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No. 141

DESCRIPTION AND OPERATION OF AN AUDIO-FREQUENCY AMPLIFIER UNIT FOR SIMPLE RADIO RECEIVING OUTFITS

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DESCRIPTION AND OPERATION OF AN AUDIO-FREQUENCY AMPLIFIER UNIT FOR SIMPLE RADIO RECEIVING OUTFITS.

ABSTRACT.

This is the fifth circular in a series of descriptions of very simple radio receiving outfits. In Circular No. 133 an electron-tube detector unit to be used in conjunction with the single-circuit set (Circular No. 120) or with the two-circuit set (Circular No. 121) is described. This circular describes an audio-frequency amplifier unit, one or two of which may be used with the apparatus just mentioned, to increase the receiving radius of the station, as well as the volume of sound in the telephone receivers. The amplifier unit (or two of them) may be used with the receiving sets either exactly as described in Circulars Nos. 120 and 121, or with the crystal detector replaced by the electron-tube detector unit.

A suitable antenna is described in Circular No. 120, and auxiliary condensers and a loading coil are described in Circular No. 137. One of these condensers is used in the antenna circuit so that the receiving set may be more easily tuned to wave lengths below 300 meters (hereafter abbreviated m; the other condenser will somewhat improve the reception from spark stations. The loading coil is not an essential part of the receiving set, unless one desires to receive stations transmitting on wave lengths up to 3,000 m (wave frequencies down to 100 kilocycles per second).

The cost of the materials for a single amplifier unit described in this circular may be between $13 and $20, including an electron tube. If a storage battery and "B" battery are not already at hand these will add $17 to $25 to the cost.

CONTENTS.

I. INTRODUCTION.[1]

Many radio receiving sets include either a radio-frequency or an audio-frequency amplifier. A radio-frequency amplifier amplifies

[1] This is the fifth of a series of circulars describing very simple radio receiving equipment which were originally prepared for the Boys and Girls' Radio Clubs of the States Relations Service, Department of Agriculture, and are now obtainable only from the Superintendent of Documents, Government Printing Office, Washington, D. C., at the prices named.

Bureau of Standards Circular No. 120, Construction and Operation of a Simple Homemade Radio Receiving Outfit. Price, 5 cents. (Formerly Letter Circular 43.)

Bureau of Standards Circular No. 121, Construction and Operation of a Two-Circuit Radio Receiving Equipment with Crystal Detector. Price, 5 cents. (Formerly Letter Circular 44.)

Bureau of Standards Circular No. 133, Description and Operation of an Electron-Tube Detector Unit for Simple Radio Receiving Outfits. Price, 10 cents. (Formerly Letter Circular 48.)

Bureau of Standards Circular No. 137, Auxiliary Condensers and Loading Coil Used with Simple Homemade Radio Receiving Outfits. Price, 10 cents. (Formerly Letter Circulars 46 and 47.)

the radio-frequency signal before it is detected (rectified) by the crystal or electron-tube detector, while an audio-frequency amplifier amplifies the rectified signal after it leaves the crystal or electron-tube detector. The essential parts of either type of amplifier are the amplifier transformer and the electron tube. For an explanation of the principles of amplifiers, reference may be made to the book, The Principles Underlying Radio Communication (pp. 479–488), or to one of various books of which a list may be found in Bureau of Standards Circular No. 122, Sources of Elementary Radio Information.

This pamphlet describes an audio-frequency amplifier unit; that is, an amplifier employing a single electron tube. One or more such units is used with the single-circuit radio receiving set described in Bureau of Standards Circular No. 120, or with the two-circuit radio receiving set described in Bureau of Standards Circular No. 121, or with any other tuning device equipped with a detector. The detector may be either a crystal detector or an electron-tube detector similar to the one described in Bureau of Standards Circular No. 133.

The amplifier unit is used by connecting it to the receiving set in place of the telephone receivers and then connecting the telephone receivers to the output of the amplifier.

The audio-frequency amplifier unit is added to the tuner and detector so that the radio power received by the antenna may be transformed into sound in greater volume than would be possible by the use of a crystal or electron-tube detector alone. The use of such an audio-frequency amplifier unit increases the receiving radius of the outfits described in previous pamphlets of the series approximately 50 per cent. Still greater receiving radius may be obtained by adding another amplifier unit just like the first one. It is usually not practical to use more than two stages of audio-frequency amplification; that is, two audio-frequency amplifier units.

One of these amplifier units added to a regenerative receiving set [2] increases the volume of sound in the telephone receivers.

Since a circuit, including a crystal detector or simple electron-tube detector, will not make continuous wave [3] signals audible in

[2] See p. 487 of the book, The Principles Underlying Radio Communication, Signal Corps Radio Communication Pamphlet No. 40. This is a bound volume of over 600 pages, and is obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price, $1 per copy. Regenerative apparatus is also described in various other publications listed in Bureau of Standards Circular No. 122, Sources of Elementary Radio Information, obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price, 5 cents.

[3] See pp. 431 and 501 of the book, The Principles Underlying Radio Communication.

