RADIO Experimenters' HANDBOOK

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RADIO EXPERIMENTERS' HANDBOOK

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THE EXPERIMENTAL LABORATORY

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PREFACE

RADIO research workers, both professional and layman—seeking after the physical truths of the radio science—have a field of experimentation and application not offered by any other branch of investigation. And the thought that anyone working along these lines may stumble on an absolutely new principle that would open up new realms of radio possibilities, stirs the imagination.

Experimental research is a scientific activity not without its lure and self-satisfying qualities to the man who is interested in new knowledge and the results and benefits obtained from the application of new knowledge. From the towering mentalities of the great researchers, the Faraday's and Maxwell's of past days to our Edison's, Marconi's and Steinmetz's and down through all the ages of lowly experimenters, this urge has been apparent. From the prehistoric man, signalling by arm motions from a hilltop to a distant member of the tribe, to the modern experimenter signalling around the world on the short-waves, the prime urge of research has been to gain knowledge, to determine new truths of the physical world around us.

There are only three generally accepted ways for determining truth: the method of determining truth through *revelation,* the method of determining truth through *meditation,* and the third method of determining truth by *experimentation.*

The first method is that of the ancient priests and the religionists of all time. The truth as so determined is handed down to man through some mysterious revelation, as in the Delhi oracles, or by the dreams sent through some divine agency. By the second method, which was evolved and practiced by the Greek philosophers, truth was believed to be evolved in the minds of thinkers by serious and long-continued meditation. The third method determines truth by making an experiment, over and over again, to see whether the same thing happens, repeatedly, without any important degree of variation.

This third method is the scientist's method for determining truth. It is the method of "try it and see." It is the only truth that science will accept. The chief tool of this method is the experiment. The scientists say: "Anything you can prove by experiment may be safely accepted as a truth. Anything that cannot be proven or disproven by experiment must be treated as mere theory."

Theories are also useful to the research worker in radio, as in all fields of scientific endeavor, although they must not be relied on too fully. All the other tools the experimenter needs to furnish are "brains" and the "will to do!"

All of our present-day developments, the complete comfort and safety applications of our modern machine world, are based upon experiments and the substantiated theories of earlier research workers. In the radio field, observations have always been followed by theories, later substantiated or repudiated by experiment. Every modern radio experimenter, whether he is working in the completely equipped laboratories of the world's largest research organizations or working with a bare minimum of scientific apparatus in his home laboratory, may share these fundamental tools of science.

The radio experimenter must be encouraged! Keeping him fully informed of the latest developments in radio as well as offering educational technical data are the main duties of a radio publication. The Editors have compiled the following data with this view in mind and have dedicated this book especially to The Experimenter.

CHAPTER 1

Measurements of Voltage and Current

THE most important single item in a service or experimental laboratory is measuring equipment. Because of the cost of reasonably accurate instruments, any means of multiplying the usefulness of a single meter should relieve the budget. Below is a description of a useful d.c. meter of several volt and milliampere ranges which may be constructed without straining the purse.

The foundation of the instrument is a Weston model 301 d.c. milliammeter having a full-scale reading of one milliampere. The following ranges are secured: 1, 10, 100 and 500 milliamperes, 10, 100 and 500 volts (all 1000 ohms per volt).

The simple application of Ohm's law in the determination of the resistance values to be used as multipliers in converting a milliammeter into a voltmeter is perhaps familiar to the majority of experimenters, but will be treated briefly. The problem is to determine that service resistanc necessary to secure full-scale deflection of the meter with the full voltage of the desired value applied.

The resistance for the voltmeter ranges is determined as follows:

$$R = \frac{E}{I}$$

when R — Combined resistance of meter and multiplier
E — Voltage range desired
I — Current required to deflect meter to full scale

The resistors used as shunts to obtain the various milliampere ranges are homespun. The cheapest and simplest plan is to determine the resistance required for a shunt for the lowest range to be used and then tap this shunt at the proper point, as described later, for the ranges.

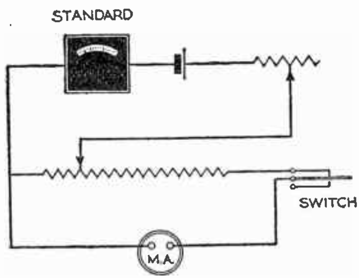
An easy way to determine the value of the 10 ma. shunt is as follows: The meter-shunt combination will carry 10 ma. The meter alone carries but 1 ma., so the other 9 ma. must be flowing in the shunt. Since the same potential exists across the meter and shunt, and the shunt carries nine times as much current as the meter, its resistance must be 1/9 that of the meter, in this case, 1/9 x 27 ohms = 3 ohms.

It will now be necessary to have access to a d.c. milliammeter of the required range and accuracy to calibrate the shunts. A piece of wire giving slightly more than the calculated resistance required for the 10 ma. shunt is shunted across the meter and its length gradually reduced until the meter needle stands at full-scale when the calibrating meter reads 10 ma. This cut-and-try process is somewhat tedious, but your trouble will be well repaid by the accuracy of the meter secured. The 100 ma. and 500 ma. shunts are calibrated as shown in the diagram, Figure 1.

The calibrating meter is connected in series with a battery and a rheostat and adjusted to read, in this case, 500 ma. Then with the 10 ma. shunt connected across the meter, connect the apparatus as shown. Since the switch forms part of the complete shunt, it must also be permanently connected in the circuit while calibrating. The connection indicated by an arrow should first be made at the extreme negative end of the shunt, then drawn carefully along the shunt until full-scale deflection of the shunted meter is obtained. The 500 ma. lead is then connected at this point. If this sliding connection is first made at the end of the shunt opposite that to which the calibrating meter is connected the meter will probably be ruined.

The point at which 500 ma. will give full-scale deflection will be found less than an inch from the negative end. In the same manner the point of connection of the 100 ma. lead is determined.

Care is necessary in connecting these two leads to the shunt. If



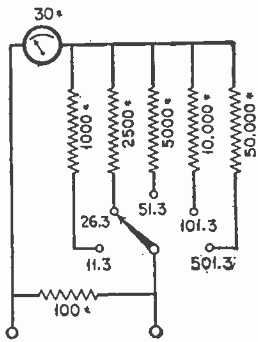


FIGURE 1 ABOVE. FIGURE 2, RIGHT.

the solder is allowed to spread over part of the shunt its value will be changed and readjustment will be necessary. Only extreme patience here will insure accuracy.

The value of the needed voltmeter multipliers for the most popular type of milliammeters are shown in the accompanying table.

A good rule to remember regarding shunts is the following: If a milliammeter with an internal resistance r is to be shunted so as to obtain a range n times as large as the original range, the required shunt is r/(n-1) ohms.

In many cases this will necessitate a shunt of a very low resistance value; these are hard to make and expensive to buy. There is another way of multiplying the range of a milliammeter: the so-called voltage-drop method.

When we add a resistor in series with the meter the shunt does not have to be so small.

Now suppose the shunt resistor is kept the same, then we could vary the series resistor for the different ranges. If we use for these series resistors the voltmeter multipliers already provided, we can save on resistors.

This is illustrated in Figure 2: the values of the resistors are marked on it. These are the series resistors needed for the voltmeter ranges.

On the lower ranges, this scheme introduces an error. The true multiplication factor on the different ranges are shown on the diagram.

When we consider that the multiplication factors are generally assumed to be 10, 25, 50, 100 and 500, we see that an error of 13% is introduced on the 10 mil range.

If one wishes to eliminate this error, all series resistors in Figure 2 should be 130 ohms smaller. The reader may convince himself of the correct ranges so obtained by applying the formulas given above.

TABLE 1

Table 1. The values of voltmeter multipliers for different meters and ranges are listed in this table.

VOLTAGE RANGE DESIRED	MILLIAMMETER SCALE					
	1.0 MA.	1.5 MA	2.0 MA	5.0 MA	10.0 MA	50.0 MA
1	1,000	667	500	200	100	20
5	5,000	3,333	2,500	1,000	500	100
10	10,000	6,667	5,000	2,000	1,000	200
15	15,000	10,000	7,500	3,000	1,500	300
50	50,000	33,333	25,000	10,000	5,000	1,000
100	100,000	66,667	50,000	20,000	10,000	2,000
150	150,000	100,000	75,000	30,000	15,000	3,000
500	500,000	333,333	250,000	100,000	50,000	10,000

MULTIPLIERS FOR A.C.

An a.c. voltmeter may have its range extended by placing a resistance in series with it just as with a d.c. voltmeter. The resistance however must be non-inductive. The difference in resistance due to skin effect is so small at 60 cycles that it can be neglected.

For a small extension of the scale of a 60 cycle a.c. meter the resistance method is best, but if one wants to multiply the scale by ten or more it is more economical to do it with condensers. For frequencies over 60 cycles the condenser method is used exclusively.

A condenser offers a reactance to an alternating current of $1/2\pi fC$ ohms. It is our problem to figure out how large a condenser we need to make the total impedance of the circuit n times as large as that of the meter alone when n is the desired scale multiplication factor. The only difficulty is that the capacitive reactance and the meter resistance cannot be added arithmetically, but must be added vectorially because the current in the condenser is 90 degrees out of phase with that in the meter itself.

Take as an example the Jewell voltmeter pattern 78 of 0-5 volts. We should like to extend this meter to 150 volts. The multiplication factor, n, is then 30. In the Jewell catalog we find the meter resistance is approximately 50 ohms. The total impedance wanted in this circuit is 1500 ohms.

$Z=\sqrt{r^2+X^2}$. Substituting values:

$1500=\sqrt{2500+X^2}$. Solving for X:

$X=\sqrt{2{,}250{,}000-2500}=\sqrt{2247500}=1499$ ohms.

In these expressions Z is the total impedance of the meter circuit; X is the reactance of the condenser and r is the resistance of the meter.

The required capacity for the condenser can now be obtained from the formula given above. It will be found to be 1.73 mfd.

In most cases the capacity will be found an odd value. The thing to do is to take the nearest capacity value available, in this case 1.75 mfd.

As a check we shall now calculate the value of this capacity as a multiplier. The condenser of 1.75 mfd. has a reactance of 1515 ohms at sixty cycles; adding to this the meter resistance, vectorially, we find the impedance to be 1516 ohms. Dividing by the meter resistance the multiplication factor is found to be 30.3.

MEASUREMENT OF CURRENT AND VOLTAGE AT RADIO FREQUENCIES

Ordinary moving-coil type of a.c. meters cannot be used at radio frequencies. For this purpose one must employ the "hot wire" type of milliammeter, or better yet the thermoammeter.

In the back of every thermoammeter common to the radio laboratory is a small device known as a thermocouple. It is the heart of the instrument, and without it the associated d.c. meter could not measure radio-frequency currents. The function and construction of the thermoammeter is simply this. A radio-frequency current flows through a short length of resistance wire, which in turn is heated as per the well-known formula:

$$P = RI^2$$

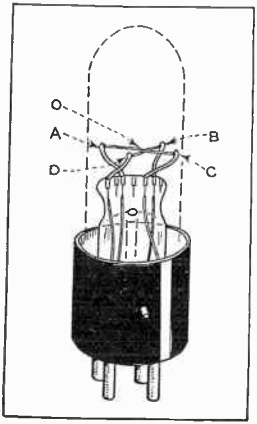
in which P is the small amount of power consumed by the instrument and displayed as heat; R is the resistance of the heater wire; and I the current flowing through the heater. At the center of the heater wire is soldered the couple (the hot junction) which is two pieces of dissimilar wires. The other two ends of the couple (the cold junction) are led to the two terminals of a milliameter. The phenomenon known as the Seeback effect is responsible for the current that actuates the milliameter.

Most thermoammeters will stand but a ten per cent. overload, and for this reason a burnt-out thermoammeter is a most frequent nonentity on the shelf of the radio experimenter. Since it costs half the instrument's worth to have it repaired commercially, it often remains in its state of uselessness.

May we add to the already endless uses for burnt-out radio tubes one more. An ideal thermocouple can be built from the base, stem, and associated leads of a four-prong tube.

Remove the glass envelope of an -01a or other 4-prong tube, leaving the element support or stem solidly in the base, clip the support wires at the top of the stem. Remove the plate, grid, and filament leaving half an inch of the leads projecting above. Arrange the four leads, which should all be the same length, so that the upper ends form a half inch square. With some of the wire, usually nickel or nichrome, from the grid of the dismantled tube form a V by soldering to two adjacent points of the square, the point of the V being in the center of the before-mentioned square. A clean piece of copper wire from an old audio transformer about the same size as the grid wire forms another V, and the points of the two V's are hooked together. The copper V should be pulled tight and soldered to the two remaining points of the square, as shown in the drawing (Figure 3).

If the radio-frequency or alternating current is run from one point diagonally across the square to the other point, a thermal d.c. e.m.f. of small magnitude will be observed at the other two corners of the square. The burnt-out thermoammeter may now be called to use again. Locate



DIAL CALIBRATION DECIBELS	INPUT VOLTAGE	FACTOR
0	2.00	1.00
.5	2.12	1.05
1	2.25	1.12
2	2.52	1.26
3	2.82	1.41
4	3.17	1.58
5	3.56	1.78
6	4.00	2.00
7	4.48	2.24
8	5.02	2.51
9	5.63	2.82
10	6.33	3.16
12	7.96	3.98
14	10.03	5.01
16	12.62	6.31
18	15.90	7.94
20	20.00	10.00
22	25.2	12.59
24	31.7	15.85
26	39.9	19.95
28	50.2	25.12
30	63.4	31.63
32	79.6	39.81
34	100.2	50.12
36	126.2	63.10
38	158.9	79.43
40	200.0	100.00

FIGURE 3, LEFT. FIGURE 4, RIGHT.

the two leads in the thermoammeter that connect to the hair springs and solder them to the two terminals of the back of the case. Now the tube base couple may be connected and radio-frequency or alternating currents measured. Five amperes, more or less, is a fair load for the one described above.

The new couple may now be calibrated against a standard and will remain constant indefinitely if handled carefully. By retrieving wires of various sizes from wire-wound resistors such as the Electrad a number of couples may be made which will cover the entire range of r.f. current used by the experimenter. The wire on these resistors is either nichrome, constantan, or advance. By calibrating against standards and with the old scale used arbitrarily, a graph may be plotted—current versus scale reading—for each couple. A plug-in thermocouple arrangement makes a very useful laboratory instrument. Copper against nickel, advance, nichrome, or constantan all give high thermoelectric powers, so the builder should not be without materials.

Do not try to calibrate any thermoammeter with direct current, as different readings for the same current will be obtained when the polarity is reversed. This is due to the fact that a perfect point contact between the heater and couple is generally impractical, and some of the calibrating current may get through to the milliammeter. However, any commercial-frequency alternating current is quite satisfactory for calibration purposes as well as radio-frequency current.

For the measurement of voltages at audio and radio frequencies, where it is essential that the instrument take no power from the circuit, the vacuum tube voltmeter is the most popular instrument.

Since the vacuum tube is always operated so as not to take grid current, it consumes no power from the input potentiometer. Therefore the latter can be calibrated directly in decibels. The dial is turned to hold a constant reading on the vacuum tube plate meter for various input voltages. The voltmeter may be calibrated to read the absolute values of input voltages. If this is done with the potentiometer dial set at zero decibels, then higher ranges may be measured. The actual voltage will be that read from the plate-meter calibration times a factor determined by the dial setting (see the chart in Figure 4).

However, the real usefulness of the meter is not so much in measuring absolute values of voltages as in determining relative values. The calibrated dial makes this possible without resort to curves. Dependence upon the constancy of tubes and batteries is not necessary when obtaining relative values.

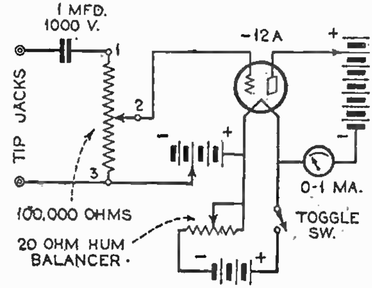
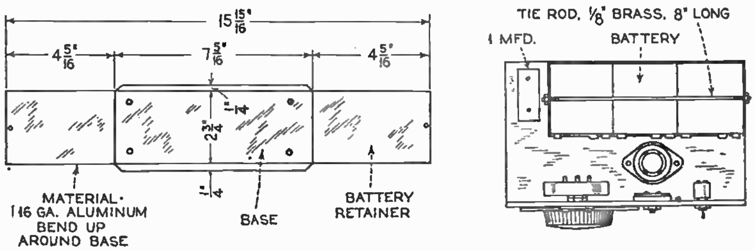


FIGURE 5, LEFT.
The vacuum tube voltmeter is as simple as it is valuable, which can be seen in this diagram.

FIGURE 6, BELOW.
This illustrates the placing of the parts as uesd in the vacuum tube voltmeter described in this chapter.



There is little novelty in the circuit of the instrument shown in Figure 5, save, perhaps, in the absence of the grid bias potentiometer. The novelty is rather in the directly calibrated dial and in the choice and layout of the components. The apparatus is assembled on a 5½-inch by 9-inch formica panel, and a 5½-inch by 9-inch wooden baseboard. Three Burgess No. 5156 tapped 22.5-volt batteries are mounted on the rear of the baseboard, and supply "B" and "C" potentials. Figure 6 shows the general layout with details on the battery retainer.

In making the dial, an old 4-inch bakelite dial is turned down to below the etched lines and figures. Then a 4½-inch disk of aluminum is marked out, sheared and filed as nearly round as possible, fastened to the back of the bakelite dial with three screws and the whole dial given a final turning and polishing.

Figure 4 is a table for calibrating the dial. With type ·12A tube, put the grid bias at—4.5 volts, and select a plate voltage that will give an initial plate current of .05 milliamperes. Apply a 2-volt, 60-cycle alternating current to the input of the instrument. Turn the dial completely clockwise for maximum plate current, around 0.2 to 0.3 milliamperes. Read the value closely and make a slight scratch on the dial opposite the line on the indicator. Then apply 2.12 volts a.c. Turn the dial to retain exactly the same plate current as before, and lightly mark the dial for 0.5 db. Increase the voltage to 2.25, mark the dial setting for 1 decibel. Continue the calibration according to the chart

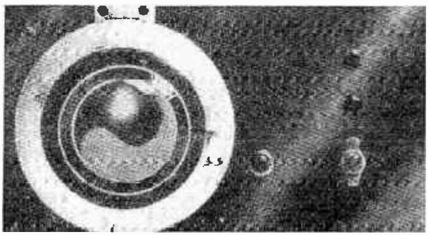


FIGURE 7
The completed instrument has the neat and workmanlike appearance shown above.

in Figure 4. A "B" eliminator transformer with 2.5, 5, 7.5, 110 and 300-volt windings, with a rheostat for voltage control, can be used as the 60-cycle source.

Remove the dial, and with a sharp wood chisel and a hammer make a radical indentation at each scratch, just to a circle ¼-inch inside the edge. With a set of ⅛-inch steel figures, mark the graduations with the corresponding values in decibels. Line the figures to a $\frac{7}{16}$-inch inner circle .A little advance practice with the figures on scrap aluminum will aid in doing a nice job on the dial. Finally put the dial in a chuck, and give the aluminum face an emery-cloth finish. Reset it on the Tonatrol shaft, with the shaft turned completely clockwise and the dial at zero.

If an input-voltage plate-current calibration for the zero db. setting is made, then for any other dial setting the input voltages are larger by the factor shown in the third column of Figure 3.

Parts List—Weston milliammeter, 0-1 ma.; Electrad Super Tonatrol, 100,000-ohm.; Frost hum balancer, 20 ohms; Yaxley toggle type battery switch; Yaxley tip jacks (2 required); Polymet filter condenser; 1 mfd.. 1000 volts; Burgess No. 5156 "B" batteries, 22½ volts each (3 required); UX type tube socket; 4-inch bakelite dial (see text)

CHAPTER 2

Measurement of Resistance

THE most popular form of ohmmeter consists of a small battery, a milliammeter and a resistor. The resister is so chosen that it will limit the current in the circuit to the maximum current the meter is designed for. Then, when an unknown resistor is added to the circuit the meter will go down more or less according to the value of the unknown resistor. The value can be calculated by means of Ohm's Law. This meter is so simple and well known that it needs no further description.

Another type of circuit, more adapted for the measurement of small resistances, consists of a similar circuit, but now the unknown resistor is placed in parallel with the meter and thus forms a shunt of unknown value. This circuit is shown in Figure 1.

The scale for low resistances is now well spread out. For example: when the unknown resistor is equal to the meter resistance the pointer will drop to half scale.

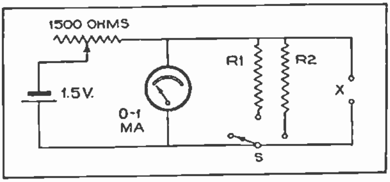


FIGURE 1

When an 0-1 ma. is used, the resistance of the meter is approximately 30 ohms. This means a difference in deflection from zero to half scale for a resistance variation from zero to 30 ohms. Higher up, the scale becomes gradually more crowded, but for resistance below 100 ohms it has sufficient accuracy.

It is possible to spread the scale still more for very low resistors by shunting the meter with a small fixed resistor, as shown at R1 or R2, and again adjusting the rheostat for full deflection of the meter. If R1 equals 1/9 of the meter resistance then a new scale is obtained which will be suitable for the measurement of resistors down to .2 ohms. This process can be repeated by employing another smaller shunt if necessary, so that resistances down to .01 ohms can be accurately measured.

Calibration of this instrument can be done by comparison with standard resistors or by calculation. If V1 represents full scale reading and V2 the reading of the meter with an unknown resistor as shunt, and if r represents the meter resistance then the unknown resistor is

$$Rx = r\left(\frac{V_1}{V_2} - 1\right)$$

The most accurate way of measuring resistance as well as capacity and inductance is by means of the Wheatstone bridge.

In its most elementary form the Wheatstone bridge consists of four resistors arranged as indicated in Fig. 2. The values of three of these

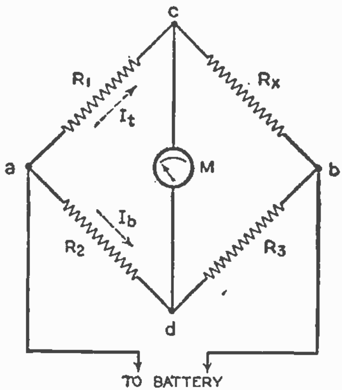


FIGURE 2

resistors are known and R_X represents the unknown resistance whose value is to be determined. The values of R^1, R^2 and R^3 are varied until no current flows through the meter. When this condition of no current through the meter M is found the bridge is said to be balanced.

It can be shown that the unknown resistance Rx is:

$$Rx = \frac{R_1 \; R_3}{R_2}$$

From the standpoint of simplicity it is not necessary that three variable resistances be used. In practice R1 can be fixed and the ratio of R3 to R2 adjusted to satisfy the equation. Also it is not necessary that the absolute values of R3 and R2 be known. It is simply necessary that we know the ratio, that is, whether R3 is ten times R2, one-half of R2 or any other value. With these ideas in mind, it is possible to work out a very simple bridge arrangement, as illustrated in the picture diagram of Fig. 3. In this dagram we use a single length of resistance wire such as manganin or nichrome. The total length of this wire should be about 24 inches. Across the terminals 1 and 2 is connected a fixed resistor R_1 whose value is accurately known. Across terminals 3 and 4 is connected a resistance whose value is to be determined. A low-range milliammeter is connected to the meter terminals, a few dry cells are used as the battery and the slider on the resistance wire is then moved back and forth until the meter reads zero current. The value of the unknown resistance will then be equal to

$$\text{unknown resistance} = \text{R1} \; \frac{\text{distance in inches from A to slider}}{\text{distance in inches from B to slider}}$$

The distances are readily measured by providing the bridge with a scale marked off in inches as indicated in the picture diagram Figure 3. The circuit will most accurately measure the value of an unknown resistance when the balance point is near the center, but reasonably ac-

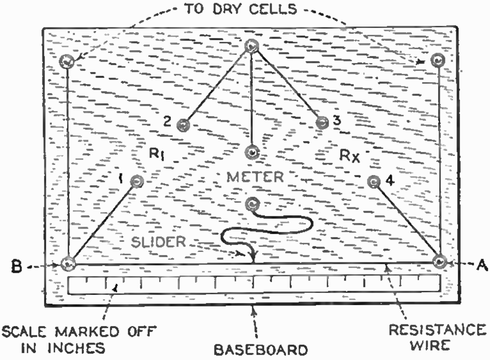


FIGURE 3

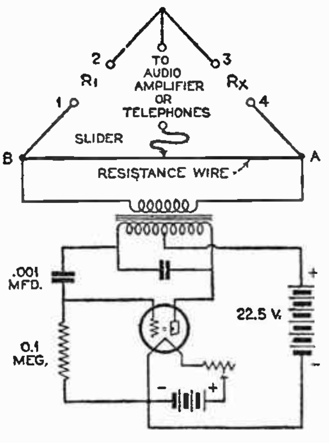
The slide-wire type of Wheatstone bridge is the simplest kind that can be made. By careful operation, good accuracy can be obtained.

curate measurements can be expected when one distance is up to about ten times as large as the other distance.

This simple bridge circuit is designed for use with d.c. voltages obtained from a few dry cells with a d.c. milliammeter used as the

FIGURE 4

Operating the bridge on a. c. makes it much more sensitive because a pair of phones will detect a current of one micro-ampere. The same hook-up can be used for capacity measurements.



indicating device. For a number of reasons, including the fact that satisfactory meters may not be found in the laboratories of many experimenters, it is suggested that the bridge be designed for a.c.

To operate the simple bridge circuit from a.c. only minor changes are necessary. The revised circuit is given in Figure 4. The oscillator consists of a single tube which may be a -99 operated from dry cells. In place of the d.c. indicating milliammeter, an audio transformer is used in conjunction with a single- or two-stage audio amplifier. In many cases it will be found possible to dispense with the audio amplifier and simply connect earphones directly across the bridge circuit. Since a good pair of earphones are sensitive to microamperes of current, it is obvious that much closer balances can be obtained than by the use of a d.c. milliammeter.

The same method of obtaining a balance is used with the a.c. bridge circuit, the slider being moved one way or the a.c. bridge circuit, the slider being moved one way or the other to a point where silence is obtained.

The same a.c. bridge circuit shown in Figure 4 can be used with a small change for the measurement of capacity. To measure the capacity of the condenser, the condenser whose value is to be determined is connected across terminals 3 and 4 and a standard condenser is connected across terminals 1 and 2. A balance is obtained in the same manner as when measuring resistors. The formula to determine the value of the unknown capacity is somewhat different, however, and becomes

$$\text{Value of unknown capacity} = \text{capacity of standard} \times \frac{\text{distance in inches from A to slider}}{\text{distance in inches from B to slider}}$$

It will be noted that the two distances in the above equation are reversed from the arrangement in the equation for determining resistance. This is due to the fact that the larger the capacity of the condenser the lower its impedance. In using this simple capacity bridge a number of fixed known capacities should be available for connection between points 1 and 2.

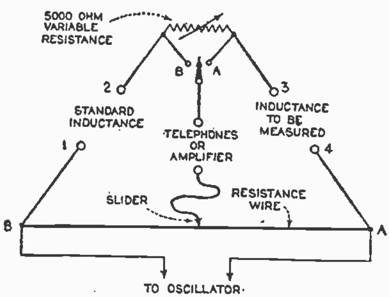


FIGURE 5

The measurement of inductance is similar in many respects to the measurement of resistance. The general circuit of Figure 4 is again applicable with the addition of one variable resistor and with the difference that for R1 must be used a standard inductance, i. e., a coil whose inductance is known. This standard inductance is connected across terminals 1 and 2 and the coil whose inductance is to be determined across terminals 3 and 4. (see Figure 5). At balance the inductance of the coil under test is determined from the formmula: Unknown inductance =

$$\text{standard inductance X} \frac{\text{distance in inches from A to slider.}}{\text{distance in inches from B to slider.}}$$

For inductance measurements a series of inductors are necessary.

By reference to Figure 5 which is the circuit diagram of the bridge for inductance measurement, it will be noted that there is an additional 5,000-ohm variable resistance connected in the circuit, the two ends of which are brought down to the terminals of a single-pole, double-throw switch. This additional resistance in the circuit is necessary due to the fact that the bridge must be balanced for both inductance and resistance and there may be comparatively large differences in the resistance of the standard coil and the resistance of the coil under test. With the switch Sw thrown in one position (position A) the resistance is placed in series with the standard inductance; when thrown to the opposite position (position B) it is effectively in series with the unknown inductance. It will be found possible only to balance the bridge when the switch is thrown so as to place the resistance in series with the inductance which has the lowest resistance. This can of course be determined by actual trial and error.

Condensers of a capacity of ½ mfd. and up can be checked rapidly by the circuit of Figure 6. It consists of an a.c. voltmeter with perhaps

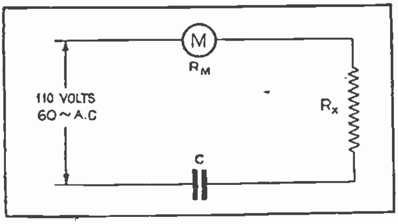


FIGURE 6

a series resistor. The insertion of a condenser in the circuit will decrease the meter reading when the instrument is connected to the a.c. line. From the amount of decrease the capacity can be obtained by calibration or calculation.

Small condensers and small coils are best measured at radio frequencies by the substitution method. When a tuned circuit is in resonance with a r.f. oscillator, and we replace the condenser by another one, resonance would be obtained again if the second condenser had the same capacity as the first. The same reasoning can be applied to the coil.

If the second condenser is variable and calibrated, it can be adjusted until resonance is obtained again. The capacity of the first condenser can then be accurately determined.

CHAPTER 3

Measurement of Frequency, Tube Constants and Miscellaneous Measurements

THE problem of measuring the frequency of a radio-frequency current became of importance with the very inception of radio as a means of communication, but in those first years of radio's development the need for accurate measurements was not very great. The passing years have seen, however, a rapidly increasing need for measuring frequency with a considerable degree of accuracy.

Frequency meters naturally divide themselves into two classes:

1. Those used for measuring the frequency of a transmitter.
2. Those used for generating a current of known frequency.

The simple wavemeter, Figure 1, consists of a coil L and a condenser C1. By using the correct constants for the coil inductance and

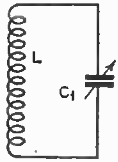


FIGURE 1

The simplest kind of wavemeter consists of an inductance and capacity, forming an oscillatory circuit. This is loosely coupled to the circuit under measure; Resonance is indicated in any of the ways described below.

the condenser capacity the simple wavemeter may be used at any desired frequency; in all cases it is best to use a straight-line frequency condenser (or one having approximately such characteristics) so that a reasonably straight-line calibration curve of frequency against dial setting will be obtained.

When such a wavemeter is used without any indicating device we must depend for indications of resonance upon the effect of coupling between the wavemeter and the receiver or oscillator in whose circuits are flowing the currents the frequencies of which are to be determined. In the case of a receiver the decrease in signal strength can be used to indicate when the wavemeter is in tune with the signal and then by means of a calibration curve the frequency of the signal can be determined. In all cases the coupling between the set and the wavemeter should be as loose as possible; practically, this means that the wavemeter should be placed as far as possible from the receiver. If this is done the point on the wavemeter corresponding to resonance will be indicated more sharply and greater accuracy can be obtained. When the simple wavemeter is used to determine the frequency of an oscillator the change in antenna current or plate current meter readings can be used to indicate resonance. If the wavemeter is placed very close to the transmitter, a change in antenna current or plate current will be indicated all the time the wavemeter circuit is in tune or partially in tune with the oscillator frequency, and fairly exact determinations of the frequency will be difficult—we might say impossible. Again the solution is to increase the distance between transmitter and wavemeter until a very sharp indication is obtained; when the coupling is made very loose one small sharply defined change in antenna current or plate current will be found and the accuracy with which the wavemeter may be set to resonance is greatly increased.

A number of different types of indicators can be used with the simple wavemeter to show resonance. Several of the more common methods are illustrated in Figure 2. We have left a hot wire or thermocouple meter M directly in the tuned circuit, right a small flashlight lamp is used to show resonance, in Figure 3 resonance is indicated by a small lamp placed in series with a single-turn loop placed adjacent to the wavemeter coil. All these arrangements, Figure 2 especially,

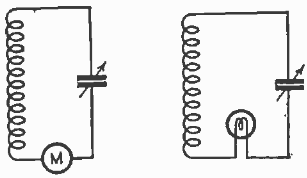


FIGURE 2

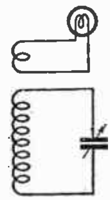


FIGURE 3

have the disadvantage that they introduce additional resistance into the wavemeter circuit so that the exact point of resonance is more difficult to determine. If a simple wavemeter circuit is to be used, it is generally best that dependence for resonance indications be placed on noting a change in receiver output, or plate or antenna current readings in the case of an oscillator. Greater accuracy can almost invariably be obtained in this manner than would be the case were some indicating device used in the wavemeter circuit.

If a simple wavemeter is well dsigned with good, low resistance sturdy coils, its inherent accuracy may be very high, but even in such cases the peak of the resonance characteristic is so flat (comparatively speaking) that the accuracy with which the dial may be set to resonance is far less than the inherent accuracy of the wavemeter. Anyone who has worked with the ordinary wavemeter is aware of the difficulty in accurately setting it at resonance. This is true no matter what type of indicating circuit is used, although, of course, those which introduce a minimum amount of resistance into the wavemeter circuit are the best. To get away from the difficulty of properly adjusting a wavemeter to resonance, engineers of the General Radio Company developed what was termed the incremental capacity method of indicating resonance. The circuit of such a wavemeter is shown in Figure 4. It consists of a coil L and a condenser C with an indicating meter M (the condenser shunted across the meter is used simply to make the meter indications more constant over the entire band covered by the wavemeter) and in parallel with the tuning condenser C is a push-button and a small capacity Ca.

When testing for resonance by means of this circuit the main tuning condenser C is slowly adjusted and the push-button switch is opened and closed. There will be found an adjustment of C where the meter reading does not change whether the push-button is closed or open. Under this condition the reading of the dial can be used to determine the frequency from the proper calibration chart.

The principle of the method can be understood by reference to Figure 3, which shows the resonance curve of an ordinary tuned circuit. There are two values of capacity, C1 and C2, both of which cause the same current to flow in the circuit. C1 represents the capacity slightly less than C0, the capacity necessary to tune to resonance, and C2 represents a capacity somewhat greater than that necessary to tune to resonance. In tuning the wavemeter the correct adjustment indicated by no change in the meter reading with push-button opened or closed is obtained when the main tuning capacity has a value equal to C1 so that when the push-button is pressed, placing Ca (Figure 4) across the circuit and thereby increasing the total capacity to C1, we reach a point on the opposite side of the resonance curve where the current is equal to that obtaind with C1 alone.

The ability of this method to give accurate indications is due

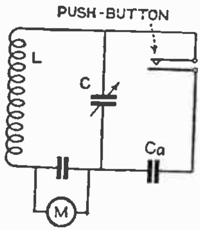


FIGURE 4

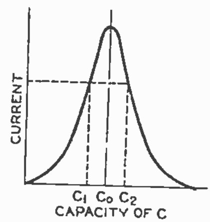


FIGURE 5

to the fact that the adjustments are actually made along the sides of a resonance curve where a very slight change in capacity produces a large change in current. For this reason the condenser dial can be adjusted much more closely than would be possible were an attempt made to actually tune to resonance. The precision with which frequency measurements may be made with a wavemeter of this type is very high, apparently in the order of one part iu twenty thonsand. This means that an oscillator may be set within one thousand cycles of a desired frequency around twenty thousand kilocycles or 15 meters. A transmitter may be adjusted within a few hundred cycles in the region around 5,000 kc. or 60 meters.

