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Essentials of V. T. Transmitters

By K. B. Warner

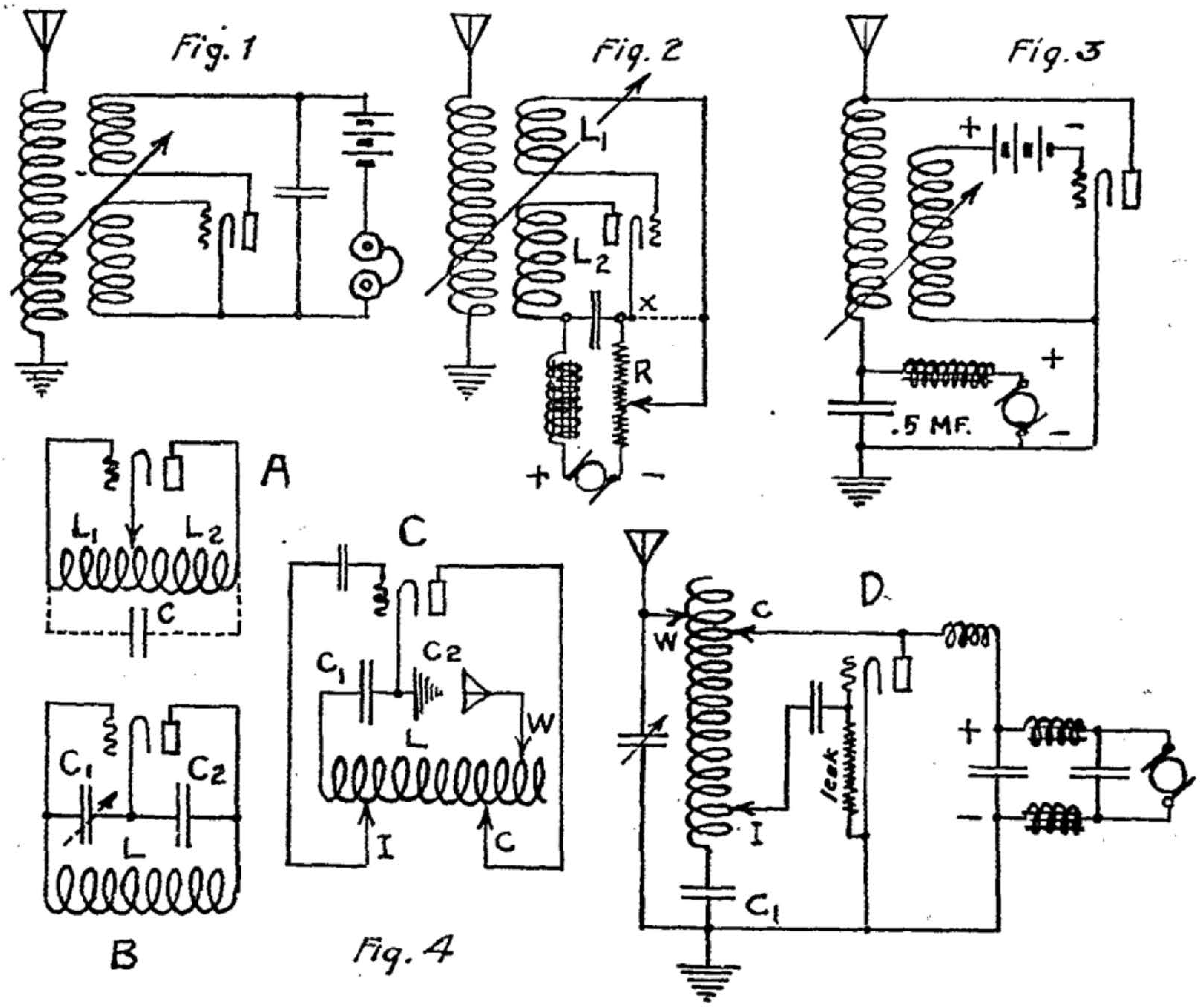
A GREAT cloud of mystery seems to overhang the subject of vacuum-tube transmission in the mind of the average amateur and the writer hopes in this article to explain some of the fundamentals. It is a subject in which we are all vitally interested, and the time to begin studying is at hand, for it is only a question of a short time until small power tubes for the amateur will be available.