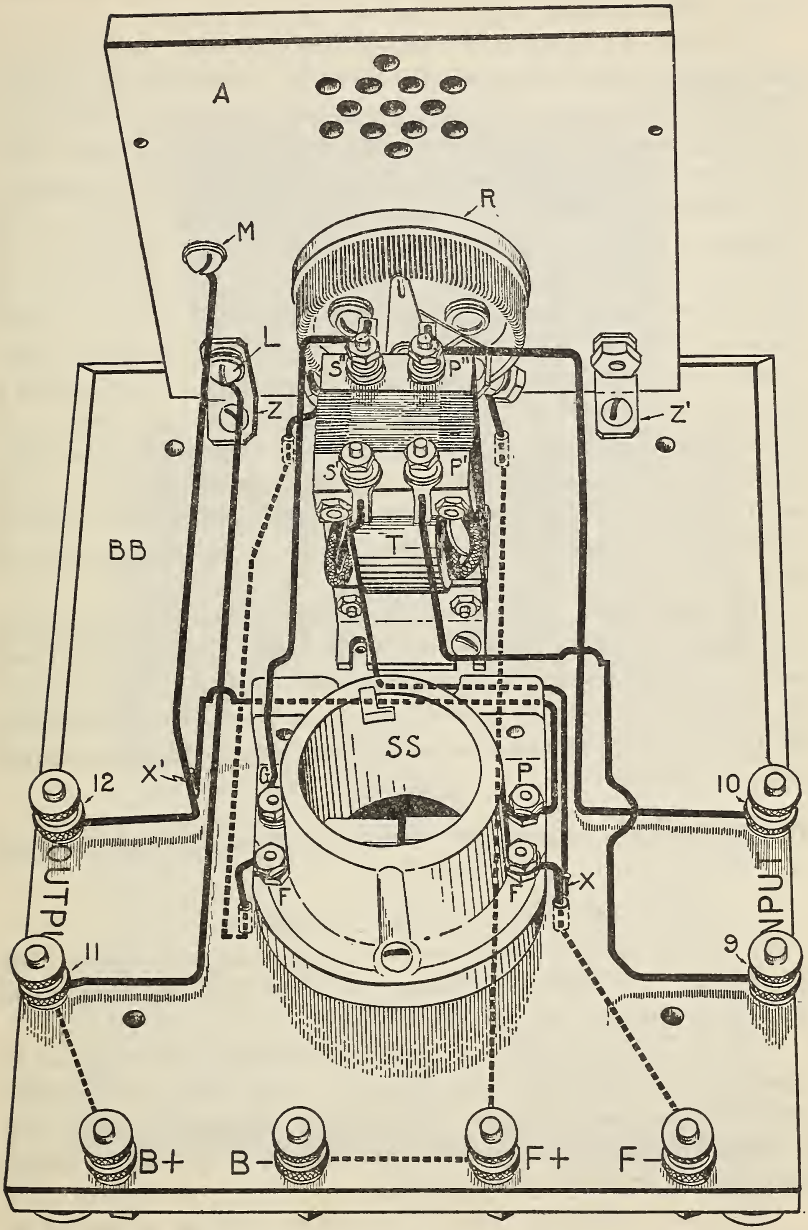

Fig. 1.—*Diagram showing location of parts and wiring of audio-frequency amplifier unit.*

the telephone receivers, the addition of an audio-frequency amplifier to these circuits will not accomplish this result.

The cost of this audio-frequency amplifier unit, complete with an electron tube, is between $13 and $21. This does not include the cost of batteries. If an electron-tube detector is used in the receiving set, the same batteries are used for the amplifier unit. If, however, a storage battery for lighting the tube filament is not already available, this item will add from $15 to $22 to the estimate; and, if dry batteries are not already available, the addition of two dry batteries for supplying voltage to the plate of the tube will add from $2 to $3 to this estimate. The cost of the tuner, crystal detector, telephone receivers, and antenna equipment, which are usually used with this amplifier and which is itemized in Bureau of Standards Circulars Nos. 120 and 121, is between $11 and $23. If the electron-tube detector unit described in Bureau of Standards Letter Circular 48 or Circular No. 133 is used in place of the crystal detector, the cost of the complete equipment is increased by an amount varying between $7 and $13.70.

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.

II. ESSENTIAL PARTS OF COMPLETE RADIO RECEIVING STATION.

A complete radio receiving station comprises:

Antenna, Lightning Switch, Ground Connections, and Telephone Receivers.—These are described in Bureau of Standards Circular No. 120.

Tuning Device.—This is either the tuning coil described in Bureau of Standards Circular No. 120, or the two-circuit coupler and variable air condenser described in Bureau of Standards Circular No. 121, or any commercial tuning device which covers the required wave-frequency range.

Detector.—This is either the crystal detector arranged as shown in Bureau of Standards Circulars Nos. 120 and 121, the electron-tube detector unit as described in Bureau of Standards Letter Circular 48 or Circular No. 133, or some satisfactory commercial electron-tube detector unit.

