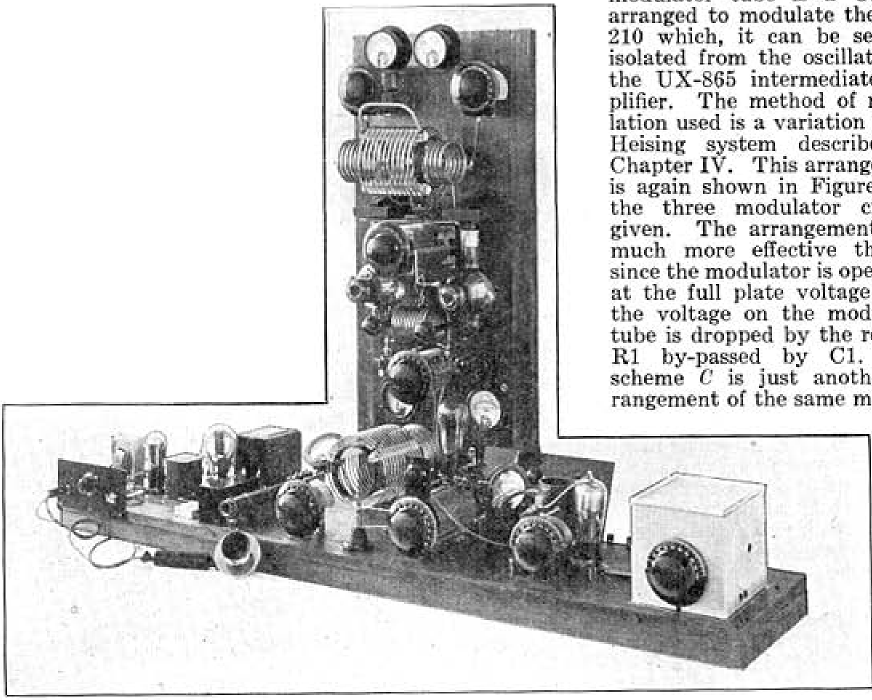
tube being modulated, and the oscillator should preferably be crystal-controlled. The crystal-controlled transmitter last described provides an illustration of good modern practice in 'phone work when fitted with a modulator. The circuit of a complete radiotelephone transmitter is given. It comprises the three-tube crystal oscillator and intermediate amplifier unit, the "push-pull" output amplifier, and a modulator unit. The modulator tube is a UX-250 arranged to modulate the UX-210 which, it can be seen, is isolated from the oscillator by the UX-865 intermediate amplifier. The method of modulation used is a variation of the Heising system described in Chapter IV. This arrangement is again shown in Figure *C* of the three modulator circuits given. The arrangement *B* is much more effective than *A* since the modulator is operating at the full plate voltage while the voltage on the modulated tube is dropped by the resistor R1 by-passed by C1. The scheme *C* is just another arrangement of the same method, though a separate choke is provided for the modulator and modulated tube. The circuit *B* or *C* may be used with a great many combinations of tubes, some of these being shown in the full-page set of diagrams. In any of them the general arrangement of the apparatus and the adjustment and operation of it will be similar to that of the crystal-controlled transmitter described. The only important differences are in the adjustment of the bias and grid excitation of any tubes in the transmitter which come after the tube being modulated. Tubes amplifying the modulated energy must operate as linear amplifiers in just the same way that the audio-frequency amplifiers of a broadcast receiver operate. Also, the output of the final amplifier—if the modulated tube is before it—must have its output reduced to one quarter of the maximum value before modu-



A COMPLETE MODERN AMATEUR 'PHONE TRANSMITTER

Though this outfit is much more complex than the average transmitter is likely to be, it serves to illustrate most of the principles discussed in the text

