Radio Receivers and Servicing

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COMMERCIAL RECEIVING SETS
SERVICING OF D-C RADIO SETS

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Published by
INTERNATIONAL TEXTBOOK COMPANY
SCRANTON, PA.

Printed in U. S. A.

INTERNATIONAL TEXTBOOK PRESS
Scranton, Pa.

72925

CONTENTS

NOTE.—This book is made up of separate parts, or sections, as indicated by their titles, and the page numbers of each usually begin with 1. In this list of contents the titles of the parts are given in the order in which they appear in the book, and under each title is a full synopsis of the subjects treated.

COMMERCIAL RECEIVING SETS

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Serial 2484 Edition 1

BROADCAST RECEIVERS

DEVELOPMENT

1. The art of radio passed gradually from the experimental stage to the commercial and more permanent state. Many still remember the home-made radio sets with all sorts of makeshifts to avoid the necessity of securing expensive parts and instruments. As the number of receivers increased, the cost of the parts came down, and the competition between the various manufacturers made possible the choice of supplies and instruments of an endless variety.

Then the ingenuity of the constructor came as a personal factor, and every one at some time or another boasted of a receiver that surpassed the other fellow's in some way or another. At first, it was the distance-reaching ability; all that was required of the set was to intercept the call letters so as to record as many stations and as far away as possible. Then as the broadcast programs were improved both in quality of transmission and of material broadcast, the objective shifted from the mere recording of call letters to the ability of listening to good programs from nearby stations.

Then came the simplicity of operation afforded by the reduction of tuning controls and the elimination of batteries, which was a tremendous problem even for engineers, but undaunted home constructors attacked it just as assiduously as the manufacturers themselves.

The result is that the home-constructed set is rapidly vanishing and the commercial receiving set taking the field almost exclusively, at least so far as the reception of broadcast programs of speeches and music and code telegraphy is concerned. Television for the present is now appealing to the custom-set builder almost as much as aural reception did about a decade ago.

CLASSIFICATION OF SETS

2. Radio receivers may be classified according to the use for which they are intended. Accordingly, there are receivers for telephony and for telegraphy. Each of these two categories may be subdivided according to the nature of the service to which they are put, and, therefore, there are sets for private use and sets for station traffic.

By far the greatest number of sets are made for private use and for the reception of broadcast programs. Sets for private reception of telegraphy are not made commercially except for short waves and these are intended mostly for television work. Long-wave receivers for both telegraphic and telephonic communications are installed on board of ships and in some large stations for trans-atlantic communication.

With this classification in mind, radio sets will be described in the following order: (*a*) Broadcast receivers; (*b*) short-wave receivers; and (*c*) long-wave receivers for long-distance telephony and telegraphy such as is used on ships, etc.

INSTALLATION OF BROADCAST RECEIVERS

ANTENNA INSTALLATION

3. Ideal Antenna.—An efficient antenna and ground system is an important factor in the performance of any radio receiver. The ideal antenna for broadcast reception would consist of a single wire of the inverted **L** type strung between two wooden masts in a large open field. It should have a horizontal length of approximately 65 feet and be suspended 30 or 40 feet above the ground. The end of the antenna at which the lead-in is attached should point toward the direction from which the best reception is desired.

The ideal ground system would be a wide copper ribbon of but a few feet in length and running directly to the supply end of a residential cold-water piping system where good contact could be made over a comparatively large area of the pipe. Unfortunately, such an antenna and ground system cannot be erected in most locations. Nevertheless, the ideal conditions should be kept in mind because their closest possible approach will provide the best possible results.

4. Antenna Construction.—An antenna should be well insulated at both ends and erected as far as possible away from trees, buildings, electric wires, and other antennas. It is usually best to erect the antenna at right angles to any street-car or power line. The lead-in wire should preferably be part of the antenna wire so that no joints or connection need be employed. If joints are unavoidable, they should be securely soldered to preclude any possibility of corrosion or looseness. The lead-in should be secured by stand-off insulators so that it will not possibly come in contact with any grounded object.

5. Lightning Arrester.—The lightning arrester should be located in such a way that rain, snow or ice will not collect on it. The installation is quite simple. The antenna lead-in is connected to one of the binding posts and the ground to the other. If the lightning arrester is thought to be defective, it should be disconnected and the results noted. An increase in the volume of the signal would indicate a defective lightning arrester.