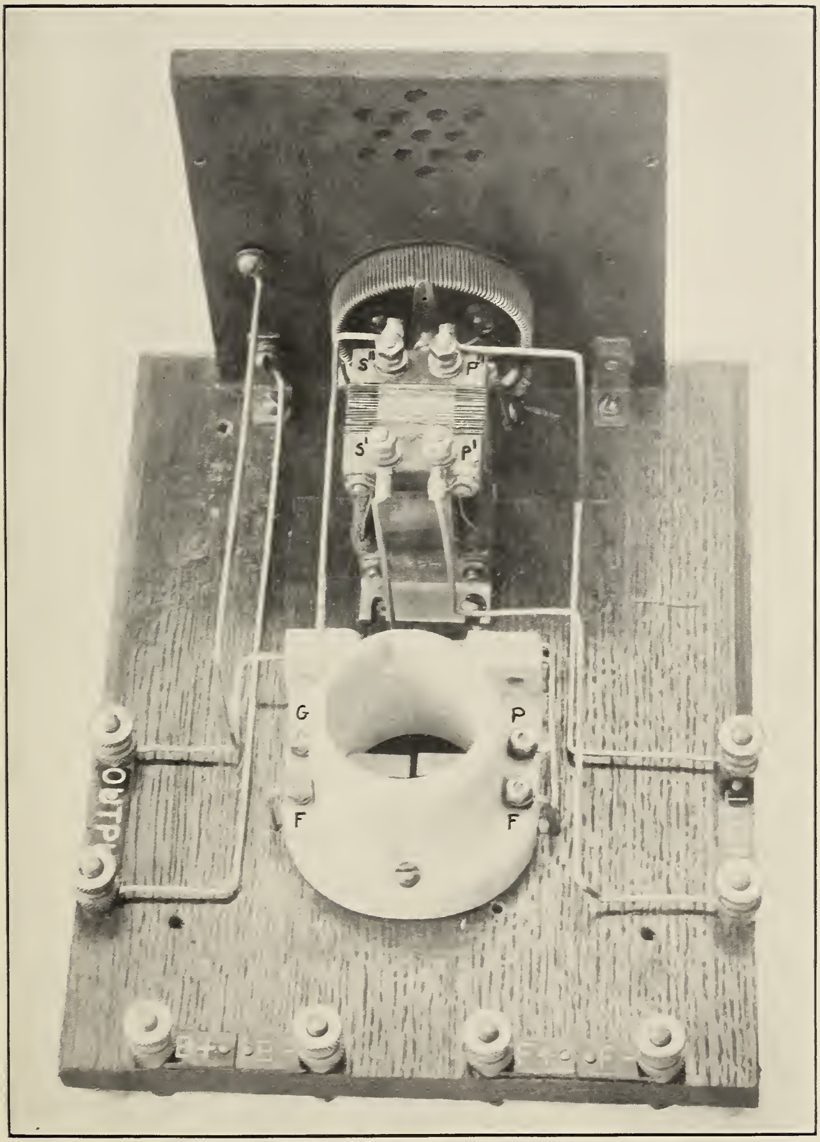

FIG. 2.—*Assembled audio-frequency amplifier unit.*

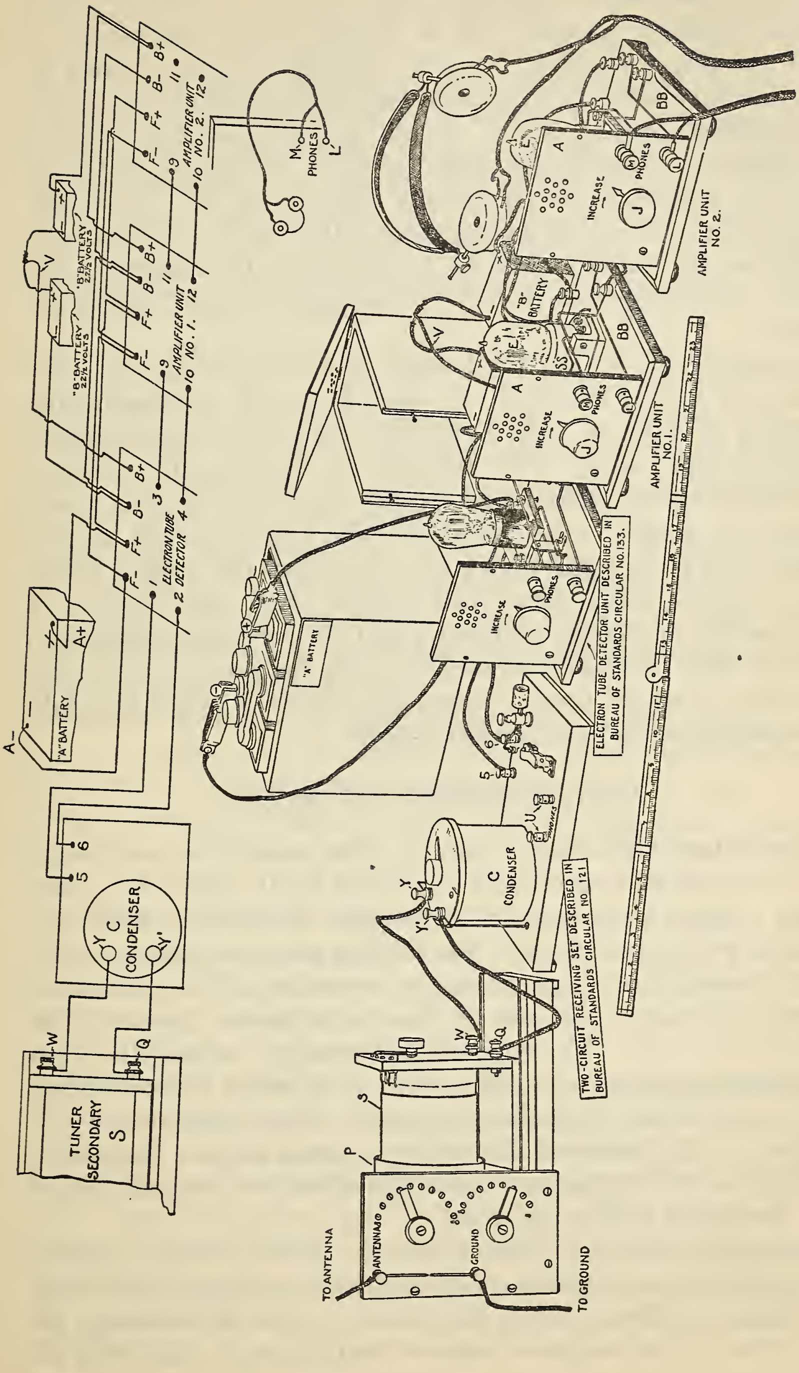

FIG. 3.—*Method of connecting two-circuit receiving set, filament battery, plate battery, telephone receivers, and two audio-frequency amplifier units, ready for use.*

Audio-frequency Amplifier Unit (Figs. 1, 2, and 3).—The audio-frequency amplifier unit is composed of a baseboard *BB* and an upright panel *A*. On the baseboard *BB* is mounted an electron-tube socket *SS*, an audio-frequency amplifier transformer *T*, and eight binding posts. On the upright panel *A* is mounted a filament rheostat *R* (the adjusting knob *J* is shown in Fig. 3) and two telephone-receiver binding posts *L* and *M*. The photograph (Fig. 2) shows the arrangement of these parts. This circular tells how the various parts are assembled on the baseboard and panel. No description is given of the construction of any of the parts.

Accessories.—Under the heading of accessories may be listed a six-volt storage battery ("A" battery) having an ampere-hour capacity of about 60, used for lighting the electron-tube filament, a 45-volt dry battery ("B" battery) for supplying the electron-tube plate voltage, binding posts, stiff copper wire (tinned wire is usually preferred), wood boards for the baseboard and upright panel, two brass angle braces for supporting the upright panel, miscellaneous wood screws, and suitable stain and varnish. A composition insulating material panel is sometimes substituted for the wood panel and the amplifier unit inclosed in a wood cabinet with a hinged cover. When the cabinet is added the eight baseboard binding posts are left exposed.

III. DESCRIPTION OF PARTS.

Baseboard (*BB*, Figs. 1 and 3).—The base *BB* is any kind of dry, well-seasoned wood about 6¼ inches by 8¼ inches by ½ inch thick. Eight holes are drilled through the base in which the binding posts are fastened. The binding posts are spaced so that they present a neat appearance or according to the dimensions given in Figure 3, Bureau of Standards Letter Circular 48 or Circular No. 133. The baseboard is arranged so that the three remaining sides and a hinged cover may be added without changing the positions of the binding posts. Under each of the four corners of the baseboard *BB* rubber or wood feet are fastened in order that the binding-post heads and wiring on the under side of the baseboard will be protected.

