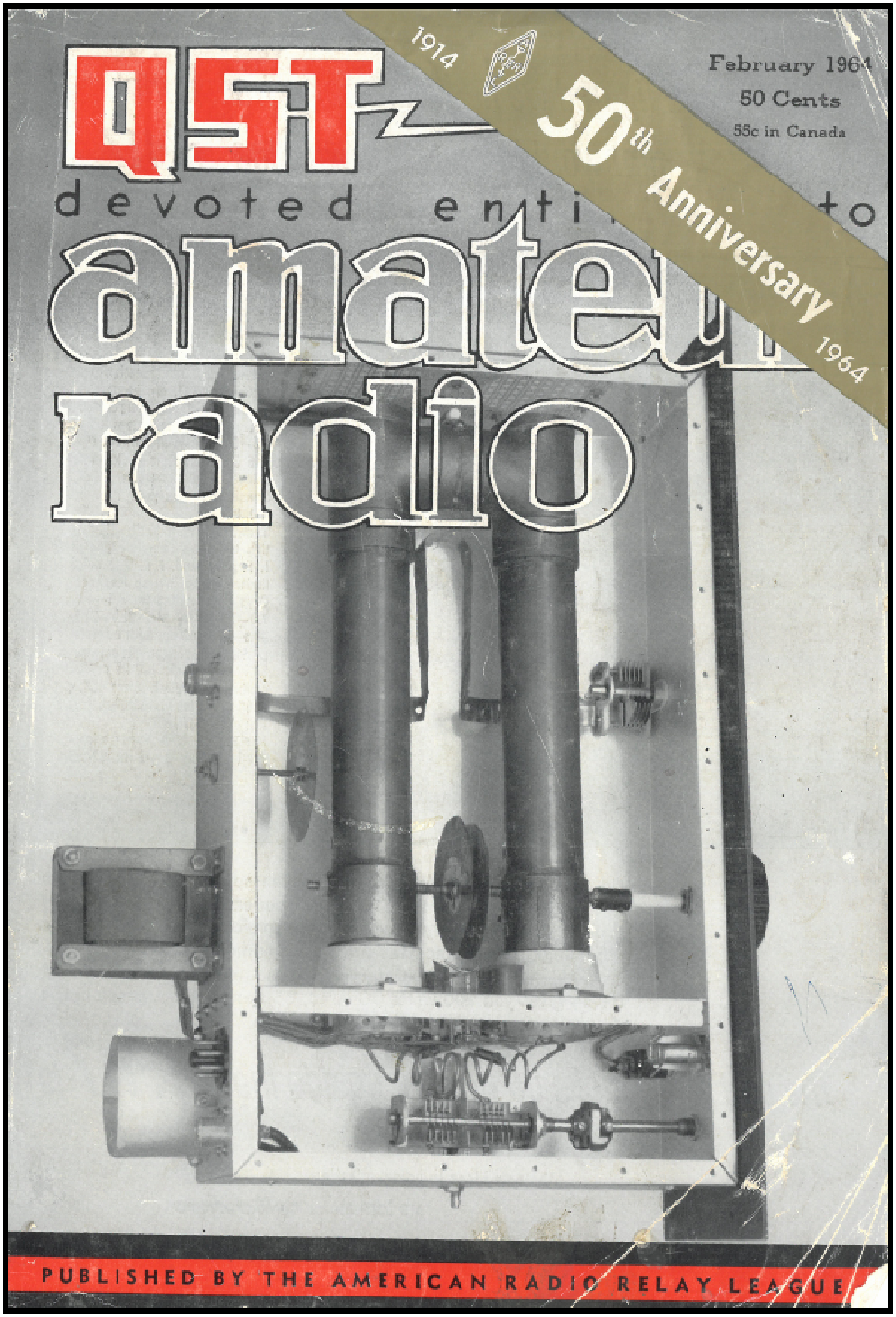
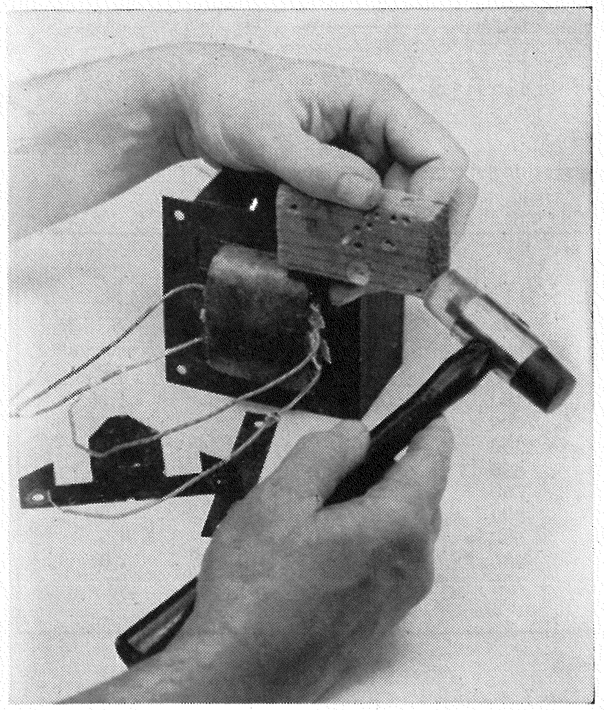
Tailor-Made Volts TJP Feb 1964 QST Article by Lewis G.McCoy