A word about the merits of continuous-wave transmission. This is practically an untouched field in the amateur realm, for heretofore the elaborate and expensive apparatus required, and the deep theory involved, have prohibited general experimentation. VT transmission is by continuous waves (hereinafter called C.W.), and, similar to the better-known methods of generating persistent oscillations, such as the Poulsen arc, the G.E.-Alexanderson alternator, etc., but the vacuum tube is the only method adaptable to small powers and has the additional advantages that its generated oscillations are without the irregularity in amplitude characteristic of arcs and, most important, is sufficiently flexible to efficiently generate the high frequencies necessary for operation on amateur wavelengths. Theoretically the decrement of C.W. is zero; practically, the only measurable decrement is caused by the effective resistances of the transmitting and receiving antennae. To put this in the simplest possible language, with VT transmission all our energy is concentrated on as near one wavelength as is possible by any known method. This is the entire secret of its great efficiency; the energy is not distributed over a more or less broad band of wavelengths. The writer has personally seen a distance of 37 miles worked with a small one-tube set with portable antenna 20 ft. high, in daylight, with three watts antenna energy. Radio Utopia is not yet here, however. It would be if all of us used CW, as I can imagine no more feasible way of minimizing QRM than by having everyone's decrement approach zero. The trouble is that a jambing spark station with broad tune will still come in, tho the oscillating VT used in reception will change its note to a hiss, but if it is sufficiently close or powerful its broad tune is to be found all over the tuner the same as in the old days, and will drown out the signals from the feeble CW station which are concentrated on one tune. The practical problems of this situation will have to be worked out as we proceed in the installation of amateur CW. It is new ground for all of us. For instance, two CW transmitting stations may beat upon each other and under certain conditions make a continuous howl in a third receiving station. However, the writer has no doubt that these practical problems will be solved as they arise, and surely we are all interested in so efficient a method of transmission as afforded by VTs.

There is nothing complex in the basic theory of such transmission. Consider a simple inductive-feedback oscillating receiving hookup as shown in Fig.1 This is a miniature transmitter, for oscillating energy exists in the plate circuit, the power furnished by the B battery, and the circuit is coupled to the antenna so that a small amount of energy is actually being radiated. The ordinary receiving tube, however, is not capable of handling much energy, and as the oscillations are in the plate circuit, the hookup can be improved to better transfer them to the antenna. Such a circuit is shown in Fig. 2. Note that the grid and plate circuit inductances L1 and L2 are coupled electromagnetically to the antenna inductance. These first mentioned circuits are aperiodic, and the period is therefore determined by the constants of the antenna circuit alone. The action is very simple. Consider a surge in the plate current. An EMF is induced in the antenna coil and the resultant current in turn induces an EMF in the grid circuit, which if made in the proper direction will react on the circuit thru the characteristics of the tube in such a manner as to sustain the operations at a frequency dependent entirely on the antenna circuit.

Now there is no great reason why inductive coupling should be necessary between plate and antenna, and increased efficiency is obtained by the direct coupling shown in the simpler circuit of Fig. 3, the action of which is otherwise quite the same.

We hear much these days about capacity feed-back. This is a subject on which books may be written, but the fundamental



idea can be obtained from Fig. 4. Circuit A is a symbolic representation of inductive feedback as just explained, the oscillating circuit consisting of the whole inductance and its distributed capacity, C, and the necessary coupled inductances of the grid and plate circuits represented by the (aperiodic) inductances L1 and L2 on either side of the filament connection. Now notice Circuit B, in which the only change is to move the filament connection to the center of total capacity instead of the center of inductance. The only oscillating circuit present is L-C1-C2. A change in the plate-filament current imposes a charge on C2, which discharges thru the oscillating circuit, in doing which it charges C1, and the potentials thereon, being transmitted direct to the grid, are such (if the phase relationship is right) as to continue the circuit in an oscillating condition thru the characteristics of the tube. If C1 is made variable, a very convenient method of varying the impressed grid potential is made available, and this will control the amplitude of the generated oscillations. Now in Circuit A, the aerial and ground would be connected to the extremities of the inductance, the antenna capacity thus adding to the distributed capacity illustrated. In Circuit B, condenser C2 is actually formed by the antenna system, and in this manner the entire oscillating energy is directly introduced into the radiator. Circuit C is an evolution from this, and shows several methods of control. If the antenna tap W is made variable, we have a means of varying L-C1-C2 and so controlling the wavelength. For practical working it is necessary to control the voltages impressed across the condensers. Circuit B showed how this could be done in the case of C1 by making it mechanically variable, but this is not possible where the capacity is formed by the antenna. However, we may vary the effective capacity by the insertion of more or less series inductance, the reactance of which is directly opposed to the reactance of condensers. This is shown by taps C and I in Circuit C, which serve to introduce a variable inductance in series with C2 and C1 respectively; thus controlling, in the first case, the oscillations set up by a change in plate current, and in the second case, the amplitude of the potential transferred to the grid for the purpose of sustaining the operations. A more understandable hookup embodying these features is shown in Circuit D. The theory of the capacitive feedback is very beautiful, but its successful operation presupposes an antenna of practically all capacity—little inductance or high-frequency resistance. It is probably this last factor which has presented the greatest handicap to its satisfactory functioning on very small antennae, and the tendency in design of small sets seems now to be firmly established in favor of the electromagnetic.