Upright Panel (*A*, Figs. 1 and 3).—Panel *A* is any suitable dry, seasoned wood about 4½ inches by 5 inches by ⅜ inch thick. In Figure 1 a back view of the panel is shown which brings the two holes for the telephone receiver binding posts *L* and *M* in the lower left corner. (If the panel is viewed from the front these two holes will be at the lower right corner.) This panel is made to present a good appearance, it being the front panel. Four holes are drilled in panel *A*, one for the bolt which fastens the panel to the brace (see *Z′*, Fig. 1), two for the telephone-receiver binding posts *L* and *M* (Figs. 1 and 3), and one for the shaft of the filament rheostat *R* (see Fig. 1). The exact location and diameter of the hole for the rheostat shaft is determined from the rheostat itself. It is drilled so that the rheostat occupies as low a position as possible, allowing room enough to do the necessary wiring. Satisfactory upright panel measurements are given in Figure 4 of Bureau of Standards Letter Circular 48 or Circular No. 133.

ELECTRON TUBE (*E*, FIG. 3).—The electron tube is a commercially available tube generally called an amplifier tube or "hard" tube. The several parts of an electron tube (sometimes called a vacuum tube) are described in chapter 6, The Principles Underlying Radio Communication.

ELECTRON-TUBE SOCKET (*SS*, FIGS. 1 AND 3).—The electron-tube socket is one of the various commercially available types.

AUDIO-FREQUENCY AMPLIFIER TRANSFORMER (*T*, FIG. 1).—The audio-frequency amplifier transformer is one of the various commercially available types.

BINDING POSTS.—The binding posts used on the baseboard are $\frac{6}{32}$ or $\frac{8}{32}$ brass machine screws, each equipped with two nuts and two washers, if regular binding posts are not used. The telephone-receiver binding posts, *L* and *M* (Figs. 1 and 3), are of the set-screw type to admit the tips of the telephone-receiver cords.