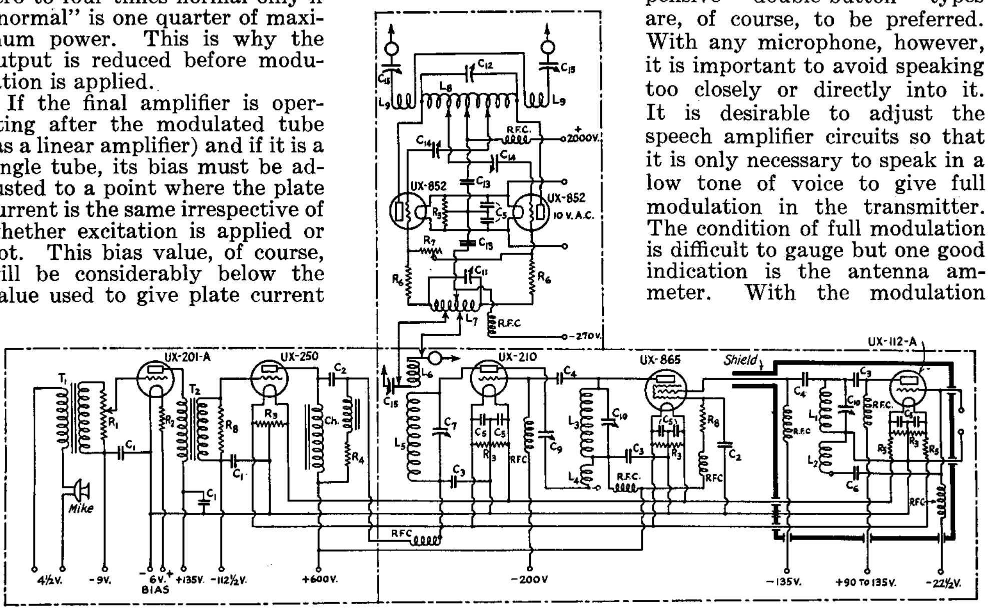
RADIOTELEPHONE TRANSMISSION

Any amateur transmitter with a d.c. plate supply and an r.f. output not appreciably modulated by it may be modulated for 'phone operation providing it is tuned to one of the frequency bands in which 'phone is legal. However, the self-excited transmitter and some oscillator-amplifier transmitters are not really satisfactory for this work. If the carrier of such transmitters is modulated at all fully, the frequency of the output varies with or is "fluttered" by the modulation. Bad distortion and serious interference usually result. For completely satisfactory 'phone transmission the frequency of the output should be set by an oscillator well isolated electrically from the lation is applied. The output will have been reduced to one quarter when the antenna current has been halved and it is this halving of the antenna current which provides the most useful indication. In tuning the output stage the grid excitation is first increased to the point where maximum antenna current is obtained. The excitation is then decreased by decreasing the resistance of the grid resistor R7 until the antenna current has dropped to half of its former value. When the previous amplifier is then modulated fully, its output will swing from zero to four times normal. This means that the excitation of the final amplifier will swing between the same limits. The output power of the final amplifier will be able to follow this excitation and swing from zero to four times normal only if "normal" is one quarter of maximum power. This is why the output is reduced before modulation is applied.

If the final amplifier is operating after the modulated tube (as a linear amplifier) and if it is a single tube, its bias must be adjusted to a point where the plate current is the same irrespective of whether excitation is applied or not. This bias value, of course, will be considerably below the value used to give plate current "cut-off" as in telegraph work. When the amplifier is two tubes in "push-pull", the bias may be operated at "cut-off" for either 'phone or telegraph. A "push-pull" amplifier is capable of operating as a linear amplifier under these conditions.

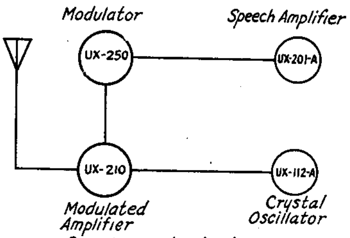
The adjustment of the modulator unit consists chiefly in varying the bias on both the speech amplifier and the modulator to the point where no appreciable flutter of plate current can be observed even when the microphone is spoken into loudly.

The microphone is an important item in any 'phone transmitter. The ordinary hand microphones usually are good enough for speech transmission but the more expensive "double-button" types are, of course, to be preferred. With any microphone, however, it is important to avoid speaking too closely or directly into it. It is desirable to adjust the speech amplifier circuits so that it is only necessary to speak in a low tone of voice to give full modulation in the transmitter. The condition of full modulation is difficult to gauge but one good indication is the antenna ammeter. With the modulation



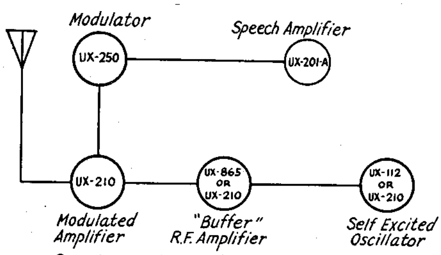
THE WIRING OF THE COMPLETE 'PHONE TRANSMITTER ILLUSTRATED

