERIMENTERS.

It will be well to note that trial windings may be wound on one of these transformers at any time. That is, *one turn* of a 10 foot length of insulated wire may be wound on over the secondary winding, and the terminals of the 10 foot length employed as "live ends", when the transformer primary is operating. If the pressure is not sufficient, wind on another turn, and again test the pressure between the terminals of the test wire. Repeat the process as desired, for gradually increasing the useful pressure.

USEFUL APPLICATIONS OF LOW-PRESSURE TRANSFORMERS.

Many of the small transformers made as specified on pages 4 to 9 have been employed to ring door bells in place of batteries; to operate small arc lights using small pencil carbons; to operate low pressure incandescent lamps; for electro-welding; to charge storage cells, using an electrolytic rectifier, and to operate small direct-current *series* motors, either fan motors or those on toy electric railways.

It is possible to operate a direct-current series motor from alternating-current mains, because the reversal of the alternating-current occurs at the same instant in both the field windings and in the armature windings, so that the armature pull, or the turning effort always acts in the same direction. The direction of armature rotation may be reversed by reversing the connections of the armature terminals relative to the field terminals. That is, to reverse the direction of armature rotation, reverse *either* the field *or* the armature connections but not both. This rule holds true for a series motor when operated by either direct-current or alternating-current.

TO OPERATE SPARK COILS.

Another useful application is for operating spark coils for gas or gasolene engine ignition.

The transformer may have the terminals of one of its secondary sections connected with the primary of an ordinary jump spark coil, allowing the vibrator to operate as usual. No fixed directions can be offered to govern this class of service, since spark coils are so varied in construction. Judgement must be exercised as regards the pressure to be applied to a given coil; starting with a low pressure and gradually increasing it as required.

STEP-UP TRANSFORMERS.

As many questions have been received regarding the use of low-pressure transformers to step-up the pressure, a few words may be in order regarding the matter in general. As outlined in this book, the designs are not such as to warrant primary or secondary pressures much exceeding 25% greater than the values mentioned. It is however perfectly permissible to apply a low pressure to the secondaries of these transformers and then obtain 110 volts (or 220 volts) from the primaries. That is the transformers may be used as step-up transformers, if their rated pressures are not exceeded. Some have built 8 to 16 volt alternators and used these transformers to step the pressure up to 110 volts. In such cases what are called primaries in this book become in reality secondaries, and vice versa.