This is not a technical article; rather is it designed to set forth the practical fundementals for amateur construction, but the numerical values of the different factors in the set will depend entirely on the tubes used.

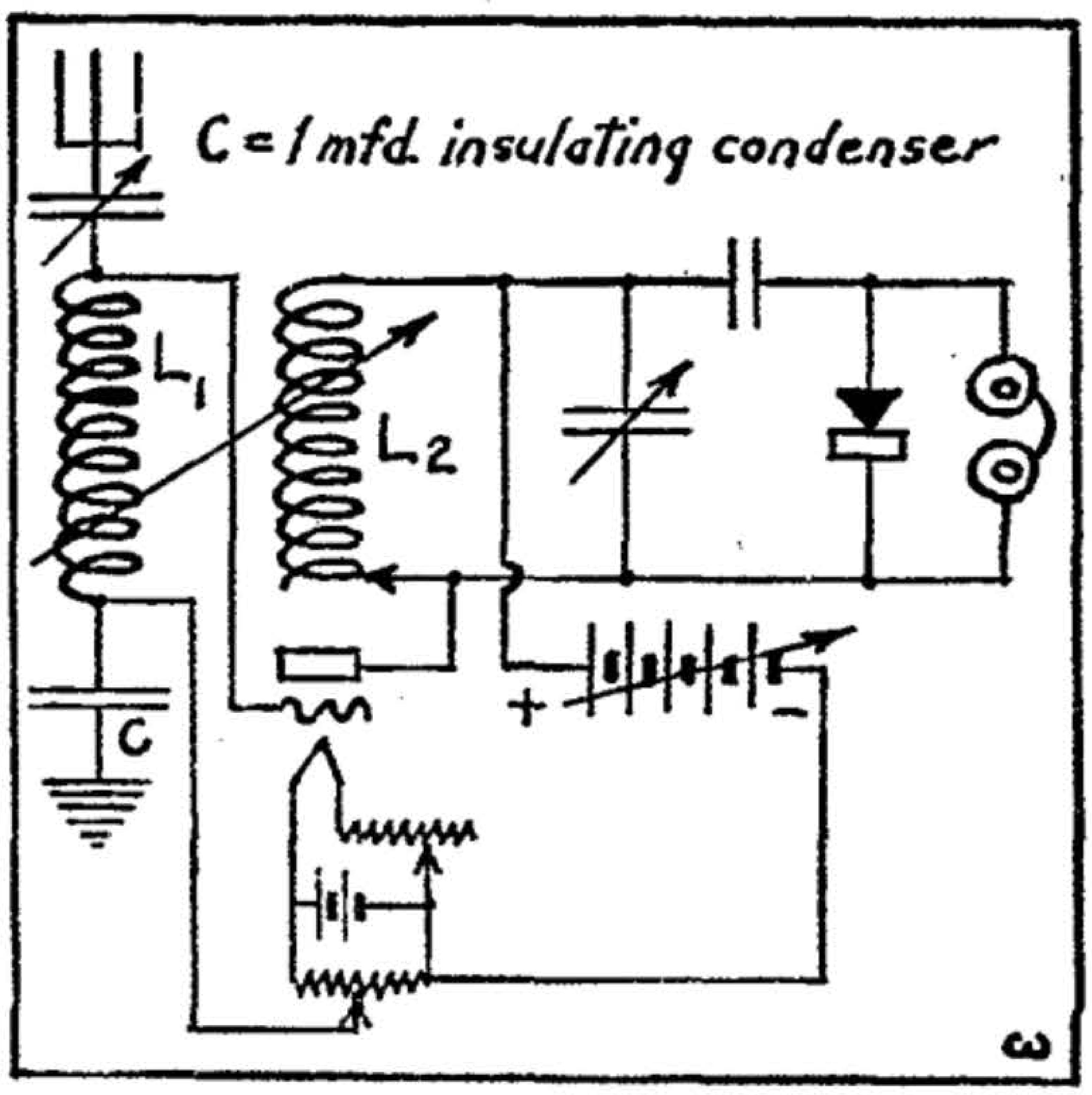
Do not overlook the fact that for oscillation generation the tube is functioning on the straight portion of its characteristic curve, exactly like an amplifier. If the normal free grid potential is not the value requisite to shift the axis of oscillation to the center of the straight portion (and it probably will not be), it will be necessary to impose a permanent negative potential upon the grid sufficient to shift the axis to the correct point. This is extremely important, for if in such a case the grid were allowed to become momentarily positive, an excessive current would flow and the tube be burned out. Fig. 3 illustrates the simplest method of obtaining the desired results: by the insertion of a series battery of the correct voltage. Another way is shown in Fig. 2 where a resistance R is introduced in the negative leg of the power supply and the grid-circuit connection shifted from the normal point X to a position along the resistance R where the drop is sufficient to give the required negative potential. Values of grid condensers, if necessary, and their attendant leaks, will vary with the tubes, and should be available from the manufacturers. Bear in mind that if a grid condenser is used simply to insulate the grid from the plate potential as in some hookups, a shunt leak will not suffice: the leak must be bridged from the grid direct to the filament, or it would partially defeat the purpose of the condenser. Iron-core choke coils of high inductance are necessary in the power supply to prevent the passage of oscillating energy. As the voltages employed are quite small in comparison with spark transmitters, standard air variable condensers, and inductances not a great deal different from receiving coils, will suffice. The power supply is a serious question. Most small tubes operate on 350 to 500 volts. As the power consumed is small, it should not be difficult to build a high-voltage storage battery capable of being charged in several units in parallel and discharged in series. There is also on the market now a line of small motor-generators, having a standard induction motor for 110 a. c. and the generators being available in different voltages quite suited to the operation of such tubes. When a generator is employed, however, smoothing inductances and capacities will probably be necessary to form a kind of filter-box to iron out the commutator ripple.