In using a wavemeter of this type, care is required, since it depends for its operation on not tuning the wavemeter circuit to resonance with the source of operations. Under such conditions the reactive impedance of the wavemeter circuit may be reflected into the oscillator circuit and thereby alter the effective impedance of the oscillator circuit and hence change its frequency. For this reason this type of wavemeter must be used with care and with as small a coupling between the oscillator and the wavemeter as is possible.

The wavemeter in one of the forms described in the preceding paragraphs is about the only device that can be used by itself to indicate frequency. Other methods of determining frequency involve the use of oscillating wavemeter circuits. Such circuits will now be described.

Oscillating wavemeter circuits depend for their operation on the phenomena of beat notes. As most readers know, whenever two radio-frequency currents are impressed on a detector circuit a beat note is produced whose frequency is equal to the difference in frequency between the two r.f. currents. Consequently, if we set up an oscillating tube circuit and calibrate the condenser dial in frequency as we would a wavemeter we can determine when the oscillating wavemeter is exactly in tune with the signal whose frequency is to be determined, by listening to the beat note in a detector circuit and adjusting the wavemeter dial to give zero beat.

Various circuits can be used in the design of an oscillating wavemeter. The circuit of Figure 6 shows one which is really a single-

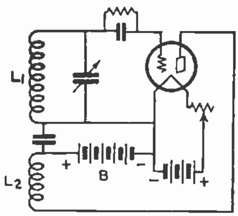


FIGURE 6

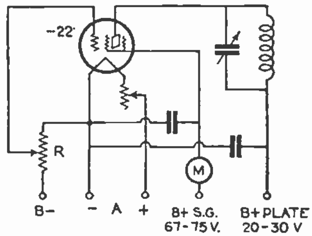


FIGURE 7

tube receiver, with the difference that the tickler or feedback coil L2 is fixed rather than variable; the numbr of turns on the tickler should be adjusted to make the circuit oscillate with fair uniformity over the band it is desired to cover. Determination of the proper number of turns can best be done by "trial and error". As a general rule it will be found that the higher the frequency band the greater the number of tickler turns L2 requires with respect to the number of grid turns of L1.

The circuit of Figure 6 does not, however, yield to very accurate or permanent calibration and a much better and simpler unit can be built using a dynatron circuit. The circuits of two dynatron oscillators, one for d.c. and one for a.c., are shown in Figure 7 and 8. They make use of screen-grid tubes operating at such voltages that they have negative resistance characteristics. Under such conditions the tube will oscillate if a tuned circuit is placed in the plate circuit. The dynatron circuit, in addition to being simple because it requires no tickler coil, has the advantage of a very high order of frequency stability. In fact, much better frequency stability can be obtained from the dynatron circuit than from any ordinary oscillator circuits using three-element tubes. Its stability is stated to be comparable to that of a crystal with temperature control. This allows it to be used for precise measurements, since it can be calibrated and will hold its calibration over long periods of time.

Referring again to the circuits of Figure 7 and 8 it will be noted that the plate voltage is less than the screen-grid voltage. It is only under such conditions that the negative resistance effect is obtained. Some curves, on the type—24 tubes, taken from a recent General Radio Experimenter, illustrated this point These curves, given in Figure 9, show that with a screen-grid voltage of 75 that the plate current increases as the plate voltage is decreased over a range in plate voltage from about 10 to 40 volts. With screen voltages of 75 the plate voltage

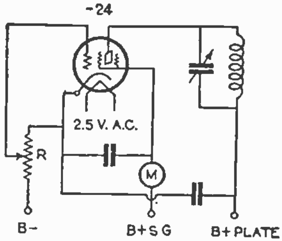


FIGURE 8

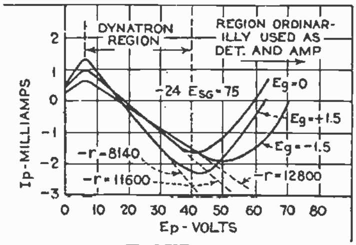


FIGURE 9

should therefore be about 20 or 30 volts; screen voltages of 67 require plate voltages of not more than about 20 or 25 volts. Slight changes in voltage can be taken care of in the circuit of Figures 7 and 8 by always adjusting the 2,000 to 3,000-ohm potentiometer R to give the same reading on the 10ma. meter M connected in series with the screen grid.

In using the oscillating wavemeter circuits we must depend upon beat notes for indications. To determine the frequency of a signal the oscillating wavemeter can be brought near the receiver and the wavemeter dial varied until zero beat note is obtained between the signal and the current from the wavemeter. Under such conditions the wavemeter's frequency is the same as that of the signal. To check a transmitter the signal from the transmitter can be picked up on a monitor (described later) and the oscillator wavemeter adjusted to zero beat with the transmitter signal.

Undoubtedly, the best standard of frequency which the experimenter, the short-wave experimenter particularly, can use is a quartz crystal whose fundamental frequency is known. A quartz crystal when placed in a circuit such as that indicated in Figure 10 will generate not only its fundamental frequency but additional harmonic frequencies as high or even higher than the twentieth. If an oscillating receiver, the old stand-by three-circuit tuner for example, is placed near the crystal oscillator a number of beat notes or heterodyne whistles will be heard in the phones connected in the plate circuit of the oscillating receiver. These whistles or beat notes are due to the fact that the currents being generated in the receiver are beating with the currents being generated by the crystal. As the frequency of the oscillating receiver is brought near that of the crystal (or any of the harmonics of the crystal) a high-pitched note is heard and, as we continue to tune the receiver this note gradually decreases in pitch until it reaches zero and then again begins to increase.

Because of the many harmonics generated by a quartz crystal oscillator it can be used very effectively in calibrating wavemeters. For example, suppose we set up apparatus as shown in Figure 11 where we indicate the crystal oscillator, a single-tube oscillating receiver with a

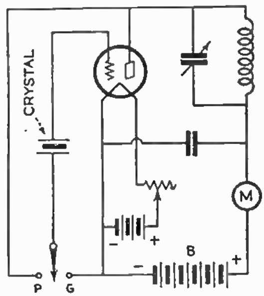


FIGURE 10

milliammeter M in the grid circuit and the wavemeter to be calibrated. The receiver circuit constants should be such that the set can be made to oscillate at the fundamental frequency of the crysal and, by listening in the headphones as the set is tuned, this frequency can be found by a beat note which will be very loud. If the coupling between the crystal oscillator and the receiver is too close this beat note will not gradually go to zero but will ''pull in'' and it will be difficult to find the exact setting for the tuning condenser on the receiver. The remedy of course is to increase the separation between the crystal oscillator and

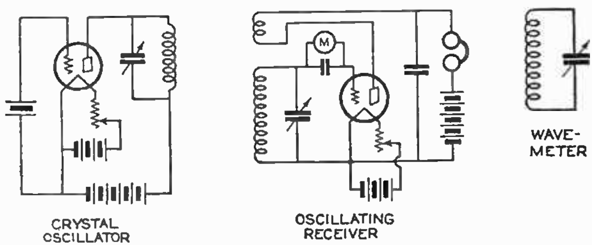


FIGURE 11

the receiver until a very smooth beat note is obtained, which will permit the tuning condenser on the receiver to be accurately adjusted to zero beat note. Now bring the wavemeter to be calibrated within a short distance of the oscillating receiver. At the same time we should listen on the headphones to determine if the tuning of the wavemeter is affecting the frequency being produced by the receiver. If such an effect is taking place a beat note will be heard as the wavemeter is brought near the resonance. For most accurate results it is essential that the wavemeter be placed far enough away from the oscillating receiver that the receiver keeps to zero beat with the crystal as the wavemeter is tuned through resonance.

If the tests are carefully made it will be possible to very accurately adjust the dial on the wavemeter to the point corresponding to that at which the meter in the grid circuit of the receiver shows a dip. Since the receiver had been previously tuned to the fundamental frequency of the crystal oscillator it follows that this point on the wavemeter corresponds to the frequency of the crysal.

Now, as we listen carefully in the headphones the r.f. being produced now by the oscillating receiver should gradually be increased—which means that the dial will have to be turned in a direction such as to decrease the capacity of the tuning condenser. Another beat note will be heard which will be due to the beat between the oscillating receiver and the second harmonic of the crystal and at the point of zero beat the receiver will therefore be oscillating at a frequency exactly twice the fundamental frequency of the crystal.

The procedure then is to again bring the wavemeter near the oscillating receiver and adjust the wavemeter dial until a dip is obtained on the meter in the receiver circuit. This gives a second point on the wavemeter calibration. We then proceed to tune the oscillating receiver to the third harmonic of the crystal, then the fourth, fifth, etc., each time finding the corresponding point on the wavemeter.

It is best to plot calibration curves of the wavemeter as each point is obtained and if the measurements are correctly performed a smooth curve will be obtained. Incorrect points on the wavemeter may be obtained due to adjusting the receiver such that one of the harmonics it generates beats with one of the harmonics of the crystal. But such calibration points will not fall in line with the other points previously obtained and in this way the errors can be detected. After the main points have been plotted, intermediate points can be obtained by making use of these beats between harmonics of the receiver and crystal.

It may soon be found that the receiver can no longer be tuned so as to make its fundamental correspond with the desired harmonic of the crystal, thereby making it necessary to change coils in the receiver. The change in coils is accomplished without difficulty by noting the point where the preceding harmonic was tuned in on the wavemeter and then adjusting the receiver with the new coil so that its frequency corresponds to this last point on the wavemeter. This, of course, necessitates some overlap in the ranges of the various coils used in the receiver.

In calibrating oscillating wavemeters the procedure is somewhat simpler in that we need merely to pick up the desired crystal harmonic on the receiver and then adjust the dial of the oscillating wavemeter to give zero beat note with the crystal signal. Such tests are best carried out with the receiver in a non-oscillating condition.

The crystal circuit by itself is of course an excellent wavemeter and it finds general use in modern broadcast stations not using crystal controlled transmitters. In such stations a crystal oscillator perhaps with headphones or an audio amplifier coupled to the plate circuit is used so that the beat note between the transmitter and the crystal can be heard. The transmitter can then be held to a frequency that will give zero beat.

The amateur not only has to assure himself by means of some frequency meter that his transmitter is operating within the desired amateur band but also that its note is clean. This necessitates that the amateur be able to listen to the signal being sent out by his own transmitter and has brought about the design of a number of small units generally termed monitors. A monitor consists essentially of a simple single-tube receiver mounted inside a shield and placed so that it picks up only a moderately strong signal from the transmitter. By means of a pair of headphones connected to the output of this small monitor receiver the operator is thereby enabled to listen to his own transmitter. Shielding of the monitor receiver is essential in practically all cases since otherwise the signal impressed on the monitor receiver would be so great as to block it and nothing but a series of thumps would be heard in the phones. The circuit of a simple monitor receiver is shown in Figure

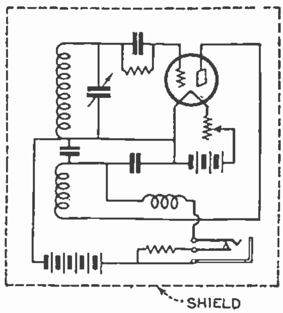


FIGURE 12

12 and it will be noted that all the apparatus, including the batteries, is placed inside the shield. In some cases it may be found that the phone cords pick up quite a bit of r.f. and then it will be necessary to shield the phone cords also.

It is not essential that the monitor have the frequency stability and permanence of calibration required of a wavemeter. The monitor is merely used as a check on one's own transmission and it is not a matter of serious importance if it requires some slight adjustment each day.

In many cases it is a good idea to arrange for a double-pole, double-throw switch so that the phones may be connected either to the short-wave receiver or to the monitor. In this way a quick change over can be made from one to the other and all transmissions can readily be monitored; should anything go wrong with the transmitter or antenna to cause a frequency to change, the trouble is immediately apparent.

MEASUREMENT OF TUBE—CONSTANT

Although the laboratory measurement of the characteristics of tubes is a rather complicated task, it is not difficult for the experimenter to build apparatus that will give (considering the simplicity of the apparatus) surprisingly accurate results. In these pages are described some simple tube measuring devices with which the experimenter can measure the amplification constant, mutual conductance and plate impedance of the more common types of tubes. With the apparatus dynamic and static characteristics can also be plotted; dynamic characteristics show the characteristics of tubes in an actual circuit and static characteristics show the operation of the tube without relation to the circuits into which it normally works. After all, it is upon tube characteristics that the radio engineer must base the design of radio receivers; every experimenter really interested in knowing more about radio should understand the meaning of the various tube characteristics, how they are determined and be able to measure in his own lab the constants of tubes.

There are two simple methods of measuring the amplification constant of a tube. Both methods have much in common, but one uses d.c. voltages entirely and the other the use of an audio oscillator and a pair

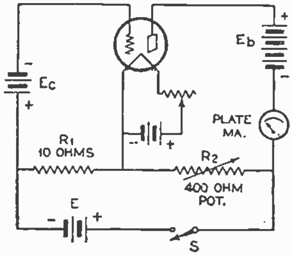


FIGURE 13

of earphones. The simplest circuit is shown in Figure 13. Here we have a tube supplied with plate voltage Eb and a grid bias voltage Ec, these two values being those at which the amplification constant is to be determined. In addition we have two resistors, R1 connected in the grid circuit and R2 connected in the plate circuit. Connected across these two resistors is a battery E, in series with a switch S. Now when we close the switch a current, I, will flow through R1 and R2 and by Ohm's law the voltage drop across R1 will be

$$\text{Voltage across R1} = \text{IR1}$$

and the voltage across R2 will be

$$\text{Voltage across R2} = \text{IR2}$$

Dividing the second equation by the first (just simple algebra) we have

$$\frac{\text{Voltage drop across R2}}{\text{Voltage drop across R1}} = \frac{\text{IR2}}{\text{IR2}} = \frac{\text{R2}}{\text{R1}}$$

But the resistance R1 is in the grid circuit and therefore when the key is pressed the voltage on the grid is changed by a value equal to IR1. Therefore the voltage drop across R1 produces a change in grid voltage, which is an important part of the measurement of amplification constant. Recalling the explanation given in the preceding paragraphs we will realize that to determine the mu (amplification constant) of the tube we will have to change the plate voltage by an amount equal to mu times the change in grid voltage and when this is done the plate current will be the same before the key is pressed and after the key is pressed. Now if the grid voltage is changed by an amount equal to IR1, then to give no change in plate current the plate voltage will have to be changed by mu times IR1. The change in plate voltage is due to the voltage drop across the resistor R2 connected in the plate circuit, the voltage drop being equal to IR2. Therefore IR2 must be made equal to mu × IR1. In equation form:

$$mu \times IR1 = IR2$$

and, dividing by I, we have

$$mu \times R1 = R2$$

$$mu = \frac{R2}{R1}$$

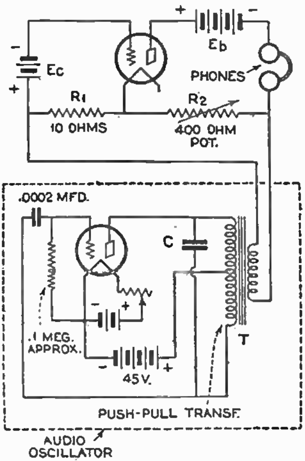
In other words, when R1 and R2 are so adjusted that pressing the key produces no change in the reading of the plate milliammeter, then the amplification constant of the tube is simply equal to R2 divided by R1. In use we can fix R1 at say 10 ohms and then simply adjust R2 until pressing the key produces no change in plate current. For R1 we must use a calibrated variable resistance. A good 400-ohm potentiometer with a dial may be used with quite accurate results. If we obtain no change in plate current with the dial set at 50° (100 division dial), then the resistance will be half of 400, or 200 ohms. 200 divided by 10 the value of R1, gives the tube an amplification constant of 20.

The method is most accurate when the value of the voltage E is very small. In using the method E should therefore have the lowest value which will permit accurate adjustment to the balance point. A 4.5-volt "C" battery is usually satisfactory. The polarity makes no difference; in one case we decrease the grid voltage and increase the plate voltage, and if the battery is reversed we increase the grid voltage and decrease the plate voltage. No matter what the polarity of E, balance point will be obtained at the same setting.

For most accurate results the measurement of amplification constant should be made with very small changes in grid and plate voltages. By slightly altering the circuit of Figure 14 we can obtain a method, using a.c. instead of d.c. to change the voltage, that makes it possible to obtain more accurate measurements. It is of course useless to use the a.c. method if the experimenter must rely on an ordinary 400-ohm potentiometer for R2, but if a good calibrated variable resistance is available the system using a.c. can be used.

In the a.c. method we replace the battery E and the switch S with a small a.c. oscillator. The plate meter may or may not be left in the circuit, but it is not used for determining the balance point. Instead we use a pair of earphones in the plate circuit. The complete arrangement is shown in Figure 14. The audio oscillator need consist simply of a —99 or a —01A type tube connected as indicated. The transformer T is a standard push-pull output transformer, the secondary of which is connected across R1 and R2. The fixed condenser C across the primary controls the frequency of the oscillation. This condenser should have a value such that the circuit oscillates at about 1,000 cycles, a frequency to which the ear and earphones are quite sensitive.

In the use of this system we simply turn on the oscillator, listen in the earphones and then adjust R2 until no sound is heard in the earphones. The sensitivity of the arrangement can of course be increased by using an audio amplifier to boost the signal before it is impressed on the earphones; the amplifier input would be connected across the points where the earphones are connected in Figure 14. Having determined the point at which no sound is heard in the earphones, we note the value



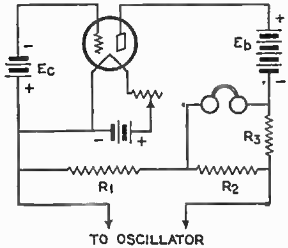


FIGURE 14, LEFT—
FIGURE 15, ABOVE.

of R2, divide it by 10, the resistance of R1, and the quotient is the amplification constant of the tube.

The circuit for measuring the plate impedance of a tube is shown in Figure 15. This circuit is really more simple when used with earphones and oscillator, since if d.c. is used some arrangement is necessary to balance out the normal current through the meter. But since every experimenter has a pair of earphones and an audio oscillator can be easily built, there is no reason why the a.c. method, with the greater accuracy it permits, should not be used. In Figure 15, Ec is the grid voltage and Eb is the plate voltage at which the tube is to be tested. As in measuring amplification constant, the circuit is balanced by adjusting R2, the 400-ohm potentiometer, until there is no sound in the earphones. The plate impedance is then equal to

$$\text{Plate impendance} = \frac{R1 \times R3}{R2}$$

The value of R1 depends somewhat on the plate impedance of the tube being measured . The values in Table 2 will adequately cover the usual range of tubes.

Those experimenters who want to build up these simple bridges will of course prefer to combine the circuit for measuring amplification constant with the circuit for measuring plate impedance. The combined circuit is therefore shown in Figure 16. The two double-pole, double-throw switches serve to arrange the circuit for the measurement of amplification constant when they are both thrown to the ''mu'' side;

with the switches in the other position the circuit will measure the plate impedance Rp.

It is not necessary to arrange any circuit for the measurement of mutual conductance, since it is readily calculated if we know the plate impedance and amplification constant of the tube. The mutual conductance is:

$$\text{Mutual conductance} = \frac{\text{Amplification constant}}{\text{Plate impedance}}$$

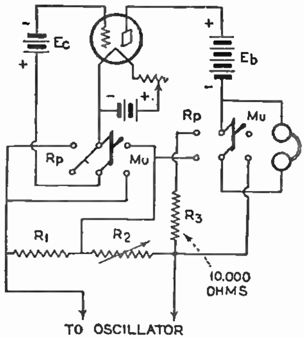
This gives the mutual conductance in "mhos." But the mho is too large a unit for convenient use and we therefore use micromhos; we find the same case in condensers where the unit is the farad and is so large that we generally use microfarads, millionths of a farad. Since it takes a million micromhos to make one mho, the following formula for micromhos is

$$\text{Mutual conductance in micromhos} = \frac{\text{Plate impedance}}{\text{constant} \times 1{,}000{,}000}$$

In Table 1 is given a group of figures showing the results of some

FIGURE 16

To the right is shown the combined circuit for measuring amplification factor and plate impedance. All constants of a tube can be obtained with this circuit.



measurements on a group of tubes. With these figures and the formulas given above, the reader should be able to calculate the three constants of the tubes from the data given in the table. We will work out the first case for tube No. 1 and we suggest that the reader work out the others.

With tube No. 1 a balance was obtained with R1, 10 ohms, and R2, 90 ohms. The amplification constant is equal to

$$\text{Mu} = \frac{\text{R2}}{\text{R1}} = \frac{90}{10} \qquad \text{Mu} = 9$$

and this value of 9 was entered in the fourth column of Table 1.

When measuring Rp, the values shown in the table were obtained at balance. The formula is

$$Rp = \frac{R1 \times R3}{R2} = \frac{300 \times 10{,}000}{300} \qquad Rp = 10{,}000$$

and this value was placed in column 8.

The mutual conductance in micromhos is found by multiplying the

TABLE 1

TUBE Nº.	AMPLIFICATION CONSTANT			PLATE IMPEDANCE				MUTUAL CONDUCTANCE
	R_1	R_2	Mu	R_1	R_2	R_3	Rp	(CALCULATE FROM Rp AND Mu)
1	10	90	9	300	300	10,000	10,000	900
2	"	83		"	245	"		
3	"	97		"	395	"		
4	"	60		150	250	"		
5	"	77		"	325	"		
6	"	85		"	300	"		
7	"	75		300	200	"		
8	"	70		"	275	"		
9	"	80		"	350	"		
10	"	65		"	175	"		

TABLE 2

FOR TUBES WITH A PLATE IMPEDANCE IN THE ORDER OF--	R_1 SHOULD HAVE A VALUE OF--
2000 OHMS	50 OHMS
5000 "	150 "
10,000 "	300 "
30,000 "	1000 "

amplification constant by 1,000,000 and dividing by the plate impedance. In this case we have

$$\text{Mutual conductance} = \frac{9 \times 1{,}000{,}000}{10{,}000} = 900 \text{ micromhos}$$

With this one example worked out the reader should have little difficulty in filling in the remaining blank spaces in the table; and if he feels so inclined to build up a simple tube measuring unit and actually determining the constant of a number of tubes.

The mutual conductance of a tube is so important a factor that it is desirable to measure it directly rather than indirectly. This can be done with the apparatus described below.

We may define mutual conductance as ratio of change of space current to change of grid voltage, which is similar to saying if the space current of a tube changed one ampere for one volt of grid-voltage change, the Gm would equal one mho.

The mho is obviously too large a value to be used in every day practice, and the term actually employed is micromho, just as a farad is too large a measure of capacity, so we use the microfarad. A micromho is one-millionth of a mho. The Gm of modern radio tubes, with proper potentials applied to their electrodes, is almost always in the neighborhood of 1000 micromhos. This might be expressed as "one millimho," but the term is seldom or never used.

As was noted, we have two factors to watch, the grid-voltage change and the plate-current change. Since 1-volt change of grid voltage is desirable, we may readily obtain that change by using a tapped resistor across a dry-cell so that changing the tap to which the grid is connected will cause just 1-volt difference in grid voltage. See Figure 17. Here R_1 is a 1500-ohm resistance accurately tapped at 1000 ohms. If one will carefully observe the potentials of the various batteries, he

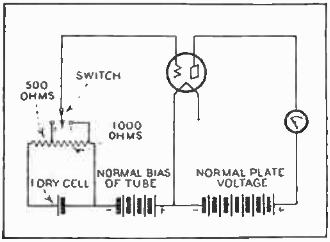


FIGURE 17

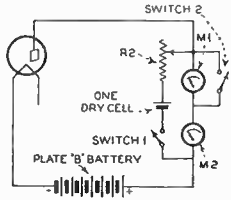


FIGURE 18

will note that as the switch is thrown from position 1 to position 2, 1-volt of positive bias is applied to the grid, making it 1-volt less negative than the normal C battery voltage. When this change occurs, a rise in plate current occurs simultaneously.

With only one meter in this circuit, we would have quite some difficulty in accurately observing this change. Hence we use two meters, as shown in Figure 18. This is done so that one meter can measure the total plate current, as will be done by M_2 and while M_1 may be a small-range meter used only to observe the change in plate current. The method employed in their use is to set the apparatus up with switch 1 open and switch 2 closed. Unless this precaution is observed, the low range meter will probably be burned out. With proper potentials applied to the tube from the A, B and C batteries and the grid switch in position one, the plate current will be shown on meter M_2. Now close switch No. 1 in the plate circuit and adjust the "bucking current" by means of the potentiometer R_2 until the meter reads as close to zero as it can be observed. Now open switch No. 2, leaving switch No. 1 closed. Some current reading will probably be shown, indicating that a true zero was not reached in the first adjustment of R_2. Readjust R_2 until M_1 reads zero. Now change the position of the grid switch to position two. A marked change of current through M_1 will be noted. If the scale of M_1 is clear and easily read, it may be interpreted directly in terms of Gm, 1 milliampere change equalling 1000 micromhos.

Now just a word of warning. **Close switch No. 2 before making any other changes in the circuit**, unless you feel that you have money to throw away buying new meters!

The writer realizes that the size of meters chosen, etc., is not given in the above text, nor is any form of mounting shown. As the apparatus is always used as a laboratory set-up in our laboratory, meters are chosen according to the tube under test. If the reader intends to build this as a permanent piece- of equipment, a 50-milliampere meter would be a good choice for M_2, while a 3-milliampere meter is large enough for M_1. The matter of mounting the apparatus may be left entirely to the ingenuity and taste of the builder. The complete circuit is shown in Figure 19.

Incidentally, battery operation is desirable instead of a power supply, due to perfect regulation and ease of voltage changes for various

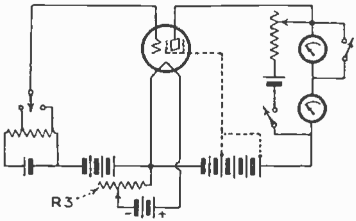


FIGURE 19

tubes. The applied voltages should always be the minimum specified by the tube manufacturers.

The following is an exact list of parts as used in our laboratory set-up. Of course other parts than those specified, provided they are of equal characteristics, may be used with the same results.

List of parts: M1, M2, Weston meters (see text); R1 Electrad c-20 Truvolt resistor with extra tap. Taps so adjusted to give 500 ohms and 1000 ohms. R2 Electrad RI-283 10,000 ohmms, wire-wound rheostat, for low plate current tubes. Electrad RI-233 3000 ohmms wire-wound rheostat for high plate current tubes. R3. Electrad 5-ohm rheostat for high current tubes; Electrad R1-270 for low current tubes.

SET ANALYZERS

The average set tester consists of a multiple range voltmeter and milliammeter with the necessary switching arrangement to put the meter in any one of the tube circuits of a receiver. Most up-to-date analyzers have in addition an ohmmeter, an output meter.

Below is a diagram for a set tester which has been brought up to date so that it can be used to measure the new 6-prong tubes.

The Weston Universal meter is employed in the circuit of Figure 20. All voltmeter ranges, both a.c. and d.c. can be obtained from this as well as the d.c. milliammeter ranges. The diagram should be self-explanatory but for convenience we are listing the use of the various switches.

S3 is the a.c.-d.c. switch; it serves to make the changes necessary to adapt the meter to the required purpose. S2 is a polarity reversing switch. Plate current is read by depressing S7; screen-current by pressing S8 and S9 serves to indicate cathode current of triodes and screen-grid tubes. This same switch serves to read screen current on a -47 or -33 type pentode.

Plate voltage is read by pressing S15; screen voltage — or grid voltage on triodes—by pressing S14. S12 is for control grid voltage, S11 for cathode voltage (screen voltage of type -47 and -33) while the suppressor voltage can be read by pressing S17.

S13 permits the measurement of the filament voltage and S16 of the a.c. plate to plate voltage of a -80 rectifier. S5 and S6 serve to test tubes by changing the grid bias which gives a rough check of mutual conductance. S5 is for tubes which have a cap on top and for

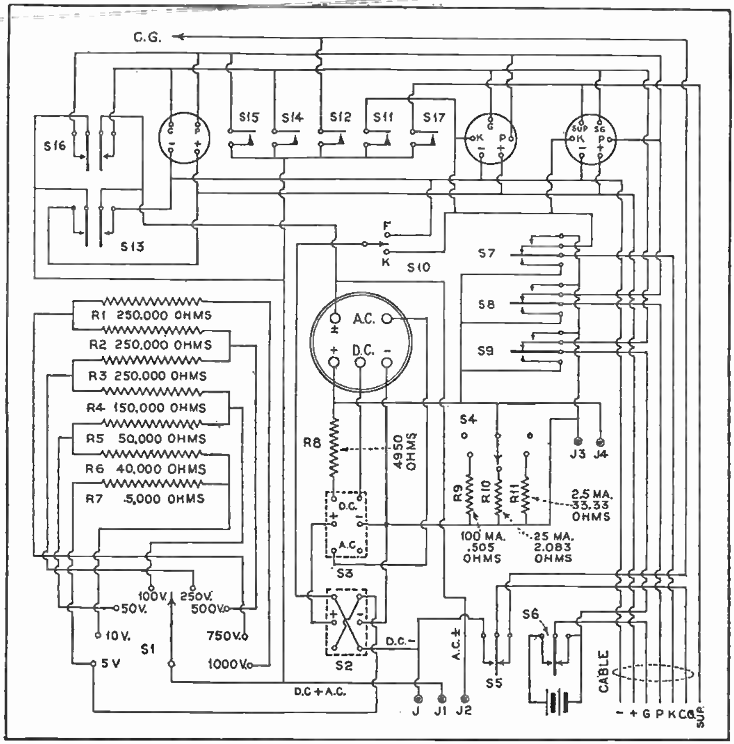


FIGURE 20

the 6- prong tubes. S6 serves for triodes and for the pentodes type -47 and -33.

The meter can be used for measurement of external circuit through the jacks J, J1 and J2.

LIST OF PARTS

J, J1, J2, J3, J4—Yaxley insultated tip jacks, type 422; R1, R2, R3—I.R.C. .15 megg. resistance, type WW4; R5—I.R.C. 50,000-ohm resisance. R1, R2, R3—L.R.C. .25 meg. resistances, type WW4 R4—I.R.C. .15 megg. resistance, type WW4; R5—I.R.C 50,000-ohm resistance, type WW3; R6—I.R.C. 40,000-ohm resistance, type WW3; R7—I.R.C. 5000-ohm resistance, type WW3; R8—I.R.C. 4950-ohm resistance, type WW3; R9—I.R.C. .505-ohm resistance, type WW4; R10—I.R.C. 2083-ohm resistance, type WW4; R11—I.R.C. 33.33-ohm resistance, type WW4; S1—Yaxley 8-point tap switch, type 1618.

S2—Yaxley push-button switch, type 2006; S3—Yaxley jack switch, type 760; S4—Yaxley 4-point tap switch, type 1515; S5, S6—Yaxley push-button switches, type 2003; S7, S8, S9—Yaxley push button switches, type 2880 special; S10—Yaxley jack switch, type 32; S11, S12, S14, S15, S17—Yaxley push-button switches, type 2001; S13, S16—Yaxley push-button switches, type 2004; 1 control-grid clip; I Blan special carrying case, 12 inches by 9 inches by 5¾ inches, inside dimensions, covered with imitation leather; 1 roll No. 18 push-back wire; Blan panel kit, consisting of 7-inch by 12-inch bakelite panel and three bakelite strips for mounting resistors, all cut and drilled according to specifications in Figure 4; 1 Weston model 301 universal meter; 1 UX type tube socket; 1 UY type; 7 Na-Ald 6-5 adapter; 1 Na-Ald 6-4 adapter; 1 7-wire cable.

This analyzer can be used as an ohmmeter when a 4½ volt battery is used in series with the 5-volt range and the unknown resistor. Placing a 1 mfd. condenser in series with the a.c. voltmeter makes it an output meter. This can be connected from plate to plate of a push-pull output stage or from plate to ground on a single output stage.

Tubes can be tested with these analyzers when the power is obtained from the socket of a receiver. If a tube is defective, there is a danger of blowing out the meters. Therefore tubes should first be

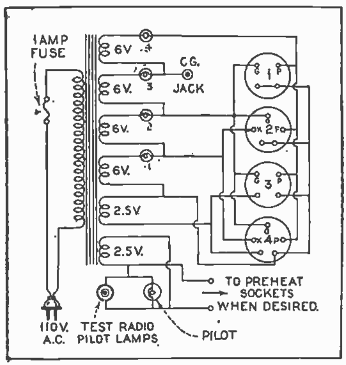


FIGURE 21

tested for shorted elements. For this purpose the arrangement of Figure 21 is suggested.

The only special equipment required is the transformer with four 6-volt and two 2.5-volt secondaries. Such a transformer can be readily made up by winding the secondaries over the primary, or on the other leg of the core of any standard replacement power or filament lighting transformer. Most power transformers have two 2.5-volt windings, so it will only be necessary to eliminate the high-voltage secondary and wind the four 6-volt secondaries.

Sockets numbers 1 and 2 are for cold tests, and 3 and 4 for heated-filament tests. One 2.5-volt winding supplies filament current to the last-named sockets and the other lights the pilot lamp and furnishes current for testing dial lights and preheating sockets when desired. The four signal lights are covered with Graybar Electric No. 4D red-lamp caps and the pilot with a number 4F green-lamp cap.

The circuit is self-explanatory, and the various lamp combinations signal tube shorts as follows:

Lights Nos.	Location of Short
1	Cathode to filament
1 and 2	Grid to filament
1, 2 and 3	Control grid to filament
1, 2, 3 and 4	Plate to filament
2	Grid to cathode
2 and 3	Control grid to cathode
2, 3 and 4	Plate to cathode
3	Control grid to screen grid
3 and 4	Plate to grid
4	Plate to control grid (unusual)

An output meter is a far more accurate instrument than the human ear in determining maximum response in radio service adjustments. It is to the serviceman what the stethoscope is to the physician, and the economy with which it can be constructed leaves little justification for

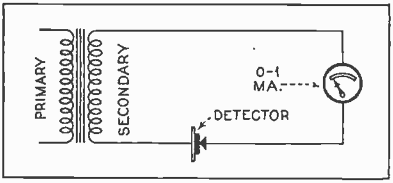


FIGURE 22

not using it. A simple arrangement is shown in Figure 22. A Jewell 0 to 1 milliammeter is connected in series with a fixed carborundum detector and the secondary of a 4 to 1 audio-frequency amplifying transformer. The primary is connected across the plate of push-pull output tubes, or from plate to high-voltage source (in parallel with the output) in the case of a single power tube.

MODULATION PERCENTAGE

The amateur will undoubtedly be interested in knowing how efficient he is modulating his carrier. Very expensive measuring equipment is used for this in the big stations; an inexpensive method therefore should be welcome to the amateur fraternity.

When in a radio transmitter we have super-imposed on the radio-frequency carrier-wave an electric wave generated by the sound waves of speech or music, we call the action **modulation**, and the carrier wave is said to be **modulated**. If this action is properly performed, the energy in the carrier remains constant; but the total energy is increased by virtue of the contributions of the modulating wave. It may be demonstrated mathematically that if a frequency fm is employed to modulate a carrier frequency fc, the resultant energy is largely contained in the three frequencies of (fc + fm), and (fc—fm) which are found in the output of the system. For example, a carrier wave of 1,000,000 cycles per second when modulated by a wave of 1000 cycles per second would yield frequencies of 1,000,000 cycles, 1,001,000 cycles and 999,000 cycles per second. Following the illustration further, if modulation is produced by a band of frequencies from 50 to 5000 cycles per second, the products of modulation will, in addition to the carrier, consist of two bands of frequencies, one from 1,000,050 to 1,005,000 cycles per second, the other from 995,000 to 999,950. These are called the side-bands, and the amount of energy contained therein depends on the strength of the modulating waves and the modulation circuit employed. Since the program sounds are carried by energies resident in these side-bands, it is important to concentrate within them as large a proportion as possible of the total output power of a radio transmitter. In fact, the Federal Radio Commission has laid down definite minimum requirements for broadcasting stations in order that they shall make fullest use of their assignments of power.