FILAMENT RHEOSTAT (*R*, FIG. 1).—The filament rheostat is one of the various commercially available types designed for panel mounting and having a neat-appearing knob and pointer. The rheostat has a resistance of about 7 ohms and a current-carrying capacity of about 1½ amperes.

ACCESSORIES.—The accessory batteries are commercial articles. The purchaser of the six-volt storage battery ("A" battery) for lighting the filaments should get full instructions from the dealer for testing and recharging the battery. The 45-volt dry battery ("B" battery) usually used for the plate circuit can not be recharged. The normal life of a dry battery of reliable manufacture is about six months. Storage batteries for use as "B" batteries are available. Their first cost is greater than that of dry batteries, but they may be recharged.

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Satisfactory dimensions for the brass angle braces are given in Figure 1, Bureau of Standards Letter Circular No. 48 or Circular No. 133.

IV. ASSEMBLY AND WIRING.

Wood Finish.—It is essential that the wood be protected from moisture. The wood is first dried, and then finished with stain and varnish; a good grade of varnish, preferably insulating varnish, is used. Shellac or other alcohol dissolved resins are not used. This method of wood finishing is found more satisfactory than treating with paraffin, as described in Bureau of Standards Circular No. 120. The exact method of drying and finishing wood depends upon the condition of the wood itself. The wood is usually placed in a warm oven for an hour or so to insure more or less complete drying. The use of lampblack or carbon pigment stains is avoided, and the stain and varnish is thoroughly dried before the apparatus is mounted on the wood baseboard and panel.

Baseboard (Fig. 1).—The eight brass machine screws or binding posts are put in the holes already drilled in the baseboard. If machine screws are used, the heads are put on the underside of the baseboard with a brass washer between the head and the baseboard. A brass washer and two nuts are then fastened to each screw, on the upper side of the baseboard, with the washer next to the baseboard.

The tube socket *SS* and the transformer *T* are next screwed to the baseboard. The exact location of these parts varies according to the particular type used. One can get an idea of the relative position of the several parts from Figure 2. The tube socket *SS* is mounted so that the two terminals marked *G* and *P* (Fig. 1) are nearest the upright panel. Wood blocks are put under the socket *SS* when necessary, so that the four terminals of the socket do not touch the wood baseboard. This is done by cutting off two round wood blocks just long enough to raise the socket terminals clear of the base, and mounting them so that the screws which hold the socket to the baseboard will pass through holes in the centers of the blocks.

After the socket *SS* and the transformer *T* are mounted, the parts are wired. No. 14 bare (preferably tinned) copper wire is used in wiring. This makes the connections stiff and self-supporting. This wire is ordinarily furnished in rolls and is straightened before being used. This is accomplished by clamping or otherwise fastening one end of the wire solidly and pulling on the other end just hard enough to stretch the wire slightly. All wires are run as direct as possible consistent with good spacing and neat appearance, and all bends are made at right angles. When a wire is attached to a binding post, a loop or eye is formed on the end of the wire and the wire at the eye flattened with a hammer. This gives more contact surface. Special lugs are sometimes soldered to the ends of the wires before the connections are made.

A small hole is drilled through the baseboard near each of the tube-socket terminals marked F (see Fig. 1). A short piece of wire is fastened to the right socket terminal marked F and is then led through the small hole in the baseboard to the underside of the baseboard. The same wire is led to the underside of the binding post marked $F-$ and fastened between the machine-screw head and washer underneath the baseboard. All wires which are run on the underside of the baseboard or are hidden by parts of the apparatus are shown by dotted lines. A wire is soldered (at X) to the wire leading from the right-socket terminal marked F just above the baseboard and led to the secondary terminal S' of the transformer T and soldered or otherwise fastened thereto. This wire is shown as part solid and part dotted. The wires do not touch the wood boards except at the terminals and where the wires pass through holes in the baseboard. The wires may be raised more or less to accomplish this. Another wire is soldered to a primary terminal P', of the transformer and led to the "input" binding post No. 9. Humps or bends are shown in this and other wires to indicate that the wires cross but do not touch.

A wire is soldered to the other primary terminal P'' of the transformer T and goes from there to the other "input" binding post No. 10. A similar wire reaches from the other secondary terminal S'' of the transformer to the electron-tube socket terminal marked G. The secondary transformer terminal which connects to the terminal G of the electron-tube socket is that terminal which is internally connected to the outside end of the secondary coil of the transformer. This is sometimes determined by inspection; in other cases it is necessary to try out the completed amplifier unit, as described under "Operation." If good results are not obtained, the wire leading from G to S'' is removed from S'' and connected to S', and the wire leading from X to S' is removed from S' and connected to S''.

A wire connects the binding post $B+$ and the "output" binding post No. 11, on the under side of the baseboard. The remainder of the wiring is left until the upright panel is assembled and fastened to the baseboard. The procedure in making soldered connections is given in Bureau of Standards Letter Circular 48 or Circular No. 133.