6. Indoor Antenna.—If an outside antenna cannot be erected, an inside antenna may be employed. It should consist of an insulated wire, which may be concealed behind the picture molding, or better still, strung up in the attic.

Even a good inside antenna will usually perform much more satisfactorily than the many freak antennas that are advertised as radio cure-alls and are supposed to eliminate static, improve the reception of distant stations, etc.

Frequently, good results may be obtained by coupling the input circuit of the receiver to the power-supply line or to a telephone line. The antenna binding post is connected to one terminal of a small-capacity condenser and the other terminal of the condenser is permanently connected to one side of the power-supply system. This feature is already incorporated in certain radio receivers. The coupling to a telephone line may be very easily made by running an insulated wire next to one of the conductors in the telephone cable, and connecting this wire to the antenna binding post. It is important that all connections in the antenna and ground system make perfect electrical contact.

7. Ground Connection.—The ground wire should be run as directly as possible from the ground binding post on the receiver to a cold-water pipe. Connection may be made to the pipe by means of a suitable ground clamp. If the location of the receiver is such that a comparatively long ground lead is necessary, it may be well to try a connection to a nearby steam pipe or radiator. The connection should never be made to a gas pipe.

Since the majority of house-lighting circuits are grounded, it may, in some cases, be unnecessary to use a ground wire on certain receivers. It is best, however, to use a ground wire on the receiver at the time of installation and ascertain whether better reception is had with or without the ground connection.

In the event that the receiver is not grounded, the metal parts of the receiver will be at a higher potential than the earth. Care must, therefore, be exercised because with one hand touching a grounded object and the other in contact with the metal parts of the receiver, a perceptible but harmless shock may be felt. It may be noticed that a slight spark will occur when the ground wire is attached to the receiver. This occurrence is entirely normal and will cause no damage to the receiver. It can in some instances be eliminated by merely reversing the attachment plug in its socket.

8. Aerial and Ground Convenience Outlets.—Radio wiring has now taken its place along with the services installed for gas, electricity, water, and refrigeration in the modern buildings. And just as there are appropriate outlets for the control and convenient operation of these other services, so there have been made available radio convenience outlets for every radio wiring requirement.

A typical antenna and ground outlet is shown in Fig. 1. The installation is quite simple. First of all, a location convenient to the position of the receiver is determined. Then an opening just large enough to receive the switch box or the receptacle, as the case may be, is made in the wall. The lead-in wire is brought from the lightning arrester behind the wall to the opening, and enough wire is pulled through so that it can be worked conveniently. The ground wire is similarly brought from the nearest ground connection to the opening in the wall. The ends of the antenna and ground wires are then attached to the jacks in the outlet. The excess wire is neatly coiled and pushed into the outlet box or opening. The wall plate is then lined up and fastened in position.

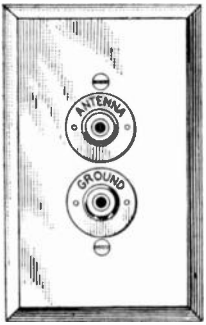


Fig. 1

The usual procedure for long or short lead-ins, such as shielding and the like, should be followed. A good rubber-covered solid conductor is preferable.

Connection to the receiver is made with a flexible conductor and phone-tip plugs. Solid No. 14 wire can be used, but the other method of connecting is much better looking and therefore more desirable.

CENTRALIZED RADIO INSTALLATIONS

9. **Systems.**—As the number of receiving sets has multiplied itself almost to the saturation point, and the quantities of wires for aerials that are stretched over the roofs of the metropolitan apartment houses form veritable cobwebs, many managers have forbidden the use of external antennas in many new buildings. To obviate the difficulties, there is suggested and actually carried out in many cases the centralization of radio reception in the large apartment houses and hotels and even hospitals. To this end there are two main systems: In the first one there are two or more radio receiving sets fed by an antenna for each one. These sets are tuned permanently to some good local station and the audio output of each set is fed to a very high-powered amplifier stage that can operate several dozen loud

speakers at the same time. The leads coming out of each of the high-powered amplifiers are carried in standard conduits to the various apartments, where plug-in boxes conveniently located and provided with switches and volume controls permit the listeners to select the program that suits them best and also to regulate the intensity of the reproduction. All there is in the apartment is the loud speaker.