C1—1-μfd. 300-volt condensers.
C2—1-μfd. 1000-volt condenser.
C3—1000-μμfd. 500-volt condensers.
C4—250-μμfd. 500-volt condenser.
C5—2000-μμfd. 500-volt condensers.
C6—500-μμfd. 500-volt condenser.
C7—350-μμfd. transmitter-type variable condenser.
C9—A 23-plate midget condenser with plates double-spaced.
C10—350-μμfd. receiver-type variable condensers.
C11—1000-μμfd. receiver-type variable condenser.
C12—250-μμfd. "treble-spaced" transmitting condenser.
C13—1000-μμfd. 500-volt condensers.
C14—Receiver-type variable condensers cut down to 3 plates.
C15—500-μμfd. receiver-type variable.
R1—200,000-ohm potentiometer.
R2—4-ohm fixed resistor.
R3—100-ohm center-tapped resistors.
R4—5000-ohm resistor to carry 100 ma.
R5—5-ohm fixed resistors.
R6—100-ohm fixed resistors.
R7—10,000-ohm "Adjustat."
L1—16 turns of 14-gauge wire on 3" diameter tube, as plate coil for crystal operation, 6 turns of same wire for plate coil of self-excited oscillator.
L2—4 turns of same wire. When running as a self-excited oscillator, a 500-μμfd. fixed condenser is shunted across the extremities of L1-L2, i.e., from grid to plate.
L3—20 turns of 14-gauge wire space-wound on 3" diameter tubing.
L4—15 turns of 22-gauge d.c.c. wire on 2" diameter tubing mounted inside lower end of L3.
L5—3500-kc. inductance.
L6—6 turns of ⅜" outside-diameter copper tubing, turns 4" inside diameter.
L7—10 turns of 3/16" diameter copper tubing, turns 3" inside diameter.
L8—3500-kc. inductance.
L9—Each 5 turns of ¼" diameter copper tubing, turns 3" inside diameter.
T1—High quality audio transformer with new primary of 250 turns of 30-gauge wire. Any modern high-quality microphone transformer undoubtedly would be better.
T2—Audio-frequency transformer.
Ch.—Double "B-eliminator" choke.



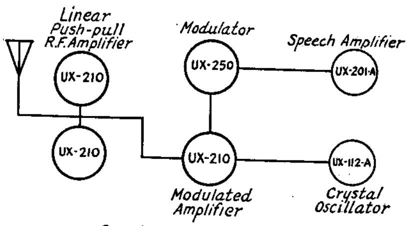
Carrier output 7½ watts.
Peak modulated output 30 watts.

A



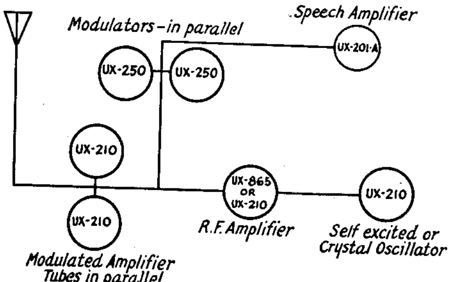
Carrier output 7½ watts
Peak modulated output 30 watts

B



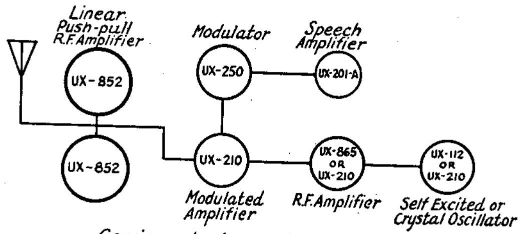
Carrier output 3.7 watts
Peak modulated output 15 watts

C



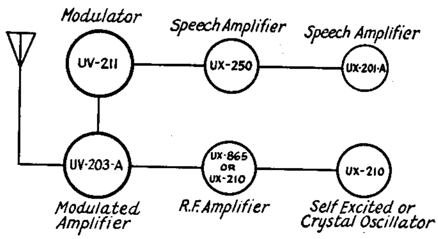
Carrier output 15 watts
Peak modulated output 60 watts