UPRIGHT PANEL (*A*, FIG. 1).—The filament rheostat *R* is mounted on the upright panel *A* so that the two terminals will be in a convenient position for wiring. Two binding posts of the set-screw type, *L* and *M* (Figs. 1 and 3), are inserted in their proper holes, and the upright panel mounted in position by bolting it to the two brass angle pieces (Z and Z') shown in Figure 1. One of the telephone-receiver binding posts *L* serves as a bolt. Two small holes are drilled through the baseboard near the two terminals of the filament rheostat *R*. A wire is run from the "output" binding post No. 11 (Fig. 1) along the upper side of the baseboard to the back of the telephone-receiver binding post marked *L*. A wire is fastened to the other "output" binding post (No. 12) and led to the rear of the upper telephone-receiver binding post *M*. A wire is fastened to the electron-tube socket terminal *P* and led to some convenient point X' on the wire leading from binding post No. 12 to *M*. The two wires are soldered together at this point.

A wire is run from one of the filament rheostat binding posts through the hole in the baseboard and thence along the under side of the baseboard to the binding post marked $F+$ and is continued from $F+$, still underneath the baseboard, to the binding post marked $B-$. This wire is shown in Figure 1 by a dotted line. Likewise a wire is run from the other rheostat binding post, underneath the baseboard and up through the left hole in the baseboard at the rear of the electron-tube socket *SS* and connected to the left binding post marked *F*. This completes the assembling and wiring of the audio-frequency amplifier unit.

V. CONNECTIONS.

If the two-circuit tuner and the electron-tube detector are used with the audio-frequency amplifier unit, the several parts are arranged as shown in Figure 3. Two amplifier units are shown, making a two-stage amplifier. If only one unit is used, the connections are correspondingly simpler. If a "hard" or amplifier tube is used in the electron-tube detector unit, the connection *V* from the "B" battery is not used, but instead the wire *V* is connected to the binding post $B+$ on the amplifier No. 1. Increasing the number of "B" batteries used to supply voltage to the plates of the amplifier tubes will usually increase the intensity or loudness of the amplified radio signals, but at the same time the quality of the tone will be impaired. The voltage should never be increased to as much as twice the rated plate voltage of the electron tube.

The two-circuit tuner and the tuning condenser C (shown at the left) are described in Bureau of Standards Circular No. 121. The location and wiring of the two additional binding posts, 5 and 6, on the baseboard supporting the tuning condenser C, are given in Figure 6, Bureau of Standards Letter Circular 48 or Circular No. 133.

If the single-circuit tuner and electron-tube detector are used with the audio-frequency amplifier, the arrangement of the parts is also similar to that shown in Figure 3, except that the single-circuit tuner (as described in Bureau of Standards Circular No. 120 and altered in Fig. 5, Bureau of Standards Letter Circular 48 or Circular No. 133) replaces the two-circuit receiving set. The binding posts, 5 and 6, on the single-circuit tuner are connected to the electron-tube detector binding posts Nos. 1 and 2, respectively.

If the electron-tube detector is not available, one method of connection is to use the audio-frequency amplifier with the single-circuit or the two-circuit radio receiving set shown in Bureau of Standards Letter Circular No. 48 or Circular No. 133. In this case the telephone receiver binding posts (X, Fig. 5, or U, Fig. 6, Letter Circular 48 or Circular No. 133) are connected directly to the amplifier "input" binding posts Nos. 9 and 10.[4] The connections to the "A" and "B" batteries are the same as shown in Figure 3 of this circular, except that the wiring to the electron-tube detector is omitted. Great care is taken to see that the "B" or plate battery is not connected to the binding posts marked $F+$ and $F-$. The voltage of this battery is too high for the electron-tube filament and will burn it out.

The antenna and ground wires are connected, as described in Bureau of Standards Circular No. 120 and as shown in Figure 3.

To Summarize.—If the audio-frequency amplifier unit is used (1) with the two-circuit tuner and tuning condenser (Circular No. 121) and electron-tube detector (Letter Circular 48 or Circular No. 133), the connections are: W to Y, Q to Y', 5 to 1,

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[4] This means that the crystal detector is used.

6 to 2, $A-$ to $F-$ to $F-$, $A+$ to $F+$ to $F+$, "B" battery $-$ (black) to $B-$ to $B-$, "B" battery connection V to detector $B+$, "B" battery $+$ (red) to amplifier $B+$, 3 to 9, 4 to 10, 11 to 9, 12 to 10, and the telephone receivers to L and M; (2) with the single-circuit tuner (Circular No. 120) and electron-tube detector, the connections are: 5 to 1, 6 to 2, and so on as given in (1); (3) with the two-circuit receiving set when the crystal detector replaces the electron-tube detector, the connections are: W to Y, Q to Y', U (right) to 9, U (left) to 10, $A-$ to $F-$, $A+$ to $F+$, "B" battery $-$ (black) to $B-$, "B" battery $+$ (red) to $B+$, and the telephone receivers to L and M; (4) with the single-circuit receiving set when the crystal detector replaces the electron-tube detector, the connections are: X (right) to 9, X (left) to 10, and so on as given in (3).

VI. OPERATION.

The two filament rheostat knobs marked J (Fig. 3) on the two audio-frequency amplifier units, and also the filament rheostat knob on the electron-tube detector unit, are turned to the extreme left or to the "off" position. Two electron tubes marked E ("hard" or amplifier tubes) are inserted in the sockets of the amplifier units (Nos. 1 and 2), and a third electron tube (preferably a "soft" or gas tube) is inserted in the socket of the electron-tube detector unit. The three filament rheostat knobs are then turned to the right until the filaments of the electron tubes become lighted, the brilliancy depending upon the type of electron tubes used. When one of the telephone-receiver terminals is removed from its binding post (either L or M) and again touched to the post, a sharp "click" in the telephone-receivers will be an approximate indication that the circuit is in working condition. If the test buzzer, as described in Bureau of Standards Circular No. 120, is available, it is attached by a flexible wire to the binding post W on the two-circuit tuner, or, if the single-circuit tuner is used, the test buzzer is attached to the binding post marked "Ground" to determine when the detector is in working condition.