In the second system, a single large aerial in the roof acts as a pick-up for all the stations simultaneously, as it is not tuned; and from the ramifications of the aerial wire that pass through all the apartments a connection may be made to a receiving set, the input of which has an enormous impedance, so that the connection of the set does not alter materially the voltage of the signal in the aerial and the individual listener can choose the station which he prefers.

10. The first system of reception; namely, the distribution of audio currents through a number of centrally located radio sets that send the audio-frequency currents to the various rooms, where loud speakers or head phones may be used, is shown in Fig. 2. In the second system the aerial with its lightning arrester is brought in the penthouse or other convenient location, and through a panel with fuses the system of distribution starts sending the radio-frequency currents through loaded lines into the connection boxes in the rooms. The outlet boxes contain pin jacks to connect the radio sets, and also power supply to operate them from the 110-volt lines. Of course, all the sets have to start with a coupling tube, so that there will be no interference between radio sets and no change of the constants of the transmission line, and so that the plugging in of a set will not cause any disturbance when other ones are operating from the same line. The same principles involved in the design of cables for telephony in regard to loading, which consists of inserting inductances at regular intervals so that all the frequencies pass with approximately the same attenuation, are followed here, and at the same time filters are used so that only frequencies within the broadcast range will be admitted into the system and interference will therefore be minimized.