Going back to our idea of modulation by a single frequency (1000 c.p.s.) and referring to Figure 23, we see that the maximum effect on the carrier current Ic will be produced when the amplitude of the

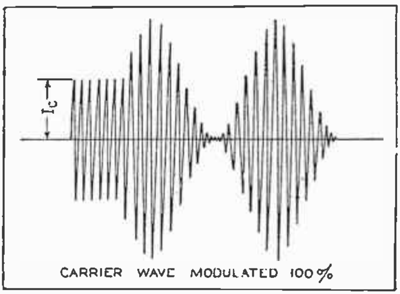


FIGURE 23

carrier is alternately reduced to zero and inceased to double its unmodulated value by action of the modulating wave. The resultant current we know is made up of three components, the carrier frequency current Ic, the uppper side-band current I_1, and the lower side-band current I_2. In order that the resultant current shall at intervals be zero, it is evident that I_1 and I_2 each must have maximum values of $Ic/2$ if Ic is the maximum value of the carrier. Now since the power in the various components varies as the square of the current, the power will be proportioned as follows:

Carrier power proportional to Ic^2.
Upper side-band power proportional to $\frac{1}{4}Ic^2$.
Lower side-band power proportional to $\frac{1}{4}Ic^2$.

The total side-band power is thus 50 per cent. of the carrier power; and this condition is referred to as 100 per cent. modulation since the carrier current is changed the maximum amount possible. If the carrier amplitude were reduced to only one-half its unmodulated value, the relation would be:

Carrier current = Ic, Carrier power proportional to Ic^2.

Upper side-band = ¼Ic, Upper side-band power proportional to $Ic^2/16$.
Lower side-band = ¼Ic, Lower side-band power proportional to $Ic^2/16$.
The total side-band power is now ⅛ or 12½ per cent. This is the condition for 50 per cent. modulation.

We may now set up a general relation for the side-band power as a percentage of the carrier power for any given modulation. Thus

$$Psb = Pc \left\{ \frac{M^2}{20{,}000} \right\}$$

where Psb is the power in the side-bands, M is the percentage modulation and Pc is the power in the carrier being modulated.

This increase in power taking place when modulation occurs will be made manifest by an increase in the effective value of the radio-frequency current output, and this increased effective value is given by the relation—

$$I^1 = I \sqrt{1 + \frac{M^2}{20{,}000}}$$

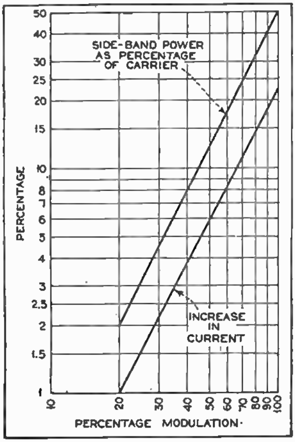
where I^1 is the value to which the output current will increase from its modulated value of I when the modulation is M per cent. Thus for 100 per cent modulation the antenna current of a broadcast station would increase by the factor $\sqrt{1.5}$ or 22½ per cent.; and for 50 per cent. modulation it would increase by the factor $\sqrt{1.125}$ or 6 per cent.

The relations for side-band power and percentage increase in current are given in Figure 24 in graphical form, and enable one to estimate the degree of modulation from the observed increase in output radio-frequency current when modulation occurs; and from this to estimate the amount of power in the side-bands.

Unfortunately, certain operating conditions do not make this method of measuring modulation particularly accurate; and a system employing an indicating meter calibrated to read percentage modulation directly is much to be preferred. If we insert a d.c. milliammeter in the plate lead of the modulated oscillator or amplifier as shown in Figure 25, the meter will read the average value of the current supplied to the tube. This current contains as a component the modulating current which supplies the side-band energy; and on inserting an audio-frequency transformer in series with the d.c. meter, audio-frequency voltages will be induced in its secondary proportional to the magnitude of the audio-frequency modulation. We may now connect a thermo-couple type of meter to the secondary to serve as an indicating instrument.

To design the system for accurate and convenient calibration requires the consideration of a few simple principles. First of all, the winding of the transformer which is placed in the plate lead of the tube must carry the average plate current without heating, and its insulation must be sufficient to withstand the surges occurring in the circuit. Second, the meter should be chosen to indicate percentage modulation directly, and for this purpose a one-ampere meter of the thermo-couple type is preferable. Third, the transformer must be designed to operate below the saturation point of the iron, and to have a reasonably good frequency characteristic, especially at low frequencies where deepest modulation is encountered. Fourth, it should have the proper turns ratio to make the 1-ampere meter read percentage modulation directly. The choice of turns ratio is not difficult, as will be demonstrated. Let us suppose that our radio-frequency tube draws 200 milliamperes. For 100 per cent. modulation the peak value of the audio-frequency current component will be 200 milliamperes also, and the root-means-square value will be 200 X 0.707 = 141.4 milliamperes. Now for this condition the modulation meter should read 100 per cent.; i.e., 1 ampere, or 1000 milliamperes. The turns ratio, therefore, must be 1000:141.4 or 7.07:1.

A very satisfactory transformer for the amateur to use for this purpose is a Jefferson toy transfomer. If the 115-volt winding is connected in the plate circuit of the radio-frequency tube, the modulation meter should be connected to the low-voltage side at a tap determined by the average plate current drawn by the radio-frequency tube. For the 200 milliampere tube we would divide 7.07 into 115 to obtain 16.3 as the proper voltage tap to use. The error will be small if the tap on either side of the theoretically correct value is used. For other values of plate current the voltage tap will be in proportion; thus for 100 milliamperes we should use 8.1 volts, and for 50 milliamperes, 4 volts approximately. The variation in accuracy of the Jefferson trans-



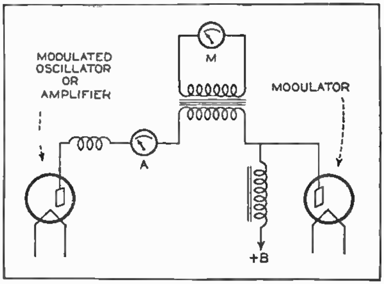


FIGURE 24, LEFT—
FIGURE 25, ABOVE.

former over a frequency range from 200 to 1500 cycles is within three per cent., and the effect of saturation with plate currents from 50 to 250 milliamperes is very small.

The amateur will find this system a relatively inexpensive and satisfactory one to employ in his phone transmitter; and, having installed it, he will be interested to check the readings of the modulation meter against values obtained from the curve of Figure 24 as determined by observation of increase in radio-frequency output current. Any marked difference in the two values should lead to an investigation of the operating conditions obtaining in his radio-frequency circuits.

CHAPTER 4

Design of Parts

RESISTOR DESIGN

The chart of Figure 1 enables one to determine the resistance of a wire of any material listed, when the cross-sectional area and the length are known. When a given resistance is required, the accompanying chart is useful in finding the correct length of resistance wire needed.

The resistance, R, of a wire is found from the formula

$$R = \frac{1k}{A}$$

Where A = the cross-sectional area of the wire
1 = the length of the wire
and k = the specific resistance of the conductor.

In America, the specific resistance is usually given in ohms per mil foot, and, consequently, A is then measured in circular mils and the length in feet. However, sometimes the specific resistance is given in ohms per centimenter cube; if the same formula is to be used, the quantities A and 1 must then be measured in square centimeters and centimeters respectively.

For the convenience of those who may have to work wtih other units, some equivalents have been placed on the chart along the regular

MATERIAL	OHMS PER MIL-FOOT
ADVANCE	293.5
ALUMINUM, PURE	15.8
ALUMINUM WIRE	15.7
ALUMINUM BRONZE	53.3
ARGENTAN	171.5
BRASS, 90.9 COPPER, 9.1 ZINC	21.9
BRASS, 65.8 " 34.2 "	27.8
BRONZE	107
CALIDO	601.5
CLIMAX, NICKLE STEEL	524
CONSTANTAN	295
COPPER, ANNEALED STANDARD	9.6
COPPER, ELECTROLYTIC	9.4
COPPER, HARD DRAWN	9.65
COPPER IRON	24.6
EXCELLO	550
FERRO NICKLE	162.5
GERMAN SILVER	199
GOLD	13.25'
IDEAL	295
IA IA, SOFT	284
IA IA, HARD	302
IRON, VERY PURE	53.3
IRON, SOFT STEEL	71
IRON, HARD STEEL	275
IRON, CAST, SOFT	448
IRON, CAST, HARD	590
KRUPP METAL	512

MATERIAL	OHMS PER MIL-FOOT
LEAD, PURE	119
LEAD-BISMUTH	381
MANGANESE-COPPER	601.5
MANGANIN	249, 445
MERCURY	567
MOLYBDENUM, HARD DRAWN	29.5
MOLYBDENUM, ANNEALED	25.3
MONEL METAL	246
NICHROME	595
NICHROME II	662
NICKLE, ELECTROLYTIC	41.7
NICKLE, COMMERCIAL WIRE	59.7
NICKLE STEEL	177
PHOSPHOR BRONZE	46.7
PLATINUM, DRAWN	61.4
PLATINUM-IRIDIUM	190.4
PLATINUM-RHODIUM	127
RHEOTAN	268
ROSE'S METAL	398
SILVER, ELECTROLYTIC	8.86
SUPERIOR	525
TANTALUM	8.80
THERLO	281
TIN	63.3
TUNGSTEN	26.35
WOOD'S METAL	312
YANKEE SILVER	199
ZINC	32.4

divisions. To illustrate the use of the chart, let us take an example. Suppose it is required to find the resistance of 10 feet of German silver of number 22 B. & S. gauge. Draw a line from the division point marked "German silver" on the k scale and the point on the 1 scale marked 10 feet; note the intersection on the turning scale. A line drawn from this point through the division marked 22 intersects the resistance scale at 3.1 ohms, which is the answer to our problem.

When the resistance is known, but the length of the wire has to be found, the same work may be done backwards.

In some cases, when long wires have to be employed, it is necessary

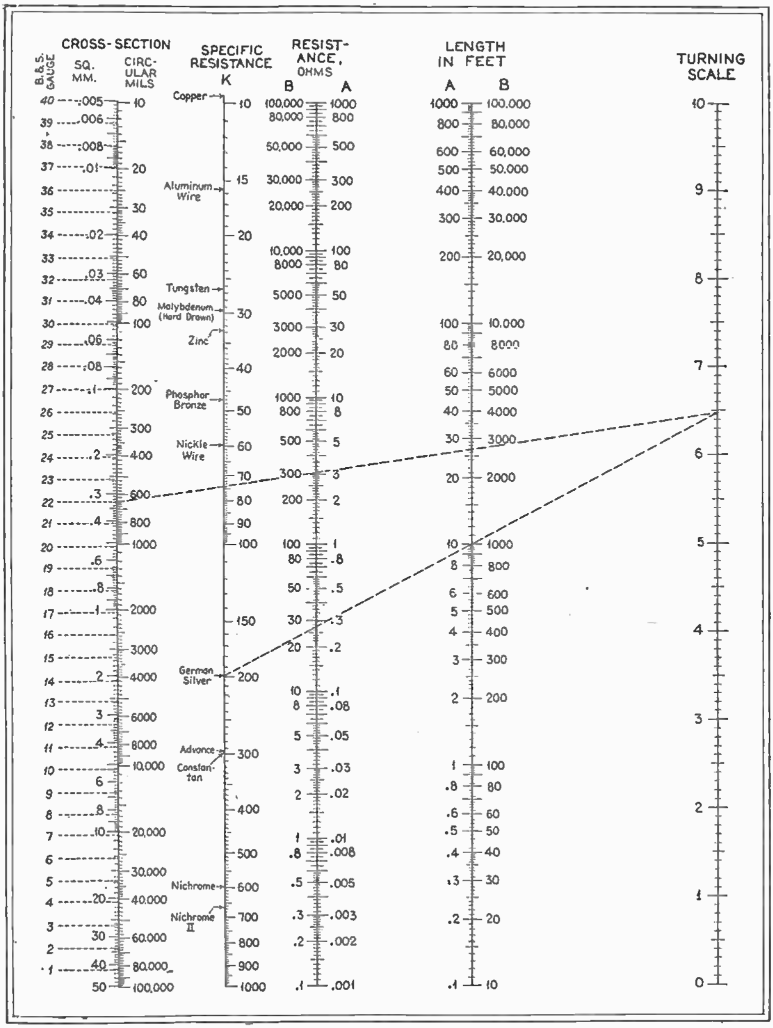


FIGURE 1

This chart enables you to find the resistance of any piece of wire as explained in the text, the factor K is expressed in ohms per mil-foot and can be found from the table on the preceeding page.

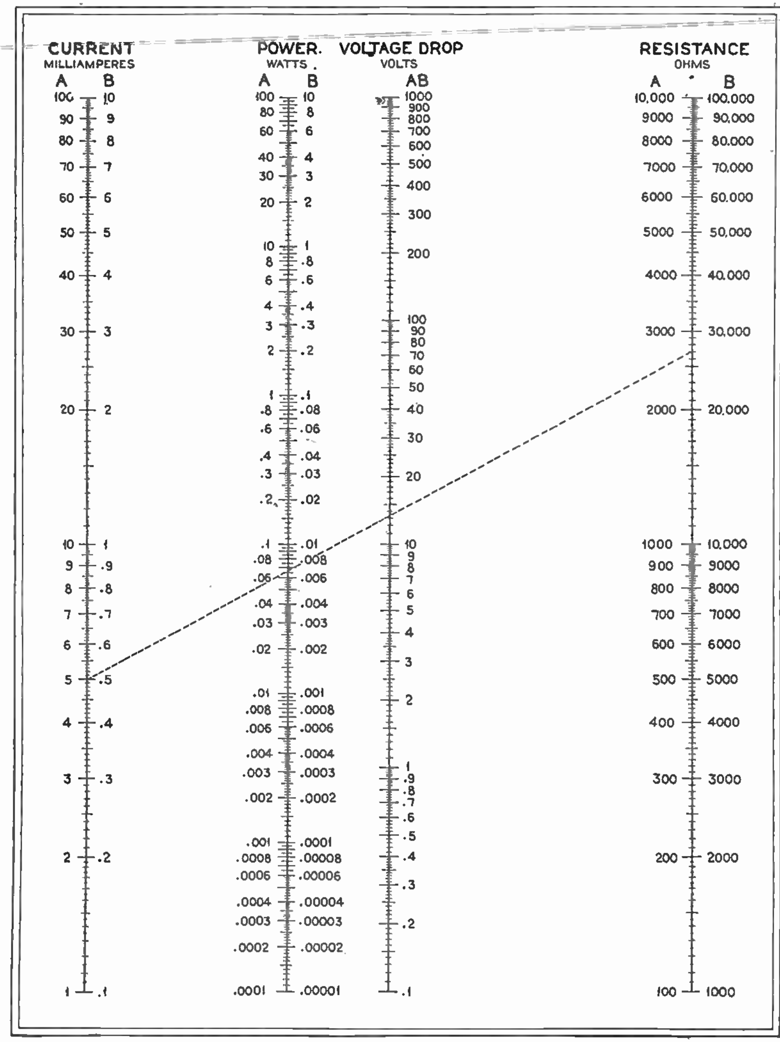
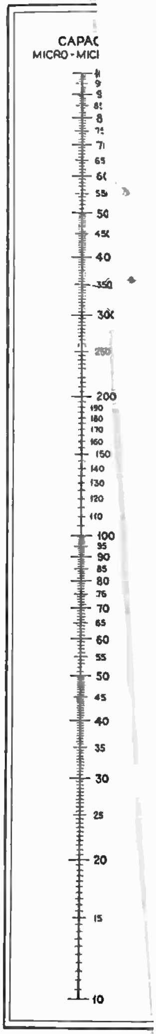


FIGURE 2

This chart is designed to solve the formula R = E I and W $=I^2R$ simultaneously. See explanation on page 43.



to read the 1 and R scales on the "B" side. The relation will always hold as long as you read both R and 1 on the "A" side or both on the "B" side.

For the benefit of those who must work with other units than the ones used in Figure 1, we list the following equivalents:
1 microhm per centimeter cube equals 6.0153 ohms per mil foot
1 ohm per mil foot equals .16624 microhms per centimeter cube
1 circular mil equals .0005065 square millimeters
1 square millimeter equals 1972 circular mils
1 foot equals .3048 meters and 1 meter equals 3.2809 feet.

The standard method of arriving at the **maximum** rating of resistors of the vitreous enamel type is the input in watts required to produce a temperature rise of 250 degrees Centigrade (482 degrees Fahrenheit) at the hottest point of the resistor, when the resistor is surrounded by at least one foot of free air, the surrounding air being a a temperature not exceeding 40 degrees C. (104 degrees F.).

This is a standard of the National Electrical Manufacturers' Association and the Radio Manufacturers' Association.

As a matter of safety and to insure long life, resistors are generally operated at about 25% of their maximum watts dissipation rating and at about three-fourths of their maximum current-carrying capacity rating. Such use makes plenty of allowance for poor ventilating conditions such as are found in the usual installations.

Many people have difficulty in determining resistance values needed for radio circuits and determining the power consumed. The chart of Figure 2 is designed to simplify these calculations.

In Figure 2 are shown scales on which are measured off: **current, watts, voltage drop** and **resistance**. The resistance in a circuit and the power can be found with but one index line, drawn through the divisions on the **voltage** and **current** scales. This chart consists really of two charts: one for the calculation of resistance, by Ohm's Law, and one for the calculation of power consumed. They have been drawn so that the current and voltage scales coincide and therefore both equations are solved at once with one operation.

Example: Let us suppose that the bias resistor for a –27 type tube has to be found. In the manufacturer's specifications we find the plate current is 5 ma. and the required grid bias -13.5 volts. Drawing a line from 5 on the **current** A scale through the point 13.5 on the **voltage drop** scale, we find that it intersects the **resistance** scale at 2700 ohms and this is the resistance needed. The power disspation is .0675 watts as found on the **watts** (A) scale. If two tubes are used in push-pull and they have the same bias-resistor, one must of course add the currents of the two tubes before referring to the chart; similarly, when dealing with a screen-grid tube or a pentode, the screen and plate current must be added, for they both pass through the cathode lead.

In Figure 3 is shown a chart which is designed to find the total resistance of two resistors in parallel or, conversely, what shunt is necessary to lower the resistance of a circuit to a given value. This chart also applies to condensers in series.

Examples:

Problem 1. Let it be required to find what is the resistance equivalent to 100 ohms and 150 ohms in parallel. A transparent ruler laid point and through the point representing the number of plates (30). Now note the intersection on the turning scale No. 1. Finally draw the last line from the point representing the ~~dielectric constant, 3.65,~~ ~~through the point~~ on the turning scale No. 2, which shows the necessary area of the plates as 84 square inches. As a check-up, an actual calculation gave the area as 83.7 square inches

TUNED CIRCUIT

The chart in Figure 5 shows the relation between frequency, inductance and capacity.

DESIGN OF COILS

The inductance of a single layer solenoid is given by the equation:

$$L = 4\pi^2 n^2 \frac{a^2}{b} K \text{ cgs. units}$$

where a is the radius of coil in centimeters,
b is the length of the coil in centimeters
n is the number of turns
K is Nagoaka's constant

A table of Nagoaka's constant for different shapes of coils is found in many textbooks. Since this formula is hard to solve some

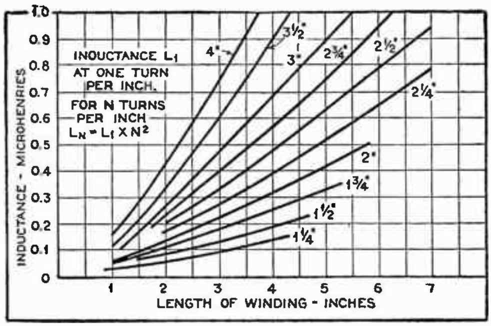


FIGURE 6

others which give an approximate value, have become more popular. These are:

a for a single layer coil

$$L = \frac{a^2 n^2}{9a + 10b}$$

b. for a spiderweb coil

$$L = \frac{a^2 n^2}{9a + 11c}$$

c. for a multilayer coil with rectangular crossection

$$L = \frac{.8 a^2 n^2}{6a + 9b + 10c}$$

where L is the inductance in microhenries
a is the average radius of the coil
b is the length of winding
c is the depth of winding. (all dimensions in inches)
n is the number of turns.

This calculation can again be saved by using the charts in Figures 6 and 7.

The curves given in Figure 6 may be used to determine the number of turns, length of winding, etc., which will be needed to give the necessary inductance value.

For example, if we have a coil three inches in diameter, wound twenty turns to the inch for three inches, its inductance will be the

NUMBER OF TURNS PER INCH				
B. & S. GAUGE	DOUBLE SILK	SINGLE COTTON	DOUBLE COTTON	ENAM.
14	–	15.6	13.6	15.2
15	16.3	16.1	15.1	17.0
16	18.2	17.9	16.7	19.1
17	20.3	19.9	18.2	21.5
18	22.6	22.1	20.2	23.9
19	25.1	24.4	22.2	26.8
20	27.8	27.0	24.3	30.1
21	30.8	29.8	26.7	33.7
22	34.2	33.0	29.2	37.7
23	37.7	36.2	31.6	42.3
24	41.6	39.8	34.4	47.1
25	45.8	43.6	37.2	52.9
26	50.5	47.8	40.1	59.1
27	55.5	52.0	43.1	66.2
28	60.9	56.8	46.2	74.1
29	67.1	61.3	49.2	83.3
30	73.2	66.5	52.5	92.2
31	79.3	71.9	55.8	103.4
32	86.5	77.2	58.9	115.6
33	93.6	82.8	62.1	129.3
34	101.0	88.4	65.3	144.9
35	108.5	94.3	68.4	162.3
36	116.2	100.0	71.4	181.8
37	124.2	105.8	74.3	202.4
38	132.2	111.6	77.1	227.7
39	140.2	117.2	79.8	252.5
40	148.3	122.8	82.3	280.1

TABLE 1

value for one turn per inch (0.47 micro-henries) multiplied by 20 squared ($20 \times 20 = 400$) or
$0.47 \times 400 = 188$ micro-henries = .188 milli-henries.

By figuring backwards from the chart we can compute in advance how many turns our coil should have, knowing the diameter of the coil and the number of turns per inch we can get on.

The alignment chart in Figure 7 permits the design of any single layer solenoid; it is based on Nagoaka's formula.

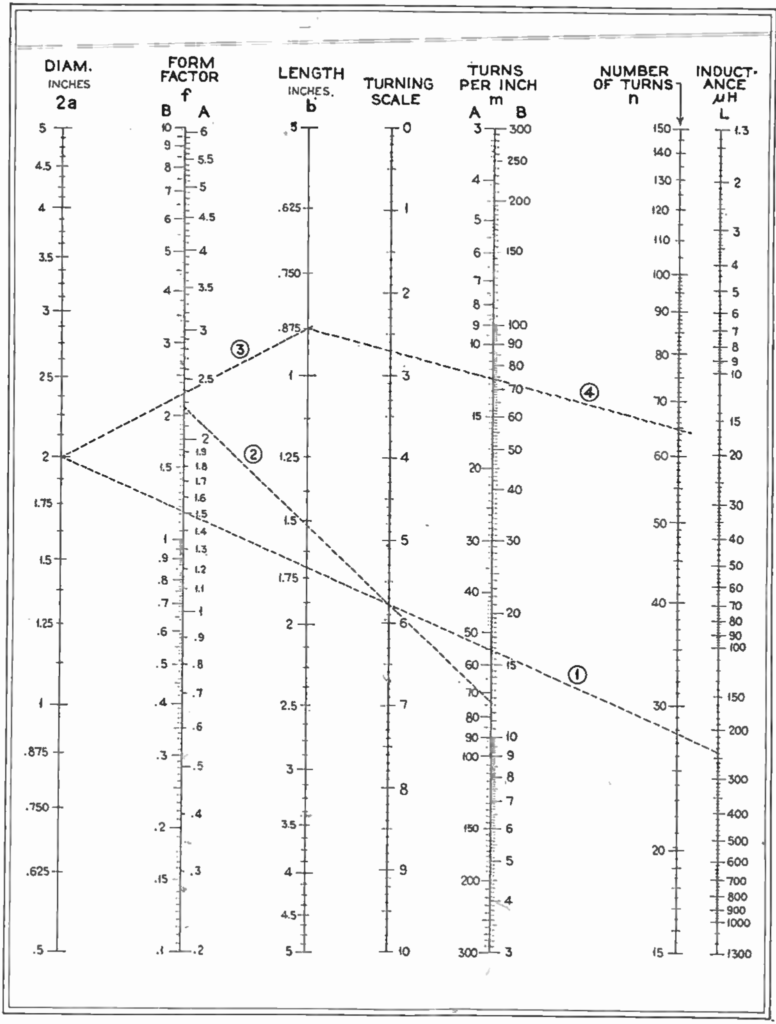


FIGURE 7

This chart helps you to find the inductance of single-large coils by Nagoaka's formula. An example is given in the text on page 51.

The use of this alignment chart is best explained by an example. Suppose an inductance of 240 microhenries is desired; it is to be wound on a form 2 inches in diameter, with number 28 enameled wire. In the accompanying table it is found that this wire winds 74 turns to the inch.

(1) Draw a line from 240 on the inductance scale (extreme right) to 2 on the diameter scale (extreme left) and note the point of intersection on the turning scale (center). (2) Draw a second line from 74 on the turns-per-inch scale through the newly found intersection and find the form-factor on the f (A) scale to be 2.25. (3) A third straight line from 2 on the diameter scale through 2.25 on the f (B) scale intersects the length scale at ⅞ inch, which is the length of the coil. (4) The last line, from ⅞ on the length scale through 74 on the turns-per-inch (B) scale, indicates the number of turns as 65.

TRANSFORMATION DESIGNS

Transformers, generally, are divided into two distinct types, the "core" type and the "shell" type. Figure 8 shows a typical lamination of the shell type. It will be noticed that the dimension A is equal to the sum of the dimensions B and C. This is because the winding, in

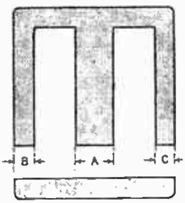


FIGURE 8

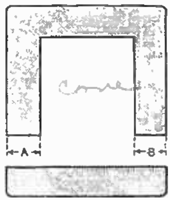


FIGURE 9

this type of transformer, is all placed on the center leg of the core, and the magnetic path divides between the other two legs equally. An additional piece is shown at the bottom of the illustration, which only serves to complete the magnetic path, and if it were possible to wind the wire on the center leg with this piece in place it might well be a part of the lamination, instead of a separate piece.

The core type transformer differs from the shell type in that there is no center leg to the core, and all dimensions are equal. Figure 9 shows a typical lamination of this type. The windings in this instance, instead of being on the center leg, are on one or both of the outside legs.

The volts-per-turn of wire in a transformer is a function of the primary wattage. The primary wattage is the sum of the wattage of the various secondaries, plus approximately ten per cent. for core loss. This may be expressed

$$Wp = Ws1 + Ws2 + Ws3 + \frac{Ws1 + Ws2 + Ws3}{10} \quad (1)$$

where Wp represents primary watts and Ws1, Ws2, etc., the wattage of the individual secondaries. (The wattage of any one secondary is the voltage multiplied by the amperage, considered in phase.)

$$E = \frac{\sqrt{Wp}}{50} \qquad (2)$$

where E is the volts-per-turn. This formula applies to 60-cycle supply, and a core of the "shell" type.

$$E = \frac{\sqrt{Wp}}{83} \qquad (3)$$

WIRE TABLE					
SIZE	DIAMETER		AREA	TURNS PER INCH	
B.&S.	ENAM.	D.C.C.	CIRC. MILS.	ENAM.	D.C.C.
8	.1307	.1413	16510.	7.7	7.0
9	.1166	.1252	13090.	8.6	7.9
10	.1041	.1118	10380.	9.6	8.9
11	.0927	.1006	8234.	10.8	9.9
12	.0828	.0902	6530.	12.1	11.0
13	.0740	.0812	5178.	13.6	12.1
14	.0659	.0733	4107.	15.2	13.6
15	.0589	.0655	3257.	17.0	15.1
16	.0526	.0592	2583	19.1	16.7
17	.0469	.0536	2048.	21.5	18.2
18	.0419	.0487	1624.	23.9	20.2
19	.0373	.0446	1288	26.8	22.2
20	.0334	.0408	1022.	30.1	24.3
21	.0297	.0368	810.1	33.7	26.7
22	.0265	.0335	642.4	37.7	29.2
23	.0238	.0308	509.5	42.3	31.6
24	.0213	.0283	404.0	47.1	34.4
25	.0191	.0261	320.4	52.9	37.2
26	.0170	.0240	254.1	59.1	40.1
27	.0153	.0219	201.5	66.2	43.1
28	.0135	.0205	159.8	74.1	46.2
29	.0122	.0192	126.7	83.3	49.2
30	.0108	.0179	100.5	92.2	52.5
31	.0097	.0168	79.70	103.4	55.8
32	.0087	.0158	63.21	115.6	58.9
33	.0077	.0150	50.13	129.3	62.1
34	.0069	.0143	39.75	144.9	65.3
35	.0062	.0136	31.52	162.3	68.4
36	.0055	.0130	25.00	181.8	71.4
37	.0049	.0124	19.83	202.4	74.3
38	.0044	0119	15.72	227.7	77.1
39	.0039	.0115	12.47	252.5	79.8
40	.0034	.0112	9.888	280.1	82.3

Again E is volts-per-turn. This formula applies to 25-cycle supply and a core of the "shell" type.

$$E = \frac{\sqrt{Wp}}{25} \qquad (4)$$

This formula applies to 60-cycle supply and a core of the "core" type.

$$E = \frac{\sqrt{Wp}}{41} \qquad (5)$$

This formula applies to 25-cycle supply and a core of the "core" type.

Since the volts-per-turn solution of any of the preceding formulas is usually a fractional term, it will be more convenient to change it to "turns-per-volt" in computing the number of turns in the various windings. This may be done by inverting the fraction and dividing as indicated. For instance, if the solution of any one of the formulas should give us $E = 1/4$, the turns-per-volt will be four. (We will use the term "Tv" to indicate turns-per-volt in any following formula.)

The total number of turns in any individual winding is the voltage across that winding times turns-per-volt, or

$$N = V \times Tv \qquad (6)$$

where N in the total number of turns in the individual winding, V is the voltage across the winding, and Tv is turns-per-volt.

It is customary to use wire with an area of 700 circular mils to 1000 circular mils per ampere, depending on the ventilation of the transformer. If at all in doubt it is best to use a wire too large rather than oue too small, so 1000 circular mils iu all computations.

The size of the core in a transformer is always the area, in square inches, of a cross section of the leg of the core on which the winding is placed. In the shell type this is the center leg, and in the core type, either of the outside legs. To make this clearer, the area in square inches is the dimension A in Figure 8, times the height of the stack of laminations. As the dimension A decreases, the height of the stack will, of course, increase, and vice versa.

Having defined the "cross-section" of the core, let us see how we determine the necessary cross-section to use.

$$A = \frac{E \times 100{,}000{,}000}{4.44 \times F \times B} \qquad (7)$$

where A is the area in square inches, E is the volts-per-turn solution of one of the formulas (2), (3), (4) or (5), F is the frequency of the supply current and B is the number of lines of magnetic force per inch. With the vast majority of steels on the market we may use 50,000 lines per inch, so we will adopt that as standard. With very high-grade steel, or in transformers that are large, such as lighting-line transformers this might be increased, but again it is best to err on the side of designing our transformer too well rather than too poorly. Using 50,000 lines per inch, we can reduce the formula to

$$A = \frac{E \times 100{,}000{,}000}{13{,}320{,}000} \qquad (8)$$

where F is 60 cycles, or

$$A = \frac{E \times 100{,}000{,}000}{5{,}550{,}000} \qquad (9)$$

where F is 25 cycles.

Since the frequencies usually encountered are 60 cycles and 25 cycles, these formulas may be further reduced to—

$$A = E \times 7.50 \qquad (8a)$$

where A is the area, E is volts-per-turn, and the frequency is 60 cycles.

$$A = E \times 18 \qquad (9a)$$

where the frequency is 25 cycles.

CHAPTER 5

Circuit Design

IN going about the right way in figuring a voltage divider network it is first necessary to determine the load to be imposed upon the voltage divider.

For example let us arbitrarily assume that we have a receiver requiring several simultaneous voltages as follows: 450 volts at 100 ma., 250 volts at 25 ma., 180 volts at 6 ma., 90 volts at 16 ma., and 45 volts at 3 ma. Summing up all these currents, we find that we must have a power transformer capable of supplying, at the voltage divider, 450 volts at 150 milliamperes. This, however, is not all, since we have not taken into consideration the bleeder current. This is the current flowing in the resistor connected between the lowest side of the voltage supply (usually the + 45-volt tap) and ground. For such high currents as are being drawn by the receiver of this case we can assume a safe bleeder current of about 25 ma.

It is clear now that we need a power transformer capable of supplying 450 volts at the filter output, as 175 ma. As shown in Figure 1. the first section of the voltage divider will have to cause a drop of 200 volts with a current of 75 milliamperes flowing through the resistor

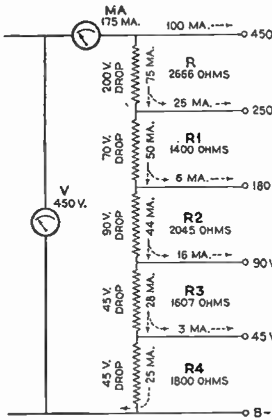


FIGURE 1

causing the voltage drop. The value of the resistance causing this drop, according to Ohm's law, is E/I or 200/.075 or 2666 ohms. This resistor is indicated in the diagram of Figure 1 as R.

At the 250-volt tap the current divides, 25 milliamperes of the 75 ma. current flowing through resistor R flows out of the pack into the receiver load while the remaining 50 ma. of current flows through the resistor R1. Accordingly Ohm's law gives the value of R1 as E/I equals 70/.05 or 1400 ohms. Here likewise the current divides, 6 milliamperes flowing to the receiver load and the balance of the 50 ma. or 50-6 = 44 ma. flowing through resistor R2. Hence the value of R2 is found through the same formula, E/I or 90/.044 = 2045 ohms. Here again as at each tap the current divides, 16 ma. flowing out to the receiver load, while the remainder of the 44 ma. or 28 ma. flows through resister R3. Resistor R3 should cause a voltage drop of 45 volts, allowing 3 ma. to flow through to the 45-volt tap into the receiver load, permitting the remainder of the 28 ma. or 25 ma. to flow through resistor R4 as bleeder current. Therefore, E/I or 45/.028 = 1607 ohms, or the value of R3. The value of R4 is likewise found, E/I or 45/.025 = 1800 ohms.

The calculation of each section can be accomplished with the chart in Figure 2 (on page 42); this also shows the power consumed.

AUDIO DESIGN CHARTS

The charts in Figures 2, 3 and 4 gives the solutions to three of the basic problems in audio amplifier design.

The first problem we will consider is that of the effect of a mismatch in a circuit transmitting power from a generator, e, having an internal resistance, r, and delivering its power to a resistance R.