As described in the text, first free the laminations with a knife blade. The laminations can be driven out of the stack. A piece of wood butted against the lamination ends and gently tapped with a hammer will drive out the pieces.

An Almost-No-Cost

Power Transformer

BY LEWIS G. McCOY,* W1ICP

The voltage-doubling power supply has it over the center-tap and bridge circuits in practically every department, especially in the 750-volt range. The catch is that you can't find a suitable transformer in the catalogs. If you really want a supply that will handle up to a quarter kilowatt, though, you won't let that stop you. The bonus is that you can save money, too.

Tailor-Made Volts

As many readers know, *QST* has featured several rigs using parts from old TV sets — particularly TV power transformers — as a means of saving money. The only trouble with the TV power transformer is that often it isn't exactly right for the job. An ideal transformer for a good many amateur rigs would be one that could be used in a voltage-doubling circuit making use of the low-cost "surplus" silicon rectifiers. With a transformer having a total secondary voltage of, say, 300 volts, with plenty of current rating, it would be possible to build a supply that would give 750 volts d.c. at 300 ma. or more, and do it simply and cheaply. Unfortunately, there "just ain't no such animal" available commercially, at least not economically. Until some of the transformer manufacturers take the tip and make such a unit, the only way to get one is to build it yourself. That is exactly what we did.

The average TV transformer will deliver 300 watts plus, which is ample power, so actually what would be required for our purposes? We would want the above-mentioned 300 volts a.c. with plenty of current; also, a 6.3-volt winding to take care of the heaters, and maybe a bias winding to eliminate the need for a separate bias transformer. Well, old TV transformers seem to be abundantly available, either on a give-away basis or for a few bucks from TV servicemen. How about rewinding one? Don't throw up your hands in horror — the job is really quite simple. We did exactly that and wound up with just what we wanted. The job took about seven hours from start to finish. Transformer winding isn't exactly a lost art, but few hams seem to know much about it. In this article we hope to show you how easy it actually is.

Before getting into the actual description of winding a transformer, let's take a look at a typical power transformer to see how it's made. A power transformer consists of a laminated iron core, windings of various sizes to provide the necessary voltages and currents, insulating paper, nuts and bolts to hold the unit together, and metal covers to protect the windings.

The iron laminations consist of E- and I-shaped sections as shown in Fig. 1. These are assembled in a stack to make up the total core. The method of stacking is also shown in Fig. 1. In the actual construction of a transformer the laminations may be put together in groups. In other

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words, there might be three E and I sections stacked the same way, then three more of each type section stacked in the alternate arrangement. An insulating and bonding agent, usually varnish or shellac, is applied between laminations. This reduces the power loss in the core and serves to make a tight form, minimizing hum or vibration.

The windings are put on in layers, each layer of wire being separated from the next by an insulating layer of paper. The current-carrying capability of a winding is determined primarily by the size of wire used in it. Fig. 2A is the schematic diagram of a typical TV power transformer. Such a transformer usually has several filament windings plus a high-voltage and primary winding.

How To Determine Power Capability

One of the first things a builder must know when scrounging an old TV power transformer is how much power it will handle. If we are going to build a transmitter that requires 300 watts of power, we cannot get it from a transformer that has only 200 watts capability. The amount of power that a transformer will handle can be determined quite closely from the cross-sectional area of the core. This is the cross-sectional area *inside* the windings, and does not include the area of the part of the core that surrounds the winding. Fig. 3 shows this area.