D



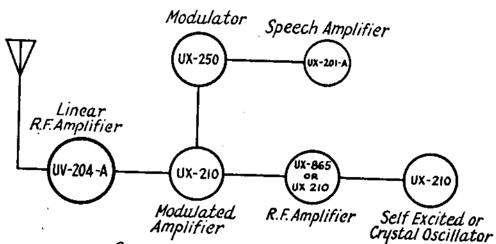
Carrier output 37 watts.
Peak modulated output 150 watts

E



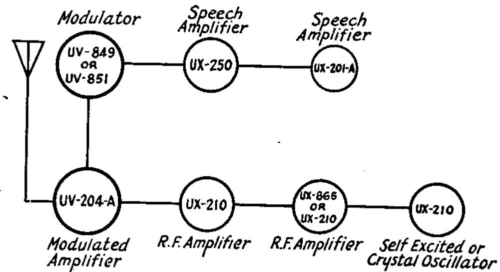
Carrier output 50 watts
Peak modulated output 200 watts

F



Carrier output 62.5 watts
Peak modulated output 250 watts

G



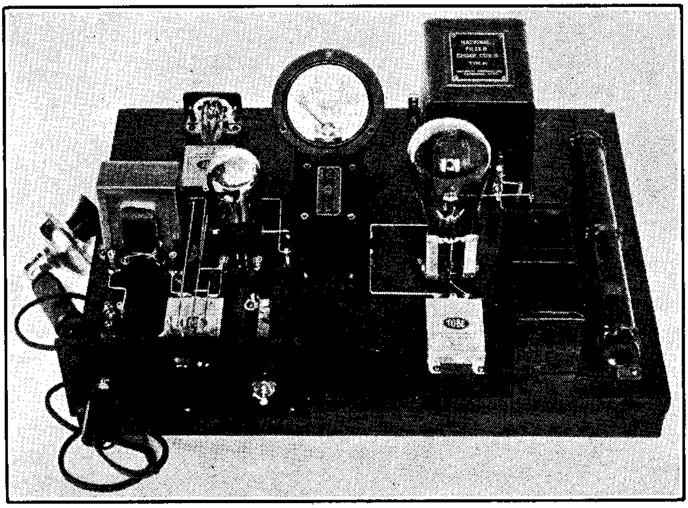
Carrier output 250 watts
Peak modulated output 1000 watts

H

systems discussed, the antenna current will rise by about 25% of its steady value when a note is hummed into the microphone providing the modulation is fairly complete and providing there is no serious distortion. Distortion is best detected by listening, inside the station, with a pair of 'phones connected in series with 20 or 30 turns of wire and a crystal detector. The coil of this 'phone monitor usually will give sufficient "pick up" if it is placed in the vicinity of the antenna or feeder leads.

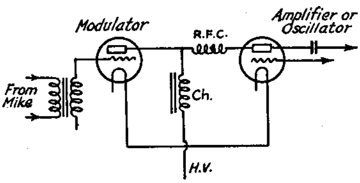
An excellent article on amateur radiotelephone transmission, with detailed explanation of the problems of modulation, appeared in *QST* for April 1929. Valuable information on adjustment appeared in *QST* for August 1929.

For successful amateur radiotelephone work it is very necessary that a suitable receiver be used. A receiver fitted with a "peaked" audio-frequency amplifier will be quite unsatisfactory on account of the distortion introduced by the "peaked" stage. Many amateurs have success with receivers of the type described in Chapter V fitted with good audio-frequency transformers and with bias on the audio tubes correctly adjusted for distortionless amplification. However, a high degree of radio-frequency selectivity is very valuable in amateur 'phone work. Though tuned radio-frequency amplifiers operating on the incoming frequency are not practical, the desirable selectivity can be obtained readily by the use of a super-heterodyne. A full description of one receiver of this type appeared in the March 1929 issue of *QST*.

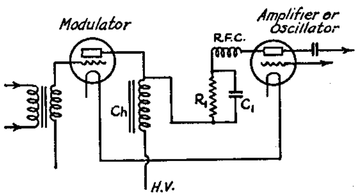


THE MODULATOR AND SPEECH AMPLIFIER UNIT

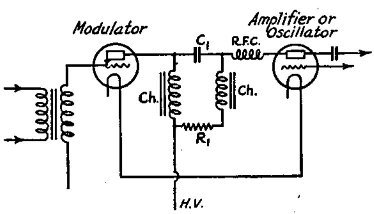
On the small panel is the microphone jack, the gain control and the microphone switch. Behind it, the microphone transformer and speech amplifier can be seen. The modulator tube with its associate apparatus is at the right.