Nothing has been said about the location of the telegraphic key. I leave this to the builder. Three methods of its use are familiar. First, the simple "cut-in", which is simply placing the key in the ground-lead and interrupting the CW to form dots and dashes—a proceedure wholly safe at the voltages used. Second, a buzzer chopper can be inserted in the ground lead, and its operating battery controlled by the key, this method producing audio-frequency trains of waves which will be audible on a non-oscillating detector. Third, and by considerable the best method, the compensated, as employed by most commercial CW stations, wherein a very small series inductance in the ground lead (sufficient to change the wavelength by 5 to 10 meters) is shunted when the key is depressed. Other methods will perhaps present themselves, but these are the best. Such a transmitter can also be employed as a simple radiophone by the insertion of a microphone in the ground-lead.

To summarize, then: Above all, know your tubes. Manufacturers should furnish characteristic curves. Study these until you can proceed intelligently in the construction of a set to embody this particular type of tube. A motor-generator and filter-box seems the best source of plate current. The voltages used will be the only determining factor in the inductances, the desired wavelength being known. Electro-magnetic feedback, either inductive or direct, is better in practice than capacitive feedback. Make your tickler coupling variable to control the feedback. Determine, from the grid voltage-plate current curve, the normal potential to be kept upon the grid to bring the operation to the center of the "straight-line" or amplifying portion of its characteristic, and provide a means of keeping the grid definitely at this value in operation.

"Try This on Your Paragon"

FROM abroad has come this unusual hookup, said to be a development of British naval experts, and for which extreme sensitivity and selectivity are claimed.



At first sight it is difficult to puzzle out the functioning, but we believe we have it. The VT is connected as the coupler between primary and secondary! When signals are being received, an oscillating potential exists across the terminals of the primary, L_1, which potentials are directly conveyed to the grid-filament circuit of the tube. The tube is therefore acting as a radio-frequency amplifier, since the oscillating component of its output current is conveyed to a rectifier for detection. This is not all, however, for in the plate circuit is the inductance L_2—the secondary

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