It isn't actually necessary to take the transformer apart to measure the area. Lamination sizes are standardized, so if you know the outside width, length, and height of the lamination stack it is easy to determine the power capabilities. Nearly all TV transformer cores have the same width and length, but the height of the stack will vary. The width and length are commonly 3¾ by 4½ inches, and for a core of this size the tongue of the E lamination is always 1½ inches wide. With such a core all you then need for finding the cross-sectional area is the height of the stack. For example, suppose the height is 2¼ inches. This multiplied by 1½ equals 3⅜ square inches. Looking at the graph in Fig. 4 we see that 3⅜ square inches gives a power capability of 350 watts. This means that we can rewind a transformer having a core of these dimensions and expect to get about 350 watts from it.

There are two things to look for when getting an old TV transformer. First, take the one with the highest stack of laminations. This will be the one with the best power capabilities. Second, some transformer manufacturers soak the coils in tar. This type can be rewound but it can be a rather messy job and is best avoided. You may have to remove the housings on the transformer to make sure the windings aren't coated with tar. However, the tar-coated jobs are fairly rare, in our experience.

Taking the Transformer Apart

The first step in the rebuilding process is to remove the transformer from the TV chassis. At this point you can save yourself some further work if you first check out the windings and label them. The primary or input winding will be connected to the a.c. line, probably through a switch on the front of the chassis and a fuse or fuse holder on the rear. The 5-volt winding will be connected to the filament terminals (2 and 8) on the rectifier socket, which is usually a 5U4G. Two of the leads from the high-voltage winding will be connected to the plate terminals (4 and 6) on the rectifier-tube socket. The center-tap lead of the high-voltage winding probably will be grounded to the chassis. There will probably be two 6.3-volt windings. The leads from one of these will go into the shielded compartment on top of the TV chassis and be connected to a tube socket in the compartment. The other 6.3-volt winding — and this is the one that you'll probably keep intact on the transformer — supplies

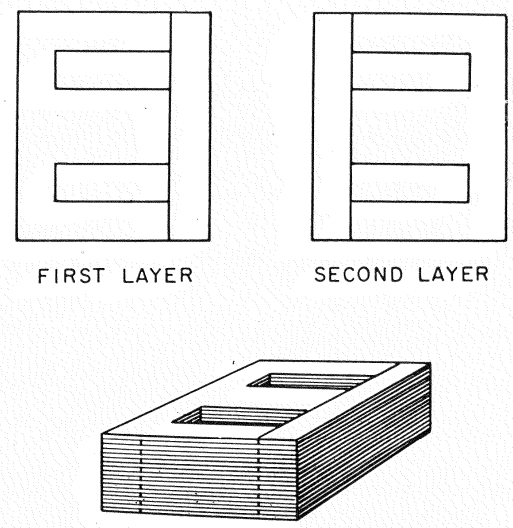


Fig. 1—How the core is assembled. Alternate layers have the E laminations facing oppositely. Sometimes two or more laminations of the same kind are grouped together and handled as a single lamination, to save assembly time.

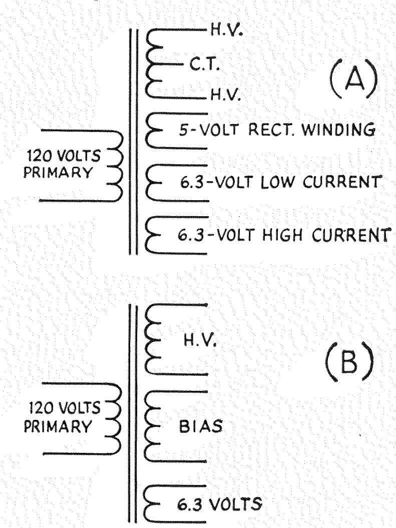


Fig. 2—(A) Typical schematic of a TV power transformer. (B) The same transformer as rewound according to this article.

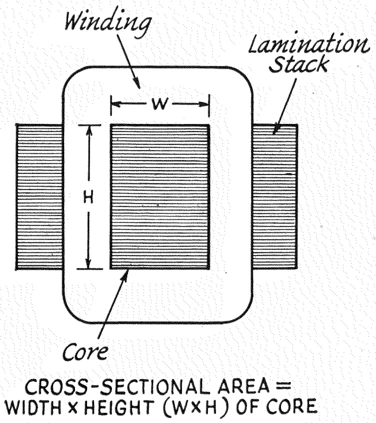


Fig. 3—This is a cross-section drawing of a typical power transformer. The cross-sectional area referred to in Fig. 4 is determined by multiplying the tongue width by the height of the center core.

all the other tube heaters in the set. Tag all leads before removing the transformer.

