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S. W. STRATTON, DIRECTOR

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CONSTRUCTION AND OPERATION OF A TWO-CIRCUIT RADIO RECEIVING EQUIPMENT WITH CRYSTAL DETECTOR

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ABSTRACT

The apparatus used for the reception of radio messages may be a homemade affair, very simple and inexpensive, or may be elaborate and expensive. All that is necessary for receiving radio messages is a device for collecting power from the incoming radio waves, a suitable circuit adjusted or "tuned" electrically to the frequency of the incoming waves, and apparatus for changing the received power into audible sounds.

The device for collecting power from the incoming waves is the "antenna." To the antenna is connected the "receiving set." The receiving set may be adjusted or tuned to the frequency of the incoming wave by varying the inductances and the capacity which are included in the circuits.

This Circular describes the construction and operation of a homemade and inexpensive two-circuit radio receiving set employing a crystal detector. The cost of the materials need not exceed $15. The descriptions are meant to be so elementary and explicit that the set may be constructed by persons having no previous experience with radio.

CONTENTS

1. INTRODUCTION

This Circular[1] describes the construction and operation of a simple radio receiving set which will receive messages from high-power radiotelephone stations over a distance of about 75 miles

[1] This is the second of a series of circulars on the construction of radio receiving equipments. Those who expect to construct the set herein described should first obtain a copy of Bureau of Standards Circular No. 120, Construction and Operation of a Simple Homemade Radio Receiving Outfit, by writing the Superintendent of Documents, Government Printing Office, Washington, D. C., and inclosing 5 cents. Cash may be sent at risk of sender or remittance may be made by money order. Stamps will not be accepted. Circular No. 120 was originally issued in mimeographed form as Bureau of Standards Letter Circular No. 43.

Persons who desire an elementary text covering the principles and practice of radio communication should purchase a copy of The Principles Underlying Radio Communication, Signal Corps Radio Communication Pamphlet No. 40. This is a book of 600 pages and contains 300 illustrations, including circuit diagrams. Price, $1 per copy. Orders should be sent to the Superintendent of Documents.

A much more elementary discussion of radio principles may be found in Signal Corps Radio Communication Pamphlet No. 1, Elementary Principles of Radio Telegraphy. Price, 10¢. An elementary discussion of electrical principles may be found in Signal Corps Training Pamphlet No. 1, Elementary Electricity. Price, 15¢. Orders should be sent to the Superintendent of Documents.