A



B



C

CONSTUCTIONAL AND OPERATING HINTS

There is almost an infinite number of possible variations in the circuits, the apparatus and its arrangement in amateur transmitters. We could fill this Handbook with nothing more than description of effective transmitters and the methods of building and adjusting them. It is impossible, however, to give more than a few typical examples from which the amateur can gain a sufficiently general idea to enable him to make modifications to suit his own ideas or the apparatus available. We will now treat some miscellaneous considerations, ideas and methods but we cannot possibly cover the entire field. New schemes, apparatus and operating methods are being evolved constantly and if the amateur would be familiar with them and improve his station continually with their aid we can only suggest that he read and study the magazine *QST* each month.

TUBES IN PARALLEL

One vacuum tube is shown in most of the circuits we have drawn. This does not mean that only one tube can be used. Two or three tubes may be used in parallel to obtain greater power outputs than one tube can supply. Connecting tubes in parallel means connecting grid to grid, plate to plate and filament to filament. The efficiency of one tube is better than that of several, however. On the shorter wavelengths particularly it is better to use a single tube. With more than one tube we may get into difficulties with "parasitic" oscillations in the inductance of leads and the interelectrode capacities of the tubes. The use of one tube results in more certain operating, cooler tubes, and a steadier wave with fewer harmonics. The simpler our oscillator circuit, the easier it will be for us to get it working and to get the "bugs" out of it.

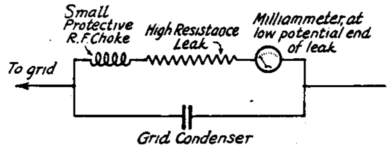
PARASITIC OSCILLATIONS

Parasitic oscillations usually occur when there is more than one tube operating in parallel or on very high frequencies where there are leads and distributed capacities in the circuit with a strong natural period of their own. Heating of the grid and plate leads inside the base is almost a sure sign of parasitic oscillations. A large input and low available output also lead one to suspect trouble of this sort. The current at ultrahigh frequencies may not show up on any meters at all but if it is there it is robbing the antenna of useful power. An R.F. ammeter placed in the grid lead may show a high reading—if parasitic oscillations are present.

Little grid chokes are used directly in series with the grid of each tube (if more than one tube is used) to cut down intertube H.F. currents and prevent loss of energy through parasitic oscillations. A resistance of about 100 ohms will do as well. Both are occasionally necessary. A few dozen turns of fine wire wound over and over on a ¼" diam. tube fastened down by a screw through it into the baseboard, will be effective. These chokes or resistors are in series with respect to the parasitic oscillations that we want to prevent between tubes. With respect to the main oscillating circuit the chokes are in parallel and have little effect.

METERS

The meters shown in the diagrams that we have discussed so far are really necessary to adjust the circuit properly for best efficiency. After the set is once adjusted and in operation, meters are useful but not necessary. We should have as many meters in the set as we feel we can afford. A filament voltmeter is of first importance. If we do not use a filament voltmeter or some indication of the operating temperature of the filament, the life of the tube may be much shortened by improper operation. An indicating device for the filament is, there-



LOCATING THE GRID MILLIAMMETER IN A TRANSMITTER TO AVOID BURNOUT

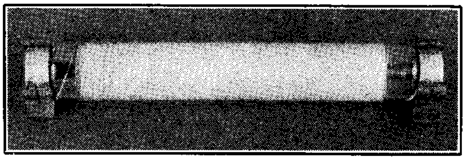
fore, a matter of economy. Next we need an antenna ammeter. The antenna ammeter can be placed at the point in the antenna circuit where the antenna current is greatest (at the voltage node or current loop) but its indication will be useful wherever it is and the exact location is not extremely important. If we can afford it we should have a plate milliammeter of the proper range. All meters should be selected with regard to the tubes employed and the current and voltage that we may expect in the different circuits of the transmitter. With these three meters we can get along very well indeed in operating our transmitter. A plate voltmeter can be used if it is available but is not very useful after the circuit is once adjusted. Another milliammeter for the grid-leak circuit may be purchased after all the above have been obtained.