The test buzzer is not at all necessary when the receiving set employs an electron tube for a detector, as the "settings" of the filament rheostats largely determine the operating condition of the receiving set after it has been tuned to the proper wave frequency (wave length). When a crystal detector is used in place of the electron-tube detector unit, a buzzer test is desirable to locate a sensitive point on the crystal.

When the crystal detector is not used the electron-tube detector unit is merely substituted for it as shown in Figure 3 and the tuning of the receiving circuit is the same as described in Bureau of Standards Circulars Nos. 120 and 121. When the signals from a desired transmitting station are heard as loud as possible by tuning, the intensity is sometimes improved by adjusting one or more of the knobs on the filament rheostats, so as to increase or decrease the filament current (current from the "A" battery). The knobs are kept in the positions of minimum filament currents without reducing the strength of the incoming signals.

If the electron-tube detector unit is equipped with a "soft" or "gas" tube, the voltage of the "B" battery is changed until the greatest signal intensity is obtained. This necessitates the use of a tapped "B" battery. This means that the wire *V* (Fig. 3), instead of connecting to the wire which connects the two "B" batteries, is provided with a clip which is connected to successive tapped terminals on one of the "B" batteries until the required voltage is obtained.

When two audio-frequency amplifier units are used a continuous "howl" is sometimes produced in the telephone receivers. In this case the wires leading to the "input" binding posts of one or both of the amplifier units are reversed; that is, binding post 3 is connected to binding post 10, and 4 to 9, and binding post 11 of amplifier No. 1 to binding post 10 of amplifier No. 2, and also 12 to 9.

In case the apparatus fails to operate the trouble may be attributed to a variety of causes. An inspection is first made of the various parts of the receiving equipment to determine if they are properly connected, special care being taken to see that the positive (+) and negative (−) terminals of the "A" battery are connected, respectively, to the binding posts marked $F+$ and $F-$, and that the positive (+, red) and negative (−, black) terminals of the "B" battery are connected, respectively, to the binding posts marked $B+$ and $B-$.

To determine if the various parts of the receiving circuit are in working condition the telephone receivers are removed from the "phone" binding posts on the amplifier unit and connected to the "phone" binding posts on the crystal-detector receiving set. The wires connecting to binding posts 5 and 6 (Fig. 3) are temporarily removed and the fine, coiled wire brought in contact with the crystal. The receiving set is then adjusted as described in

Bureau of Standards Circular No. 120 or 121. This furnishes a means of ascertaining if the tuner is in working condition, and also the crystal detector, although the latter is, of course, not used with the electron-tube detector and amplifier units unless the electron-tube detector unit is omitted.

The wires are now reconnected to the binding posts 5 and 6 and the telephone receivers are connected to the "phone" binding posts on the electron-tube detector unit. One of the wires which is connected to one of the "output" binding posts of the electron-tube detector unit is temporarily removed and tests made to determine if the electron-tube detector is in working condition.

The telephone receivers are next connected to the "phone" binding posts on amplifier No. 1, the wire reconnected to the "output" binding post of the electron-tube detector unit, and one of the wires disconnected from one of the "output" binding posts (11 or 12) of amplifier No. 1. Tests are then made to determine if amplifier No. 1 is in working condition.

The telephone receivers are then removed from amplifier No. 1 and attached to amplifier No. 2. The wire is reconnected to the "output" binding post of amplifier No. 1. The connections are now as shown in Figure 3.

If the crystal detector is used in place of the electron-tube detector unit the same general scheme of testing is followed.

VII. APPROXIMATE COST OF PARTS.

The following list gives the cost of parts of one audio-frequency amplifier unit and the "A" and "B" batteries. It does not include the cost of the telephone receivers or of any of the other equipment used to make up the outfits described in the previous circulars of the series. Some of the parts are the same as listed in the electron-tube detector circular with some of the prices revised. If audio-frequency amplifier units are used with the electron-tube detector unit the same "A" and "B" batteries are used, except that if a single "B" battery is used with the electron-tube detector unit one additional "B" battery is required.

Audio-frequency Amplifier Unit.