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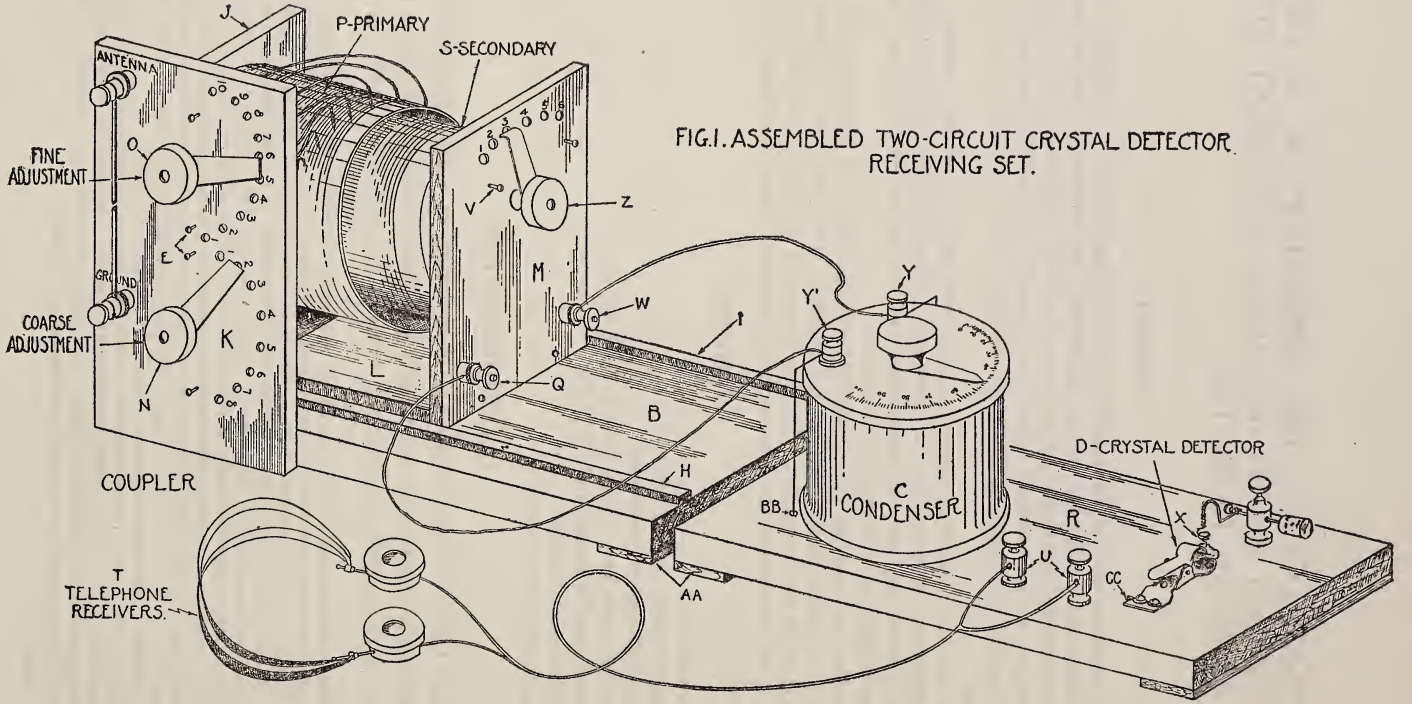

FIG. 1. ASSEMBLED TWO-CIRCUIT CRYSTAL DETECTOR RECEIVING SET.

and from medium-power stations over a distance of about 10 miles. The complete equipment will respond to about the same wave frequencies (wave lengths) as the equipment described in Circular No. 120. Besides receiving over greater distances, another advantage of this set is that it is more "selective," which means that it is easier to distinguish the message from one of two radio transmitting stations when both of the transmitting stations are using wave frequencies (wave lengths) that are nearly the same. This greater selectivity is brought about through the use of two complete electric circuits, both of which are tuned to the incoming waves. This is in contrast to the single-circuit equipment, as described in the first pamphlet.

The total cost of this equipment can be kept down to about $15. Most of the equipment mentioned in Circular No. 120 can also be used with this set, and the cost of the additional apparatus will be about $5.

This publication describes simple apparatus of satisfactory performance without reference to the possible existence of any patents which might cover parts of the apparatus. Apparatus in general similar to that described can be purchased from responsible manufacturers whose announcements can be found in current radio periodicals.

2. ESSENTIAL PARTS OF RECEIVING STATION

Antenna, Lightning Switch, Ground Connections, and Telephone Receivers.—These are completely described in Circular No. 120. The other essential part of the equipment is the receiving set, which is made up of the following parts:

Coupler (Left Half of Fig. 1).—This is composed of a fixed section and a movable section. The fixed section is made up of the coil tube *P*, the upright support *J*, the contact panel *K*, and the base *B*. The movable section is composed of the coil tube *S*, the supporting contact panel *M*, and the base *L*. The movable section is so arranged that coil tube *S* slips inside of the coil tube *P* when *M* is pushed to the left. The coil tubes are made by winding wire on cardboard tubing.

This Circular tells how to construct a coupler. It is of course possible to purchase a coupler of the type here described at almost any store which handles radio supplies. Another type of coupler which may be employed (called a "vario-coupler") has a rotating spherical coil inside the cylindrical coil. In purchasing any coupling device care should be taken to select one which will

operate satisfactorily with the condenser available, so that the receiving set may be tuned to the wave frequencies (wave lengths) desired.

VARIABLE CONDENSER (*C*, FIGS. 1 AND 2).—The variable air condenser should have a maximum capacity rating between 0.0004 and 0.0005 microfarads (400 to 500 micromicrofarads).