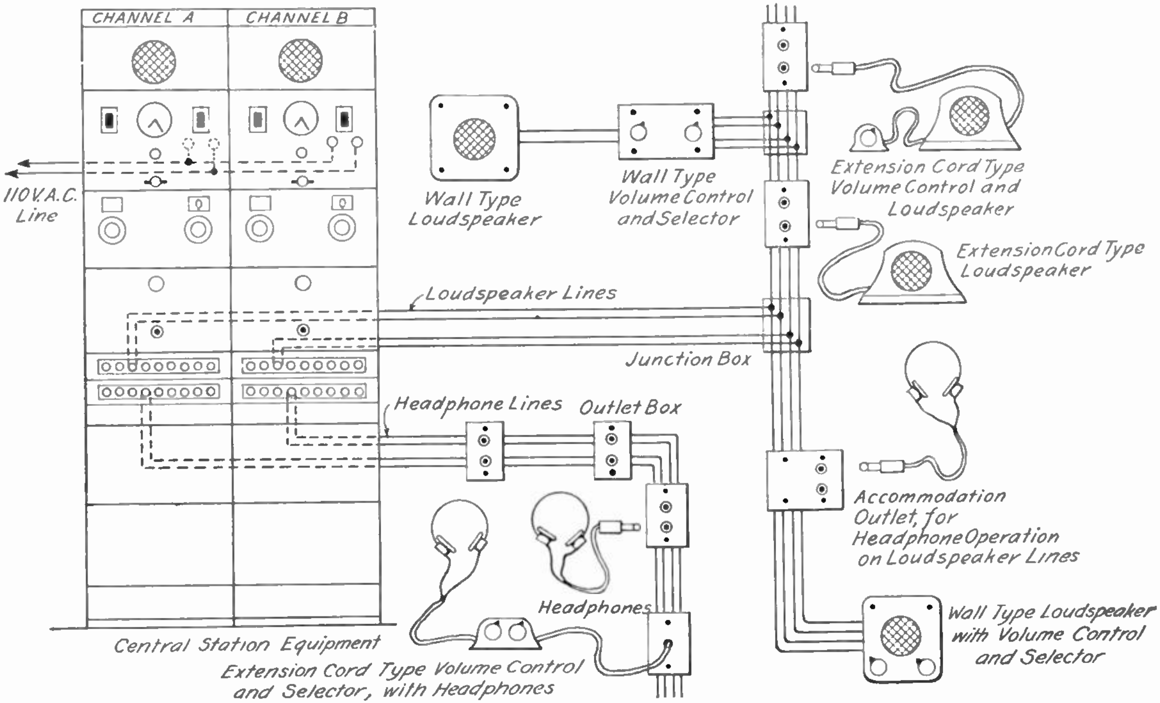

CHANNEL A
CHANNEL B
110V.A.C. Line
Wall Type Loudspeaker
Wall Type Volume Control and Selector
Extension Cord Type Volume Control and Loudspeaker
Extension Cord Type Loudspeaker
Loudspeaker Lines
Junction Box
Headphone Lines
Outlet Box
Accommodation Outlet, for Headphone Operation on Loudspeaker Lines
Headphones
Wall Type Loudspeaker with Volume Control and Selector
Central Station Equipment
Extension Cord Type Volume Control and Selector, with Headphones

FIG. 2

There is a system of r-f distribution in which there are no coupling tubes and that permits the operation of a plurality of radio receivers from a single antenna. It consists of a very well installed and efficient antenna from which a loaded line "riser" comes down either outside the buildings, or through the dumb-waiter shafts, or in a special conduit. It is terminated at the basement of the building by means of a resistance which will prevent the formation of nodes and loops in the line. The radio receivers are connected to the line through small coupling con-

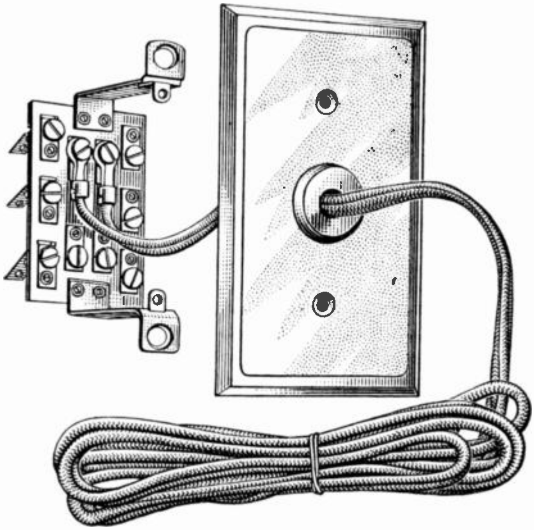


Fig. 3

densers. The loading inductances and the coupling condensers are enclosed in small cylindrical containers called multicouplers.

In this system there is less interference from any one set to any other than in the case of individual antennas supplying each receiver.

11. **Equipment.**—The equipment required in centralized installations consists chiefly of outlets, controls, and the wiring. A cord terminal unit is shown in Fig. 3. This unit is intended for use with both the portable and the wall-type loud speakers as well as with telephone receivers. Provision is made for ter-

minating as many as four channels plus two loud-speaker leads in soldered connections on the back of the terminal unit.

In Fig. 4 is shown a loud speaker mounted in a wall receptacle and supplied with a volume control and channel selector. In certain installations the volume and channel controls are mounted in portable units, either separately or both in one case.

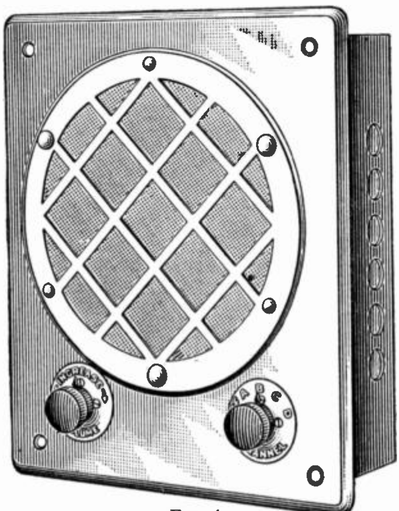


FIG. 4

PHONOGRAPH PICK-UPS

12. Another useful accessory in centralized radio installations as well as for home use is an electric phonograph. One type is shown in Fig. 5. The unit consists essentially of an induction-disk turntable motor and turntable equipped with standard automatic trip-stop having brake and switch arranged for manual as well as automatic operation. An electric pickup arm is included in the equipment.

The motor-speed regulator is accessible from above the motor board and is provided with a screwdriver slot as means for its manipulation. A volume-control knob is placed above the motor board with a locking device to control the output volume. Needle cups and triple clips are provided for holding three needle cases. An accommodation light with a special type of shade reflector is provided. The power input plug is of the recessed design and is located in the side of the chassis.