RADIO-FREQUENCY CHOKES

Several ideas for mounting plug-in chokes will suggest themselves to the builder. The R.F. chokes can be wound on wooden dowels, each end of the winding being connected to some short right-angle brass pieces fastened to each end of the dowel. These brass angles should be mounted so that the projecting portions on each end are in the same plane. They will plug into the jaws taken from a discarded knife switch. Some glass tooth-brush holders from the "5 & 10" make even better forms that will mount nicely in large cartridge fuse clips. The aluminum caps clamp the wire and make good contact with the clips which should be mounted near the back of the transmitter frame where the chokes will be readily accessible when changing wavelength.

Radio-frequency choke coils should be constructed to work best on the particular wavelength to which the transmitter is tuned. Often one choke will work in the set for several frequency bands.

Every radio-frequency choke coil has a natural period of its own due to its inductance and distributed capacitance. When connected



ONE METHOD OF MAKING RADIO-FREQUENCY CHOKES

The former on which the wire is wound is a "5 and 10" glass toothbrush holder. The threaded aluminum caps clamp the ends of the wire and serve to make contact with the two large cartridge fuse clips which constitute the mounting. Such a choke can be replaced readily by others of different values when necessary.

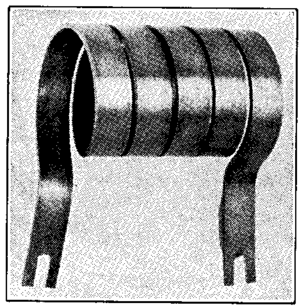
in a tube circuit the choke-period is changed. For every apparatus layout and tube equipment there will be a "best" choke. The best we can do is to specify what works best for our particular set. Mount the choke at right angles to the main coil and at a distance from it and everything else. Keeping coils away from each other and isolated as much as possible makes their losses lower and keeps induced voltages out of the argument.

For a short-wave transmitter the best chokes appear to be those that tune more sharply to a given frequency. Investigation usually proves that the chokes have standing waves on them under operating conditions. Single-layer coils, space-wound, not over three inches in diameter, seem to make the best chokes. Spacing the windings decreases the distributed capacity and, what is more important, raises the voltage break-down values at the end turns where the voltage-per-turn is always high in a sending set of any power.

In a choke the voltage at the end next the transmitter is highest (loop) while at the power supply end the voltage is minimum or zero (node). This may be checked with a Westinghouse Spark-C or any form of neon-lamp indicator. A screwdriver or other metal object with an insulated handle may be used likewise for making such an investigation of conditions as mentioned before.

COIL CONSTRUCTION

The tuning coils of the transmitter are extremely important items. Modern self-excited transmitters have large values of capacity across the coils to aid in obtaining a steady output frequency and in consequence the currents in the coils are of a high order. If the coils are made with a conductor which is too small, their resistance will cause serious losses in the circuit which will make themselves evident in the form of heat. In even a low-powered transmitter the coils can become too hot to touch if the coils are made with wire, tubing or strip which is too small. In such cases the transmitter usually oscillates unstably unless excessive grid excitation is used. It is quite common to hear the complaint that the plate current of the transmitter cannot be kept down to the rated value without the tube going out of oscillation. Almost invariable this is due to losses in coils which are not sufficiently heavy, or in high-resistance connections between the coils and their tuning condensers. In the transmitters described, heavy copper tubing was used for the coils but this does not mean that it is the only satisfactory conductor. It is, however, readily available, easy to wind, and it enables the construction of coils without the need of wooden, bakelite or hard-rubber insulating supports for the turns. It is absolutely essential that the coils be mechanically substantial—that they do not vibrate—since the slightest movement of their turns will mean variation in the output frequency of the transmitter. Coils made of copper or brass strip usually will vibrate unless the strip is very heavy or unless a supporting frame is used.



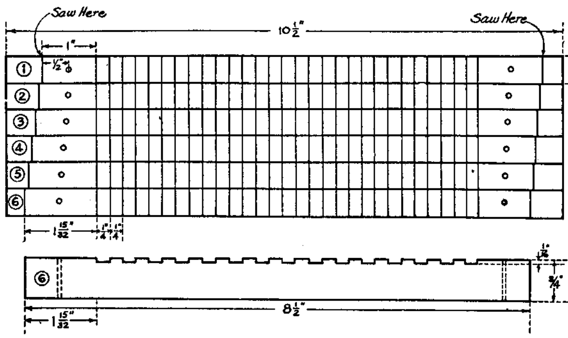
THE PLATE TANK INDUCTANCES

for a high-powered amateur transmitter can be made in this manner. The copper strip is ⅛" thick and ¾" wide.