If you get a transformer that has *already* been removed from the set, get someone with an a.c. voltmeter to check out the various windings and mark them for you, assuming you don't have a meter yourself. There is a color code for the transformer leads and the information for identifying the leads is given in the construction practices chapter of the ARRL *Radio Amateur's Handbook*. However, the leads are not always marked according to the code. Also, the colors tend to fade with age, so it is best to actually check the transformer with a meter.

When checking out the transformer with a meter you'll find that the voltages are slightly higher than what is actually called for because you'll be checking them without a load on the windings. For example, the 5-volt rectifier winding will show something over 5 volts. However, if the leads came off the rectifier socket, the winding *is* a 5-volt winding.

After identifying the windings, remove the four nuts and bolts that hold the transformer together and also take off the metal covers, assuming the unit has them. Don't worry about the transformer falling apart when you remove the bolts; it won't. Look the unit over carefully and try to determine which layers of windings are which. In most cases the winding nearest the core will be the primary. Usually the order will be something like this: first, the primary; next, the high voltage; then, the 5- and 6.3-volt low-current filament windings; and last, the heavier-current 6.3-volt winding.

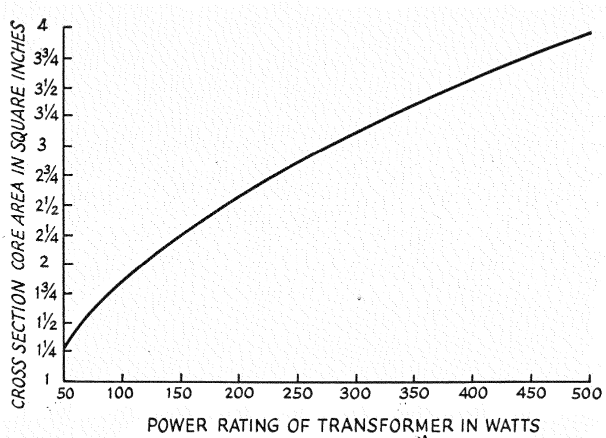


Fig. 4—This graph provides a simple means for determining the power capabilities of an unknown transformer. First determine the cross-sectional area of the core. Find your cross-sectional area figure on the vertical axis and then go across the graph to the curve. Drop from intersection point vertically to the bottom of the chart to find the power in watts.

Examine the lamination arrangement. Note that the laminations are probably inserted in groups. On one side of the stack there may be three I units and below that three E units, alternating through the entire stack. Note how the top and bottom of the stack are assembled so that you'll be able to put it back in this same order when you complete the winding job.

Getting the laminations apart is not a difficult job, but it should be done carefully. Insert a thin knife blade between the end piece and the rest of the core to break the varnish seal, so the end piece will be loose. Using a block of wood butted against the edge of the piece, drive it out of the core with light taps of a hammer. Alternate between the two ends so the piece will come out straight. Continue by breaking the next group of laminations free with the knife blade, then carefully driving them out. After a few groups have been removed the hammer won't be needed, as the broken-loose laminations can be pulled out by hand. Be careful not to bend the laminations when removing them. If the edges get nicked in hammering, file them smooth before reassembling the core after the new windings are finished.

Once the laminations are removed you are ready to go to work on the windings. The first thing to do is remove the high-voltage winding by pulling out the wire. If you are lucky you can start it just by pulling on one of the high-voltage leads. However, it is more than likely that the end of the winding will break off, because the wire size will be rather small. If it breaks you'll have to dig in with a knife or probe to get at the wire. Once you get it started the layers come out rather easily. Wind the wire that is removed on a spool or piece of wood as you may want to save enough to use for a single-layer bias winding when rewinding the transformer. When you get most of the high-voltage winding out you'll see that you can separate the primary winding section from the outer windings, as shown in the photograph. Be careful not to disturb the insulation around the primary winding. Incidentally, in the unit we took apart, and this will probably hold true for most TV transformers, the wire size on the primary was No. 18 enameled.

After you've cleared away the high-voltage winding, remove the 5-volt rectifier-filament winding and *most* carefully count the number of turns. There will probably be approximately 10 turns, but count them to make sure. The number of turns on this winding will tell you how many turns you need for each volt you expect to get from the new windings you will put on. For example, if there are 10 turns on the 5-volt winding, the transformer is wound on the basis of two turns per volt. It doesn't make any difference whether the windings are near the center of the core or the outside; the turns per volt will be the same.