The output jack is a standard telephone jack mounted flush in the motor board. A flexible "patching" cord is provided with a plug on each end, for connecting this unit with the record input jack.

The chassis is provided with brackets for mounting the unit horizontally and in proper position on the RCA Centralized

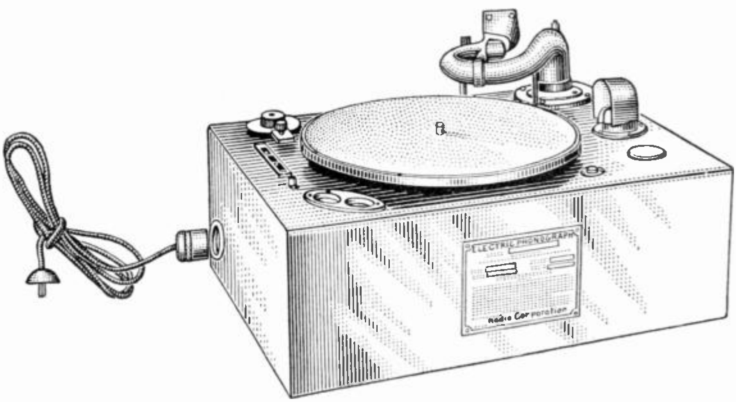


FIG. 5

Radio panels. It is also provided with rubber feet and may be placed on a table or in some other convenient locality near the panel.

13. There are two general systems of electric reproduction through a radio set or rather through an amplifier and loud speaker from a gramophone record; namely, the magnetic and the condenser pick-ups. The first one, and by far the most common, consists of an electromagnetic motor similar in construction to the type in use in cone loud speakers. It has an attachment where the needle is screwed in the same manner as in an ordinary phonograph. The needle, as it travels in the grooves of the record, moves radially with respect to the record, and thereby displaces an armature in the magnetic field of a strong permanent magnet generating an electromotive force in the windings surrounding the armature. This is the reverse process of a loud speaker, where the current moves the armature and the attached needle or rod drives a cone diaphragm. There are no acoustic vibrations coming from the device, but the voltages developed by the reproducer are made to act upon the grid of one of the audio amplifiers directly or through one of the audio transformers and after sufficient amplification they act upon the loud speaker. The volume control is effected by means of a resistance or a potentiometer in the leads coming from the pick-up unit, which modifies the intensity of the applied voltage.

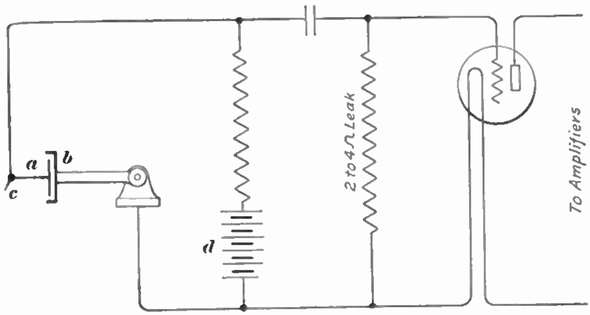


FIG. 6

14. The condenser pick-up is an instrument similar to a broadcast condenser transmitter and consists of two plates *a* and *b*, Fig. 6, insulated from each other, one of them having the needle *c* attached to it and the other rigidly held in the supports of the tone arm, which travels along in the same manner as the magnetic pick-up with the record. The variations in capacity cause a charging and discharging current from a local battery *d* to pass through a grid leak or high resistance and the drop across it is applied to the grid of an amplifier tube of the radio set or to its own amplifying system. This kind of pick-up is not available at present in the open market, but it is being developed in the research laboratories. It has the advantage of more faithful reproduction.