One satisfactory type of coil using strip is that illustrated. Copper strip ⅜" wide can be used for low-powered transmitters but ½"-wide strip is preferable for a power of about 50 watts. For a transmitter of 250 watts or more the self-supporting strip inductance could be used. In this case ¾"-wide strip ⅛" thick is used.

The constructional details of the former for the smaller coils are shown in the sketches. The number of turns necessary for the various frequency bands will be approximately those specified for the copper tubing coils. Experiment will be necessary to determine the exact number, however, and for this reason the former-wound coils are not quite as practicable as the self-supporting type. With the latter coils the spacing of the turns can be varied until the required value of inductance has been obtained.

The first cut shows how the notched strips are laid out. All six oak strips can be sawed straight across in a miter-box to a depth of $\frac{1}{16}''$. Then they can be staggered the right amount and the ends sawed off. The staggering will make the winding progress ahead the right amount from turn to turn. If a miter-box is not available each strip can be notched separately in a vise. Be sure to leave room on the ends for the mounting bolt and so that the ends can be sawed off the necessary amount.



LAYOUT FOR WOOD STRIPS FOR INDUCTANCE

The notches should be sawed a few thousandths of an inch wide so the strip will slip into place easily. When the strips are staggered the right amount strip number 1 can be placed next strip number 6 and the grooves will progress uniformly as shown by the dotted line.

The staggering is necessary in order to give the proper pitch to the winding that will be put on later. A hole is drilled one-half inch from the ends of each strip using a No. 27 drill. After soaking the strips in boiling paraffin for at least an hour they can be removed. Despite the fact that the paraffin is not visible on the surface of the wood, the wood is impervious to moisture and full of paraffin. Now you can bolt the wooden strips to the end rings which were previously drilled, taking care to see that they are put on in the correct order and that none of them is reversed in the process. It is a good idea to number the ends of the strips when they are first sawed to avoid trouble.

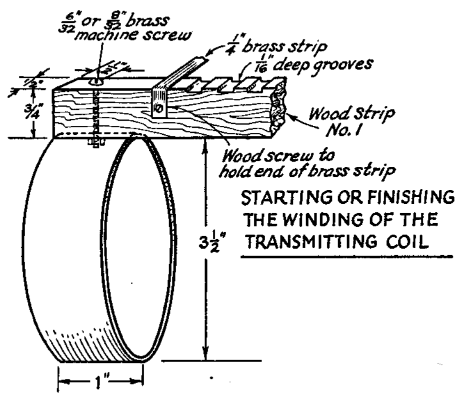
The brass (or copper) strip is next wound on after anchoring the end with a wood screw or a brass machine screw as shown in the diagram. If one strip is not available it will be necessary to solder shorter lengths together before starting the winding on the form. After the winding is completed, the small brass angles can be attached to hold the coil off the base in a horizontal position.

CONDENSERS

The performance of any transmitter can be impaired seriously if the insulation between points of high voltage is poor. A common location for trouble of this type is in the condensers. Without any external indication, there can be radio-frequency leaks through the insulation which will make it impossible to obtain a clean note from the transmitter. In some cases the signal emitted under such conditions is a rough "hash" and no amount of tuning will improve it. A great deal of trouble will be avoided if the best condensers available are built into the set at the start.

The variable condensers for transmitters operating from a plate supply of 500 volts or less may be of high-grade receiver type. For transmitters operating from higher voltages than these, special transmitting condensers are desirable. Several makes of such condensers are well advertised. They are available in many capacities and voltage ratings.

It is not necessary that the condensers specified for the transmitters described should be variable over the entire range, since they will be operated chiefly at values between 200 and 500 μμfds. Variable condensers of 200 or 250 μμfds. can be connected in parallel with fixed air-dielectric condensers of about the same capacity. Such fixed condensers can be bought but the resourceful amateur will find that they can be built up from copper sheet or aluminum dish pans supported with glass rods or glazed porcelain. Many possible constructional methods present themselves, the chief considerations being to keep down the size of the unit so that its field will not be too extensive, to reduce the supports to a minimum without sacrificing solidity, and to provide good contact between the plates and heavy conductors to them.



STARTING OR FINISHING THE WINDING OF THE TRANSMITTING COIL

The fixed condensers in other parts of the set also are important. Mica or glass dielectric is satisfactory for these, and several types of suitable condensers are available. Receiver-type condensers, providing they are rated at not less than 500 volts, can be used in transmitters employing the UX-210 tube but special transmitting condensers will be necessary when higher plate voltages are used.