Next, check to see which 6.3-volt winding has the smaller-size wire winding and remove that one. Set the 6.3-volt winding with the larger wire aside for later use. You are now ready to start winding the new high-voltage coil.

Putting On the New Winding

In the transformer shown in the photograph we wanted a high-voltage winding for a voltage-doubling circuit that would provide 750 volts d.c. at about 300 ma., plus some additional current to take care of the other tubes in the transmitter. To arrive at an approximate figure for the a.c. voltage required for a voltage-doubling circuit, divide the desired d.c. voltage by 2.2. In our case this worked out to about 340 volts a.c. At 2 turns per volt this amounted to 680 turns of wire. One nice thing about winding your own transformer is that you can put taps on the winding to allow for any variations or mistakes you might make in figuring. We tapped at 520 turns and again at 600 turns just in case a lower voltage was wanted.

In our case the wire size needed for the high-voltage winding at the current desired was No. 24. Table 1 gives the current-carrying capacity and other pertinent information you'll need for all the wire sizes (enameled) between No. 18 and No. 30. Having selected a wire size, make an estimate of the area the entire winding will occupy. Allow a little space between each end of a layer and the core when calculating the number of turns on a layer. In our case the safe winding length was 2 inches, so we allowed 90 turns for the first layer and guessed that we might average 80 turns per layer throughout the winding. With 680 turns, this meant that about 9 layers would be needed. Based on the turns per inch in the table, the thickness of a 9-layer winding would be about 1/5 inch for the wire alone, but some allowance also has to be made for the paper wrap between layers. Use your best judgment in deciding whether you can get all the needed layers in. If it looks as though you can't, use the next smaller wire size and try again.

You can calculate how much wire of a given size you'll need by measuring the average distance around the winding form — in other words, how long a piece of wire is needed to make a single turn. The table gives the number of feet per pound. In our case the length was about one foot per turn, so we needed about 680 feet. No. 24 runs 817 feet per pound, so two half-pound spools of wire did the job. We used Belden Nylclad wire, the Nylclad being a very tough insulation material.

If you are going to wind more than one transformer you may want to devise some type of winding jig, but for a single transformer it isn't worth the bother. We ran off about 40 feet of wire

Table 1

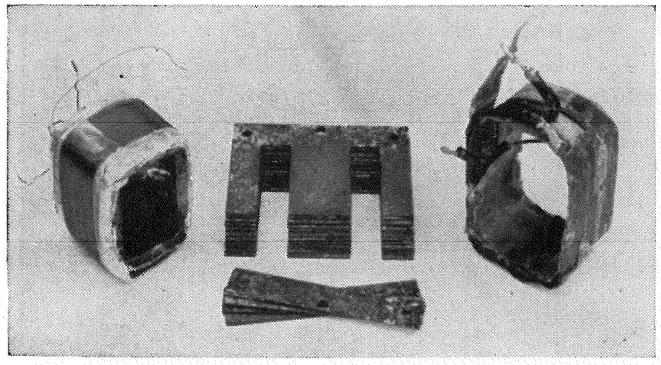
Wire Size	*Turns Per Inch Enamel*	*Current-Carrying Capacity in Amperes*
18	23.6	2.32
19	26.4	1.84
20	29.4	1.46
21	33.1	1.16
22	37.0	.918
23	41.3	.728
24	46.3	.577
25	51.7	.458
26	58.0	.363
27	64.9	.288
28	72.7	.228
29	81.6	.181
30	90.5	.144

NOTE: The turns-per-inch figures may vary a little, depending on the enamel thickness, and in any case it is rarely possible to wind exactly the theoretical number in an inch of space. However, the figure gives a reasonably-close approximation of the winding space required.

The current-carrying-capacity figures can be increased as much as 40 per cent without danger of overheating the wire. For example, No. 24 can carry as much as 800 ma.

from the spool and then clamped the spool in a vise. Starting at the free end of the wire, and making sure there were no kinks, we started winding the wire over the section that had the primary winding. Start as close to the edge as possible and keep the wire taut as you wind on the turns. The reason for starting close to the edge is that as you put layers on, each layer has to be progressively narrower, otherwise the end turns may slip off. After the first layer is wound, hold the ends in place with Scotch tape. Ordinary household waxed paper can be used between the layers. A single layer or sheet of paper is adequate insulation between layers. (We measured and cut up a supply of waxed-paper sheets beforehand.) Wrap a sheet tightly around the first layer of winding and fasten the end of the paper with small pieces of Scotch tape. Try to keep the starting point for the next layer as close to the outside turn of the previous layer as possible and always wind in the same direction. No. 24 winds 45 turns to the inch, and we got two full inches on the first layer, or 90 turns. It took nine layers altogether, and on the last one we were down to about 70 turns. Take your time, keep the wire taut, and by all means keep track of your count by making notes. It is easy to lose your place in counting; needless to say, this can be highly provoking. Be sure to bring all leads and taps out on the same side of the core so the transformer covers will go back in place without interference. Note how it was done originally, before taking the transformer apart.