CRYSTAL DETECTOR (*D*, FIGS. 1 AND 2).—This is essentially the same crystal detector as was described in Circular No. 120 except that a few improvements have been made in its construction.

ACCESSORIES.—Under the heading of accessory equipment may be listed binding posts, switch arms, switch contacts, test buzzer, dry battery, and boards on which to mount the complete apparatus. The binding posts, switch arms, and switch contacts may be purchased from electrical dealers who handle such goods or they may be readily improvised at home. The pieces of wood on which the equipment is mounted may be obtained from a dry packing box.

3. DETAILS OF COUPLER CONSTRUCTION

MOVABLE COIL TUBE, COIL-TUBE SUPPORT AND BASE (*S*, *M*, AND *L*, FIG. 1).—The coil tube *S* is a piece of cardboard tubing 3⅝ inches in diameter and 4 inches long. A round cardboard table-salt box which can be obtained at a grocery store is about 3⅝ inches in diameter and can be used for this purpose. One of the cardboard ends or caps should be securely glued to the box. This tube is wound with No. 24 (or No. 26) double cotton-covered copper wire.

The method of winding the wire is much the same as described in Circular No. 120. Punch two holes in the tube three-eighths inch from the open end, as shown at *R*, Figure 2. Weave the end of the wire through these holes so that it is firmly anchored and has one end extending about 10 inches inside the tube. Punch a hole *F* about five-eighths inch from the other end (which has the cardboard cover secured to it) in line with the holes punched at *R*. Draw the free end of the wire through the inside of the tube and thread it out through the hole at *F*. Now wind on 10 turns of wire (starting from *R*) and take off a 6-inch twisted tap, as described in Circular No. 120. Hold the turns tight and punch a hole *B* directly underneath this tap. Insert the end of the tap into the hole and pull it through the inside of the tube so that the turns are held in place. The hole for this tap should be slightly staggered from the first two holes (*R*) which were punched.