BATTERY-OPERATED BROADCAST RECEIVERS

TYPES OF BROADCAST RECEIVERS

15. Radio sets for broadcast reception may be classified, according to the source of power that supplies them, into d-c and a-c sets. The d-c sets may be operated from batteries or from d-c electric-light mains. Each of these two general categories can be subdivided, following the radio circuit used, into several types, but there are only two which comprise the vast majority of the commercial sets; namely, the tuned radio-frequency sets and the superheterodyne sets. Other types such as the regenerative detector and the three- and four-circuit tuners

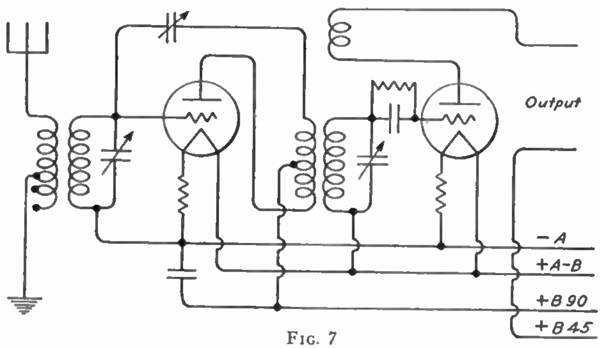


Fig. 7

have become obsolete in this country, although there are quite a number of regenerative detector sets made in Germany and other European countries. In the following paragraphs will be given some of the principal types of sets belonging to each of the following classes: (*a*) battery-operated sets; (*b*) d-c power-operated sets; and (*c*) a-c power-operated sets.

In addition to the receivers, there is a multitude of commercial appliances to convert one class of sets into another, and also to increase the maximum volume without distortion of a given set.

REGENERATIVE SETS

16. Regenerative Receiver With Neutralized R-F Amplifier.—A circuit diagram of receiver with a regenerative detector is shown in Fig. 7. The circuit consists of one stage of

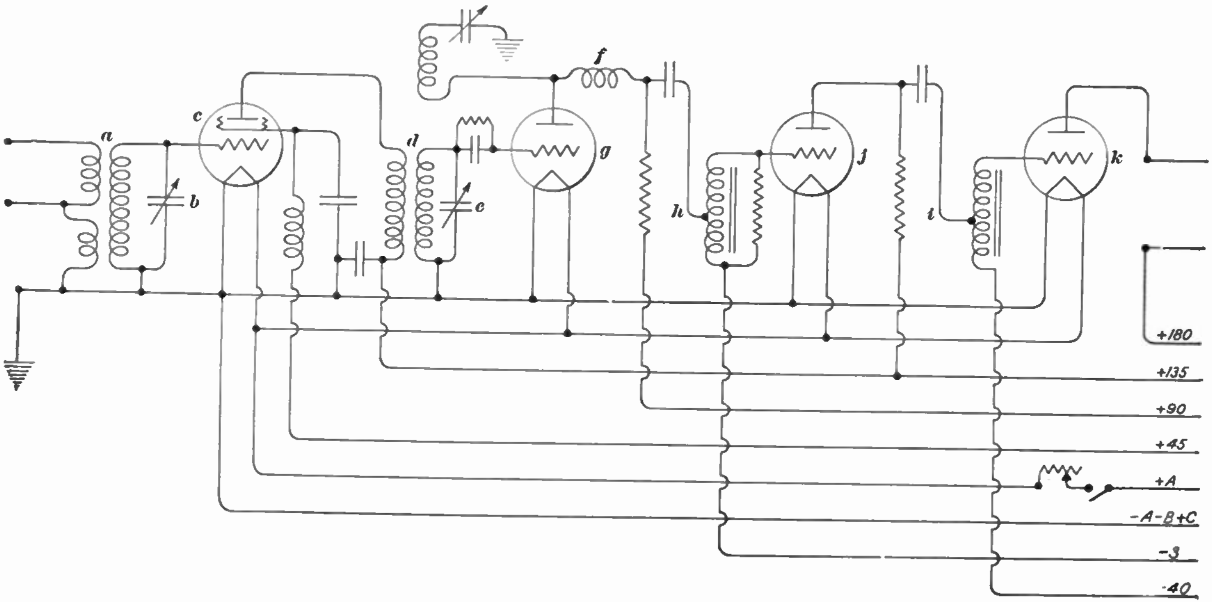


Fig. 8

tuned r-f amplification followed by a regenerative detector. The r-f stage is neutralized. The output of the detector may be amplified at audio-frequency in the customary way. This circuit is employed in several commercial broadcast receiving kits.