This function has been ploted in Chart 1 (Figure 2). It is interesting to note that the curve when plotted logarithmically in "a" is symmetri-

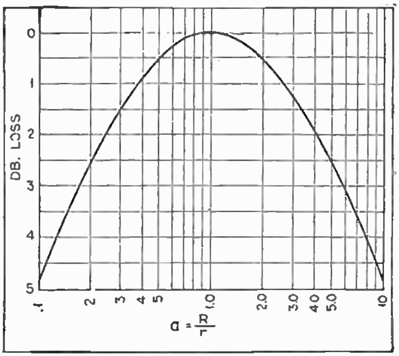


FIGURE 2

This curve illustrates the loss of power in d.b. due to mismatching the output circuit to the generator.

cal about the value a = 1. A second chart deals with the losses sustained due to the departure of an actual transformer from the ideal in matter of primary inductance.

As an example of the application of this chart let us suppose that the requirement is for an output transformer for operation into some specific load and that the frequency characteristics shall not suffer more than one decibel at 60 cycles due to the primary reactance. What value of primary inductance is required and how much will the gain be down, at 30 cycles. The tube resistance for a -45 tube is about 1800 ohms. For operation of a single tube the turns ratio will be chosen such that the tubes see twice its own impedance, so we refer to the curve Rx=2Rp and find the value of "b" corresponding to one decimal. On the abscissa. This is found to be 1.38, hence

$$b = 1.38 = \frac{2\pi fL}{r} \text{ and } L = \frac{1.38\ r}{2\pi f}$$

substituting the frequency we have

$$L = \frac{1.38 \times 1800}{2\pi 60} = 6.59 \text{ henries}$$

To find the loss at 30 cycles we note that b is obviously one half the value at 60 cycles or $\frac{1.38}{2} = .69$. Referring to Figure 3, we see the loss is 2.9 DB.

It will be apparent from the above that the shape of the functions given in Figure 3 is the shaping of the normal frequency characteris-

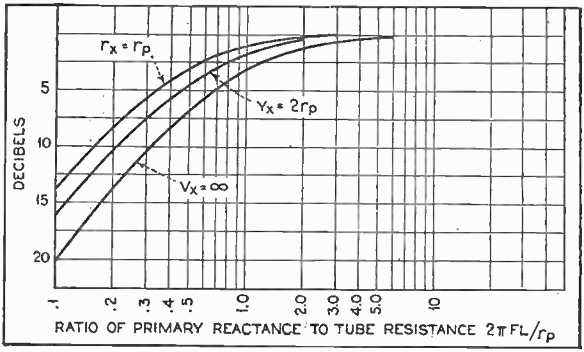


FIGURE 3

tics of the amplification with respect to frequency when all regenerative and degenerative contributions have been eliminated. Thus when the loss at any specified frequency has been evaluated the frequency characteristic has been determined.

The third condition we will ascertain is the loss in amplification incurred by shunt capacities in a transmission system such as an amplifier or a line which is short relative to the wavelengths being transmitted.

The function has been plotted for the values a = .25, a = 1, a = 2, a = 10 in Figure 4, a represents the ratio of the load-impedance to the generator impedance. Here again another case is interesting in which a is infinite. This is the case in which the load is entirely that of the capacity of the circuit and applies when the shunt capacity is large and the frequency is high, such as would be the case in operating a resistance coupled amplifier at radio frequencies, using commercial tubes. Let us apply this chart to two exemplary problems.

First let us suppose that an amplifier is to be connected to a speaker in a remote part of a building by means of a cable having a capacity of 0.2 mfd. The conductors of the cable are not large, so it is desirable to keep the current as low as possible to avoid transmission losses. At the same time it is desirable to keep the transmission constant to within 2 decibels at 6000 cycles. For what line impedance should the line transformers be designed? Maximum power is to be taken from

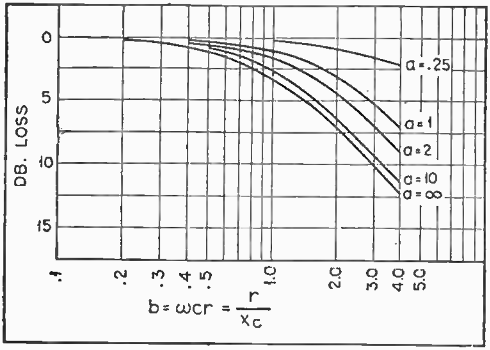


FIGURE 4

the amplifier, hence a = 1. The value of b for 2 DB loss is (from Figure 4) 1.5 hence,

$$aCr = 1.5$$

$$r = \frac{1.5}{2\pi \times 6000 \times .2 \times 10^{-6}} = 199 \text{ ohms}$$

and we see that 200 ohm line transformers would suffice.

A HOMEMADE CONDENSER MICROPHONE

To build the unit described here, procure at almost any second-hand radio store a type D76841 or 523-W Western Electric phonograph horn attachment. The maker's name and type number are plainly stamped on the front or back. Thousands of these units have been sold in years past, so obtaining one ought not to prove difficult. This unit must be remodeled according to the drawing in Figure 5. It is important that the backplate shall be perfectly smooth and parallel with the diaphragm.

A sheet of tinfoil from an "Old Gold" cigarette package serves well as a diaphragm. If preferred you can obtain Duralumin of 1 mil thickness.

Of course, the diaphragm should be reasonably flat and smooth before it is placed in position for clamping. It will not be necessary to make holes in the foil. Be certain to have the diaphragm very securely clamped. Go over the five screws several times, tightening a little each round. It will be seen that the diaphragm stretching-process can easily be accomplished by virtue of the fiber gasket and threaded back case. When the back case is screwed into the adjusting ring it will push the diaphragm forward and thus stretch it.

The stretching process is a delicate operation, but can be accomplished in this manner. Put a very thin film of non-medicated vaseline on the rim of the back case, A. This is to prevent tearing of the diaphragm. A further precaution is to remove all microscopic burrs

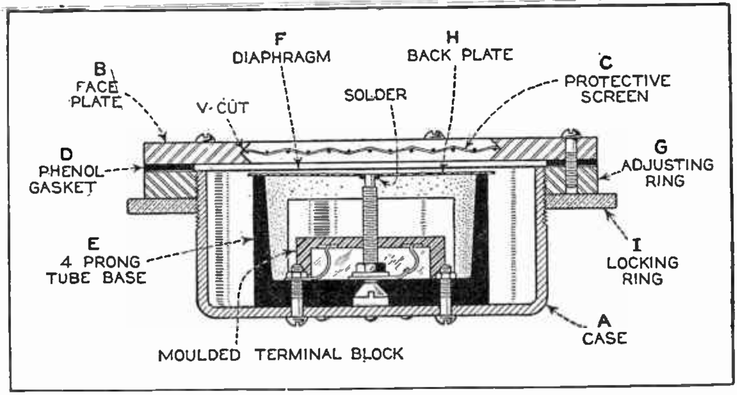


FIGURE 5

from the mouth of the back case with very fine sandpaper. Connect a pair of phones and a 22½-volt B battery in series with the two terminals of the head and screw the back case into place. As the dia-

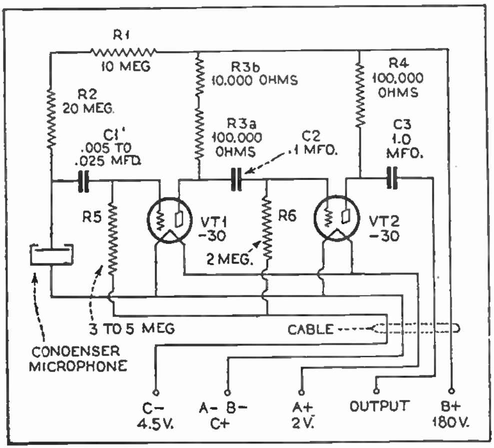


FIGURE 6

phragm comes close to the back plate, H, clicks and scraping sounds will be heard in the phones. Continue to advance the back case until there is no contact between the diaphragm and this back plate. Now blow on the diaphragm. At first the diaphragm will bellow in under the gentle air pressure and clicks will be heard. Slowly advance the back case until ordinary blowing on the diaphragm does not produce a click in the phones. The locking ring should then be brought into place and the diaphragm again tested by blowing for tension. The head is now ready to attach to an amplifier. The amplifier can be a two tube resistance coupled one as shown in Figure 6. The wires from microphone to amplifier should be very short. The entire amplifier should be carefully shielded.

ONE TUBE A. C. RECEIVER

This simple receiver, the circuit of which is shown in Figure 7, is built in a cigar box. The type -37 automobile tube and the Pilot Wasp coil are mounted in a pair of UY sockets on top of the box. A bell-ringing transformer used for lighting the tube filament was originally placed inside the box but had to be removed and fastened on

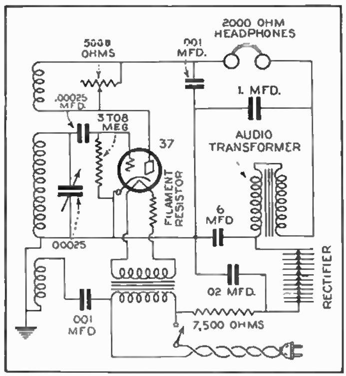


FIGURE 7

the end of the box to eliminate hum from magnetic coupling with the choke. The .00025 variable condenser is an old circular plate type of compact construction.

A dry rectifier bank taken from an Elkon EBH unit is used. With the 7500-ohm resistor in series, this rectifier delivers 70 volts d.c. and the actual voltage applied at the plate of the tube is 55 volts. The circuit is self-explanatory and all values are given except for the filament resistor. The value of this will depend on the bell-ringing transformer used.

As a safety precaution, the receiver is not grounded to the power line, consequently it will work only when the live wire is connected to the plate and the set grounded.

It will be noted that no antenna is employed. This is unnecessary, as advantage is taken of the double ground system provided by the actual ground and the ground through the power supply line. This receiver has been bringing in stations in the Bay district on a 24-inch cone speaker but is too feeble for good tone quality under these conditions. Using headphones, distant stations have been tuned in late at night (or early in the morning). As with every one-tube set, the tone is good with headphones. Some one tried using short-wave coils, but they have not been very promising on this particular set.

A TWO, PENTODE, S.W. RECEIVER

Now that we've heard so much about a radio tube called "pentode," let's see what a pentode is and how it can help us short-wave fans.

In the first place a pentode is a screen-grid power tube, called "pentode" because of an additional screen on the filament. But don't let that extra screen bother you, because it is connected direct to the filament inside the tube. Being colder than the filament, it collects any electrons coming towards the filament and grounds them, but allow-free passage to electrons going toward the plate. As far as short-wave fans are concerned, it's easier to think of the pentode as a screen-grid power tube.

Its chief advantage is its immense gain; in fact, the gain of a pentode is so great that it can be fed by the detector regardless of

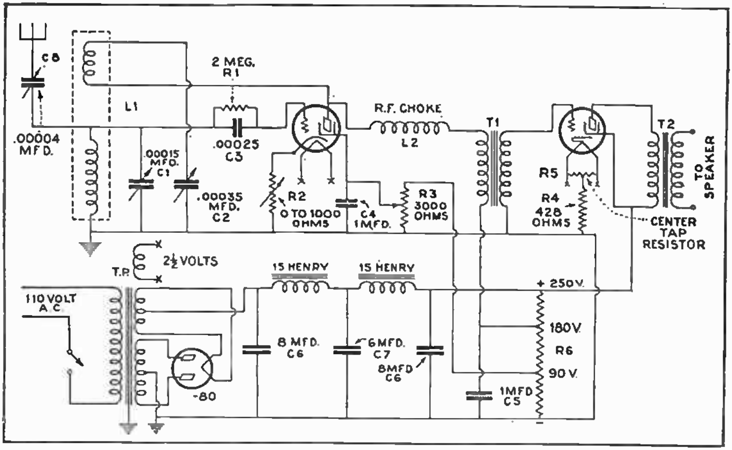


FIGURE 8

With this simple short-wave receiver quite good reception can be had, enabling you to listen in on foreign programs.

whether it be a grid leak and condenser or a bias type. Thus the first audio stage of our short-wave set can be done away with, and good riddance to it and its howls, hums and line noises. So much for why to use, now for how to use it.

Here are the current requirements:

Filament voltage	2.5 volts a.c.
Filament current	1.5 amps.
Plate and screen-grid voltage	250 volts
Plate current	32 mils
Screen-grid current	.6.5 mils.
Control grid bias	—16.5 volts

It uses a UY base. The plate and control grid and filament connections are the same as on the type -27 tube . The screen-grid connection is to the point where the cathode connection is on a -27 tube. The pentode -47 has no cathode.

The grid bias required is —16.5 volts. The combined plate and screen grid mils is 38.5.

By Ohm's law, $\frac{16.5}{.0385} = 428.57$ Ohms so if the filament transformer winding is center-tapped, just put a 429-ohm resistance between the center tap and the ground. A 500-ohm Electrad resistor can easily be made 429 ohms by loosening one end clamp and sliding it toward the center, then tightening it again. If the filament winding on the transformer is not center-tapped, a center-tapped resistor on the tube socket will suit just as well.

In the circuit, Figure 8, a type -24 screen-grid tube is used with a condenser and grid leak and both "C" bias and screen-grid voltage variable. The filament supply is from the same winding as the pentode. This, of course, makes the heater in the -24 about 15 volts positive to the cathode. But it was used in this way and no difficulty was experienced. It is obvious of course that as the grids of both tubes are at ground potential, if the grid of the -24 has a —1.5-volt bias, the cathode is at +1.5 to the ground. The Pentode has a bias of —16.5 volts, thus the filaments of both pentode and -24 are +16.5 from ground or +15 from the cathode of the -24.

The coils may be of any standard make or homemade. Silver-Mashall type 131 plug-in coils were used, but any other well made coil will suit as well, as Pilot or Nationals.

Here is a list of the necessary parts:

C1—Any good .00015 vernier condenser; C2—Any good .00035 vernier condenser

C3—Any good .00025 grid condenser; C4—Any good .1 mfd. by-pass condenser; C5—Any good mfd. byy pass condenser; C6, C7—Electrolytic filter condensers recommended

CP—Any good midget condenser

R1—2 meg. grid leak

R2—0 to 1000 ohm wire-wound resistance

R3—300 ohm wire-wound potentiometer

R4—429 ohm bias resistor (must be able to stand 40 mils without undue heating)

R5—Center-tapped filament resistor

R6—Voltage divider with taps at 90 and 180 volts

L1—Any good plug-in coil see with tickler windings

L2—Samson r.f. choke

T1—Amertran 3-to-1 audio transformer

T2—Output transformer. Must be able to stand 32 mils on the primary. Bear in mind that the output impedance of the -47 is 35,000 ohms. Try to get an adequately high impedance rimary in the output transformer. A low impedance will work, but greater efficiency may be expected if the primary of the output transformer has an impedance about equal to ¼ of the plate impedance of the -47.

VT1—Type -24 tube

VT2—Type -47 pentode tube

TP—A good solid power transformer.

REMOTE CONTROL DEVICE

Herewith you will find a schematic sketch and description of a remote control device in which readers will be interested. (See Figure 9.

To date the supporters of this method of remote control have been confronted with the problem of reversing the direction of rotation of the receiver dial by a simple means.

As you will see from the description, a simple and effective means is suggested for overcomingg this difficulty.

R1, R2 and R3 are the fixed resistances of the Wheatstone bridge R4 is a resistance equipped with a sliding contact which is attached to dial D. Thus, by merely moving the dial to either left or right, different values of resistance are obtainable.

The dial D is a special feature in itself. As seen in the diagram to the right, it consists of two parts built on a common

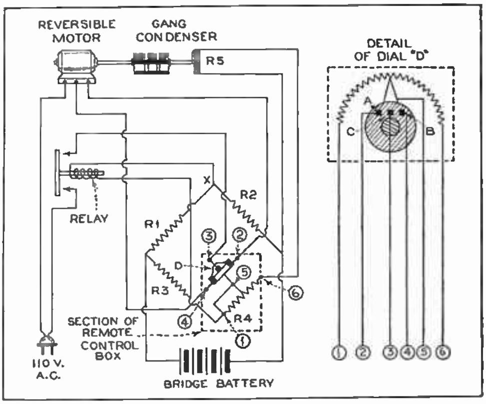


FIGURE 9

shaft. The top portion, that which is clasped by the fingers when tuning, is so built that it has a "play" of about ¼ inch in order to enable it to make contact with either lead 4 (when rotating the dial to the right) or lead 2 (when rotating the dial to the left). The purpose is to make contact with only one lead at a time and be independent of the other. Thus when the dial is being turned to the right contact is made with lead 4 and that with lead 2 is broken. As the dial is further turned to the right, a sliding arm which is attached to the lower portion of the dial is caused to move over the resistance R4 and the resistance is increased. In the same way, when the dial is turned to the left the upper portion of the dial breaks contact with lead 4 and makes contact with lead 2, and as the upper portion is further turned to the left the lower portion is also forced to turn to the left and, consequently, moves the slide arm to lessen the resistance of R4.

The movement of the lower portion of the dial D is made possible due to the fact that the leads 2 and 4 are connected to the electrodes

A and B, which are rigidly fixed to the lower portion and stick out about ¼ inch so as to enable the electrode C of the upper portion to push against either A or B, depending upon whether a turn is made to the left or right.

In practice the operator turns the dial D to a predetermined point; the resistance R4 is thus varied, and contact with one of the electrodes is made. A difference of potential across XY is the result and the relay is caused to close. The reversible motor then receives energy and therefore starts rotating in a direction dependent upon the lead with which contact had been made. Thus, when the dial is turned to the left, contact is made with lead 2 and the circuit is closed for rotating the motor to the left. In the same way, when the dial is turned to the right the circuit which causes the motor to turn to the right is closed. However, as the motor is started and rotates the tuning condensers of the receiver, it performs a null-adjustment by varying the resistance R5. The motor rotates only as long as there is an unbalanced condition in the bridge and it immediately comes to rest when a balanced condition is obtained.

In the system just described it is only necessary to have a resistance with a sliding contact, as well as an automatic circuit switch for the reversible motor (dial D of diagram) and by merely rotating the dial remote tuning is made possible.

A UNIVERSAL A.C. DYNATRON OSCILLATOR

Many experimenters while aware of the need of accurate and stable test oscillators, are using obsolete battery-operated models. It was with the idea of modernizing this test equipment that the accompanying circuit was developed. (Figure 10) The parts were mounted in a

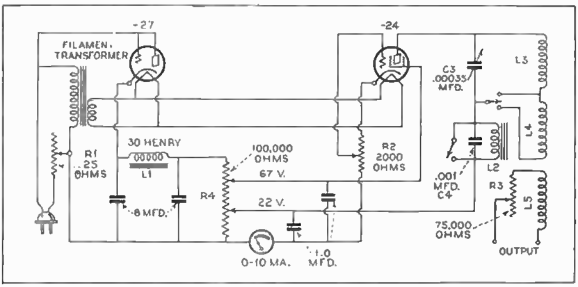


FIGURE 10

heavy aluminum can, and the whole works incorporated in a portable test set. No difficulty should be encountered in its construction, and the device has limitless possibilities.

Any frequency, audio or radio, may be had by using the proper coils and condensers in the plate circuit. The constants shown will cover the broadcast and intermediate bands, and modulate either at the chosen audio frequency. The various inductances used are as follows; L1—30 henry choke; L2—primary of audio transformer; L3—

broadcast coil; L4—4.5 millihenry lattice-wound coil mounted in end of L3; L5—3 or 4 turns on end of L3.

When the oscillator has been calibrated at a given current, as indicated by the meter, ma., the frequency will remain constant at that current drain regardless of varying line voltage or ageing of the tubes. For extreme accuracy as a frequency meter the coupling resistor R3 should be at a minimum setting. No attempt should be made to use a series resistor instead of the voltage-divider system for providing the reduced voltage for the plate circuit.

A 175 KC. OSCILLATOR

Many inquiries to the **Service Bench** have requested data on the calibration and construction of an oscillator suitable for lining up intermediate-frequency amplifiers at exactly 175 KC. It is important that the correct intermediate frequency be very closely approximated, because some superheterodyne oscillating systems are designed to track only at that frequency difference. The design of the i.f. oscillator itself presents no difficulties, but the manner of accurate calibration has

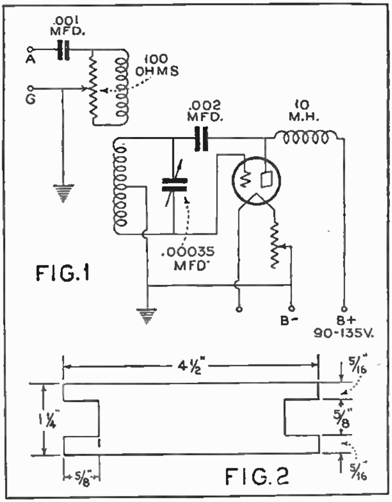


FIGURE 11

stumped many servicemen. A standard broadcast frequency oscillator is readily calibrated by cross reference to various stations of known frequency. However, such facilities are not generally available in the neighborhood of 175 kilocycles, and a precision wavemeter runs into well above one hundred dollars.

As a matter of fact an intermediate-frequency oscillator can be easily calibrated by reference to the same broadcasting stations used in plotting a curve on the higher frequency generator. But matters are facilitated if the broadcast-frequency oscillator is used, rather than the stations from which it has been calibrated.

First of all we shall describe briefly a simple i. f. oscillator, the circuit of which is shown in Figure 11. This is of the familiar parallel-feed type. All values are given on the diagram, with the exception of the coil and the rheostat. This latter will be determined by the available tube and battery supply. Practically any triode can be used. The coil is wound on the bobbin form shown in Figure 11, with number 20 double cotton-covered wire. There are 14 layers with 14 turns to a layer, the center-tap being taken at the 98th turn. The coupling coil is wound with 4 turns of wire over the main coil.

Set the tuning condenser at about the midway position, and locate a harmonic of the oscillator on a sensitive broadcast receiver. Unless the oscillator is modulated, for instance, by applying a.c. to the plate, it may be necessary to have the receiver oscillating in order to pick up the oscillator. This latter method is productive of more accurate results and is advised. Any t. r. f. receiver can be made to oscillate by adequate coupling between a grid and plate circuit, or, in some cases, merely by increasing the screen potentials. Also, by following a non-oscillating tuner closely with the broadcast oscillator it will not be difficult to beat the i. f. oscillator and locate the whistle.

The local oscillator (broadcast frequency) should now be adjusted for zero beat with the i. f. oscillator, and the exact frequency of the intermediate-frequency harmonic noted. Proceeding in the same manner, locate an adjacent harmonic—either up or down, the direction being suggested by the greatest available tuning range. Note the exact frequency of this last harmonic. As harmonics are merely multiples of the fundamental, the difference between any adjacent harmonics will be the frequency at which the i .f. oscillator is functioning. Simple! If this frequency is lower than 175 KC., reduce the value of the tuning condenser, if higher, vice versa, continuing these adjustments until the difference between two convenient adjacent harmonics is exactly 175 kilocycles. It is, of course, possible to calibrate the i. f. oscillator, in this manner, over quite a range of useful frequencies. As a matter of fact, by means of the harmonics, this single oscillator can be employed for both i. f. and r. f. purposes. The method of complete calibration is described in detail by John F. Rider in his "Servicing Superheterodynes," by whose permission much of the data given above has been summarized.

CHAPTER 6

Helpful Rules for S. W. Reception

The following twelve suggestions are worth the careful reading of anyone interested in short-wave reception and should be particularly valuable to beginners.

1. Don't expect to find stations on all parts of the dials. Short-wave stations are widely separated except in a very few places.
2. Don't expect broad tuning. Most distant stations tune very sharp.
3. Don't expect to hear the world the first day you tune. It requires some knowledge of tuning to get excellent results.
4. Don't expect to hear a station simply because it is on the air. Many things govern short-wave reception.
5. Don't get discouraged. If reception is poor one day, it may be fine the next.
6. Don't skim over the dials. Tune slowly.
7. Don't pass up any weak signals. Oftimes a weak program can be brought out plainly by careful tuning.
8. Don't tune for stations when they are not on the air. Use a good station list.

S. W. RECEIVING ANTENNA

The Bell Telephone transatlantic radio system uses uni-directional receiving types of antenna "arrays" that are well worth a little study as these systems may be adaptable to the amateur on a smaller scale. A long array, generally speaking, makes the system still more directional. This type of antenna receives broadside in distinction to the loop and is also bi-directional, but by placing two similar arrays one a quarter wavelength behind the other, the combined system then becomes strongly uni-directional. It was only with the advent of the discovery of the great usefulness of short waves that such types of antenna became feasible. Even so, such an array as used by the Bell system may reach dimensions of the order of several hundred feet in length.

Such dimensions are of course impractical for the amateur, but we believe the same system using only a few sections would be worth while to any one who has a reasonably big back yard. Of course these special antennas are not flexible as regards usefulness for any wave except that for which they are constructed.

By referring to Figure 1 you will see a diagrammatic sketch of such an array on a small scale. This shows an arrangement set up anywhere in the United States for uni-directional reception from Europe of a wavelength of 25.53 meters. This may be G5SW in England. The sketch shows the minimum number of bays or sections that could be useful and would require a free open space at least 25 feet by 100 feet in area. More sections in a longer array would be preferable. Arrays for different wavelengths can be calculated on the same method.

When a wave reaches the front, or a broadside of such an array the voltages which are produced in the vertical wires are in phase and the currents are additive. Voltages developing at central points in any of the vertical wires are also reflected back from the open ends of the antenna array with their phases reversed so that they reinforce just at the right instant, the poin on the oncoming wave at the point where the receiver connection is taken off. The quarter

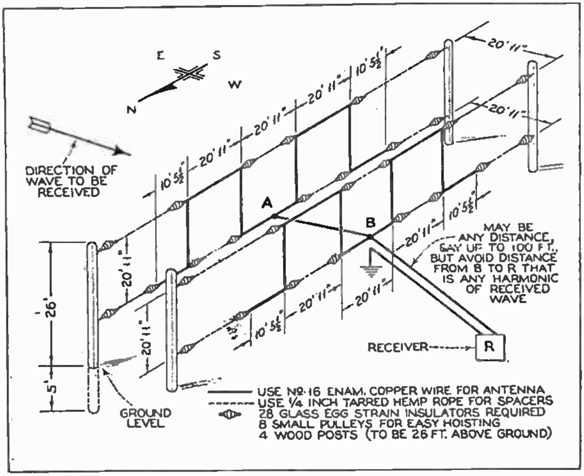


FIGURE 1

wavelength connection between the front and back array causes waves to cancel that come from the B side.

When a wave strikes the antenna from either end on, conditions are very much changed. The current produced at any instant by the advancing wave will be out of phase with the reflected waves and will cancel.

To bring out a little clearer this action, refer now especially to Figure 2 in connection with Figure 1. At (a) Figure 2 are shown two positions of a wave with respect to such an antenna. The arrow shows the direction of the wave. One curve shows the position of the wave where it coincides with sections B and A at the present instant.

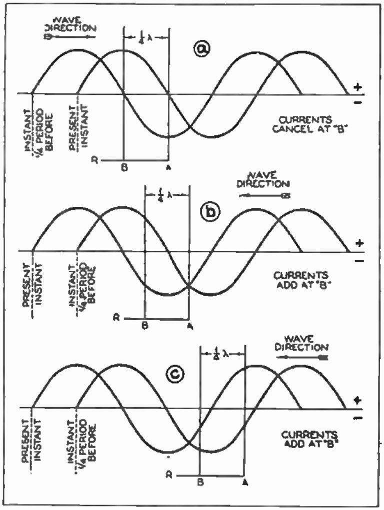
Remembering that array A is connected to array B through a quarter wave wire, note the instantaneous voltages on the two antennas. The point on antenna A had a potential exactly equal and opposite at an instant just one-fourth period before the present instant, therefore its effect arrives at point B just in time to cancel the voltage there at the present instant.

By studying sketches (b) and (c) it will be seen that waves arriving from the opposite direction or broadside to antenna A will be additive at point B and so reinforce each other at the receiver.

Figure 3 shows another form of array which is very directional to waves for which it is designed and will well repay a little time in construction and experimentation.

TRANSMITTER REMOTE CONTROL

Herewith is a method for the remote control of a radio transmitter using a single circuit between the transmitter and the location of operation. By having two relays at the transmitter in series with



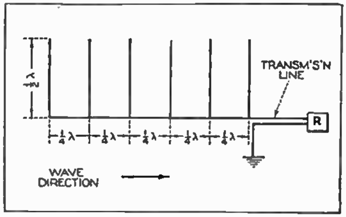


FIGURE 2, LEFT— FIGURE 3, ABOVE.

each other and the remote-control line, it is possible to have one of them throw the power line on to the transmitter and the other to be used for keying. At the operating point a key in series with a battery is connected across the control line. The battery may be the six-volt supply used to light the filaments of the receiver. A high-capacity electrolytic condenser with a 15-volt rating and a capacity in the order of 1000 microfarads is connected in shunt with the relay used to control the power line. The power relay should be light-moving and high-resistance, appering in Figure 4.

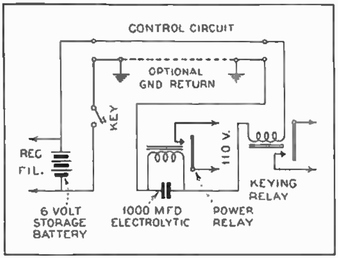
When the operating key is pushed down and held, the capacity across the power relay charges and furnishes current for holding the relay upon releasing the key. Operation may then be carried on in a regular manner, the keying relay following the dots and dashes of the key, and the power relay remaining closed under the key is left up long enough.

EXTENDING BROADCAST RECEIVER WAVELENGTH RANGE

There are many battery and electric sets of the Browning-Drake type using one neutralized or screen-grid r.f. stage, followed by a regenerative detector.

With the addition of a small coil and switch across the detector coil secondary, as shown in Figure 5, there sets will bring in the police, aircraft and even the 80-meter amateur 'phones.

In making this change-over keep leads from the switch to the grid circuit as short as possible—the smaller the switch the less the detuning effect of the switch on the standard circuit. A 1500 k.c.



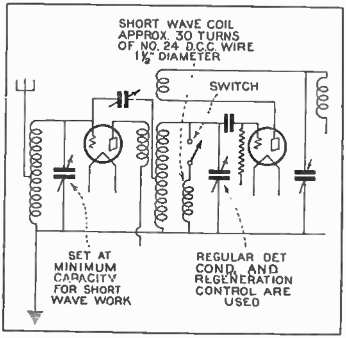


FIGURE 4, ABOVE.
FIGURE 5, RIGHT.

station may be off the dial if the capacity is too great. Get the short-wave stations first before operating on the secondary coil. It is best to use a snap switch set back from the panel and connected with a bakelite shaft.

CHAPTER 7

Optical Communication Bands

WAVELENGTHS below 10 meters are "optical" in the sense that like light, they follow more or less a straight line and cast definite shadows of relatively small objects. They do not bend around obstacles or readily follow the curvature of the earth as do the broadcast frequencies with which we are familiar. Also, they possess a greater power of penetration, and, therefore, are not reflected or refracted to any great extent by the Kennelly-Heavisde layer. aud communication is almost limited to points between which it would be possible to transmit light under perfect weather conditions. However, unlike light, these short waves are quite independent of weather and will readily penetrate clouds and fog.

When an arc or incandescent lamp is lighted, only a small amount of the power is radiated as light. Most of it is dissipated as heat that cannot be used for communication purposes. However, with the very short radio waves, a considerably greater portion of the power input is radiated. and low powers can be used for consistent communication purposes. The shorter radio waves are also fairly amenable to reflection by optical methods, thus greatly increasing the effectiveness of low powers. Communication has been carried on across the English Channel on a wavelength of a few centimeters with a power that would barely light a flashlight bulb!

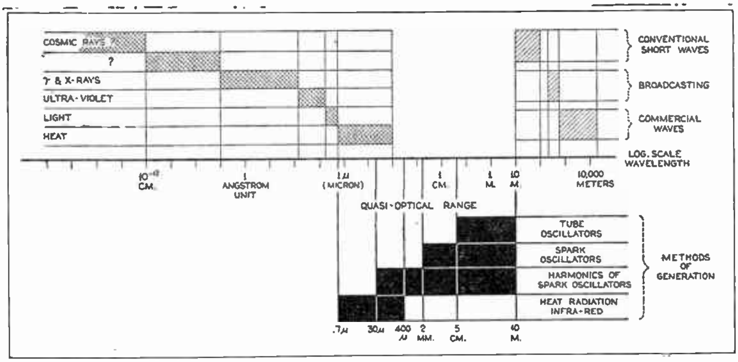


FIGURE 1

Nature finds it difficult to generate these quasi-optical frequencies and, therefore, reception on these low waves is remarkably free from static and similar noises.

Due to the fact that there is no varying reflection from the Keunelly-Heaviside layer, reception being the result of a direct ground wave without interference patterns, the usual sort of fading is conspicuous by its absence.

Figure 1 shows the entire electromagnetic spectrum, arranged in a logarithmic extension from the longest radio wave down to the shortest sub-optical manifestations. Wavelengths within various ranges are conveniently handled by a varietly of units. Very short wavelengths are generally considered in Angstrom units, which are one ten-thousandth of a millionth of a meter long. The micron is one millionth of a meter or 10,000 Angstrom units. The usual metric units, the millimeter and centimeter, are next in convenience. The entire spectrum is most readily handled mathematically, by negative powers of 10 times the centimeter.

GENERATING QUASI-OPTICAL WAVES

Figure 1 also indicates the method by which the quasi-optical frequencies are generated.

We are, for the time being, interested, in the tube oscillating systems. While shorter wavelengths can be obtained by means of the spark apparatus they are only of laboratory significance and so far give no indication of an ultimate practical application. However, the utility of the wavelengths readily generated by the tube oscillators has been demonstrated beyond a question of doubt.

ULTRA SHORT-WAVE RECEIVERS

Tubes admirably suited to the requirements of reception below ten meters are now avaiable and are represented by the -56, -57 and -58 series. These new tubes have extremely low inter-electrode capacities, high plate impedances, high amplification factors and mutual conductances, which make possible the construction of a receiver providing excellent performance on wavelengths even shorter than three meters.

The simplest type of receiver for use on this band is the straight detector circuit, backed up with a generous amount of audio-frequency amplification, made practical by the noise level of the detector output. Such an arrangement will give good reception within 25 miles or so of the new N.B.C. Empire State Tower voice and television transmitter in New York City, and is shown diagrammatically in Figure 2. Figure 3 shows the finished receiver.

SUPER-REGENERATIVE RECEIVER

Super-regenerative receivers have been particularly successful on ultra-short waves, due to the simplicity of design and the signal intensity that can be built up with a minimum of tubes.

A high noise or hiss level, between stations, is characteristic of the super-regenerator and is caused by the suppressor grid swing. This disadvantage, however, is somewhat compensated by the fact that the hiss is considerably lowered at station resonance.

The super-regenerative receiver is inherently broad, a trait that is convenient rather than detrimental at the present time, but which, in the future days of even ultra-short-wave congestion, will doubtless mitigate against the general use of this receiving system.

With the rapid development of stable ultra-high-frequency oscillating systems, such as the Dow or electronic-coupling circuits, there is little doubt that the superheterodyne will become as preeminent on the quasi-optical bands as it has on practically all lower frequencies. Apart from the sensitivity of such a receiver (laboratory experiments prove that it will bring in stations 50 or more miles distant that are inaudible on the best super-regenerators), the superheterodyne provides the added advantage of efficient elasticity. With five sets of coils, plugging into a properly designed super, it is possible to cover the enormous frequency range of 70,000 kilocycles, between ten and three meters!

The circuit, Figure 4, has been so designed that regeneration in the first detector is practically constant over the entire tuning range, removing the necessity for regeneration control adjustment except for the reception of very weak signals.