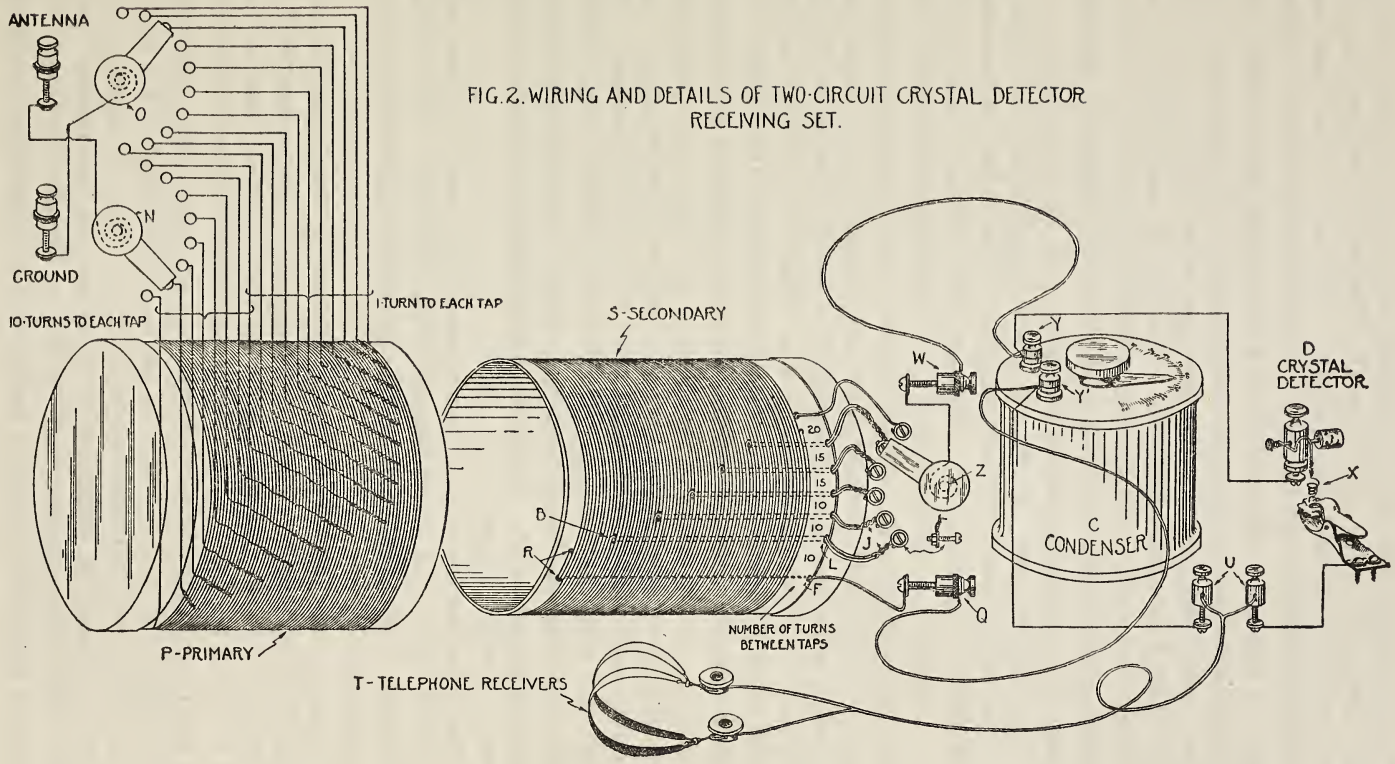

FIG. 2. WIRING AND DETAILS OF TWO-CIRCUIT CRYSTAL DETECTOR RECEIVING SET.

Punch another hole (*L*) five-eighths inch from the other end of the tube and in line with hole *B*. Thread the twisted tap out through this hole and pull it tight. Wind on 10 more turns and bring out another twisted tap; then 10 more turns and another tap; 15 turns and another tap; 15 more turns and another tap. Finally, wind on 20 more turns and bring out the free end of the wire in the same manner as the taps were brought out. The tube now has 80 turns of wire wound on it, and there are five twisted taps and 2 single wires projecting through the row of holes at the closed end of the tube. The position of the wires inside the coil tube is shown in Figure 2 by the dotted lines.

The contact panel *M* (Fig. 1) which supports the coil tube is a piece of dry wood 5½ inches high, 4 inches wide, and one-half inch thick. The contacts, switch arm and knob, and binding posts are described in Circular No. 120. The end of the switch arm should be wide enough so that it will not drop between the contact points, but still narrow enough so that it may be set to touch only a single contact at a time. Having located the hole for the switch-arm bolt, the switch arm should be placed in position and the knob rotated in such a manner that the end of the contact arm will describe an arc upon which the contact points are to be placed. The holes for the contacts should next be drilled, the spacing depending upon the kind of contacts which are to be used. One should remember that if brass bolts are used for contacts, the nuts and washers are larger than the bolt heads. One should space the holes so that the nut and washer of one contact will not touch those adjacent. Two holes should be drilled for the binding posts *Q* and *W*, Figure 1.

The movable base *L* is a square piece of dry wood 4 inches long, 4 inches wide, and about three-fourths inch thick. Care should be taken to have the ends of this block cut square with respect to the sides.

Fixed Coil Tube and Panel (*P* and *K*, Fig. 1).—The coil tube *P* (Fig. 1) is essentially the same as the tuner described in Circular No. 120, and the tuner used there may be made a part of *P* of this set. The cardboard cover should be glued to the end of the tube where the single turn taps are taken off. This tube (an oatmeal box) is about 4⅛ inches in diameter and 4 inches long. If a new coil tube is constructed, it may be improved by using a somewhat different arrangement of the twisted taps. (See coil marked "tuning coil" in Fig. 3, Circular No. 120.) Instead of taking off taps in a line from the upper right corner to

the lower left corner of the figure, start at the upper left corner and progress downward to the lower right corner. The end of the coil tube where the 10-turn taps are taken off should have the cardboard cover glued to it. This is the top of the coil tube as it is shown in the diagram (Fig. 3, Circular No. 120). In all other respects the tube is wound exactly as described in Circular No. 120.