17. Regenerative Receiver With Screen-Grid Tube R-F Amplifier.—In Fig. 8 is shown the circuit diagram and in Fig. 9 the assembled chassis of the Silver-Marshall type-740 broadcast receiver. The circuit employs one stage of tuned r-f amplification with a screen-grid amplifier tube, followed by a

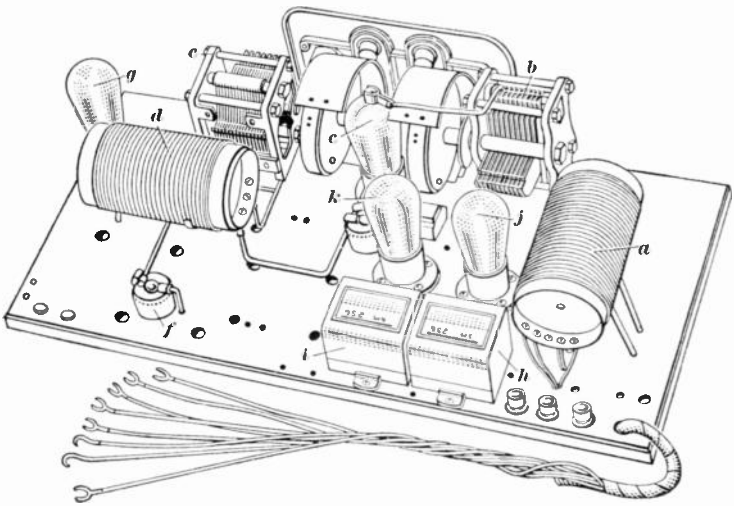


Fig. 9

regenerative detector and two stages of high-gain a-f amplification employing the Clough audio system.

The first r-f transformer *a*, Figs. 8 and 9, has a tapped primary permitting of broad and sharp tuning connections. The secondary in conjunction with the condenser *b* constitutes the first tuned circuit the output of which is amplified by the screen-grid tube *c*. The next transformer *d* is equipped with a tickler coil for the purpose of regeneration. The secondary circuit is tuned with the condenser *e*. A choke coil *f* in the plate circuit of the detector tube *g* prevents r-f currents from entering the a-f amplifier.

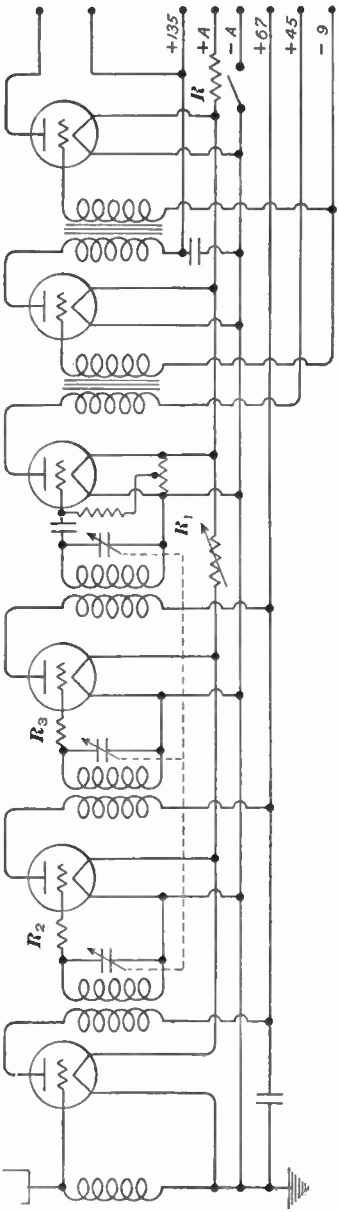


Fig. 10

The audio system has a novel form of coupling. The couplers *h* and *i*, Figs. 8 and 9, consist of a combination of plate resistance, coupling condenser, and auto-transformer. The advantage claimed for these units is fidelity of reproduction and high-gain step-up from one circuit to another. The tube *j* is the first audio amplifier and the tube *k* is the power or output tube. When a 171-A, 245, or 250 tube is used in the output stage, it is necessary to use an output device, which may be either a choke - condenser combination or an output transformer.

BATTERY-OPERATED TUNED R-F SETS

18. Radiola 16.—With very few exceptions battery-operated r-f sets constituted the vast majority of broadcast receivers of the past 3 years. They were only exceeded in quantity by the power-operated receivers of the same type.