The principal problem in ultra-short-wave super design, oscillator instability or "drift," has been overcome by the use of an electronic-

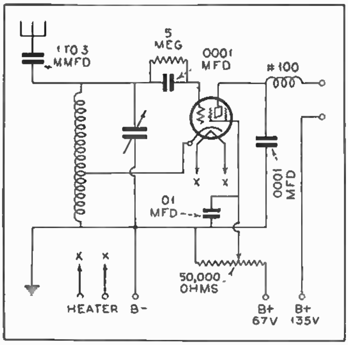
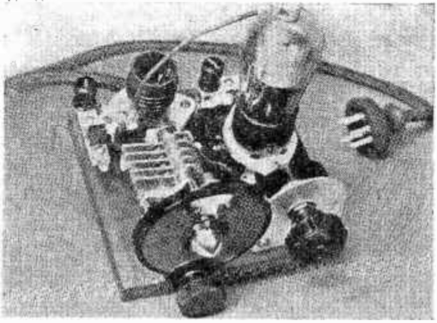


FIGURE 2

coupling system whereby the frequency determination circuit is isolated from the load or oscillator-frequency supply circuit.

In Figure 4, both the screen-grid and the plate of the oscillator tube function as anodes, the screen-grid, the control grid and the cathode

FIGURE 3



being the elements of a triode oscillating system. These oscillations cause a periodic or pulsating flow of plate current (plate or second anode to cathode) which is used to set up an oscillatory current in an altogether independent load or work circuit. Thus there is no capacitative, inductive or any interactive coupling between the frequency-determining circuit and the rest of the receiver. The frequency of the oscillator is also independent of any reasonable fluctuation in plate or heater voltage caused by line variations, due to the fact that such changes set up counteractive effects between the two anodes.

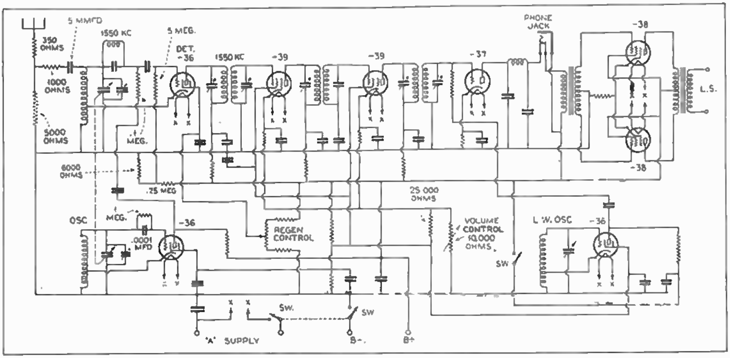


FIGURE 4

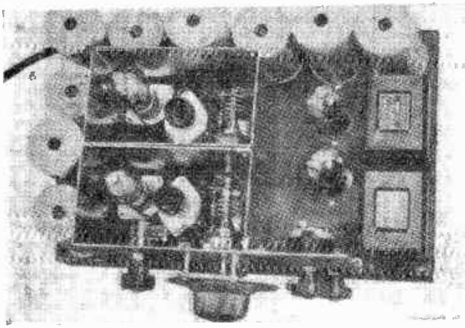


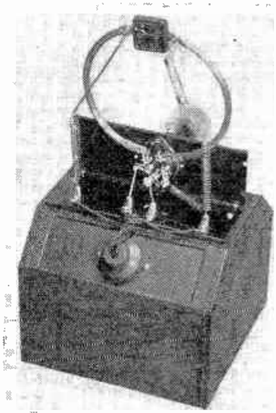
FIGURE 5

The completed superheterodyne is shown in the photograph in Figure 5.

TRIODE OSCILLATORS FOR 2 METER WORK

The tube oscillators of practical utility in the generation of quasi-optical wavelengths fall into three categories—the familiar regenerative oscillating arrangement, the Barkhausen-Kurz systems and the magnetron.

These systems will here be considered in the order indicated. Figure 6 shows a short-wave transmitter, complete with power supply, designed to operate at 2 meters. The tube used is a standard -27 type and the base has not been removed. The wiring diagram is shown in Figure 7. It is interesting to note, in conjunction with this transmitter, that the shunting of the condenser directly across grid and plate did not reduce the wavelength appreciably. However, the energy output at 2 meters was increased 75 percent by the substitution of low-loss insulation "R-39" for the standard bakelite tube base and con-



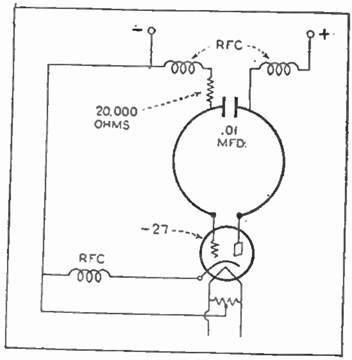


FIGURE 6, LEFT—
FIGURE 7, RIGHT.

denser molding, along with an isolantite socket in place of the bakelite. This indicates the importance of low-loss design in ultra-high-frequency work.

In the range of from 4 to 10 meters almost any of the standard triodes can be used successfully, especially in push-pull circuit.

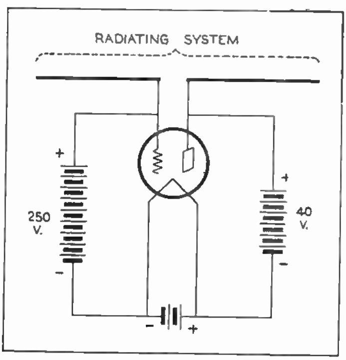


FIGURE 8

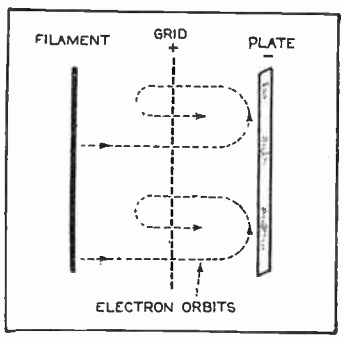


FIGURE 9

The usual triode, with base removed, is still effective between 1 and 2 meters, but its power output falls off rapidly as the wavelength is decreased. For still shorter wavelengths the Barkhausen-Kurz and magnetron oscillators are more effective.

THE BARKHAUSEN-KURZ OSCILLATOR

The Barkhausen-Kurz circuits upset not only our conventional theory of how oscillators work, but likewise our practice of maintaining the anode at a positive potential in respect to the cathode and grid. In the B-K circuits, the grid is highly positive to both cathode and plate, and the anode may often be negative in respect to the filament. A typical Barkhausen-Kurz circuit is shown in Figure 8.

The functioning of such a circuit may be explained as in Figure 9. Electrons leaving the hot filament are attracted to the grid by the high positive potential. Many of them stick to the grid, while others, impelled by their momentum, speed through the meshes. The escaped electrons are rapidly de-accelerated, particularly if the plate is negatively charged with respect to the grid, and are again attracted to the grid. Once more some electrons stop at the grid while others continue through, to reverse again with the new electrons leaving the filament, recommencing the cycle. The time required for a complete oscillation is obviously governed by the distance the electrons travel, which is partially determined by the spacing of the tube elements and by the velocity of the electrons which is a function of the potential at which the tube is operated. It is therefore apparent that the wavelength of such a circuit may be altogether independent of the values of inductance and capacity and can be varied over quite a range merely by changing the grid and plate voltages.

However, it has been discovered that the output of the Barkhausen-Kurz oscillator is increased considerably when the natural period of the circuit, as determined by L and C, corresponds to the relaxation period (the time required for an electron to leave and return to the grid) of the tube.

THE MAGNETRON OSCILLATOR

The magnetron oscillator may be described as a Barkhausen-Kurz tube operating under the influence of a magnetic field. The field is pro-

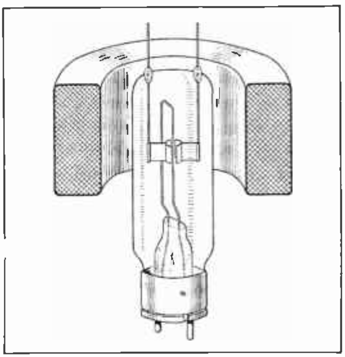


FIGURE 10

duced by a coil surrounding the tube, as suggested in the drawing, Figure 10. The efficiency of the tube is increased considerably as a critical value of field strength is approached, thus making possible relatively large outputs at wave-lengths as short as 3 centimeters!

CHAPTER 8

Photo-Electric Cell Application

EXPERIMENTERS are evincing active interest in photo-electric cells and their practical applications. One application that offers extensive possibilities is found in using a photo-electric cell to operate a light switch to automatically turn on lights at sundown and turn them off again at sunrise.

Equipment of this nature can be readily constructed by following the circuit of Figure 1.

The photo-electric cell, PE, is the Weston Model 594 Photronic Cell, and works into a Weston Model 634 relay (R1). This relay is of the very sensitive type required to operate directly out of the cell. The relay, R2, is of the power type and is capable of breaking a one-ampere circuit, thus permitting the control of electric lamps totaling up to 100 watts in power (L). The switch, SW, may be an ordinary double pole, double throw knife switch.

With this equipment, wired as shown, the cell is placed in such a position as to be fully exposed to daylight, yet protected from the light

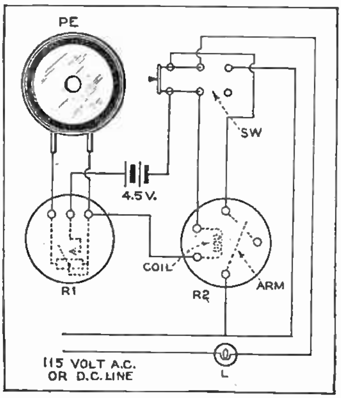


FIGURE 1

of the lamp it is to control. While the day remains bright the coil of R1 is energized, holding the circuit open. But when dusk falls the cell becomes inactive, the coil of R1 is no longer energized, and the armature is released, allowing the circuit to close. This energizes the coil of R2, closing the a.c. circuit through the armature and causing the lamp to light. At the break of day the action is reversed, thus turning off the lamp. If it is desired to turn off the lamp manually at any time it is accomplished by simply opening switch SW. Or the lamp can be turned on by throwing this switch to the right.

When the system is first put into operation, the relay R1 is adjusted at dusk so that the arm just makes positive contact and the lamp lights.

LIGHT-BEAM TELEPHONY

The essentials of a light-beam telephone are four: a means of modulating a source of light with the sounds to be carried by the light beam, an optical system adequate to carry the light between this transmitter and the receiver, a detector at the receiving end, competent to pick off the modulation of the light beam; finally, an amplifier system to raise the relatively feeble signal thus obtained to an audible level.

THE TRANSMITTER

The transmitting end of this outfit is essentially the same as the apparatus now used to make the sound track on talking-motion-picture film. What the sound camera uses for this purpose is a microphone, an amplifier and a recording lamp or light valve, the duty of these latter devices being to modulate a light beam in accordance with the sound energy entering the microphone. The only essential difference between this and the light-beam telephone is that the sound camera equipment uses a light beam which travels only a few millimeters or a few centimeters between the light source and the film. The light beam of a telephone, if it is to be useful at all, must cover many yards or even several miles.

The receiving end of the light-beam telephone has its equivalent, also, in the reproducing end of the talking-picture used in the sound film reproduction process system, the so-called "sound-head" fitted to the motion-picture machine. The difference is the same as before; this modulated light beam is a short one while the beam of a light telephone must be longer.

There are clear similarities of the light-beam telephone, also, to the old-fashioned heliograph. This heliograph employs, in fact, one kind of modulated light beam in which the light beam is interrupted at intervals by a shield or mirror which can be worked by the instrument's operator. Thus dot-dash signals can be sent to constitute a code. The light-beam telephone, now proposed, bears the same relation to the heliograph as radio broadcasting of speech or music bears to code radio.

Several varieties of suitable lamps or tubes are available, so that the amateur contemplating work in this field need fear no dearth of the necessary apparatus. One of the lamps used in sound-picture recording may be used in the transmitter, or any type of the still more powerful glow lamps now used in television receivers. Even the small neon lamps, drawing a fraction of a watt, now purchasable at low cost and used as indicator lamps in many kinds of alternating-current machinery, will serve reasonably well as a light source to be modulated. The television lamps and the recording lamps are better but more expensive. For the receiving end a photoelectric cell or similar device is employed.

PRACTICAL CIRCUITS

A set of circuits, both for sending and for receiving, which have been tried in the laboratories and found to be successful are shown in Figures 2 and 3. Many other circuit arrangements might be used the circuit constants, the voltage and so on being arranged, in each instance, to suit the particular characteristics of the glow lamp.

Provided with a modulated light source, the next step of the maker of a light-beam telephone must be to provide the optical system which will concentrate, into a single beam, as much of this modulated light as possible. The simplest system of this sort is a mere condensing lens, like those used in magic lanterns or in motion-picture projectors.

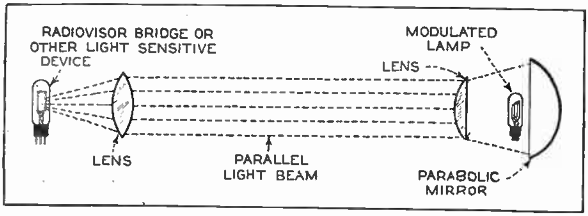


FIGURE 2

A valuable and simple addition is a parabolic mirror placed behind the light source, to catch and send back into the light beam as much as possible of the light which emerges toward the rear.

For ordinary experiments, over distances of a mile or less, nothing more complicated is necessary. An old magic lantern, projector and lens or any similar apparatus will do nicely. Such outfits often can be picked up for a few dollars at stores which handle second-hand motion-picture equipment. The modulated lamp then is placed in the position originally occupied by the arc lamp or incandescent lamp of this apparatus, the lens and mirror are adjusted to produce a light beam as nearly parallel as possible, and the transmitter is ready to work.

The easiest way to see whether the beam is approximately parallel is to hold a sheet of white paper in front of the projector at distances

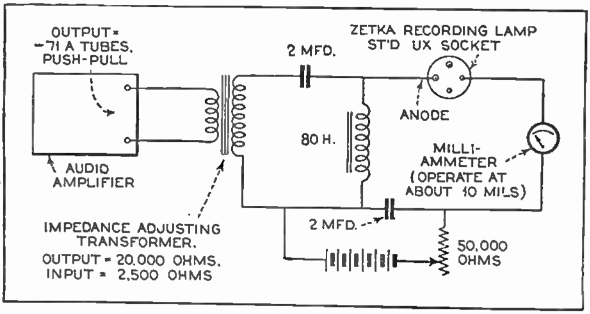


FIGURE 3

of a few inches and then at a distance of fifty or sixty feet. If the spot of light produced on the paper is of the same size at the two distances, the light beam is approximately parallel. If the sizes are different, the lens and mirror should be moved back or forth until the parallelism is better.

For the optical system at the receiving end the simplest device is an ordinary telescope or one tube of a field glass. The receiving operator merely looks through the telescope toward the sending station until he sees the small light spot made by the modulated lamp. He then clamps the telescope in that position and the adjustment is complete. If the photoelectric cell or other light-sensitive device then is placed at the eyepiece of the telescope, where the observer's eye was a moment before, the apparatus is ready to work.

For short distances it is not necessary to use a telescope. A common reading glass to focus the received light on the photoelectric cell works admirably. For short distances, like circuit tests in the laboratory, no sending or receiving lenses are needed. The photoelectric cell merely is set up so that it "sees" the modulated lamp. That is enough.

PHOTO-CELL APPLICATIONS

Some of the most interesting applications are those where the cell is used as watchdog. Ordinary burglar alarms, consisting of wires along doors and windows do the job only half-way. A photo-electric cell can be set up in a room with a light source shining upon it. If desired this light is made invisible (infra-red or ultra-violet). Any person interrupting the light beam will then set off the alarm, unknown to himself.

The work can be done still better than this, however. If a cell is set up so as to detect anyone entering a door or passing through a narrow passageway, a camera can be focused at that point. The relay is then arranged to open the shutter and ignite a flashlight, taking a picture of the intruder.

Recent events in America have made many a citizen concerned about the safety and protection of his home against undesired intruders. One might even go so far as to protect the entire property, to surround the house with a wall of light beams. This is not as impossible as it sounds. Four pillars could be placed at the corners of an imaginary rectangle which surrounds the house. Electric lamps in or on one pillar could shine onto a cell, hidden in another pillar, and so protect the entire space between them.

Here is another example of what can be done with photo-electric cells. Many years ago this idea was worked out by Meisner and by Hammond. It was called the electric dog. A small car on three wheels was supplied with an electric motor and battery. In front it had two eyes (two selenium cells). Each cell could energize an electromagnet when it was illuminated. These electromagnets attracted the steering rod. When both cells were illuminated equally, the magnets pulled on the steering wheel with equal force and it had to stay midway; in other words, the car would go straight towards the light.

If the light was off towards one side, one cell would receive more light and consequently the car would turn until it faces the light. In fact, if one walked ahead of the car with a flashlight it would follow every turn, no matter how involved the route. This system was a step in the development of a self-steering torpedo. It was reasoned that ships focused their searchlights on a torpedo so they could find its path and steer clear of it.

CHAPTER 9

Photo-Cell Amplifier

WHILE operating a photo-cell relay, the current available from a single stage of amplification was only about 7 milliamperes. In order to operate the only relay on hand with sufficiently large contacts to handle the current which was to be broken, it was necessary to have a current of about 30 milliamperes. In order to operate this relay, a "power" amplifier was developed. The hook-up of this amplifier is shown in Figure 1. Although this amplifier uses the Loftiu-

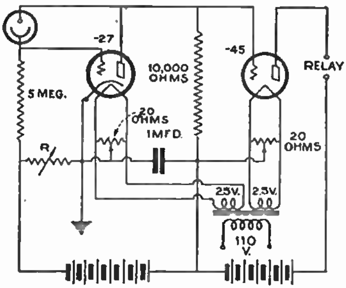


FIGURE 1

White principle, it is much simpler in operation. All of the voltage dividing equipment has been abandoned and "hum-balancing" resistors have been eliminated. The only condenser shown in the diagram is not really essential, but seems to eliminate any tendency on the part of the relay to chatter when acting at high speeds.

A "B" power unit capable of supplying 300 volts was used in place of the batteries shown in the diagram. The filament return from the -45 and lower end of the 10,000-ohm resistor in the -27 plate circuit were returned to the 180-volt tap. This is not a very critical adjustment, as any voltage from 150 to 200 will give good results. The only control necessary for the operation of this amplifier is the resistance, R, which controls the grid bias on the first tube and hence the current through this tube. This in turn controls the grid bias of the second stage and the current through the -45.

In operation, a value of light slightly below the maximum is allowed to fall on the photo-cell. This increases the current through the first tube and increases the grid bias of the second stage until the current through the relay becomes a minimum. The resistance, R, is adjusted until the relay almost trips. The light source is then cut off and the effect noted on the relay. This should allow the relay current to return to normal and close the relay. If it does not, the adjustment should be repeated with a stronger light.

A resistance of 200 ohms for R will generally be sufficient to allow for any adjustments which may have to be made. It is to be understood that this amplifier was intended to produce large currents in the power stage.

PICKLE BOTTLE CELL

Many electrical experimenters have been denied the fun of play ing with photo-electricity because they have for some reason or other decided that the marvels of this fascinating new science were either beyond their pocketbooks or beyond their technical resources. Neither one of these facts should be true, for, as far as constructional material goes, nothing could be put together much more cheaply—a pickle bottle, a couple of binding posts and little chemical with two very simple electrodes. And practically no technical skill is needed; even the rankest tinker can rest assured that he can master the construction operation of the simple cells that the present article describes in complete detail.

The bill of materials follows:

1 small pickle bottle
¼ pound lead nitrate
1 piece of sheet copper 1 inch by 4 inches
2 binding posts
1 lead electrode ½ inch by 4 inches

To this modest list of needed materials we might add a little tar or asphaltum and a few bits of metal too unimportant to mention in a bill of materials.

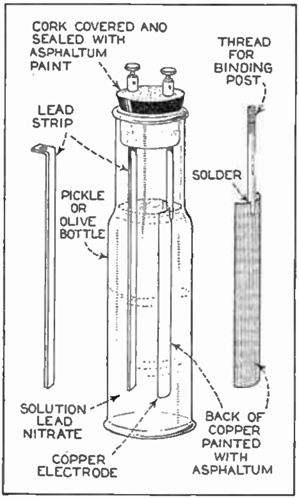
It will first be necessary to so treat the copper that a layer of cuprous oxide will be formed on the surface. If the sheet copper (after having been carefully cleaned with emery cloth) is placed in a hot flame such as that provided by a bunsen burner, or even a coal fire, the surface of the copper will become gradually black through the formation of cupric oxide, which has a chemical formula expressed by CuO. The builder is not interested in the formation of cupric oxide as such but he must tolerate it, because it must be formed during the formation of cuprous oxide, which is the light-sensitive coating that is desired on the surface of the copper plate or electrode. Underneath this surface of cupric oxide there is a surface of cuprous oxide.

This upper surface of cupric oxide is disposed of by rubbing it off with emery paper or by dissolving it off chemically with nitric, sulphuric or hydrochloric acids. Ammonia may also be used to dissolve this film. This film of oxide will have a rather golden color and be in a rather crystalline state. After the film of cupric oxide has been removed, the copper electrode with its photo-sensitive surface should be given a thorough rinsing with water.

After the copper electrode has been so treated, its back is coated with asphaltum and the terminal is added in the manner shown in Figure 2. To do this properly and to form a good electrical connection, it will be necessary to solder. Naturally, the cuprous oxide film will have to be removed at the point the soldering is done. The lead electrode is held in place by simply drilling a hole in one end and running the machine screw of the binding post through the cork.

To prevent corrosion and leakage of the electrolyte, it will be necessary to immerse the whole top of the unit in hot tar or asphaltum. Then, after the cork has been driven in place, hot tar is poured over the top to form a perfect seal. If the binding posts have become clogged with tar during this operation, it may be removed with a little gasoline so that a good electrical contact will be formed.

With this done, the device is ready for testing and use. To



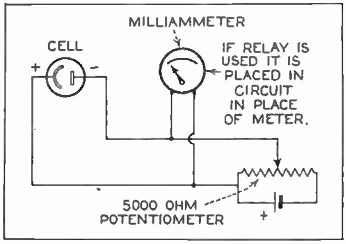


FIGURE 2, LEFT—
FIGURE 3, ABOVE.

test the cell it will be necessary to have a fairly powerful electric light, ranging in rating anywhere between 60 and 100 watts. It will also be necessary to have a good milliammeter reading about 1 to 5 milliamperes. The testing light should be arranged in a reflector, which may be a dishpan if nothing else is available.

The cell is connected directly across the meter as shown in Figure 3. Inasmuch as the cell is polarized, it will be necessary to connect the meter as shown. The lights should then be turned out and the testing lamp lighted. As the testing light is brought near the photo-cell, the meter should start to register. At a distance of six or seven feet a faint current should be noted, and by the time the light has reached a distance of three to four feet from the cell the current generated by the light should have reached at least one milliampere. When the cell has been brought to within a few inches of the light, the registration should reach about three to four milliamperes if the cell has been correctly made and the solution of lead nitrate, which should be made up of one ounce of crystals to one gill of water, is of the correct proportion.

To use this cell, and it will find innumerable applications, it will be necessary to obtain or build a small relay which will be sensitive to a change of a milliampere or two in the output of the cell.

Such a relay may be made from the parts or magnets of an old 1000-ohm telephone receiver, equipped with an armature and contacts. This relay must be used to operate a second and heavier relay if a heavy current is to be controlled by a light beam. It would be a little unreasonable to expect a relay small enough to come from the parts of a telephone receiver to be able to handle the 250-watt current of one-quarter horsepower motor. It will be found that a second relay, which is really in automatic switch, might be made from an old telegraph sounder provided with a couple of heavy contacts that may be used in connection with 110-volt lighting circuits.

SIMPLE TIME DELAY THERMO-RELAYS

Time delay relays are handy instruments to have around a laboratory, but their excessive cost usually prohibits their use by the amateur experimenter.

A simple thermo-relay as described here is easily constructed by

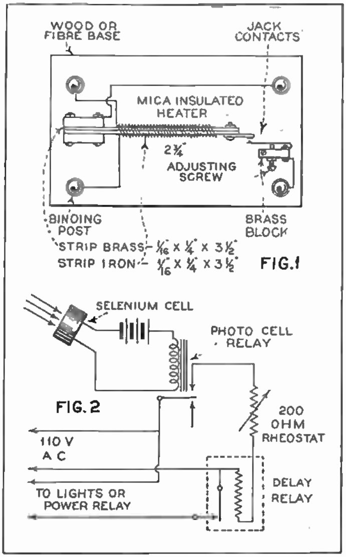


FIGURE 4

the experimenter from scrap materials. The working parts of the relay are shown in Figure 4.

The thermostat strip consists of a compound strip of two metals riveted together, one of brass and the other of sheet iron. Around this strip is wound the heater element, being insulatd from the strip itself with a sheet of mica from an old fixed condenser. The end of the bi-metallic strip has bolted onto it a contact from an old filament jack. The other contact from this jack is fastened to a block of brass which carries an adjusting screw. The size of these contacts depends on the current to be broken, but a filament type jack usually has at least two heavy contacts on it which will carry one ampere safely. When a current flows through the heater wire, heat is produced which causes the metals of the thermostat strip to expand. Since the brass expands more than the iron, the strip will bend, the concave side being the iron side. This will make the contacts on the end of the strip providing the movable contact has shifted its position sufficiently. The use of this relay in a delay circuit for switching on lights whenever the natural day light falls below a certain value is shown in Figure 4.

Using 36 turns of nichrome wire from a 30 ohm rheostat with about 5 volts available under rheostat control, closure was obtained with the following results:

¾ amp.	10 to 120 secs.
1 amp.	5 to 10 secs.
1½ amp.	1 to 7 secs.

Using 200 turns from an old air-cooled Electrad resistor, closure was obtained in from 1 to 120 seconds with as low as 100 mills for the longer time values at a voltage of about 110 volts a.c. The time of closing depends on the number of turns with which the heater element is wound, the current used, and the distance the contacts must travel from the cold position.

RELAYS FOR THE EXPERIMENTER

Relays may be divided into three classes: the armature type, the

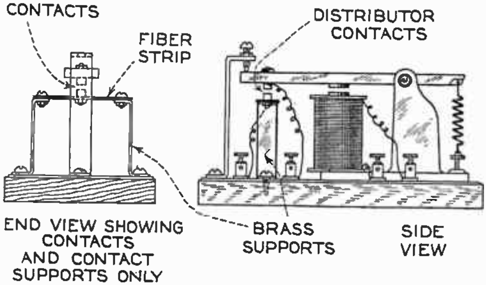


FIGURE 5

solenoid, type and the induction type. All three of these types have their own especial uses for which they are best suited.

ARMATURE TYPE

This is the type most commonly used and covers the average purposes very nicely. A 30-ohm telegraph sounder can be reconstructed to form a relay of this sort with a minimum of work. Contacts may be secured at a nominal price from any garage or auto sales store. The contacts used in the model A Ford distributor are ideal for this sort of work. These contacts come mounted on a screw and are furnished with a nut. It is a simple matter to drill a hole through the sounder arm and put a contact in place. The other contact can be mounted below on a fiber strip and arranged in place with two brass strips as shown in Figure 5.

We now have a relay which can be operated on either direct or alternating current. It is advisable, however, to use direct current if possible, as the best operation can be secured in this manner. When used on a direct current, the relay will operate on 0.2 ampere and over, and the contacts will break from 4 to 7 amperes. It is best to shunt these contacts with a condenser of about 1 mfd. capacity, to prevent arciug, especially with large currents.

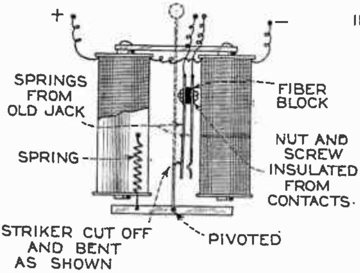


FIGURE 6

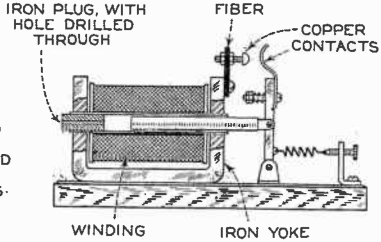


FIGURE 7

This relay is exceptionally sturdy and costs very little, as most experimenters have an old sounder in the junk box.

If a more sensitive relay is required, it can be produced by revamping an old telephone ringer. Be sure and get one of the type that has a freely pivoted armature held in position by a small spring. The striker (or hammer) should be removed and bent over as shown in Figure 6. A very good set of contacts may be had by fixing a piece of spring brass and an old radio jack spring in place as shown in Figure 6. This type of relay is far more sensitive than the sounder type previously described, and has the advantage that it is polarized and will operate on very small direct currents. It will not, however, operate on alternating current and was not intended for this use. If the ringer is of the common 500-ohm type it can be expected to operate on about 20 to 30 milliamperes. This figure depends somewhat on the stiffness of the contacts, but the figures given above constitute a reasonable estimate of what a relay of this sort can be expected to do. The current-carrying ability of the contacts is necessarily low and should not run over 200 to 300 milliamperes. Fortunately, this comes well within the rauge of the sounder type relay, and these two can be operated in series or cascade to control curents up to 5 or 6 amperes from a 20 ma. input to the first relay. The action is not as fast as could be asked, but it is rapid enough for the average purpose around an experimental laboratory.

SOLENOID TYPE

This type of relay generally takes on the form of a power-operated switch rather than a relay. However, the relay described below can be used on alternating current and will handle exceptionally large currents, and for these reasons is an addition to our set of relays. The constructional details are shown in Figure 7. The windings consisted of 500 turns of No. 20 copper wire. However, this merely determines the current and voltage at which the device operates. With the windings given above, the coil operates on ½ amp at about 30 to 40 volts of alternating current. The contacts are copper, and will handle upward of 20 amps without serious arcing.

The iron plunger should be of soft iron and should fit the brass sleeve in the same manner as a piston fits a cylinder. This prevents binding due to any sideways pull that might be developed and prevents any hum from becoming a rattle.

INDUCTION TYPE

This type of relay is one of the handiest an amateur can have around the shop. It will perform duties far above those of any other type of relay. It will delay the closing of circuits any definite length of time, or it will close one contact after another, doing duty as a sequence relay.

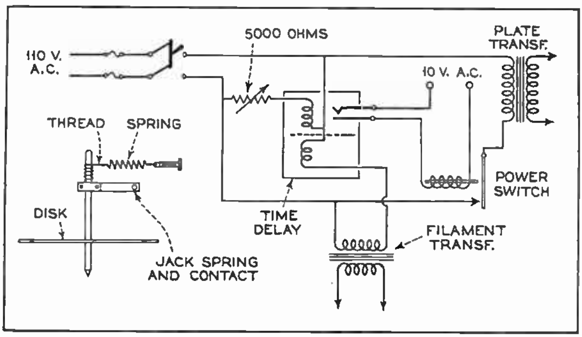


FIGURE 8

The first requisite of a relay of this sort is an old watt-hour meter. One of these can easily be secured from the junk pile of the local power company. The next step is to remove the gear train and dial. The question of removing the permanent magnets lies mainly with the use to which the relay is to be put, and the author leaves this point up to the constructor. If the magnets are removed, a very small current in the coil will operate the relay. If the magnets are left on, a much larger current will be necessary. For time-delay operation it is best to leave the magnets on. An old jack spring fitted to the shaft will furnish a contact as shown in Figure 8. A spring attached to a piece of thread wound round the shaft will turn the disc, as also shown in Figure 8.

As the contacts are small, they should not be expected to carry over .2 or .3 ampere. The connections in Figure 8 show this relay used as a time-delay relay for an amateur transmitter in the plate circuit.

CHAPTER 10

Experimental Television Data

The particular problem that confronts the experimenter, in constructing projection systems of television reception, is the selection of suitable lenses for the scanning disc, or in adapting the equipment to use lenses that are available but whose properties may not be known.

A simple description of a general-purpose lens is furnished by three items: the diameter, the type of lens (plano-convex, etc.) and the focal length. The plano-convex and the double-convex shapes are best fitted for the particular requirements of scanning. Inasmuch as either type can be designed to have the same focal lengths, the following analysis can be used for either type.

A lens operates on the principle that a ray of light changes direction when changing from one medium, such as air, to a denser medium such as glass and vice versa. In Figure 1, a bundle of light rays

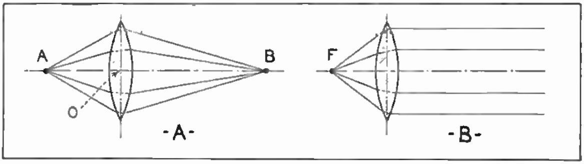


FIGURE I

originating at some point A on the axis of the lens are refocused at a point B on the other side of the lens. It may be shown that the physical distances AO and BO are related by the following equation:

$$\frac{1}{AO} + \frac{1}{BO} = \left(\frac{D'}{D} - 1\right)\left(\frac{1}{r_1} + \frac{1}{r_2}\right) = \frac{1}{F} \qquad (1)$$

where $\left(\frac{D'}{D}\right)$ is the relative optical density of the glass with respect to that of air, and r_1 and r_2 are the radii of the curved surfaces. Since all these factors $\left(\frac{D'}{D}\right)$, r_1 and r_2 are constants for a given lens, they are usually combined into one constant $\frac{1}{F}$, where F is called the focal length. It is impossible to determine the focal length of a lens from measurements alone, without knowing the optical density of the glass (which is known technically as the index of refraction). The value of this item averages between 1.5 and 1.6 but may run up to values of little under 2 for certain dense types of flint glass.

If either AO or BO is "infinity," as would be the case when the light rays are parallel (Figure 1B), as in direct sunlight, F is found to be the distance from the center of the lens to the point where the rays come to a focus. This furnishes the simplest method for the experimental determination of the focal length of a lens. Figure 2 provides a simple method for obtaining a solution for Equation 1, where a straight line intersecting the center scale will indicate points on the other scales that satisfy this relation.

In practice the present types of television discs are provided with

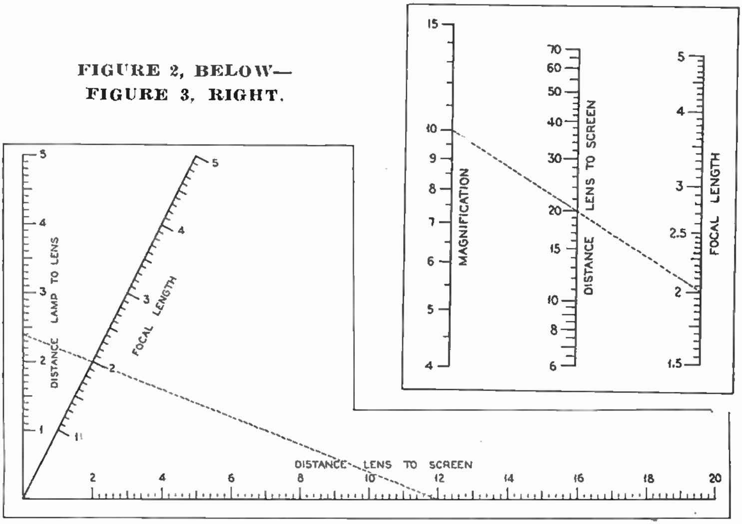


FIGURE 2, BELOW—
FIGURE 3, RIGHT.

lenses having focal lengths from 1.5 to about 3 inches. Generally speaking, lenses of the larger diameters are designed with longer focal lengths to decrease errors. On the other hand, the greater distance that the screen must be moved out to secure the required magnification precludes the idea of having the screen integral with the television cabinet.