The panel which was described in Circular No. 120 may also be used for the panel *K* (Fig. 1). If the receiving set described in Circular No. 120 has not been constructed, this panel may be made from a board 7½ inches long by 4½ inches wide and about one-half inch thick. The position of the contacts can best be determined by inserting the switch arms in their respective holes and turning the knobs so that the ends of the switch arms will describe arcs, as previously explained. The contacts, switch arms, and knobs are described in Circular No. 120.

Fixed Base and Coil Tube Support (*B* and *J*, Fig. 1).—The fixed base *B* is a piece of dry wood 5½ inches wide, 11 inches long, and about three-fourths of an inch thick. The support *J* for the fixed coil tube is 5½ inches wide (the width of the base), 6 inches long, and about one-half inch thick. Two screw holes are drilled in *J*, so that *J* may be screwed to the left-hand end of the fixed base *B*.

A strip of wood *I*, 11 inches long, five-sixteenths of an inch wide, and about one-fourth inch thick, is now fastened to the base by cigar-box nails or small brads so that it is even with the rear edge, as shown in the drawing (Fig. 1). The next step is to locate the strip *H* in such a position that the block *L* will slide easily back and forth the entire length of the fixed base *B*. Having found this position this strip is secured in the same manner as the strip *I*. Two thin wood cleats (one shown at *AA*, Fig. 1) are fastened under the ends of the fixed base *B*. It is, of course, understood that neither the movable coil tube *S* nor the switch contacts and binding posts have, up to the present time, been mounted on the upright panel *M*. The wooden parts for the loose coupler are now finished. Instructions are given below for treating with paraffin and assembling the parts.

4. VARIABLE CONDENSER, CRYSTAL DETECTOR AND BASE

Variable Condenser (*C*, Figs. 1 and 2).—The variable air condenser should have a maximum capacity of between 0.0004 and 0.0005 microfarads (400 to 500 micromicrofarads). The type pictured in Figure 1 is inclosed in a round metal case, but the

"unmounted" type may also be used. A person adept with the use of tools can make the variable air condenser, but a discussion of the method is not within the scope of this Circular. The baseboard *R* (Fig. 1) is about 10 inches long, 5½ inches wide, and three-fourths inch thick. This board is similar to the baseboard used for the set described in Circular No. 120. The strips of wood (See *AA*, Fig. 1) are fastened under the ends so that wires may be run underneath for connections. These strips should be the same thickness as those shown under the fixed base *B*. Drill the holes for the crystal detector binding post, the telephone receiver binding posts *U*, the hole *CC* for the wire from the clip, and two small holes (one hole shown at *BB*) for the wires from the condenser binding posts *Y* and *Y'*.

Crystal Detector (*D*, Figs. 1 and 2).—The galena crystal may be mounted as described in Circular No. 120, or it may be mounted as pictured in Figures 1 and 2. The holder for the crystal is a metallic pinch clip such as the ordinary battery test clip. This clip should be bent into a convenient shape so that it may be fastened to the base.

The wire *X*, which makes contact with the crystal, is a piece of fine wire (about No. 30) which is wound into the form of a spring and twisted around or soldered to a piece of copper wire (No. 24, same as used on coil tube *S*). The other end of the No. 24 bare copper wire is twisted tightly around a nail which passes through the binding post and has a wood knob or cork fixed to its end, as shown in Figure 2. It is desirable to have the fine wire (No. 30) of springy material such as German silver, but copper wire may be used if more convenient.

The importance of securing a tested galena crystal can not be emphasized too strongly, and it should be understood that results can not be obtained by using an insensitive crystal.