Winding the high-voltage layers is the toughest job as it requires the most care. Keep the turns close together and take your time. It took us a few hours to complete the job. We made our taps at the edge of the layer as we figured this would cause fewer complications than taking taps inside the layer. The taps don't have to be



At the left is the new high-voltage winding which is wound over the primary layers. When completed, this entire winding assembly will be fitted into the 6.3-volt winding section shown at the right. Some of the laminations are shown in the center.

at *exact* numbers of turns; even if the tap is "off" by as much as 30 turns the difference is only 15 volts.

When the high-voltage winding is completed it should be wrapped with several layers of paper for mechanical protection and to insulate it adequately from any winding that may go on next. At this point we put on a single-layer winding of 100 turns for bias voltage, using wire from the old high-voltage winding. We wanted about 40 volts of bias for a planned rig, so 50 volts a.c. would be adequate. When this layer was completed there was still ample room to slide the entire assembly inside the section carrying the heavy 6.3-volt winding, so we took up the slack by covering the new winding with Scotch electrical tape.

The high-current 6.3-volt winding often is made with two wires in parallel instead of using a single wire of the same total current-carrying capacity. The transformer we rewound had two No. 15 wires in parallel, the equivalent of a single No. 12. If your transformer is built this way, you can unsolder the parallel connections and bring out separate leads from each coil. These can be connected externally either in parallel for 6.3 volts or in series for 12.6 volts — or used separately if two unconnected 6.3-volt windings are desirable for some special reason.

Reassembling

Putting the laminations back in was rather simple. We put a little thin shellac on each group just before inserting it into the winding. When about half the laminations were back in, and before the shellac had a chance to dry, we clamped the partly-completed core in a vise to take up the slack and then proceeded with the remaining laminations. We found that we could get all of the laminations back in with the exception of one. *Don't* try to force those last few laminations in; you might damage the winding. The amount of iron left over wouldn't be that important to the transformer. Put back the bolts, tighten the nuts securely, and your new transformer is complete.

We tried our unit out as soon as completed and the most surprising thing was that the transformer was quieter than before rewinding. One of the problems with rewinding transformers is avoiding lamination vibration or hum. Make everything secure and you won't have the problem.

One last thing: the rewinding job described here was based on the fact that the primary was the bottom winding. You can rewind transformers when the primary is an outside winding, but it is a more ticklish job. In such cases it is probably better to remove the primary wire, which will no doubt be No. 18 enamel and will be easy to work with. Rewind it on the form at the bottom, next to the core. This will take a little extra work, but will probably save time in the long run.

There's one nice thing about winding your own transformer — you end up with exactly what you want and need, and save a lot of dough in the process. QST

Strays

Country leaders in the PACC Contest for 1963 have been named by the VERON Contest Committee. They included c.w. winners PAØLV, DL4FT, F3PK, G3EYN, GW3IAD, HB9QA, LZ1KSA, OD5LX, OH5PT, OK3KAG, ON4CE, OZ1LO, SM7BUE, SP6TQ, UA3KHA, UB5KBA, UH8KHA, UI8CO, UM8KAA, UP2QQ, VE2IL, W4HOS, YO3JF, YU1SF and 4X4MJ. Phone awards go to PAØHSJ, DJØGI, GW3LAD, and SP9AHA.

W3KW would like to hear from hams he worked from the schooner *Nanuk* in the frozen north of Alaska and Siberia during the winter of 1929–30. Calls used were WKDB and K7ABF.

K1UAK would like to meet some American Indians who are hams. Write Marie Hennelly, 100 Cedar Street, Waltham, Mass. 02154.

Feedback

In the circuit of W2DUD's product detector in the issue for Oct. 1963, the 0.01-μf. capacitor shown connected to Pin 1 of the 6BE6 should be connected to the screen, Pin 6.