The light source cannot be moved nearer the lens than the focal length of the latter, or else the transmitted light cannot be focused on the screen. The closer the lamp is placed to the position F, the greater the magnification. Figure 3 is a chart that enables the required positions to be readily determined, where a straight line across the appropriate values of focal length and magnification intersects the third scale at a point that shows the required distance from lens to the screen.

In general, the important variations in supposedly similar lenses are: variations in the focal length and in the optical centering. The latter is due to the optical center of the lens (the line connecting the centers of curvature of the two surfaces) not coinciding with the physical center. This has the same effect as if the lens mounting hole was mislocated by an equal amount. This displaces the picture line either in a tangential direction (which will produce a blurred strip in the picture) or will displace the line radially (which permits a dark streak to show up on the screen). Frequently this effect can be partially compensated for by rotating the lens around in the mounting hole by an amount determined by experiment, so that the distortion is less effective. Unless the lenses are held to closer limits by specifications, center variations might have a value of around .005 inch.

If all lenses come from the same source and are prepared in the same way, practically no variations in the focal lengths should be found. The extent of the effect can be shown by a numerical example: Assume the normal focal length is 2 inches and that a certain lens has a value of 1.95 inch; a magnification of 10 is used, and that the distance between centers of lenses is 1 inch. This particular lens will produce a line 10.25 inches long. Since the greatest displacement (1/8 inch) occurs at the edges of the picture, even this error might not be serious. If it happens that the particular lens is not located near the center of the series in the spiral, this additional magnification may cause two adjacent lines to be superimposed causing the usual dark streak.

It is not difficult to pick out a lens, having excessive errors, by successively screening over various holes in the portion of the disc that produces the section of the picture in which the distortion occurs. If the line is displaced but is of the same length as the others, the trouble is due to either eccentricity of the optical axis or to an error in the location of the mounting hole. If the individual line is of a different length, the probable cause is that the focal length is different.

The lens requirements for television scanning discs are really simple, inasmuch as the several distortional factors that complicate the design of many other optical instruments are unimportant here.

With the elimination of all complicating factors from lens design, and utilizing the nomographic charts included herewith, it is believed that this problem becomes a simple routine.

USEFUL HINTS ON TUNING IN TELEVISION PROGRAMS

Everywhere we hear that televisiou is the coming thing, not only coming, but already arrived after a fashion. The questions now arise, "How can I get the programs, what will they look like, how will I know when my radiovisor is workiug perfectly?"

Let us presume that the television enthusiast has ordered the radiovisor and receiver kit from his radio dealer or the manufacturer.

We turn on the television receiver and dial to the desired station's wave-length. As soon as the television receiver tubes warm up the neon lamp of the radiovisor begins to glow. The neon lamp of the radiovisor glows bright and dim as we look at it through a tiny hole in the scanning disc. Now we snap on the radiovisor switch. The motor starts revolving the scanning disc clockwise. The hole of the light moves across the field of vision as we view it through the magnifying lens. Then another line right below where the first one passed. Then a third and fourth. The lines come facter and faster. When the bottom one has passed, the top one starts again. The disc gains speed, the lines come in rapid succession, it looks as though all the lines were there at once; the single dot of the light has taken on the aspect of a solid mass of light about four inches square. As the scanning disc approaches the correct speed the lights and shadows take form and we see the image of the object which is being "televised."

The show is on.

Now that we are getting the program, let us see if we cannot improve the reception. The station is tuned in perfectly. We adjust the tuning knob of the television receiver, keeping our eyes on the picture. Finally we have it as sharp as possible. But what's that? The picture slips over to the right, seems to slant over and almost go off the screen entirely. There, it does go off to the right and reappears again on the left. That is a sign that the scanning disc of the receiver is not in perfect synchronism with that of the transmitter. The receiving disc is going too fast, it is gaining on the image. We turn the little rheostat on the radiovisor, the disc slows down, the picture no longer moves across the screen. But now something else is happening. The top of the picture is swinging back and forth while the bottom part stays still. We let the radiovisor run a minute or two without further adjustments. It is hunting. Soon the picture stops wobbling.

But now, though the picture is not moving across the screen and is not wobbling, it is not in the center of the screen. That means it is not framed properly. We therefore proceed to adjust the framing by means of lever or other device provided for the purpose.

If you tune your television receiver without reference to a station chart you may get a muddled pattern, think you have a television station and wonder why the pictures are not clear. Perhaps you are picking up short wave sound signals. These signals, though visible on the radiovisor, naturally form no recognizable picture. Or perhaps you have a television station, but one operating on an off-standard number of lines or scanning disc speed, such as the 48 line, 15 frames per second picture of which we spoke before. These, of course, cannot be tuned in properly with a standard 60 line 20 frames per second set. Again, indistinguishable patterns of black and white might mean a station too far distant or too weak to properly motivate the neon lamp. Finally, it might mean that the scanner is not in step. By snapping the radiovisor motor switch on and off several times the disc may be placed in step, and held there at the right speed by means of the rheostat.

Heavy black horizontal lines in the picture usually indicate that one or more of the tiny holes in the disc are closed, preventing light from coming through. Dirt or dust may be removed from the holes with a thin sliver of wood.

Sometimes tuning can be facilitated by attaching a loud speaker instead of the neon lamp to the receiver while tuning. For the ear can tune in to maximum clarity and volume better than the eye. The television station will be recognized by its high buzz saw note. This note, having been tuned in, detach the loud speaker, replace the neon lamp leads, start the radiovisor motor, and the picture will be received.

Do not expect perfect detail in the pictures. They are still crude. But progress is so rapid that week to week improvement will be discernible and the thrill of snatching pictures out of the air will outweigh any lack of detail.

CHAPTER 11

Laboratory and Shop Notes

RADIO enthusiasts will find that regular lead-covered battery lugs, such as used on the storage batteries in automobiles, are more rugged and lasting than spring clips for making connection to radio A batteries, although they are not so sightly or so easy to apply. The lugs make better contact with the battery terminals, and will not corrode. Stranded, rubber-covered wire leads can be soldered to the lugs and connected to the receiving set. These lugs can be purchased in any automobile supply store. They are properly marked, and the negative lug has a smaller opening than the positive one.

TEMPORARY WIRING HINT

Around the experimental bench one very often wishes to temporarily fasten or hold a number of small wires, or keep them together to keep track of them. Take a piece of corrugated cardboard, as shown in Figure 1, and slip the wires through the corrugations between the

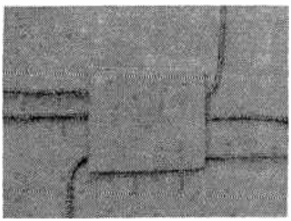


FIGURE 1

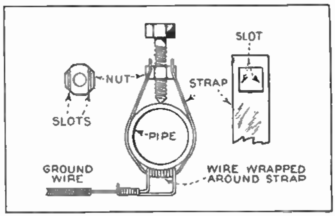


FIGURE 2

heavier holding pieces. The piece of cardboard can be glued or tacked temporarily to almost any smooth or thin surface. Any number of wires can be held or located in this simple, practical manner just where you want them to be handy to see and adjust.

SIMPLE GROUND CLAMP

Figure 2 needs little explanation, the strap being cut from scrap copper or even an empty smoking tobacco can. The nut may be slotted with a backsaw so that the slots are about one-half as deep as the nut is thick.

The bolt is to be tapered to a point on one end as shown, to help make a better ground, and will also aid whole clamp to set on pipe firmly.

HOME-MADE MALLET

Around the home workbench one often needs a small, light mallet to straighten out pieces of soft material which cannot be worked with the larger, heavier chisel mallet. Not a hard job to make one if the shop is well equipped, but this is frequently not the case. Figure 3 shows one made of an inexpensive hard-wood potato masher, which can be bought for ten cents. Cut the handle off and smooth up the round or top portion. Drill a hole an inch or so deep in the head and refit the handle as shown.

BENDING COPPER TUBING

When a copper tube is bent or wound into a coil, it will always flatten at the bends. This trouble can easily be overcome by filling the tube with resin.

One end of the tube is stopped up with a wad of cloth or paper and the tube held with the open end up. The melted resin is then poured from a ladle, with the aid of a funnel, completely filling the tube. If a long piece of tubing is being filled, it is a good plan to warm the tube by running a flame along it a few times to make sure the resin does not harden before it has run all the way down.

When the resin has hardened, the tube can be bent in any shape. Then heat it up and run the resin out.

Where there is sand available, it may be used in place of the resin. Simply fill the tubing with sand, then allow some water to run down into the tube to pack the sand. Drain off surplus water, seal

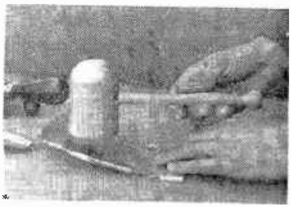


FIGURE 3

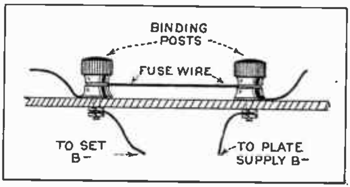


FIGURE 4

the ends of the tubing by flattening, and make the necessary bends. When dried the sand can be run out.

A PLATE SUPPLY FUSE

The way in which beginners most frequently burn out tubes in their radio receiving sets when tinkering with them is by accidentally connecting the B battery, or other plate supply, across the filaments of the tubes. This can be prevented and the tubes safeguarded if a fuse is connected in the plate voltage supply circuit as shown in Figure 4. This fuse can be made from a piece of ¼-ampere or smaller fuse wire, stretched between two binding posts about an inch apart and connected in the negative lead of the plate supply. This fuse will serve also to prevent the plate supply apparatus being ruined by a short circuit in the set.

SIMPLE EMERGENCY INSULATOR

The radio experimenter often encounters the need of some kind of a ready insulator and a great many things are made use of. The photo (Figure 5) shows one, quickly and easily made of a snap bottle stopper. The porcelain part was removed from the wire portion and the rubber gasket placed under it, the improvised insulator being then tied in place with a bit of stout cord. The neck of the stopper, where the gasket rubber formerly fitted, accommodates the wire. The rubber gasket under the bottom is firmly compressed by the cord and keeps the knob from slipping in spite of the pull from the wire.

A HANDY COIL WINDER

Many of the short-wave sets built by amateurs and described in current magazines use coils wound upon the bases of discarded tubes. These forms make excellent coils if wound smoothly, and they look nice if they are laid in shellac and given an extra coat when completed. Winding them by hand is a messy job, however, unless a winding jig is used. The coil winder shown in Figure 6 has been in use for some time and it has proved itself to be very satisfactory.

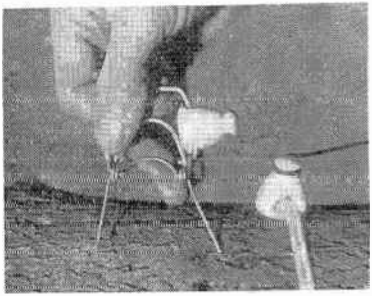


FIGURE 5

The essential parts are an old UX or UY socket, depending upon the type of tube base used, a few pieces of wood, and an old condenser shaft, threaded in a convenient size at both ends, with accessory nuts and washers.

A disc of soft wood about ½ inch thick and from 2 inches to 3

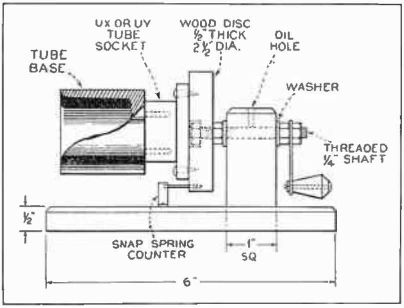


FIGURE 6

inches in diameter is cut, drilled through the center and counter-sunk to take the end of the shaft and a locking nut. This spindle turns in a hole drilled one end of a piece of medium hard wood, 1 inch square, which is fastened to one end of the baseboard. A small oil hole drilled in the top of this bearing post gives the shaft sufficient lubrication. The handle is a piece of brass or steel, drilled, and locked to the end of the spindle between nuts. The socket is centered and secured to the disc as shown in the drawing.

The coil form is placed in the socket, shellacked and wound as usual.

A SIMPLE LOW-LOSS INDUCTANCE MOUNTING

Small copper tubing inductances, customarily used in circuits such as amateur radio transmitters where only a few turns of copper tubing are used generally need no special support to make them rigid enough to avoid frequency change due to vibration or sagging of the coil. However, where a larger coil is desirable, requiring from ten to twenty turns, the tubing is not sufficiently rigid to support the coil when mounted by means of lugs at each end. Some kind of support is necessary to hold the center of the coil firm and yet not make so much contact with the winding as to cause losses due to leakage at these

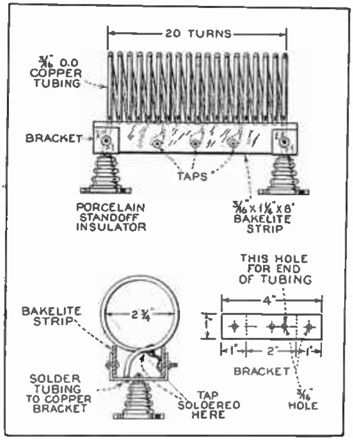


FIGURE 7

points. The arrangement in Figure 7 meets these requirements nicely.

The entire coil and mounting can be constructed at a cost of less than a dollar and the completed unit will have the finished appearance of a factory-made unit and will be every bit as efficient.

The particular coil described was made of twenty turns, 2¾ inches in diameter and wound with 3/16-inch outside diameter copper tubing. The parts used will be readily recognized by any experimenter.

In constructing a coil of this size for amateur radio use it is well to take off a few taps so that the coil will lend itself to use in other circuits than the particular one for which it is being constructed. The coil shown is tapped at three points, center and one-quarter distance from each end. The taps are taken off by means of copper strips ⅜ inch wide with one end bent three-quarters distance around the turn to be tapped and securely soldered in place, and the other end placed under the head of a number 8 or 10 machine screw to provide a convenient binding post. Strips forming these taps should be as short as possible. About 1¾ inches will be found to be about right for this size coil and mounting. For appearance sake the taps should be soldered to the portion of the turn between the two hard-rubber supports. If desired, these taps can be brought out on both sides of the coil by mounting the machine-screw binding posts on both supporting strips. This arrangement will be found particularly desirable when the coil is to be used in intermediate amplifier circuits and will be found to be a great aid in obtaining neat circuit arrangement.

A DEPTH GAUGE FOR DRILLS

Where holes of a specified depth are to be drilled a simple and fool-proof arrangement is to cut a small hardwood block of such a length that when a hole is drilled through its center it will leave the required length of the drill projecting. If this block is slipped over the drill it will be impossible to drill holes deeper than the projecting portion of the drill.

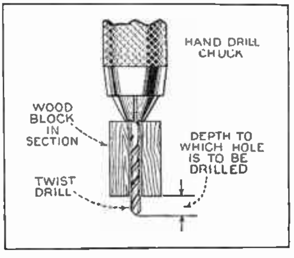


FIGURE 8

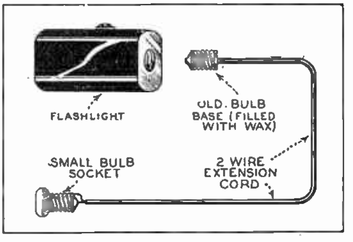


FIGURE 9

The drawing (Figure 8) illustrates this idea. It will usually be found desirable to make the hole through the wood block large enough to permit the drill to slip through easily so that the block will not turn with the drill. To facilitate this idea it may be found worth while to put a drop of oil on the top of the wood block next to the drill chuck.

A SERVICE SHOP KINK

Small glass bottles with screw caps are very handy in the service shop. The lids of about a dozen of these jars can be fastened to the underneath side of the service bench, and the jars screwed into them, thus providing an out of the way and yet convenient storage for nuts, bolts, lock washers, soldering lugs, small condensers, etc.

PORTABLE HANDY-LIGHT

Take a small flashlight, remove the lens and screw an extension cord (make by soldering a double wire into an old bulb base and having a miniature socket, such as used for Christmas trees lights, on the other end with a flashlight bulb in it) into the bulb receptacle as shown in Figure 9. This enables you to get in very small places with a good clear light—for locating balancing condensers, etc.

CONDENSER LUBRICATION

The manufacturers of variable condensers of modern design make the utmost effort to have the condensers accurate, quiet and nonmicrophonic. However, trouble is sometimes encountered in these respects in condensers of inferior construction. Sometimes these require a little more tension applied to the rotor shaft in order to avoid loosening and microphonic trouble, but when the tension adjusting mechanism is turned too tight, the rotor shaft will be too stiff in rotation unless the bearing is lubricated. It is generally known that the bearing of a condenser should not be lubricated because oil is a non-conductor of electricity. This trouble can easily be overcome simply by soldering a flexible wire or coil spring "pig-tail" between the rotor shaft and frame (or rotor terminal). Since the rotor shaft is then grounded through this "pig-tail" rather than through its bearing, the bearing can be lubricated at will.

REJUVENATING PHONOGRAPH PICK-UPS

The heart and soul of a phonograph pick-up is a permanent magnet of the familiar "U" type, and it is characteristic of a permanent magnet that it gradually loses its magnetism, although more slowly when an armature of pole piece is allowed to remain in place to complete the magnetic circuit. In the case of pick-ups, as with electromagnetic speaker units, an armature constitutes part of the actuating mechanism, but the magnetic flow is never quite complete because of the polar gaps necessary to allow free motion. It follows that if loss of volume in a phonograph pick-up is due to a gradual loss of magnetic field strength, and this can be in any measure restored by the application of a strong exterior permanent magnetic field, an increase in volume should be noted.

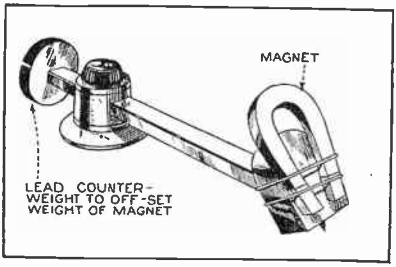


FIGURE 10

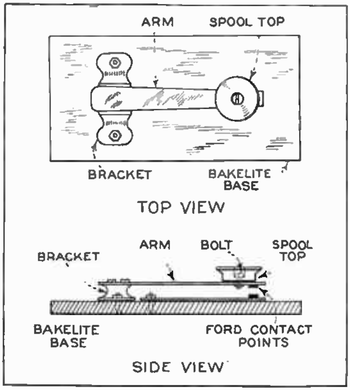
Accordingly a permanent horseshoe magnet was unearthed which had been purchased many years ago. Fortunately its power had been excellently conserved by a pole piece and it was in fine condition. It weighed ¼ lb., was 5⅛ inches long, 2 9/16 inches wide at the widest point, 1 9/16 inches wide at the poles and made of bar steel ⅝ inch wide and ¼ inch thick. In order that the strength of the pick-up magnet should be reinforced, it was necessary to know the polarity of its magnet. This was quickly determined with a magnetic compass, whose north pole pointed to the south pole of the pick-up. Accordingly, the horseshoe magnet was carefully laid down on the flat side of the pick-up (Figure 10) with unlike poles superposed, the polar gap being placed close to the lower end and fastened in place by two rubber bands. As a matter of fact and experiment it was subsequently found that if like poles were superposed, no improvement whatever occurred. From the standpoint of the system of parallel magnet reinforcement employed in the multiple magnets of magnetos, this is the opposite of what might be expected. If, however, the pick-up magnet is regarded as functioning merely as a pole piece to the more powerful magnet, the phenomenon becomes understandable.

A record was then placed on the turn-table, the amplifier turned on and the pick-up needle dropped into position. The effect was nothing short of miraculous. The volume was prodigiously enhanced, being even more than when the pick-up was new, and the lower frequencies registered with a sonorousness and clarity which was a delight to the ears.

It remained only to make a final adjustment to insure a proper distribution of the added weight of the magnet. The pick-up is normally balanced or weighted so that the optimum pressure will be brought to bear on the needle—if too much, excessive wear on the record results; if too little, there is a tendency to "jump the track," causing repeating and stuttering, particularly towards the end of the record track. Only a few minutes' experimenting was necessary to determine the best position, however, and then the magnet was securely fastened by two narrow strips of adhesive tape and the rubber bands discarded. With certain types of pick-ups it will be necessary to counterbalance the arm to compensate for the added weight of the magnet.

PEPPING UP PHONOGRAPH PICK-UPS

While it is always possible that a phonograph pick-up may lose an appreciable portion of its residual magnetism, it is not probable,



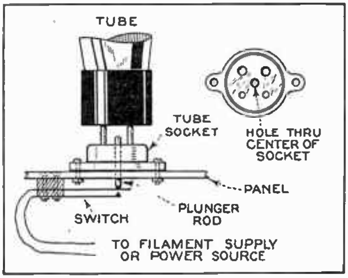


FIGURE 11, LEFT—
FIGURE 12, ABOVE.

especially if it is one of a fairly high grade. When a pick-up loses volume, if one will investigate this delicate piece of mechanism, he will likely find that rubber packing has lost its ability to act natural, and that if a new packing is substituted the pick-up will once more provide its normal output.

CHEAP TRANSMITTING KEY

A simple key is made out of two contact points from a Ford spark coil, as shown in Figure 11. The bracket is taken off one of the contacts and the contact is attached to a piece of Bakelite which serves as the base for the key. The other contact arm is taken off the bracket, turned over and again attached to the bracket, and this part is then also bolted to the Bakelite base. Finally, a round disk of Bakelite, or better still, one of the ends cut off an ordinary spool, is bolted to the upper contact arm to serve as the handle or finger button. If desired, a pair of binding posts may be mounted on the Bakelite and the two arms of the key conected to these.

SAFETY SWITCH

When building tube testers in which a switch must be turned off as soon as the tubes are tested, damage to the milliammeter may result if the switch is not turned off as a battery is connected across the milliammeter. If the tube tester were to stay idle for a few days with the switch turned on a damaged milliammeter may result.

An automatic switch, as described here, would prevent this happening.

A tube socket having a hole through its center is first procured. This is mounted in its permanent position on the panel or sub-base and a hole of the same size and directly under that in the socket is drilled through the panel. A switch consisting of two of the contact blades and the fibre spacers from an old jack is then assembled and mounted underneath the panel, in such a position that the tip of the upper jack blade is directly under the hole in the socket and panel. The two jack blades should be spaced so that they are normally spaced slightly apart. Finally a short rod, slightly smaller in diameter than the hole, is slipped down through the hole in the socket until its lower end rests on the upper jack blade. Its length should be such that its upper end projects about 3/32 inch above the top of the tube socket. The entire assembly is shown in Figure 12.

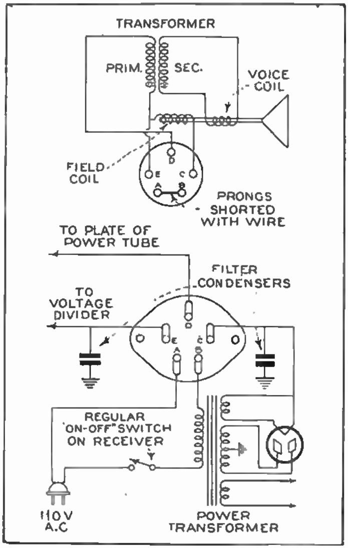
When the tube is inserted in the socket it pushes down on the rod, causing the upper blade of the switch to make contact with the lower one and closing the circuit. When the tube is removed from the socket the switch circuit opens automatically.

Such a switch as this finds many possible applications around the service shop or experimental laboratory. It is especially useful in connection with dynamic speakers which draw their field supply from the plate supply circuit of a receiver and which are connected to the receiver and plate supply by means of a plug and socket. In such installations the removal of the speaker plug from its socket without first cutting off the power subjects the rectifier and filter system to a considerable strain. Through the use of a switch such as that described, to break the a.c. line, removal of the speaker plug would automatically cut off all power.

A FOOLPROOF SPEAKER PLUG

Many persons turn their set on when the speaker plug is not in its socket thus imposing a strain on filter condensers and other expensive parts. As this is a costly procedure, the arrangement shown In Figure 13 to protect against carelessness has been devised. It is applicable to all sets having speaker plugs and sockets not using push pull speakers and the only parts required to make the changeover are a five-prong speaker plug and socket.

Many receivers use a four-prong speaker plug and socket and in many of these only three wires go to the speaker, two to the terminals of the field and one to the high end of the primary of the voice-coil transformer. The low end of the voice-coil transformer primary gets its voltage from one of the field leads and this connection is made at the rear of the speaker. If the four-prong outfit is replaced by a five-prong plug and socket there are two unused prongs which can be connected as a switch and wired in series with the primary of the power transformer. One of the 110 volt supply leads is cut and each end soldered to a filament prong on the new speaker socket. The filament prongs on the plugs are shorted. Thus when the plug is in the



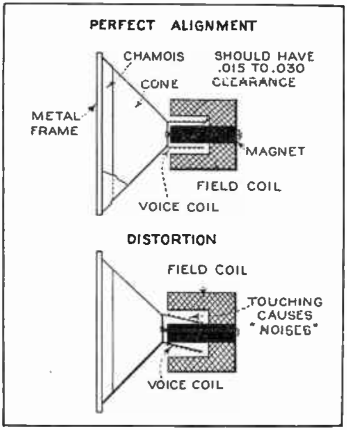


FIGURE 13, LEFT—
FIGURE 14, ABOVE.

socket there is continuity in the primary of the power transformer and the set can play. This circuit is broken when the speaker plug is removed and it is impossible for the alternating current to flow through the gap (between the filament prongs) to the power transformer, even if the set is connected to the line and the switch is turned on.

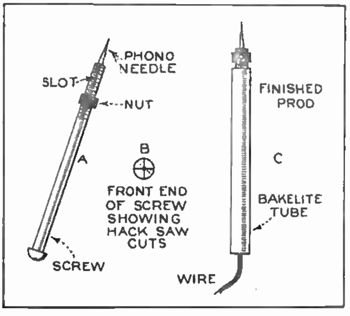
DOCTORING DYNAMIC SPEAKERS

The diaphragm of a dynamic speaker is usually securely held at the periphery or rim of the cone, with a ring of chamois skin, or some other similar substance. Warm weather, following a period of dampness, causes this material to harden and pull the paper of the cone slightly towards the top or sides. Sometimes the paper itself, after absorbing moisture, becomes dry and distorted. Under strong vibrations while in operation, the centre of the cone which carries the voice coil touches the field magnet (see Figure 14).

To remedy this condition, loosen the reproducer's clamp nuts at the rim which holds the chamois skin or leather, carefully rub the skin between the fingers until it becomes again soft and pliable and then put it back very loosely in the rim. In Majestic or similar types having a metal "spider" held to the field magnet by a small screw, make the hole through which this screw passes a little larger, the frame may then be adjusted accordingly.

HOME-MADE TEST PRODS

A good test prod can be easily made from simple parts out of the junk box. Obtain a three-inch screw and the thickest obtainable nut to fit it. The nut is screwed well up onto the shaft of the screw and then a cross-like pair of slots (see A and B, Figure 15) are cut in the threaded end of the screw. This leaves an opening at the intersection of the cuts and into this opening a phonograph needle is forced. This last operation spreads the end of the screw somewhat.



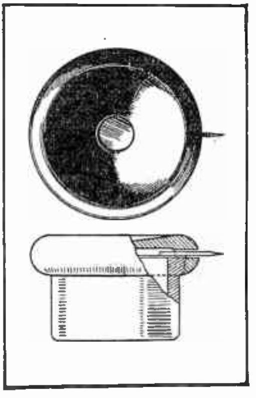


**FIGURE 15, ABOVE—
FIGURE 16, RIGHT.**

By screwing the nut down onto this expanded portion, the phonograph needle is firmly clamped in place.

The only thing then is to "dress up" the screw to make it more presentable in appearance, as shown at C. The connection wire may be soldered directly to the head of the screw.

A HOME-MADE PHONOGRAPH PICK-UP

An easy and inexpensive way to make a magnetic pick-up for a phonograph is shown in Figure 16.

Remove the diaphragm from one telephone receiver and solder a phonograph needle to its edge. The needle should be one of the kind which may be used several hundred times before being discarded However, even an ordinary needle will run 50 to 100 times before a change of tone is noticed. A hole is drilled through the edge of the cap. The needle protrudes through this hole. The phonograph reproducer should be removed and the telephone receiver put in its place and held there by elastic bands. The hole in the cap of the telephone receiver should be facing out from the tone arm opening.

The leads from the receiver may be connected to the radio in the same manner as any other pick-up unit, and the phonograph can then be run as usual. Another diaphragm can be used instead of the original and then the headphone is in no way injured for its original use.

SIMPLE LINE VOLTAGE COMPENSATOR

Either low or high line voltages may be compensated by connecting a small step-down transformer in the supply line to the radio set as shown in Figure 17. It will be noticed from a study of this

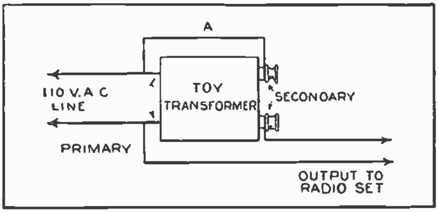


FIGURE 17

circuit that the voltage supply to the radio set includes that from the 110-volt line plus or minus the voltage developed at the output terminals of the step-down transformer. In effect, this secondary winding is connected in series between the line and the radio set.

The line is connected directly to the primary of the step-down transformer. One side of the line is also connected to one terminal of the secondary by means of the connection A. The other side of the line is connected direct to the radio set, as is also the terminal of the secondary which is not connected to the line.

Where the line voltage is high, the secondary of the step-down transformer is connected in such a way as to "buck" the line voltage, thus reducing it by the voltage of the secondary. When the line voltage is low, the secondary is connected so that its voltage will add to that of the line. To determine whether the transformer secondary is connected to "buck" or "add," a 110-volt lamp is connected to the output in the place of the radio set. With this lamp in the circuit, the transformer secondary connections are first connected one way and then reversed. The connection which results in maximum brilliancy of the lamp shows the transformer adding to the line voltage and vice versa.

For this purpose, either a bell-ringing transformer or a toy transformer may be used. Toy transformers are best because they are usually provided with secondary taps to permit a choice of output voltages. Moreover, these transformers are always rated as to power. This latter is not true of bell-ringing transformers and some of the latter type are designed for such low power as to be useless for the purpose described here. In any event, the transformer secondary voltage should be sufficient to provide the necessary compensation required in any particular case. The transformer used should have a rating of at least ten watts.

A HOME-MADE PENTODE ADAPTER

In a set using a four prong output tube, a pentode may be used by means of an adapter. This adapter is made by using the base of a four-prong tube and a five-prong subpanel type socket which fits within (or may be rested on top of) the base. The base of the tube is removed by applying a hot soldering iron to each of the prongs in turn and flicking the solder from the prongs; the glass bulb may then be removed by twisting.

Five wires are attached to the screws of the socket, the cathode wire being drawn through a hole drilled through the side of the base. The other wires are skinned and placed in the corresponding prong of the tube base. These wires are then pulled taut and soldered. The ends are then cut off in such a way as not to project beyond the side of the prong, as this will prevent the prong from entering the amplifier tube socket opening.

The cathode wire is connected to the B+ side of the output transformer.

SAFEGUARDING CONDENSERS

Most experimenters trying new circuits have had occasion to use condensers in series from time to time in order to obtain some definite value of voltage rating with the apparatus at hand. In such cases the experimenter may have wondered why some condensers in such circuits would "break down" or "puncture." He may have been further puzzled by the fact that this would occur principally in direct-current circuits.

The explanation for such condenser failures depends upon the fact that the impedance of a condenser connected in a direct-current circuit is equivalent to the leakage resistance of the condenser. In general two condensers of quite the same construction and capacitance may have widely separated values of leakage resistance. When two such condensers are connected in series the current in each will be the same, and since the voltage drop across each condenser is equal to the product of current times leakage resistance, the two voltage drops will be as widely separated as the leakage resistances.

An example of incorrect operation is shown in Figure 18. In this figure A and B are two 1.0 mfd. condensers rated at 500 volts. One condenser, however, has a leakage resistance of 9 megohms while the other has only 1 megohm. When the two condensers are operated in series on a 1000-volt circuit, the voltage drop across each is directly proportional to its leakage resistance. One condenser, therefore, has 900 volts across it while the other has only 100 volts. If the 500-volt condenser is not most conservatively designed it will soon "fail," and when it does, 1000 volts will be impressed across the remaining condenser, bringing about its failure as well.

In Figure 18 is shown a simple remedy for this condition. Each condenser is shunted by a high resistance similar to a 100,000-ohm grid leak. The resistance of these two leaks is in parallel with the leakage resistance of the condensers giving a total resistance across the condensers of 99,009 ohms and 90,909 ohms respectively. Since the voltage will divide in approximately the same ratio, the impressed voltage on the condenser will be 480 and 520, which will probably be entirely satisfactory. There seldom occur circumstances in which the 100,000-ohm resistors introduce any undesirable effects.

Little help can be obtained with a voltmeter, because the internal resistance of most such instruments is so low as to give considerable errors when parralleling the high resistance leakage path of a condenser. Protective resistances of as low a value as possible should be chosen if no means is available for measuring the leakage resistance of the condensers.

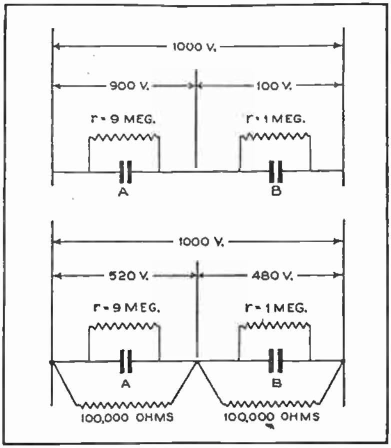


FIGURE 18

All of the preceding remarks have to do with condensers connected into direct-current circuits. When two condensers are connected in series in an alternating-current circuit the conditions are quite different from those just described. The impedance of a condenser that is charged and discharged from an alternating-current circuit is dependent upon both capacitive reactance and leakage resistance. As a general rule, however, the capacitive reactance of a condenser is quite small compared to its leakage resistance. The voltage across two condensers in series will divide approximately in proportion to their capacitive reactances $\frac{1}{2\pi fC}$ or in inverse proportion to their capacities.

USING HEADPHONES WITH STANDARD RADIO SETS

Headphones seem to have become about passe in radio circles during the past few years. Nevertheless, there are times when the use of headphones is highly desirable. For DX reception late at night they always have been, and always will be decidedly useful, if for no other reason than they keep peace in the family. Even in daylight

DX reception, which has become so popular since shortwave transmission developed, much annoyance to other members of the family can be avoided if the DX fan confines himself to headphones.

To those who are hard-of-hearing, radio offers a potential source of vast enjoyment found through no other agency. Here again headphones can be made to play an important part because, as a rule, those who are hard-of-hearing have the same difficulty in listening to loudspeaker reproduction as they have in listening to anything

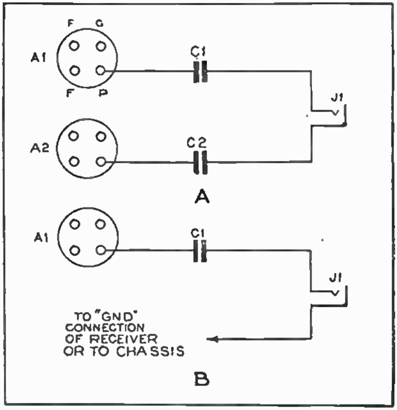


FIGURE 19

else. Either they only partially hear the programs or else are forced to turn the control up for high volume, which is often a decided inconvenience to others of the family and perhaps even to neighbors.