5. INSTRUCTIONS FOR ASSEMBLING AND WIRING

Paraffin Coating.—Thus far no instructions have been given to assemble the various parts. Before fastening the uprights to the bases and the coil tubes to the uprights, or attaching the metal parts, the wood parts and the coil tubes should be treated with paraffin. Provide a pan large enough for the base *B* (5½ by 11 inches) and enough paraffin which, when melted, will just cover the piece of wood. A pan of this size will accommodate any of the other pieces. Keep the paraffin in the liquid state and dip the several wood pieces into the paraffin, one at a time. The

longer one leaves the wood in the liquid paraffin the better, but 5 to 15 minutes will do. If it is not at all convenient to dip the parts in paraffin, the paraffin may be applied while hot with a brush. The parts to be treated with paraffin are *J*, *K*, *L*, *M*, *P*, *S*, and *R*. Do not put paraffin on any metal part except when treating the wire on coil tubes *P* and *S*. Care should be taken in melting the paraffin so that it will not overheat and become ignited. Do not get it so hot that it smokes.

COUPLER.—The movable portion of the coupler should be assembled first. As shown in Figure 1, the fittings making up this part of the set are the movable base *L*, the coil-tube support *M* and the coil tube *S*. Screw the coil-tube support *M* to one end of the movable base *L*, using the holes previously drilled in *M*. See that *L* and *M* slide freely between the strips *H* and *I*. Insert in *M* the six switch contacts (brass bolts), the switch arm, and the binding posts (*Q* and *W*) in the proper holes which have been drilled. Adjust the switch arm until it presses firmly on the contact points (boltheads) and fasten the bare end of a No. 24 copper wire between the nuts on the end of the switch-arm bolt *Z* (Figs. 1 and 2) which projects through the panel *M*. Wind this wire into the form of a spiral of two or three turns like a clock spring and later connect the other end of this wire between the head and washer at the rear of the binding post *W*, as described in the paragraph below. Insert two small screws *V* (Fig. 1) in the panel *M*, so that the switch arms will not drop off the row of contact points when the knob is turned too far.

The coil tube *S* is now ready to be fastened in position on the panel *M*. Cut a 1-inch hole in the cardboard end of the coil tube and place it with the closed end next to the panel *M* in such a position that it will be just below the row of nuts and washers (switch contacts) and in the center of the panel *M* with respect to the sides. Fasten it to the panel with short wood screws. The switch-arm bolt with the spiral wire connected to it should project through the hole cut in the end of the coil tube. Thread the end of the wire from *Z* through a hole punched near the end of the coil tube next to the panel and connect this wire to the back of the binding post *W* (Figs. 1 and 2). The wire *F* (Fig. 2) is now connected to the back of the binding post *Q*. There now remain five twisted taps and one single wire to be connected to the six switch contacts. The taps should be cut off about 1½ inches from the coil tube and the insulation removed from the pairs of wires thus formed. Each pair of wires should be twisted

together, as shown at *J*, Figure 2. The connections are now made by clamping the five taps and also the end of the single wire between the nuts and washers on the contact bolts. The connections are clearly shown in the diagram.

We are now ready to assemble and wire the fixed portion of the coupler, composed of the base *B*, coil-tube support *J*, panel *K*, and coil tube *P*. As previously mentioned, the panel *K* is practically the same as the panel shown in Circular No. 120, except that for this purpose the original panel is mounted so that the edge which was originally at the bottom now becomes the left-hand edge. This brings the series of 10 contacts at the top of the panel in our present set. When the panel is turned to this position the two binding posts will be at the top. Change the position of the right-hand binding post so that the two are arranged as shown in Figure 1. Connections between the binding posts and switch arms are made as described in Circular No. 120. Two short pieces of stiff wire should now be fastened under the binding posts at the front of the panel to form a spark gap. These wires are arranged so that there is a very short space between their ends, as explained in Circular No. 120. Screw the panel *K* to the base *B* and to the support *J*, meanwhile allowing the coil tube *P* to lie on the base so that the connecting wires will not be broken.