HIGH-IMPEDANCE TUBES

The transmitters described in this chapter were all designed for use with the tubes specified and they will not operate with the same efficiency if tubes of widely different characteristics are employed. Many of the European tubes and some manufactured in this country have a very high plate impedance and the circuits in which they operate most effectively may be different from those given. In the first place the high impedance of the tube makes it necessary to have a radio-frequency choke of very high reactance in shunt-feed circuits (such as that given for the low-powered transmitter) to attain reasonable efficiency. In practice, due to the difficulty of making high-reactance radio-frequency chokes, the shunt-feed circuits are often almost inoperable when used with the high-impedance tubes. No such difficulty is experienced when series feed circuits (such as that given for the high-powered transmitter) are employed. The large values of capacity specified for the tank circuits of the transmitters in this chapter also would result in low efficiency if used with high-impedance tubes. A greater number of turns and less capacity would be desirable. In addition, much higher-resistance grid leaks will be necessary. Some of the European tubes operate effectively with values even as high as 50,000 ohms.

TRANSMITTER ASSEMBLIES

As we have already mentioned, it is by no means necessary to arrange the apparatus in the transmitter in the manner shown in the illustration. Many other excellent schemes are possible. The board on which the apparatus is mounted can, for instance, be arranged in a vertical position, with the wiring, transformers, chokes, etc., behind it and the remaining apparatus is front. Alternatively the apparatus can be mounted chiefly on a baseboard, with the meters and controls on a vertical panel in front of it. The panel could be of bakelite or hard-rubber or may be made of well-dried wood. The important points to watch in arranging the apparatus are to make sure that the leads, particularly in the tuning circuits, can be short; to see that the coils are well clear of the condensers or other large metal bodies; and to arrange the parts in such a way that the controls are convenient and all apparatus is accessible.

UNSTEADY SIGNALS

One of the chief problems in transmitters other than those of the crystal-control type is to maintain a steady frequency. First there is the frequency creep due to heating of the tube or other apparatus in the set. This can be reduced to a minimum by tuning the set for greatest efficiency. The greater the antenna power for a given input the less will be the heating of the tube. The aim is, therefore, to keep the input at or below the rated value and to tune the set until the tube operates with the least heating. With a good antenna most tubes can be operated at the rated input without the plate showing any color. With any tube the plate should never be allowed to get hotter than a dull red. This is most likely to happen during the preliminary adjustment when the tube stops oscillating or is operating in an inefficient manner. For this reason, during adjustment, it is advisable to have the key or a convenient switch so arranged as to permit shutting off the plate power quickly when necessary.

The detuning of the antenna circuit mentioned in the paragraphs on tuning does not result in appreciably lowered efficiency in the tube. When it is said that the greatest antenna current should be obtained for a given input to keep the tube coolest it is meant that the greatest antenna current **with the antenna detuned in the manner described** should be obtained. When the antenna is detuned the plate current drops. The grid excitation should therefore be adjusted so that the normal plate current will be obtained with the antenna circuit in the detuned condition.

Another common cause of frequency instability is vibration or swinging of the antenna or feeders. The effect of such vibration or swinging is reduced considerably by the detuning of the antenna circuit but it is essential that the antenna be supported in such a way that it is steady even in a high wind. This point will be given consideration in the chapter on antennas.

Leaky insulation also is often a serious offender in this regard. Not only can a leak destroy the character of the note but it can be responsible for a wobbly frequency. Trouble of this type often can be detected by removing the antenna circuit and listening to the transmitter in the monitor. Sometimes the leak is visible in the form of a thin arc. If the leak is through bakelite a swelling on the surface of the insulation often will be noticed.

Perhaps the most common cause of all is vibration of the coils or wiring. A vibration which results in serious frequency instability often is too slight to be noticable. The coils and wiring should be watched very carefully during operation to make sure that the movements of keying, the humming of a transformer or the vibration of a generator are not transmitted to the set. The mounting of the set on rubber sponges often will aid in the elimination of the trouble.

It is only by careful and prolonged attention to such details that the performance of the transmitter can be maintained at a high standard. It is fine to aim at a neat station, an elaborate lay-out, or an imposing antenna. Of infinitely greater importance than these things, however, is the signal—the only part of the station that the whole world can examine.