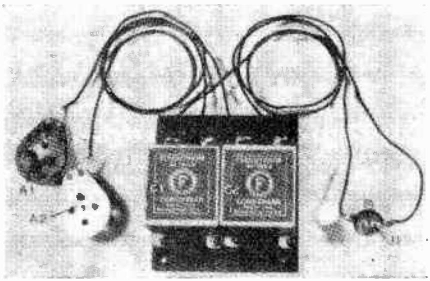


FIGURE 20

There are two devices to be described here, which permit the use of headphones with any type of receiver, and which are easily connected without change in the wiring of the receiver. The first, shown in Figure 19 and Figure 20, is all that is necessary to permit DX fans to listen in with headphones. This consists of two adapters which are slipped under the output tubes of the radio set, assuming it to have a push-pull output stage. With receivers having a single tube in the output, the circuit shown in Figure 19 (B) is used.

Leads from the two adapters connect to a pair of blocking condensers and the other sides of these condensers connect to a single-circuit jack which may be mounted on the side of the receiver cabinet. To listen in with headphones, all that is necessary is to insert the headphone plug into this jack and operate the set in the normal manner. If this equipment is to be used in DX reception, it will, of course, be desirable to put a switch in one of the voice-coil leads to the loudspeaker in order that this circuit may be opened. If the headphones are to be used by a person who is hard of hearing, the loudspeaker may, of course, be left in operation for the benefit of other members of the family.

With this first type of equipment, the volume must be controlled by the regular volume control on the receiver itself. In cases where it is desired to operate the loudspeaker and headphones at the same time, this may not prove satisfactory and therefore the unit shown in Figure 21, with the circuit in Figure 22, provides a convenient

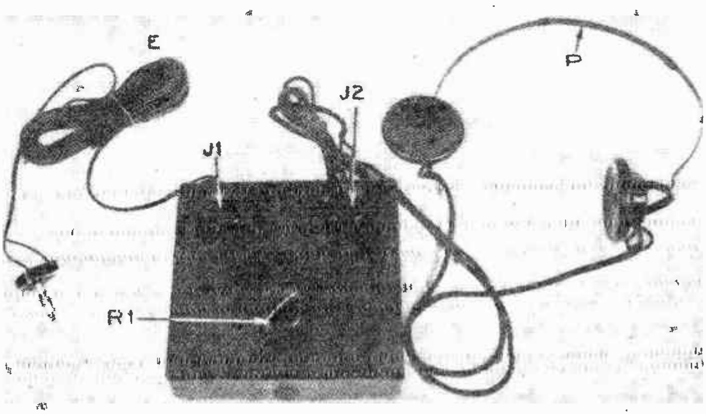


FIGURE 21

refinement for the system. This consists of an extension cord, a volume-control box and a pair of light-weight headphones. The extension cord may be of any desired length and thus permit the headphones to be used some distance from the receiver, if desired. The volume-control box regulates the volume of the headphones only and has no noticeable effect on the volume of reproduction from the loudspeaker. Thus a hard-of-hearing individual may sit comfortably in his easy chair with the volume-control box on a table beside him. Other members of the family can listen to the radio as usual but this one individual will be able to regulate the volume at the headphones to suit his individual requirements.

As a matter of convenience, the extension cord is equipped with plugs at each end and the headphones are equipped with another similar plug. The volume-control box itself includes two jacks into which these plugs are inserted. The box shown in the illustration is considerably larger than necessary, measuring about five inches square by one inch in depth. A much smaller container may be used if desired.

A word about the headphones employed with this unit, as shown in Figure 21 will be in order here. These headphones are a new type, recently introduced; they have the advantage that they can be worn for hours at a time without the fatigue that accompanies the wearing of ordinary headphones. They are extremely light; the total weight,

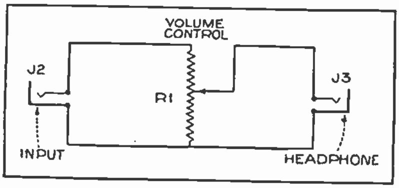


FIGURE 22

including the two earpieces, head-band and cord, is only four ounces as compared with over one pound for most other types of headphones. This offers an advantage that will be appreciated by anyone who has tried to sit through an evening with headphones clamped on his ears.

The outstanding feature of the equipment described here is its capability of attachment to any type of receiver without any changes in the receiver itself and without requiring access to the receiver wiring. The only connections to the receiver are obtained by means of the adapters which are slipped over the prongs of the output tubes. All of the parts used are standard equipment and are readily available.

List of Parts—A1, A2—Wafer-type tube adapters with plate connection brought out; C1, C2—2-microfarad by-pass condensers, 250-volt rating; E—20, 30, or 50-foot extension cord; J1, J2, J3—Carter single-circuit, open, "short" jacks; P—Trimm featherweight headphones; R1—10,000-ohm potentiometer; Bakelite panel for mounting condensers, Box for volume control.

CHAPTER 12

Antenna Notes and Experiments

SIMPLE INDOOR ANTENNA

IN place of a regular outside aerial, an indoor aerial made of a strip of ordinary galvanized-iron window screening, two to three feet wide and ten or more feet long, can be suspended in the attic close up to the roof, and a lead-in wire fastened to it. While this kind of an aerial is not as good as a one-hundred foot long copper wire, it is far more compact and easier to erect. It can be insulated from the roof

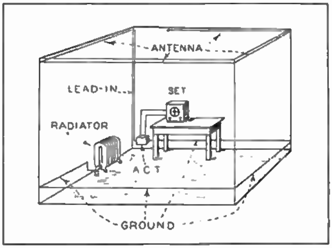
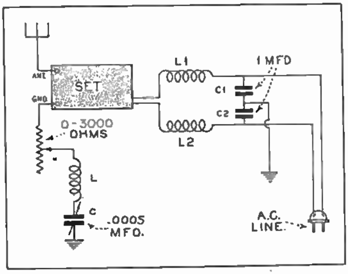


FIGURE 1



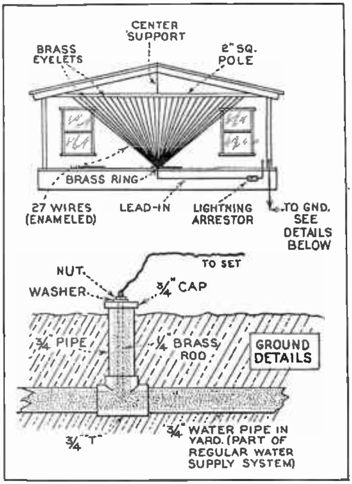


FIGURE 2, ABOVE—
FIGURE 3, LEFT.

beams, or not, just as desired; although it is better to insulate it if possible. Copper or brass screening would be far better. Even chicken-wire netting can be used, however.

EFFECTIVE INDOOR ANTENNA

To those who are not able to have an outside antenna, the sort of inside antenna shown in Figure 1 gives good results on all frequencies. For s.w. reception it is very good. Such stations as have been brought in I2RO, Rome; FYA, Paris, G5SW, Chelmsford, England; and Konigs-wusterhausen, Germany, have been brought in with impressive clarity and volume, using this type of antenna.

For antenna and ground wires use a very flexible and soft wire which can be obtained in the 25-cent stores, length 65 feet. The antenna wire is strung around the ceiling and led to the antenna-coupling transformer (ACT). The ground wire is strung around the floor; one end grounded to the radiator and the other end connected to the antenna coupling transformer. The antenna-coupling transformer has two wires, and here you have to test which wire to attach to the antenna post of the set and the other one to the ground terminal. For the antenna-coupling tansformer the multiple antenna-coupling made by the Insuline Corporation is used. This antenna will give much better results than many poorly erected outside antennas.

ANTENNA SYSTEM FOR STATIC REDUCTION

One experimentor has found that he obtains his best reception from an antenna of twenty-seven wires spread fan-shaped on one end of the house wall. Tuning was fully as satisfactory and for two months in the summertime he "listened to the sweetest and smoothest reception I ever hope to get over the air, and any one living in the tropics knows what we get during the summer months."

Sketches of the fan antenna and of the ground are shown in Figure 2.

The antenna was the result of eight years of almost constant experimenting with overheads, undergrounds, loops, coils, inside and outside, used in every possible way, length, height, material and direction, always seeking something that would lessen the so-called "tropical crackle."

Nothing, of course, will keep out the static crashes.

This big affair was tried out simply on the idea that a big man can lift a load with less effort than a child and a large amount of surface wire for pick-up meant picking up the program before reaching the noise level. When an indoor antenna of twenty feet was used it was found to be impossible to listen, but switch to the big antenna and the programs came in as smooth as oil.

A good ground is absolutely necessary and after dozens of experiments the sketch enclosed proved to be the best of all. A wave trap kept the receiver sharp enough to separate WGN, WOR, WLW and such stations, and the whole proved very satisfactory.

A HIGHLY EFFECTIVE GROUND SYSTEM

The average radio owner who appreciates good clear reception and a well-balanced aerial-ground combination is at a loss of times to know how to constant a ground that will work efficiently under all conditions.

A combination ground has been tested out and found to work very well, and here is how it was constructed: A ½-inch gas-pipe about 8 feet long was driven down into the soil and a hole some bigger than the pipe was dug around it for 3 feet down into the soil. This was well salted, with about 3 pounds of common rock salt, and a can of caustic potash was added to facilitate good chemical diffusion and draw dampness. This mixture was then well wetted with water and dirt filled around it to the top of the ground.

Another ground was constructed some 10 feet away from this, using the cells from two discarded B batteries. Holes were punched in each cell and they were then connected in series and laid in a trench dug a foot deep. The end wire from the group of cells was connected to a 4-foot metal rod which was driven into the earth, the other end of the wire from the cells was connected to the gas-pipe ground mentioned above, and then to the ground post of the set.

This combination pipe-chemical ground was well wetted down and covered with moist earth, and has proved a very simple and efficient combination. This ground can also be used as an aerial if attached to the aerial post on set, and KFI in Los Angeles was brought in with good clarity and no static on a hot July night, also CMC in Havana was picked up with good clarity when, switching to the outside antenna, it could not be heard at all. This type of combination ground is inexpensive and in some cases has greatly improved reception.

The advantages of this ground system result from two things. First, there is a larger area of ground contact obtained from the two pipes and the B battery cells; and, second, the chemicals employed attract moisture. They also filter into the ground, thus making the nearby ground a better conductor and in fact greatly increase the size of the effective "ground" area.

For the information of others who may desire to construct a similar ground, one copper pipe and one iron pipe were used in this experiment, but two pipes of either copper or iron, or any other metal for that matter, should prove equally satisfactory.

This ground system proves to be highly effective with three different receivers tried with it.

ELIMINATOR FOR "MAN-MADE STATIC"

Usually the best remedy for radio interference is to locate the source and then remedy the cause or filter the troublesome device. In some cases, however, this is impossible or at least impractical. A case of this kind has given one radio fan trouble for some years. To use his own words:

"An old transmission line which runs near me radiates a steady grinding, crackling noise for its entire length of about 20 miles and drowns out all but the most powerful local stations. After considerable experimenting, the following system was worked out and it removed the noise, although it is some trouble, as it has to be adjusted to every station separately. (See Figure 3).

"Two grounds are necessary. The tuned circuit is not, as might be supposed by an inspection of the diagram, tuned to the frequency of the station being received, but is used to produce a phase balance in the interference. part of which enters through the antenna and part of which gets by the filter. The resistance R completes the balance. Actual data cannot be given on the parts, as they vary with the installation. Reversing the two grounds used is also necessary sometimes. An 0-3000 ohm resistor (R), C of 500 mmfd. and coils ranging from 100 to 500 microhenries have taken care of all conditions I have run into.

"In the filter, C1 and C2 are 1 mfd. condensers, and coils L1 and L2 consist of 500 turns of No. 18 d.c.c. wire in a 4-inch roll.

"This circuit has also been used to stop interference caused by a vibrating battery charger."

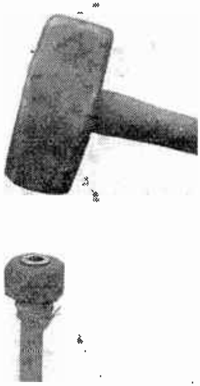
IMPROVING THE ANTENNA

A California DX fan who has been experimenting with antennas grounded at the far end, reports some interesting data:

"I have been using such an arrangement, in effect, for more than seven months, and have seen several such grounded antenna systems installed, all with results. I have found, however, that such an arrangement works best in conjunction with the regular antenna. When so used it rounds out the signal strength in all sections of the dial.

"With a grounded antenna alone (length 150 feet, lead-in 30 feet), I have found frequencies of 550 k.c. to about 900 k.c. favored at least 50% over those from 900 k.c. to 1500 k.c. In other words, the arrangement did not boast the signal in the 900 k.c. to 1500 k.c. range over that obtained with the regular antenna system, but did on the 550 k.c. to 900 k.c. range.

"My regular antenna consists of a 125-foot wire with a 25-foot lead-in to the receiver. To this I added a grounded antenna 150 feet



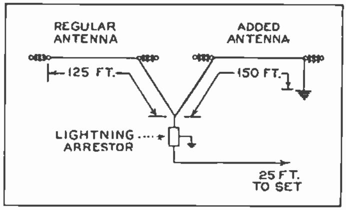


FIGURE 4, ABOVE—
FIGURE 5, LEFT.

in length, connecting the latter to the lead-in from the regular antenna, as shown in Figure 4. I have found the 150-foot length best for this added portion of the antenna system, although others may find a longer or shorter wire more effective, depending largely on the length of the regular antenna to which the addition is being made. The height of the added portion above ground does not seem to be at all important so long as it is four feet or more. As a matter of convenience, mine is twelve feet high.

"This scheme is well worth trying in any location because it boosts the signal to noise ratio to such an extent that ordinary noise doesn't mean a thing."

DRIVING IRON PIPE GROUNDS

Three-quarter-inch (O.D.) galvanized pipe is quite commonly used for ground wire connection, and it makes a good one, but driving a long piece of it down into even soft earth frequently burrs or splits and shatters the end pounded on. Special appliances are of course made for this job, but when one is without them, the photo (Figure 5) shows a little method which can be used. A ⅞-inch nut will just snugly slip over this size a pipe. With plenty of stout heavy cord wrap the pipe just below the nut, so that just a small portion of the pipe will extend above. Drive the pipe down with any kind of a heavy hammer or small sledge The end of the pipe will, of course, expand in the nut, but it cannot split or crack. The nut prevents that. When the pipe is down far enough, cut away the string or cord and, with a hammer, tap the nut some distance down on the pipe. File off the burrs you have made on the pipe end driving it, and tap the nut back up and off the pipe.

SIMPLE STATIC REDUCER

To get through the tremendous static disturbances that hamper radio reception in the tropics, grounding the free end of a receiving antenna, as shown at A, Figure 6, herewith, not only eliminates considerable static but increases strength and steadiness of reception.

Where formerly a good conventionally insulated antenna was re-

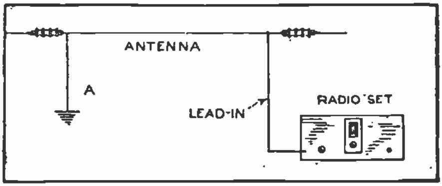


FIGURE 6

quired to get any decent reception, now a comparatively small indoor aerial under a sheet-iron roof brings in stations much better with less disturbances. This class of aerial eliminates the need of a lightning arrestor and an antenna insulator which in these hard times amounts to something in itself.

In trying this stunt it is safest to make the connection to ground (A) through a 5 mfd condenser. This is a safeguard made necessary, when using Majestic and certain other types of d.c. and a.c. receivers, by the fact that grounding the antenna may result in heavy currents from line or power supply flowing through unintended paths and per haps burning out coils or volume controls.

AUTO-RADIO ANTENNA

An extremely simple antenna for an automobile-radio can be made and installed in about fifteen minutes—at a cost of a few cents.

This antenna consists simply of a few feet of fine copper wire (enameled), somewhere between 30 and 36 gauge, which is sewed into the upholstery on the under side of the roof. The method is to thread the end of the wire through the eye of an ordinary darning needle and then using a basting stitch, with the wire as the thread, sew it into the fabric. Each stitch should be about two inches long, about 1⅞ inches of this being above the upholstery fabric and only about ⅛ inch showing from the under side. This makes the wire practically invisible.

The length of the wire used will depend upon the receiver used. In one of the Radio News test cars (Essex coach), equipped with a Marquette Motor Radio, about 22 feet of wire is used, in the form of a rectangular spiral, as shown in Figure 7. This provided more than adequate pick-up—so much, in fact, that on local stations the push-pull pentodes in the output stage are overloaded even with the volume control near the low side.

This scheme works best in cars which do not use chicken netting to reinforce the roof upholstery. However, it is so simple to install

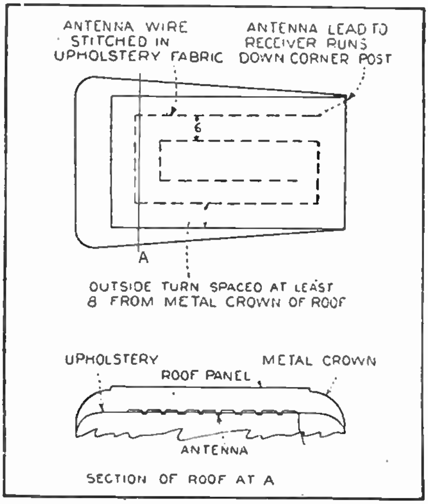


FIGURE 7

that it is worth a trial in any car in which a radio is being installed, because it offers the quadruple advantages of high effectiveness, inconspicuousness, negligible cost and easy installation.

A NOVEL ANTENNA SWITCH

A simple switch arrangement in the input to a radio receiver may be very useful in eliminating local noises and also as a simple

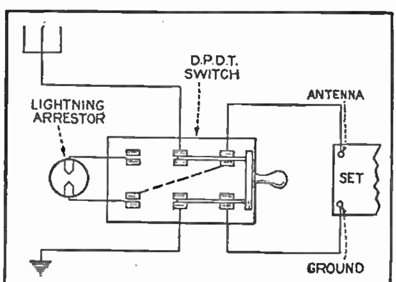


FIGURE 8

means of protection during thunder-storms. The diagram of the arrangement is shown in Figure 8. In the position shown, the switch connects the antenna and ground to the radio set in the usual manner. When thrown to the left, the antenna is connected to ground through the lightning arrester and the ground is connected to the antenna binding post of the receiver, thus employing the double-ground system of reception, the other ground being automatically provided through the power supply lines. This scheme is particularly applicable to receivers which draw their operating power from the electric light lines.

IMPROVED METHOD OF ANTENNA COUPLING

One of the difficulties encountered when endeavoring to "gang" the condensers in a tunable-frequency amplifier is to so arrange the antenna coupling that the first stage condenser "tracks" with the others throughout the desired range. To compensate for antenna effects on the tuning range of this first condenser, the design of the associated transformer is generally not the same as that of the following transformers and some form of variable connection is supplied for antennas of different lengths.

The reason for this change in tuning range is readily found on

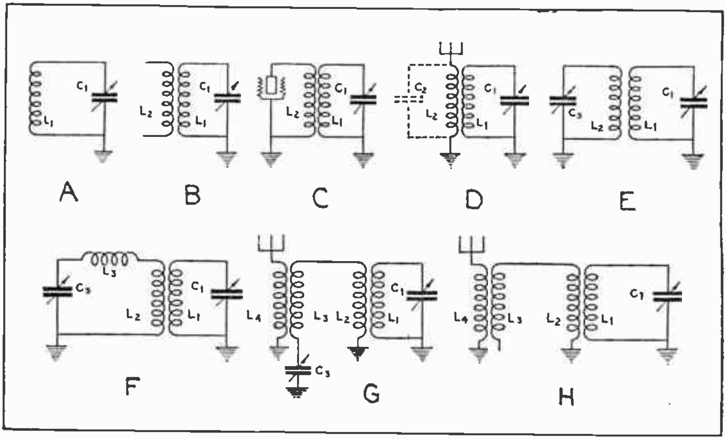


FIGURE 9

comparing the characteristics of the primary circuits. Given a simple circuit, as shown in (A) Figure 9 above, a tuning curve can be plotted which depends entirely upon the value of inductance L1, the distributed capacity of the coil, and the maximum and minimum values of condenser C1. Such a curve is shown in Figure 10, curve (A). If a second inductance, L2, circuit B, representing the usual primary of a radio-frequency transformer, is coupled to L1 and left open-circuited the tuning of curve of C1 will be practically unchanged.

To produce more nearly the actual conditions found in an assembled radio-frequency amplifier the plate and shield grid of a tube may be connected across L2, circuit C. Assuming a coefficient of coupling between L2 and L1 as normally used in amplifiers of this type, the presence of L2 and its associated circuit will now have an effect on L1; this effect being to increase the inductance of L1 and change the tuning range of C1 as is shown in Figure 10. curve (B).

Circuit C approximates the actual condition of all tunable stages except the first, which must be connected to the antenna and yet have the same tuning range as circuit C, curve (B), if perfect single-dial control is to be realized.

If an antenna now be connected to this same primary, L2 circuit D, it will be found that the effect of L2 on L1 becomes much greater since now the inductance and the capacity of the antenna has been introduced in the primary circuit. This effect is shown for short, medium and long antennas in Figure 10 curves (C), (D) and (E).

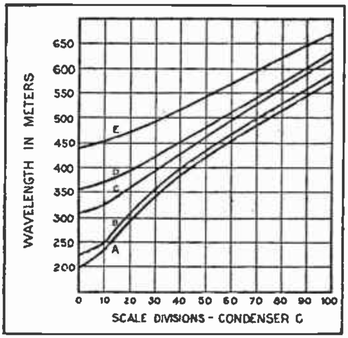


FIGURE 10

It is evident that L2 in the first stage cannot be as great as L2 of the following stages, which means that the first transformer requires special treatment in design. Further, only an approximation of the exact tuning can be made for the first condenser if such transformer differences exist, and this approximation holds for only one antenna condition. By means of taps or auxilliary condensers allowance may be made for antennas of different lengths. Luckily the conditions are not so critical but what approximations may be made with some degree of success.

However, it is possible to eliminate some of the difficulties outlined above by attacking the problem from another angle. Assuming that it would be best, from a design and cost standpoint, to keep the transformers of the first stage the same as the transformers of all the other stages, the primary, secondary and their proximity are then fixed by the result of the general transformer design dealing with selectivity and gain. Going a step further, a variable condenser, C3, circuit E, may be connected across L2, and if adjusted to the same capacity as that formed by the shield grid and plate within the tube, plus any additional capacity introduced by the connecting leads, the identical curve (B) of Figure 10 will again be obtained.

In order to secure a means of coupling the antenna to the primary circuit an additional inductance L3 can now be inserted in series, circuit F. L3 is completely shielded from L2 and L1 and the characteristics of the primary can be adjusted to their former values by reducing the capacity of C3. If now the antenna be coupled to L3 by an inductance L4, circuit G, it is evident that large changes may be made in the circuit of L4 with but negligible changes in L1, since the inductance changes produced by one circuit upon the other become progressively smaller. This is readily checked experimentally by obtaining the tuning range curves for short, medium and long antennas. It will be found that they all coincide with curve (B). A further check consists in varying the coupling between L3 and L4. It will be found that the effect on the value of C1 for a given frequency is substantially negligible.

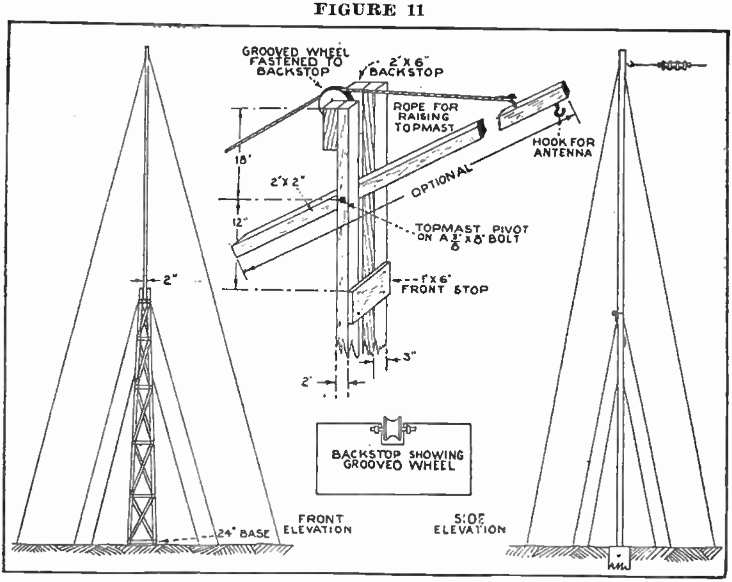
The value of L3 depends to some extent on the characteristic of the transformer L2-L1 and the desired operation of the amplifier as a whole, but is not at all critical. If it is of the order of L1, C3 will be reduced to such a small value that it can be eliminated entirely, the capacity of the winding L3 at ground being sufficient. The final arrangement then takes the form of circuit H.

The advantages of the above system of antenna coupling are: (1) it allows perfect "tracking" of the first-stage condenser with the other condensers; (2) all the radio-frequency transformers can be identical in construction; (3) it opens possibilities of volume control by variation in antenna coupling.

AN AERIAL MAST

Figure 11 shows an aerial mast that has many advantages over

FIGURE 11



those generally erected, in that the aerial wire and its attachments can be fixed at any time from the ground without lowering the main mast. It is light, but strong, and is pleasing in appearance. These points, coupled with simplicity and cheapness, make it worthy of the attention of the radio fan.

There are two sections; the lower one is a light latticed affair and the top one pivoted to the lower.

The lower mast can be built from a piece of 2 by 6, straight-grained and fairly clear. Rip this down the center and spread at the bottom to 24 inches, inside, and a little less than 2 inches at the other end. Lattice this up to suit your fancy, to within 30 inches of the narrow end. Here nail or screw a piece of 1 by 6, hereafter called the front stop, and on the other side, at the extreme top, nail or bolt a piece of 2 by 6 with a grooved pulley set in it. This is the back stop. How this pulley is inserted can be seen in Figure 11. When completed the lower mast should have suficient guys attached on each side at the top, and two-thirds of the way down, to make it secure when erected.

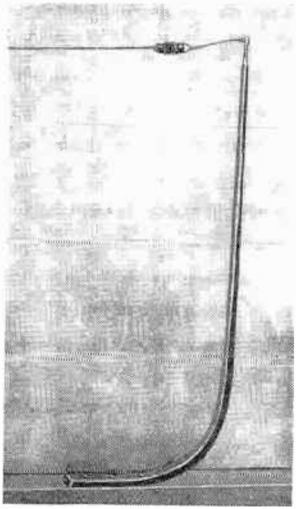
Next prepare the top mast. This is made from 2 by 2 banister stock or other straight-grained stuff and should be free of all but the smallest imperfections. This is pivoted between the legs at the narrow end of the lower mast, about 18 inchs from its top end. A ⅜-inch by 8-inch bolt is useful for this purpose. This pivot is then equi-distant between the front and back stop. A rope is fastened about two feet from the top end of the top mast and passed over the pulley. Now raise the lower mast by pushing it up with the top one, using the latter as a sort of pike pole. The lower ends of the lower mast can be pivoted between two pieces of 2 by 4 set in the ground or they may be set right in a hole. The use of cement is suggested here, bearing in mind, though, that this may make it a landlord's fixture. The lower mast is now erect, but the guy wires are dangling around and must next be fixed, being sure that the mast is perpendicular and straight with the world.

Next attach the insulator, antenna and guy wires to the top mast, which still has its high end within reach of the ground; go around to the other side of the lower mast and pull on the rope that was placed over the pulley. Up goes the top mast, carrying with it the aerial, etc. When this is nearly erect the rope will leave the pulley of itself and then is used as a guy. The top mast rests against the front and back stop. The side guys are finally drawn tight.

Whenever the aerial requires adjustment, simply loosen the ropes. The weight of the aerial will start it down. Guide the rope back on to the pulley as it goes down and do your fixing from the ground.

SIMPLE ANTENNA "'POLE''

Aerial wires are often run along the ridge of a building, frequently with clumsy aud unsightly pieces of 2″ x 4″ nailed up at each end to hold the wire. More work and material are made use of to keep these ''lumber piles'' up in the air than to hold the wire. if the wire along the building is not too long, a very neat and practical arrangement can be made as shown in Figure 12. Simply an old rib and socket from a discarded auto top. A number of small lag screws can be nicely used to secure it firmly to the capping, as the piece is light, but very strong with a bit of string. Such fastenings or holders present a neat and workmanlike appearance. You can get them of any length you wish from a junked car dealer just for



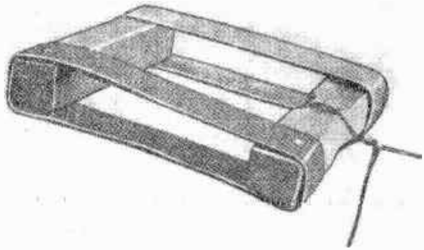


FIGURE 12, LEFT—
FIGURE 13, ABOVE.

the asking, at most for the work of tearing them from an old car yourself.

NOVEL INSULATOR

These are the days of the camp and the open road, with their difficulties. Temporary radio installations bring forth some ingenious

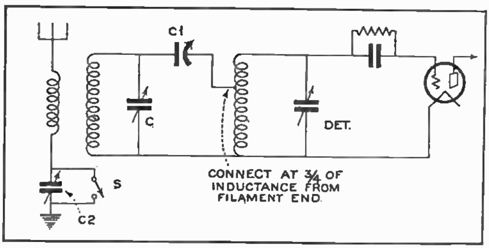


FIGURE 14

methods of "getting by" as things which should be taken care of are only too often forgotten. Figure 13 shows a novel insulator and aerial connection found attached to the side of a summer cottage.

Just two small inch-square sticks around which were tacked two rubber bands cut from an old tire inner tube. Easily made, easily put up and quite satisfactory in performance.

ANTENNA TUNING UNIT

The antenna coupling unit described here was designed primarily to aid in reducing interference and to eliminate resonant points occurring over a wide range of frequencies. Everyone has experienced the difficulties of antenna "drags" taking place while tuning a regenerative receiver due to the effect of the antenna on the oscillating detector circuit.

Figure 14 shows a circuit which was found adaptable for reception of all short waves, with a resultant increase in selectivity and sensitivity. The trap circuit also reduces radiation or so-called "blooping."

In actual measurements made while the circuit as shown in Figure 14 was in use, it was found that the signal was increased about three times in the 15,000 kc. band, and was estimated to be as high as fifty times in the lower bands.

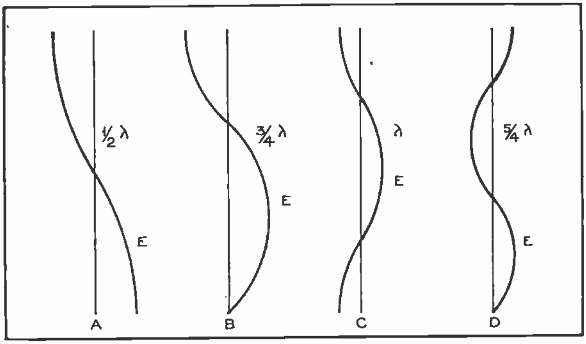


FIGURE 15

Most of the receivers developed at the present time are designed for coupling to the antenna through a small series capacity or through a few turns of inductance. Both these methods have a disadvantage of reducing the signal strength when the detector circuit is too strongly coupled to the antenna. There is also the disadvantage of poor selectivity. If the antenna is connected through a condenser directly across the grid coil of the detector circuit, the applied signal voltage to the detector will be equal to the resonant voltage across the coil. Under this condition, the detector will take an inappreciable current, resulting in no power . From this data the detector circuit may be considered to cause an increase in the antenna resistance by an amount R. The total antenna resistance will, therefore, be equal to R plus R1. Thus for obtaining increased signal strength and the greatest degree of selectivity, it is advisable to reduce the coupling below the point of strongest signal, as a marked increase in selectivity is made possible with only a slight reduction in signal intensity.

An increase in signal strength is made possible when using the circuit as shown in Figure 14, by transferring the energy at the proper point. Figure 15 shows the voltage nodes or current loops in various types of antennas. Note that it would reduce the efficiency of the antenna system as shown at a and c if the free end is grounded. However, the antenna as shown at b or d would function most efficently if grounded at the lower end.

Figure 16 shows the voltage and current distribution in a full-wave antenna. For obtaining maximum transfer of energy to the detector circuit, the type of coupling along the antenna as shown should be used. Thus the antenna should be coupled capacitively at the voltage loops and inductively at the current loop points. If an

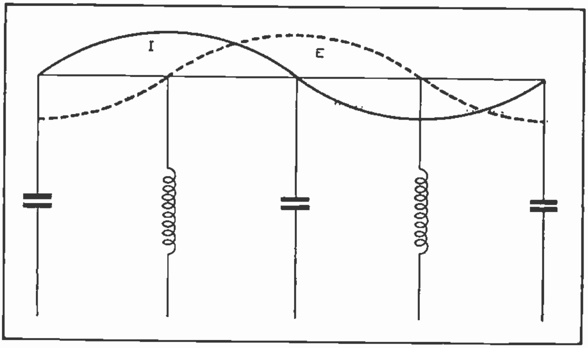


FIGURE 16

antenna as shown at 15 (d) is employed and is tuned to resonance, the antenna turns are at the current loop point, resulting in the transfer to the detecor circuit of the greatest amount of signal voltage. In an antenna operated at full wave or on its second harmonic value as shown in C, the antenna turns are at the current node point with maximum voltage in the coil system, resulting in the transfer of energy taking place capacitively rather than inductively. The signal strength would therefore be decreased due to poor coupling. At other points along the antenna the current and voltage distribution may be such that their respective fields neutralize one another through the antenna coil system, resulting in practically zero coupling.

In the antenna system, Figure 14, the current and voltage nodes and loops move along the antenna as the frequency of the tuned cicuit is varied. In general, the antenna circuit is tuned while the secondary circuit is also tuned and coupled to the antenna by means of mutual inductance between the coils in the primary and secondary circuits. When the antenna circuit is adjusted to the proper current loop point, a current taking place within the antenna coil will induce an e.m.f. in the secondary coil. If both circuits are properly tuned to the incoming signal, the current received from the signal will be relatively much larger than currents produced by interfering signals. Since the e.m.f. of signal frequency induced in the secondary circuit produces relatively large currents, and a larger resonant voltage across the coil system, it must be transferred capacitively to the detector circuit. Thus, it is once understood that a condenser-coil combination as illustrated in Figure 14 will permit a variation of voltage and current distribution along the antenna to be adjusted at will, resulting in a reduction in losses of signal voltage.

The signal is fed to the detector circuit through the variable condenser C1. The correct value of this condenser is .0001 mfd., and should be set for obtaining maximum results at 80, 40, 20 and 10 meters. The readings giving maximum results for each band should be marked on the dial controlling the condenser C.

If the antenna coupling unit as described in this article is employed ahead of a radio-frequency amplifier, increased selectivity will be obtained with a moderate gain in signal strength due to very little change taking place in the effective resistance of the antenna circuit. Also, an additional gain is made possible by operating the antenna on the proper distribution point of current and voltage loops.

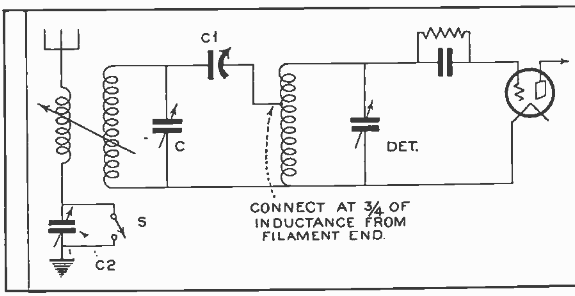


FIGURE 17

After the circuit has been built and connected as shown in Figure 14, it should be tuned to resonance with the detector circuit, and the capacity of the condenser C1 decreased until the detector circuit will oscillate vigorously with an increase of several divisions of the regeneration control dial. In order to obtain maximum results, the regeneration dial is increased to about six divisions higher than was required for previous operations, and the coupling capacity both circuits to resonance without stopping the detector from oscillating.