If the panel *K* is to be made specially for the coupler, as described in this Circular, it should be mounted according to the following instructions:

Screw the panel to the base and to the support *J* and insert the binding posts, switch arms and bolts, and contact bolts in the proper holes. The switch arms should now be adjusted so that they make firm contact on the heads of the bolts. Now insert four small screws (*E*, Fig. 1) in the front of the panel so that the switch arms will not drop off the row of contact points when the knobs are turned too far. Insert a wire between the nuts on the end of the lower switch-arm bolt *N* where it projects through the back of the panel *K* (Fig. 1). Wind the wire into a spiral of one or two turns like a clock spring and connect the end to the upper binding post which is marked "antenna." These connections will be understood by referring to the upper left-hand corner of Figure 2.

In the same manner connect another wire from the upper switch-arm bolt to the lower binding post which is marked

"ground." (See Fig. 2.) The connecting wires should be insulated except where a connection is needed and should not touch each other. Two short pieces of wire are now fastened to the binding posts in the front of the panel, as previously explained.

The coil tube *P* should now be laid on the base in about the same position as is shown in Figure 1. The 16 twisted taps and also the 2 single wires from the ends of the winding are now to be connected to the back of the 18 contacts on the panel *K*, following the method given in Circular No. 120. The order of connecting the taps may be understood by referring to Figure 2.

The following instructions will apply whether the coil tube *P* was made according to the description in Circular No. 120 or was made according to instructions given in this circular:

Carefully raise the coil tube *P* against the support *J* to such a position that when the coil tube *S* of the movable section of the tuner is pushed in the coil tube *P* the space between the two tubes will be equal all around. Mark this position of the coil tube *P* on *J*, and fasten *P* to *J* with short wood screws.

Condenser and Crystal Detector (C and D, Fig. 1).—The mounting of the condenser *C* and the crystal detector *D* on the base *R* is clearly shown in Figure 1. Crystal detectors have been previously described in this circular and in Circular No. 120. A wire is run from the binding post *Y* on the variable condenser *C* through a small hole in the base R, and is then connected to the under side of the crystal detector binding post. Another wire is now run from the clip which holds the galena crystal through a small hole *CC* in the base, and is then connected to the under side of the right-hand binding post *U*. The left-hand binding post *U* is next connected to the binding post *Y'* of the variable condenser *C* by running a wire under the base and up through a small hole *BB*. The wiring will be understood by referring to the right-hand portion of Figure 2. The wires may be the same size as were used for winding the coil tubes and should be insulated. Two pieces of wire should now be connected from the binding posts *W* and *Q* (Figs. 1 and 2) to binding posts *Y* and *Y'* of the variable condenser *C*. The telephone receivers *T* are now connected to the binding posts *U* and the receiving set is complete except for connecting to the antenna and ground.

The connection of the antenna lead and ground wire to the binding posts marked "antenna" and "ground," respectively, is made as shown in Figure 2 in Circular No. 120.

6. DIRECTIONS FOR OPERATING

Push the coil tube *S* (secondary) about halfway into the coil tube *P* (primary) and set the switch *Z* on contact point 4. The primary switch *N* is set on contact point 8. The primary switch *O* may be left in any position.

The crystal detector can be adjusted most easily by the use of the test buzzer, which is described below. If the test buzzer is not used, the wire which rests on the crystal must be placed lightly at different points on the crystal until the transmitting station is heard, when the set is adjusted as described below. To adjust the crystal by either method, first push the coil tube *S* (secondary) about halfway into the coil tube *P* (primary), set the secondary switch arm *Z* on contact point 4, the primary switch arm *N* on contact point 8, while the primary switch arm O and the pointer of the variable condenser (*C*) may be left in any position.

Having adjusted the crystal detector to a sensitive point as described below, the next thing is to adjust the switches (*N* and *O*) on the coil tube *P* (primary), the switch (*Z*) on the coil tube *S* (secondary), and also the variable condenser *C*, so that the apparatus will be in "resonance" with the transmitting station. Again insert the secondary coil tube *S* about halfway into the coil tube *P* and set the secondary switch arm on contact point 4 and the pointer of the condenser in any position. Set the primary switch *N* on contact point 1, and while keeping it in this position move the other primary switch *O* over all of its contacts, stopping a moment at each one, being sure that the ends of the switch arms rest on only one contact point at a time. If no signals are heard, set the switch arm *N* on contact point 2 and again move the switch arm *O* over all of its contacts. Proceed in this manner until the transmitting station is heard. This is called "tuning" the primary circuit.