Electron-tube ("hard," amplifier)	$6.50 to $6.50
Electron-tube socket	.25 to 1.50
Filament rheostat	.50 to 2.50
Audio-frequency amplifier transformer	5.00 to 8.00
10 feet No. 14 bare tinned copper wire, about	.10 to .10
8 binding posts, broad contact type	.40 to 1.20
2 binding posts, set-screw type (for telephone cord tips)	.10 to .30
Miscellaneous wood screws, about	.10 to .10
Wood (hard, for base and panel)	
1 piece 8¼ by 6¼ by ½ inches.	
1 piece 5 by 4½ by ⅜ inches.	
4 rubber feet, about	.10 to .10
Wood (for cover)	
2 pieces for sides, 7¼ by 5 by ½ inches.	
1 piece for back, 5 by 3¾ by ½ inches.	
1 piece for top, 7¾ by 5¼ by ½ inches.	
2 hinges for top, ¾ inch	
Stain and varnish, solder, soldering flux	
	13.05 to 20.30
Batteries:	
"A" storage battery, 6-volt 60-ampere-hour	15.00 to 22.00
2 "B" batteries, 22½ volts each	2.00 to 3.00
	17.00 to 25.00
Total	30.05 to 45.30

VIII. SUGGESTIONS TO STUDENT.

The person who desires to study the principles of operation of radio receiving sets more advanced than have been given in this series on very simple apparatus will find useful information in "The Principles Underlying Radio Communication," previously referred to, and in the periodicals and books listed in Bureau of Standards Circular No. 122, Sources of Elementary Radio Information. Both publications are obtainable from the Superintendent of Documents, Government Printing Office, the former at $1 and the latter at 5 cents.

In textbooks and articles generally, the parts of radio apparatus are represented by conventional symbols. For the assistance of the student, Figure 4 of this pamphlet shows the more common symbols which are extensively used in diagrams of apparatus and circuits. One should be familiar with these in order to read circuit diagrams.

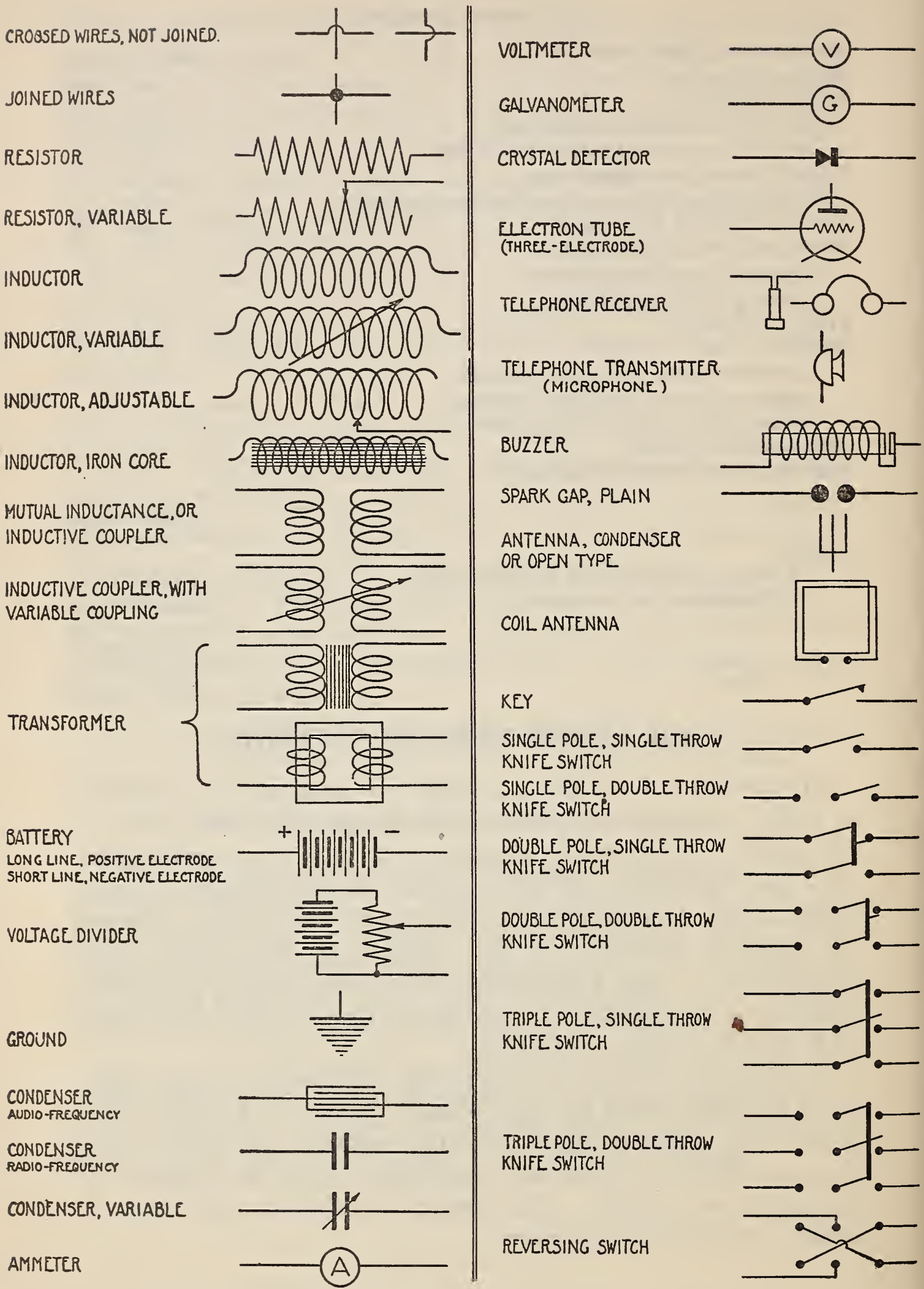

FIG. 4.—*A few common wiring symbols used in schematic wiring diagrams.*