The circuit as shown in Figure 17 gives uniform results as to signal intensity, along with any desired degree of selectivity. It must be remembered that the closer the coupling between the circuits, the larger the fraction of power which is transferred to the secondary, however, as the coupling is increased the resistance of the primary is increased. Thus the power taken by the primary circuit from the signal is reduced. In fact, the maximum power is obtained in the secondary circuit when the increase in resistance of the primary due to the coupling is equal to the resistance of the primary by itself. For this reason, there is an optimum coupling where the greatest signal strength is obtained along with increased selectivity. A further gain in selectivity is made possible by decreasing the antenna coupling.

The coupling coil is made variable and is controllled by a knob from the front panel.

The condenser C2 is a .000075 mfd. type and is placed in series in the antenna circuit and reduces the total antenna capacity as the condenser capacity is reduced, hence the shorter the walvelength to which the antenna circuits is tuned. It is therefore quite evident that a considerable range in wavelengths can be covered with one plug-in coil. The switch S enables the operator to short the series condenser, leaving the antenna loaded, which will change the distribution of the node points along the antenna.

COIL-WINDING DATA

Band	Antenna Coil	Secondary Coil
80-meter band	7 turns	22 turns
40-meter band	5 turns	13 turns
20-meter band	4 turns	5 turns
10-meter band	3 turns	3 turns

All coils are wound on 2-inch bakelite-forms with No. 22 enamel-covered wire.

The wire is wound 18 turns to the inch. The antenna coils for the circuit shown in Figure 14 are spaced ½ inch from the secondary coil. The variable antenna coupling coil for the circuit shown in Figure 17 is scramble wound and is made large enough in diameter to go over the secondary coils.

CHAPTER 13

Miscellaneous Notes and Experiments

There is really nothing complicated in recording at home, providing one devotes a little time in deciding on which is the most satisfactory hook-up to use with the particular equipment he has on hand.

The purpose of this article is to discuss some of the important things about recording and to pass on information obtained in experimenting with home recording equipment.

Before we can talk about recording we must have a fairly good idea of the electrical pick-up as used for reproducing records (see Figure 1). An electrical pick-up is made up essentially of a permanent magnet with a coil suspended between the poles. The needle

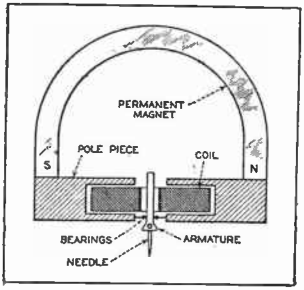


FIGURE 1

is secured to a small armature which sets in the field of the coil and is swung on a pivot. When the pick-up is riding on a record, the lateral variations on the record cause the needle to vibrate and this in turn vibrates the armature. Movement of the armature between the poles produces a corresponding variation of the mangnetic flux set up by the permanent magnet. This flux is diverted through the armature and in turn through the coil. The a.c. voltage induced in the coil can be impressed on the input of an audio amplifier and amplified in the conventional manner.

For recording, the process is reversed. The electrical pick-up or cutter is connected at the amplifier outputs in place of the loudspeaker. The a.c. voltage at the amplifier output is fed to the coil in the cutter and this in turn drives the needle. If the cutter is now permitted to ride on a blank record, the mechanical vibrations of the needle will modulate the record grooves, thus permanently recording the signals.

The average pick-up has a pressure at the needle point of 4½ ounces. This is not sufficient for recording. Experiments conducted with different values of weight at the needle point show the minimum weight for good recording to be 1½ pounds. If less than this value is used the results will be relatively poor and the record can only be played a few times before the recording is entirely destroyed.

An ideal set-up for recording should consist of an amplifier having at least two stages of a.f. amplification, with a gain of 35 db. or higher; two electrical pick-up units, one for reproducing and the other for recording; a radio tuner; a double-button microphone, and a 78-r.p.m. motor. These are hooked up as shown in Figure 2. By referring to the diagram you can see that we have three sources of input to the am-

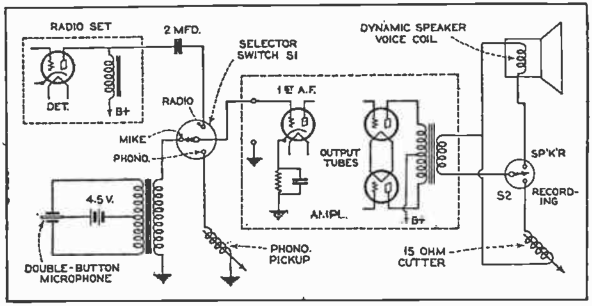


FIGURE 2

plifier, i.e., radio, microphone, and pick-up. Any one of these can be used simply by manipulating the single-pole, three-point selector switch, S1.

Going to the output circuit, we have a pair of output tubes in push-pull, step-down transformer having a 15-ohm secondary to couple to the voice coil of a dynamic speaker, and a 15-ohm cutter. For reproducing, we can flip the single pole, double-throw switch S2 to the speaker position, and to the recording position when ready to record.

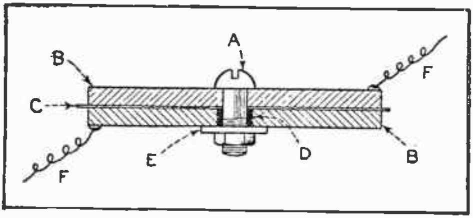
A FIXED CRYSTAL DETECTOR

While the tonal qualities of a crystal detector have always been recognized, its neglect or lack of use has been due probably to its instability when constructed along conventional lines. This difficulty has been overcome by the construction of an efficient fixed detector, as described in this article, which comprises a pair of metallic plates having a thin dielectric sheet, such as tracing cloth, clamped between the plates, and having small grains of unilateral conductive material embedded in and extending through the sheet, forming a restricted unilaterally conductive connection between the plates. The construction is shown in Figure 3 is substantially as follows:

Two plates one inch square of any metal sufficiently thick (about 3-32), having parallel smooth faces, are drilled in the center to accommodate a No. 8-32 machine screw, one plate being insulated from the screw by a small fiber washer and the other, the bottom plate, holding the machine screw.

Upon this plate, and permiting the machine screw to extend through, is placed a piece of linen tracing cloth slightly larger in area than the plate. Tracing cloth is used because it was found to be more uniform as to thickness and density and is more easily punctured than ordinary paper or other dielectrics. If the top plate is now placed in position and the nut of the screw tightened, the device would resemble an ordinary condenser. Before placing the top leaf of the holder, sprinkle lightly over the cloth dielectric fine particles of galena, iron pyrites or other such material having unilateral conductivity. The size of these particles must be uniform and no larger than the thickness of the dielectric. By passing the particles through a 100-mesh screen, the exact size may be obtained. Now the top leaf may be put in place. Previous to assembling the plates, there should be soldered to each metal plate a small wire about three inches long, forming a lead to accommodate the attaching of the crystal holder to the circuit.

After the top plate is put in place, having previously placed an insulating washer under the nut, screw down the nut, but not so



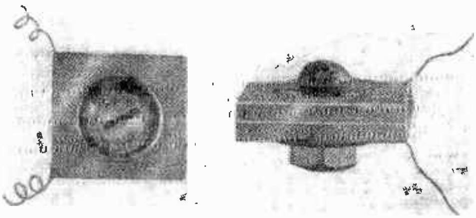


FIGURE 3, ABOVE—
FIGURE 4, BELOW.

tight as to puncture the dielectric. Place the device across a bridge circuit that will measure the unilateral conductivity; tighten the nut until a deflection is obained, reverse the current flow and note the deflection. Adjust the nut until a ratio of current in one direction to that in the other is at least six to one, keeping the lowest side down to the minimum amount of current. The smaller the current flow of the low side, the better the detector. The plates will be found held tightly together.

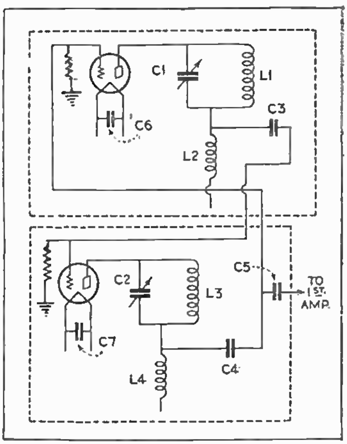
In the absence of a bridge, the crystal may be mounted directly in series across the aerial and ground, having the phones in parallel; and tune the crystal holder by tightening the nut until the loudest signal is obtained.

A microscopic examination of the dielectric shows several irregularly shaped punctures and the fact that the minerals have point-to-point contact with either or both plates. The plate holder has some capacity but is quickly drained out, due to the approximate contacts of the minerals to the plates.

By constructing a crystal holder as outlined, a sensitive detector can be made, having many points of contact instead of the single, flimsy "cat whisker" type, and lends itself to a permanence and stability not obtained otherwise. After adjusting the plates to resonance, dip the assembled crystal holder in paraffin or coil dope, which prevents the elements from oxidizing. The assembled crystal plate holder shown in Figure 4 has the ability to handle tube currents without changing its characteristics and to maintain its permanence over long periods of time.

CONSTANT FREQUENCY WITHOUT A CRYSTAL

For some time amateurs have felt a need for an inexpensive way of keeping their transmitters constantly on one wave-length. The only means of getting constant frequency is with a crystal with a temperature control. In cases where a master oscillator with an amplifier or two between the master and power amplifier, the circuit is all the more



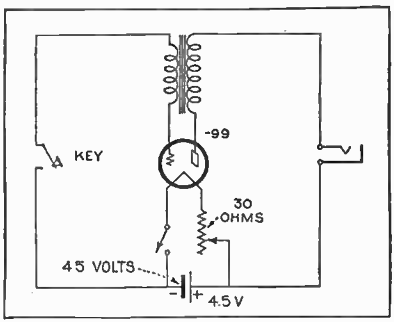


**FIGURE 5, LEFT—
FIGURE 6, ABOVE.**

useful, as a slight shift of the master throws every circuit out of tune.

Figure 5 shows the circuit of master oscillator that will cost little and give frequency stability comparable with that of a crystal. The proof of the last statement is borne out by the fact that the circuit described is now in use in a 50-watt push-pull transmitter without a choke or by-pass condenser in the plate supply to the two 50-watters. Any amateur knows that the slightest frequency shift would burn our plate supply in no time. One of the greatest advantages of this arrangement is that the frequency can be varied to suit one's requirements while still the same constancy of frequency is obtained. This gives the transmitter a flexibility which offsets any possible superior steadiness of the crystal.

The diagram needs very little explanation. Coils L1 and L3 are coils wound to your frequency. Condensers C1 and 2 match the coils to produce the correct frequency. Condensers C3 and 4 can range from .005 to .0005. Chokes L2 and L4 should be very good or two chokes should be used with a by-pass to ground from a point between them. C5 should be about .0005. Each stage should be completely shielded. The leads to the grids should be shielded or placed as far apart as possible. A—, B— and shields should be connected to

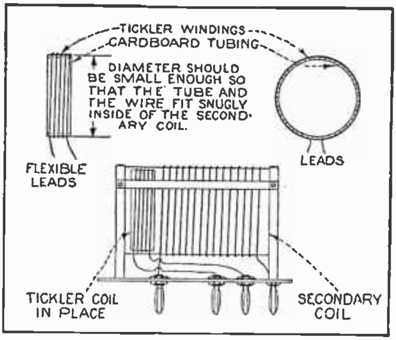


FIGURE 7

a good ground. C6 and C7 by-pass any r.f. on the positive filament side to ground as A— is grounded.

To tune this circuit shift the tuning condensers till both circuits are tuned on the desired frequency. Only when both circuits are perfectly in tune will it oscillate.

Tubes from the -99 to the -10 types have been used in this circuit, and with various plate voltages on each tube, yet have never experienced frequency shift.

SIMPLE CODE PRACTICE SET

Those interested in learning the code can easily construct a practice set which employs a single type -99 tube, a 4.5-volt battery, an old audio transformer and a rheostat, connected as shown in the diagram (Figure 6.) In this circuit the filament battery serves also for the plate supply and for this reason the rheostat must be connected in the positive side of the filament so as to raise the plate potential slightly above that of the filament. Ordinary headphones are plugged into the jack and the practice key is connected as shown. A pleasing and rather high-pitched note will be heard in the headphone when the key is pressed.

VARIABLE TICKLERS

In making s.w. coils of the cage type there is a great amount of guesswork as to where to put the tickler coils. This may be overcome by winding the tickler coil on a piece of cardboard tubing which will fit snugly inside the secondary coil frame. The tubing and its wires may be moved back and forth until the best location is found. The accompanying, Figure 7, may help the contructor.

SECRET RADIO COMMUNICATION

Figure 8 shows circuit diagrams for a simple tuning system which permits secret radio communication without resorting to the use of code words or complicated mechanical or electrical synchronizing systems.

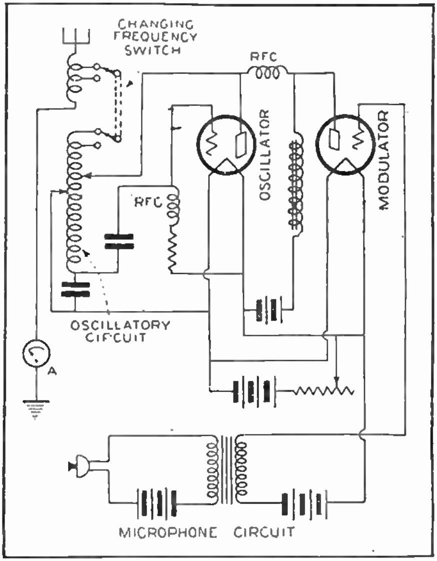


FIGURE 8

The plan outlined here should be of advantage in police work as well as in ship-to-shore communication.

The principle involved is that of splitting up a message, transmitting parts of it on one frequency and other parts on a second frequency, the shift from one frequency to another being accomplished by means of a switch located within easy reach of the operator of the transmitter. At the receiving end, a superheterodyne circuit is employed, the basic circuits of which are shown in Figure 9. This receiver consists of two frequency change or heterodyne circuits, each including its own oscillator and detector. One of these circuits is tuned to one of the frequencies of the transmitter and the other to the second frequency, and both circuits are connected to the same intermediate frequency amplifier. Thus signals on either frequency can be picked up without involving any switching arrangement at the receiving end.

In using this system a police alarm might be transmitted as follows, the Roman representing the transmission on one frequency and the Bold the transmission on the second frequency: "Squad 40, **District 10, investigate robbery of** drug store at **14410 North** Racine Avenue." Anyone not equipped with a duplex receiver tuned to both of the transmitting frequencies employed could receive only one part of this message.

1250 MILES WITH A CRYSTAL DETECTOR

Figure 10 shows the circuit of a crystal receiver which has tuned in stations up to 1250 miles distant although it cost only 90 cents to build.

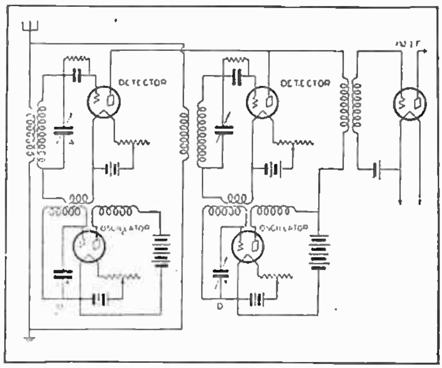


FIGURE 9

The coils used are of the spider web type, wound on forms having 13 prongs. As indicated in the diagram, one of them is an antenna

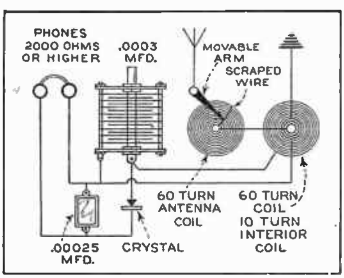


FIGURE 10

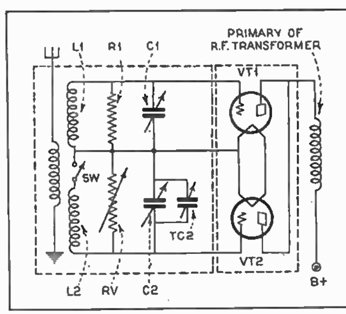


FIGURE 11

loading coil. This is equipped with a slider. The other coil is the antenna-coupling coil, consisting of primary and secondary windings. The secondary is tuned by means of a .00035 variable condenser. The number of turns for each coil is shown in the diagram.

The coils are mounted at right angles. The antenna coil is placed flat on the baseboard while the other coil is mounted in a vertical position. All windings employ number 22 d.c.c. wire.

EXPERIMENTS IN STATIC REDUCTION

Experiments with push-pull radio-frequency amplifiication have produced the static-reducing hook-up shown in Figure 11. This circuit gave very good results. The circuit of L1, C1 receives the incoming desired signal and also the normal static or interference. The resistor R1 is shunted across the circuit in order to make sure that the voltage developed across L2, C2 will be higher than the voltage across L1, C1. Circuit L2, C2 is tuned to a slightly different frequency than circuit L1, C1. The static and interference comes in through both tubes and the signal through VT1 only. As the plates are in parallel and the grids in push-pull, any impulse applied to both grids will be neutralized in the plate circuit while an impulse applied to one grid only will be passed on to the rest of the set. A signal, therefore, may enter through either tube, and so the trimmer TC2 is used to tune circuit C2, L2 to a frequency as close to the one that it is desired to receive as possible without tuning to the frequency of another station. The variable resistor Rv is used to balance the input to VT2 so that it will be exactly the same as the input to VT1 and will therefore balance out the latter. By throwing switch SW, the set becomes a conventional tuned radio set. By closing the switch, the balancing tube is in the circuit and almost instant comparisons can be made. Using this arrangement and other modifications of the same idea, it has repeatedly been found to receive medium distant stations at a time when it was almost impossible to receive local stations with the switch thrown to the conventional side, due to local interference. These results have been obtained using this circuit as the input to a shielded superheterodyne receiver.

TIPS ON DX BROADCAST RECEPTION

DX reception records are not entirely a matter of location or luck. A good antenna and ground and knowing when and where to tune for distant stations—particularly foreign stations—are all factors of the utmost importance. The following, from a fan who has made some remarkable records, contains much to interest the DX enthusiast:

Foreign reception on the broadcast band—the channels between 1500 and 550 kilocycles—is practically impossible without a good aerial and ground system. My aerial is 55 feet above the ground, and free from tin roofs or other metal masses. The length is 150 feet, including the lead-in. I find a longer aerial may give more volume, but the selectivity of the receiver is cut down so much that the slight increase in volume does not warrant the increased length. The lead-in is kept away from large metal masses, such as tin roofs, and as well away from walls as possible. My ground is made up of three ten-foot pipes, buried wire and buried copper plates, all connected together All the metal is buried in rock salt, which tends to hold moisture and provides a better electrical contact. In both my aerial and ground all connections are soldered, taped and painted.

In tuning for foreign broadcast-band stations, many things must be considered that would be minor in successful tuning for United States stations. For instance, before I hope to tune in Australia, I must consider the month of the year and the exact hours of the day. I found that stations below the equator come in best during the months of October and April—or, in other words, during the spring and fall. The reason for this is that during these particular months both the points of transmission and reception are favored with rather cool weather —a necessity for good reception. Due to time difference, a station in Australia will not come through here in the United States before about four a.m. E.S.T. In fact, all trans-Pacific reception from such countries as Japan, New Zealand and Australia is accomplished between four E.S.T., and daybreak. Four a.m., E.S.T., corresponds to seven p.m. the same day in Sydney—thus it is seen that we must wait until it is dark in Australia before we can tune in their broadcast-band stations. Among the most heard trans-Pacific stations are the following, and I suggest that readers try for them before attempting to bring in others: 4GQ Brisbane, 760 kc.; 2BL, Sydney, 855 kc.; 2YA, Wellington, 750 kc. (same wave as WGN); and JOIK, Sappora, Japan. At present there are eight ten-thousand-watt stations in Japan, and these are heard quite frequently on the Pacific coast. The Australian stations only have about three thousand watts.

Tuning for Europe and South America is more difficult, despite the fact that they are nearer than are the stations across the Pacific. This variation in reception is caused by the time difference between these countries and the United States. Europe is five to six hours ahead of our time, thus they sign off with their evening programs before it gets dark here in the States. As for South America, their time is about the same as ours, and their stations are on at the same time as our locals, which makes them extremely difficult to bring in.

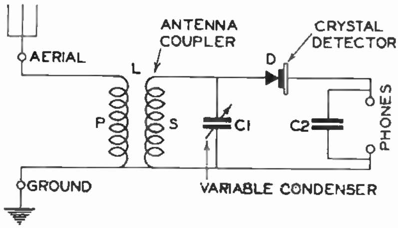
Although theoretically it should work out, reception of the early morning broadcasts of the European and South American stations is rather unsuccessful. This has and can be done, however.

Now considering United States reception. As West Chester is in eastern Pennsylvania, my best continental catches are those stations on the Pacific coast. I have learned that reception of small stations —those of 100 watts power or less—is usually accomplished after midnight. Between this hour and daybreak thousands of DX'ers are twirling the dials for these small stations that can only be picked up when on a very early morning test program or when giving a DX program for the listeners. I have heard a 100-watt station in every state that contains a station of that low a power, and a total of 63 stations in the four Pacific coast states (counting British Columbia). Like my foreign reception, these too are confirmed in letters from the stations.

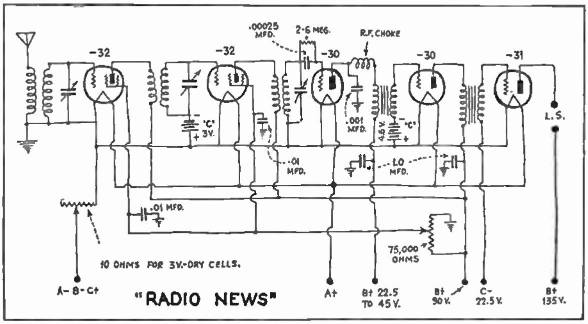
CHAPTER 14

Miscellaneous Notes and Experiments In Radio and Electronics

CIRCUIT NO. 1. is a schematic diagram of an inductively-coupled tuned crystal receiver. The capacity of the variable condenser C1 is .00035 mfd. and the fixed condenser C2 is .001 mfd. The coils may be wound on a cardboard form 1½ inches in diameter by 3½ inches in



length. The primary winding takes approximately 10 to 15 turns and the secondary winding 90 turns of No. 24 D. C. C. wire.

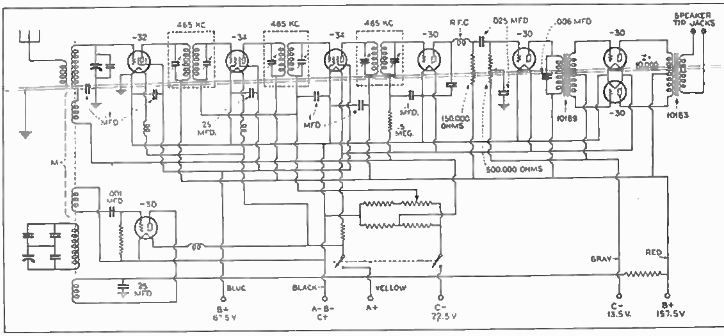


CIRCUIT NO. 2

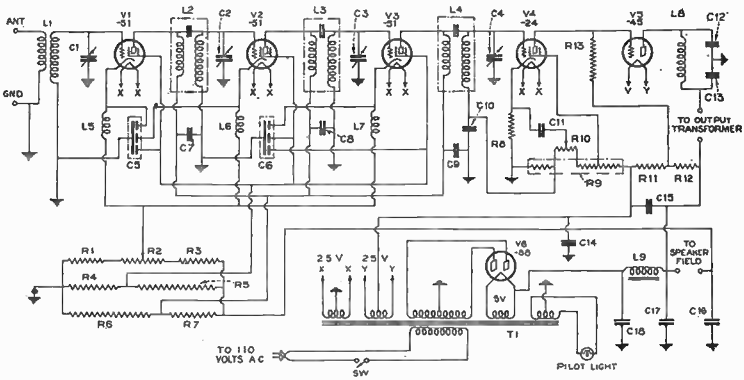
CIRCUIT NO. 2 is a schematic diagram of a tuned-radio frequency circuit using the two volt type tubes. This circuit is simple to construct and is especially adapted to portable receivers or to farms that are without electric lighting supply.

CIRCUIT NO. 3 This two-volt tube superheterodyne circuit for air-cell operation is especially adapted for use where line current is not available. It has class B audio amplification with a resultant low B battery drain.

CIRCUIT NO. 4. A compact 6-tube circuit with a direct-coupled audio amplifier, multi-mu type tubes and perfect voltage regulation. A combination of impedance and inductive coupling is employed in the r.f. tuner. The value of the blocking condensers is .00002 mfd. capacity.



CIRCUIT NO. 3

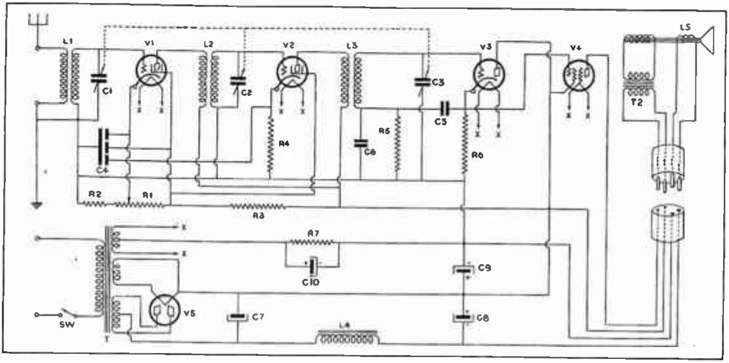


CIRCUIT NO. 4

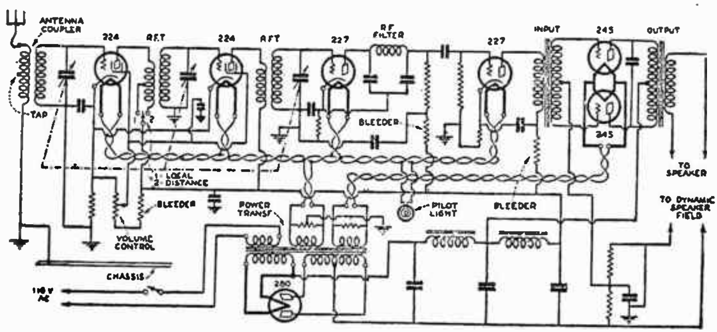
CIRCUIT NO. 5 A five-tube tuned r.f. circuit designed for midget construction. The -51 multi-mu type tubes are employed for the two r.f. stages, a -27 tube for the detector, a -47 pentode for the power stage and an -80 tube for rectification. The values in ohms for the resistances are as follows: R1, 10,000; R2, 350; R3, 15,000: R4, 1000; R5, 250,000; R6, 30,000; R7, 2000 ohms.

CIRCUIT NO. 6 is a 7-tube tuned-radio-frequency receiver with -24 screen grid type tubes. The power unit has provisions for a field voltage to a dynamic type reproducer. The receiver is equipped wtih a local distance switch and volume is controlled by varying the voltage to the screen grids of the -24 type tubes.

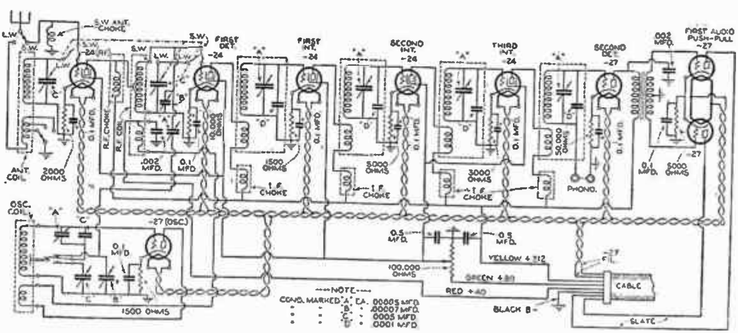
CIRCUIT NO. 7. A 12-tube all-wave superheterodyne circuit with adjustable antenna coupling and provisions for connection to a phonograph pick-up or microphone. The receiver chassis includes the receiver up to and including the first audio stage.



CIRCUIT NO. 5

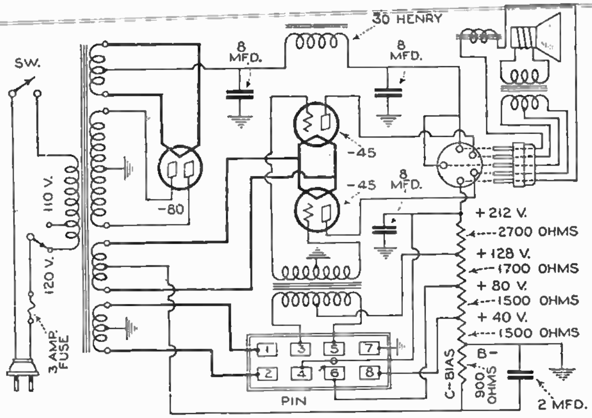


CIRCUIT NO. 6



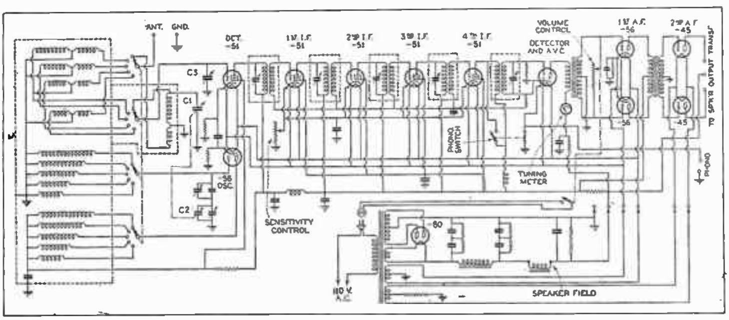
CIRCUIT NO. 7

CIRCUIT NO. 8 is the separate power amplifying unit for the receiver circuit diagram No. 7, and includes the pushpull power output stage with -45 type tubes.



CIRCUIT NO. 8

CIRCUIT NO. 9. This 12 tube superheterodyne circuit for long and short waves, is designed for band switching arrangements, a noise suppression system and automatic control of volume employing the new

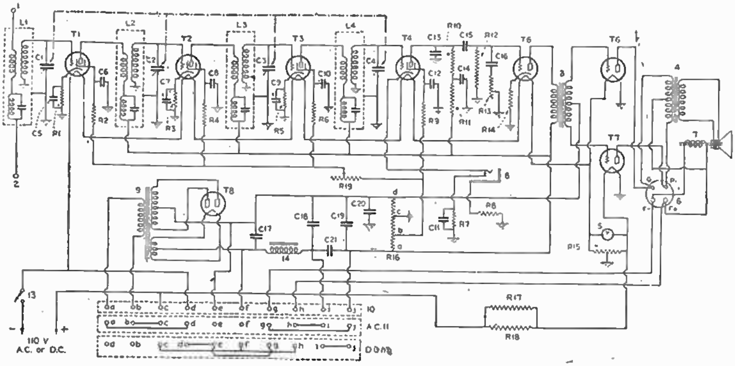


CIRCUIT NO. 9

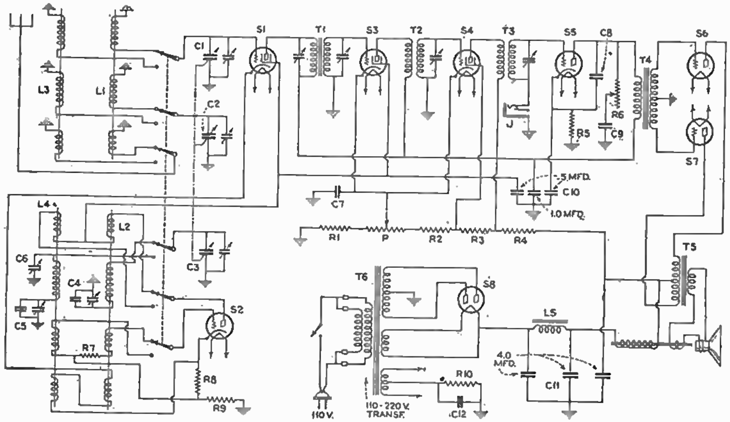
Wunderlich type tube which also functions as the second detector tube.

CIRCUIT NO. 10 is a diagram of a universal receiver operated from either 110 volt a.c. or d.c. line supply, by means of a switching arrangement which is operated by a circuit changing plug on the back of the chassis. The same tubes are employed for either the a.c. or d.c. operation and include four -24 screen grid type, one -27 type and two -45 type. The -80 type rectifier is used on the a.c. circuit but it is automatically disconnected by the d.c. changing plug.

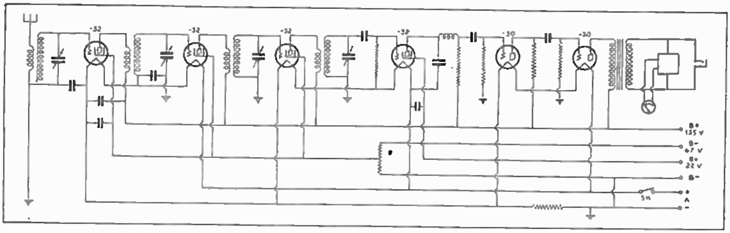
CIRCUIT NO. 11. A receiver designed to tune from 200-2,000 meters



CIRCUIT NO. 10



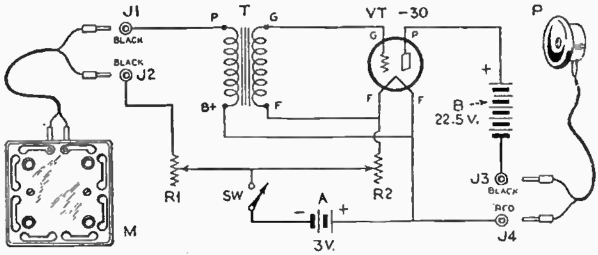
CIRCUIT NO. 11



CIRCUIT NO. 12

CIRCUIT NO. 12. A six tube tuned r.f. circuit with resistance-coupled audio amplification, especially designed for a portable radio interference measuring meter. The intensity of the interference can be measured by headphones connected in the output circuit. A highly damped output meter is employed for accurate measurements.

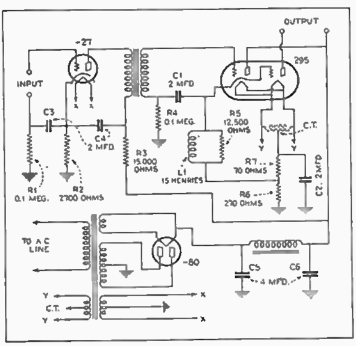
CIRCUIT NO. 13 is the schematic diagram of a powerful hearing aid for the deaf. The microphone M works through the transformer T into the grid of the -30 type tube. Single or double headphones of



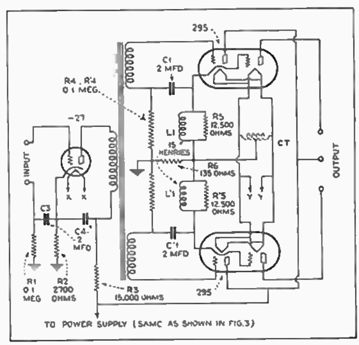
CIRCUIT NO. 13

the proper impedance are connected in series with the 22½ volt B battery to the output of the vacuum tube.

CIRCUITS NOS. 14, 15 are on newly developed audio amplifying systems for the -95 type triple-twin vacuum tube. The high gain of this



CIRCUIT NO. 14



CIRCUIT NO. 15

-95 triple-twin tube allows for unusually small input voltages. The input stage with the standard -27 type tube is adaptable to either phonograph pick-up, microphone or radio tuner.

THE END