The tuning of the secondary circuit is the next operation. Set the secondary switch arm *Z* on contact point 1 and turn the knob of the variable condenser *C* so that the pointer moves over the entire scale. If no signals are heard, set the switch arm *Z* on contact point 2 and again turn the knob of the variable condenser so that the pointer moves over the entire scale. Proceed in this manner over all the contact points until the signals are loudest. Next slide the coil tube *S* (secondary) in and out of the coil tube *P* (primary) until the signals are made as loud as possible. This

operation is called changing the "coupling." When the coupling which gives the loudest signal has been secured, it may be necessary to slightly readjust the position of the switch arm *O*, the position of the movable coil tube *S*, and the "setting" of the variable condenser *C*.

The receiving set is now in resonance with the transmitting station. It is possible to change the position of one or more of the switch arms, the position of the movable coil tube, and the setting of the variable condenser in such a manner that the set will still be in resonance with the same transmitting station. In other words, there are different combinations of adjustments which will tune the set so that it will respond to signals from the same transmitting station. The best adjustment is that which reduces the signals from undesired stations to a minimum and still permits the desired transmitting station to be heard. This is accomplished by decreasing the coupling (drawing coil tube *S* farther out of coil tube *P*) and again tuning with the switch arm *O* and the variable condenser *C*. This may also weaken the signals from the desired transmitting station, but it will weaken the signals from the undesired stations to a greater extent, provided that the transmitting station which it is desired to hear has a wave frequency (wave length) which is not exactly the same as that of the other stations. This feature is called "selectivity."

THE TEST BUZZER.—As mentioned above, it is easy to find the more sensitive spots on the crystal by using a test buzzer. This has been described in Circular No. 120 and is shown at *Z*, Figure 3, in that publication. Referring to this figure, the binding post marked "ground" should be connected by a flexible wire to the binding post *W*, which is shown in Figure 1 in this circular. The operation of the test buzzer has been described in Circular No. 120.

7. APPROXIMATE COST OF PARTS

The following parts are used in the equipment described in Circular No. 120 and are needed also for the two-circuit set described in this circular. Some of the prices have been revised.

Antenna:	
Wire, copper, bare or insulated, No. 14 or 16, per 100 feet about	$0.90
Rope, one-fourth or three-eighths inch, 2 cents per foot.	
2 insulators, porcelain cleats	.20
1 pulley	.15
Lightning switch, 30-ampere battery switch	.50
1 porcelain tube	.10

Ground connections:	
Wire (6 feet No. 10 or heavier copper wire)	$0.15
2 clamps	.30
1 iron pipe or rod	.25
Receiving set:	
3 ounces No. 24 double cotton-covered copper wire	.40
1 round cardboard box.	
2 switch knobs and blades, complete	1.00
18 switch contacts and nuts	.75
3 binding posts, set-screw type	.45
2 binding posts, any type	.30
1 crystal, tested	.25
3 wood screws, brass, three-fourths inch long	.03
2 wood screws for fastening panel to base	.02
Wood for panels (from packing box).	
2 pounds paraffin	.30
Lamp cord, 4 cents per foot, about	.40
Test buzzer	.75
Dry battery	.40
Telephone receivers [2]	4.00 to 8.00
Total, about	11.60 to 15.60

The following additional parts will be required:	
3 ounces No. 24 double cotton-covered copper wire	.40
1 round cardboard box.	
1 switch knob and blade, complete	.50
6 switch contacts and nuts	.25
2 binding posts, any type	.30
1 battery clip for crystal	.10
Miscellaneous screws	.15
1 variable condenser, 0.0004 to 0.0005 microfarads (400 to 500 micro-microfarads)	1.50 to 6.00
Total additional cost, about	3.20 to 7.70

[2] Still more efficient and expensive telephone receivers may be obtained at prices up to about $20.