Radiola 16, of which a large number are still in use, is typical of sets that have a tuned r-f amplifier and utilize grid resistors to suppress oscillations. The circuit diagram is shown in Fig. 10. There are three tuned circuits all operate l with a single control. The antenna circuit remains untuned, just a fixed r-f choke being connected from grid to filament of the first tube. Five type 201A tubes and one 112A tube are employed, the latter acting as a power tube in the second a-f stage. A single fixed filament resistor R reduces the battery voltage to a value required at the terminals of the tubes. The volume is controlled by means of the rheostat R_1, which dims the filaments of the three r-f tubes, thereby reducing the r-f amplification. The resistors R_2 (800 ohms) and R_3 (600 ohms) are the grid suppressors, which prevent oscillations due to the internal feed-back through the capacity of the elements of the tubes. There is no choke coil or output transformer in the plate circuit of the last a-f stage, since the plate current of the 112A tube is very small.

19. Fada-22 Battery Receiver.—Fada model 22 broadcast receiver represents the neutralized types of battery receivers. This receiver consists of three tuned stages of r-f amplification, a detector, and two stages of a-f amplification. The circuit diagram is shown in Fig. 11.

The coils in the r-f amplifier are completely shielded. The tuning condensers are of the gang type, being controlled by a single dial. A small vernier condenser forms part of each tuning unit for bringing each of the circuits in resonance with the others. The r-f stages are neutralized. The detector is of the biased type. The a-f amplifier is transformer-coupled with 250,000-ohm resistors across the secondaries for stability. The 112A-type tube is recommended for all the sockets except the last, where the 171A-type tube should be used.

The r-f and a-f amplifiers each require 90 volts plate potential, the detector 45, and the power tube 180 or 135 volts. The most economical operation is obtained with the last tube 171A having 135 volts plate potential and 22½ volts C bias. The first a-f tube requires 4½ volts C bias with the specified plate voltage.

The set has three controls. The first is for tuning the set to a given station. The second is the antenna control, which adjusts the antenna circuit independently of the main tuning control. The third is the volume control and off-and-on switch. This is the variable resistor and slider in the $+A$ lead.

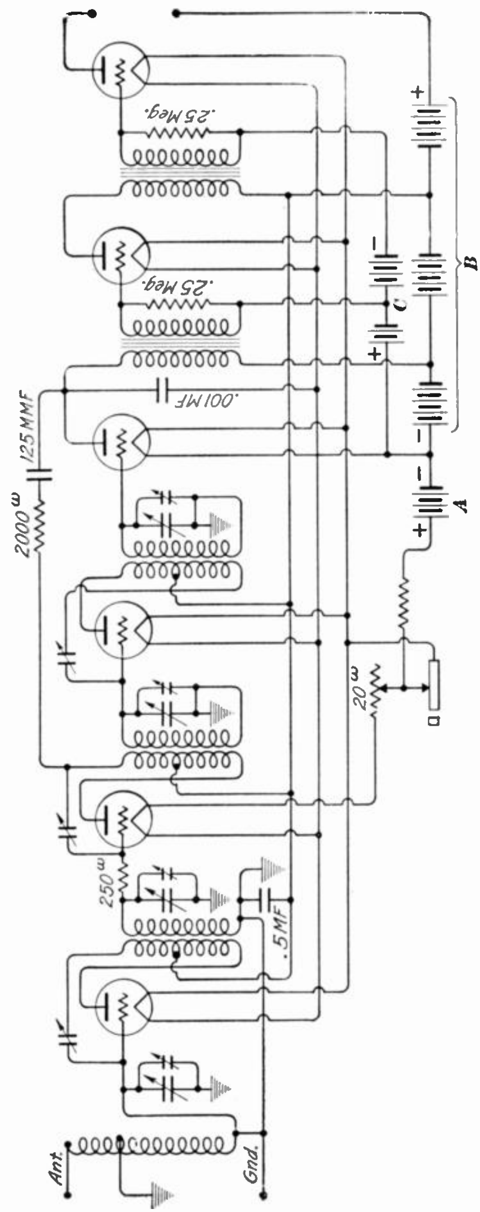


Fig 11

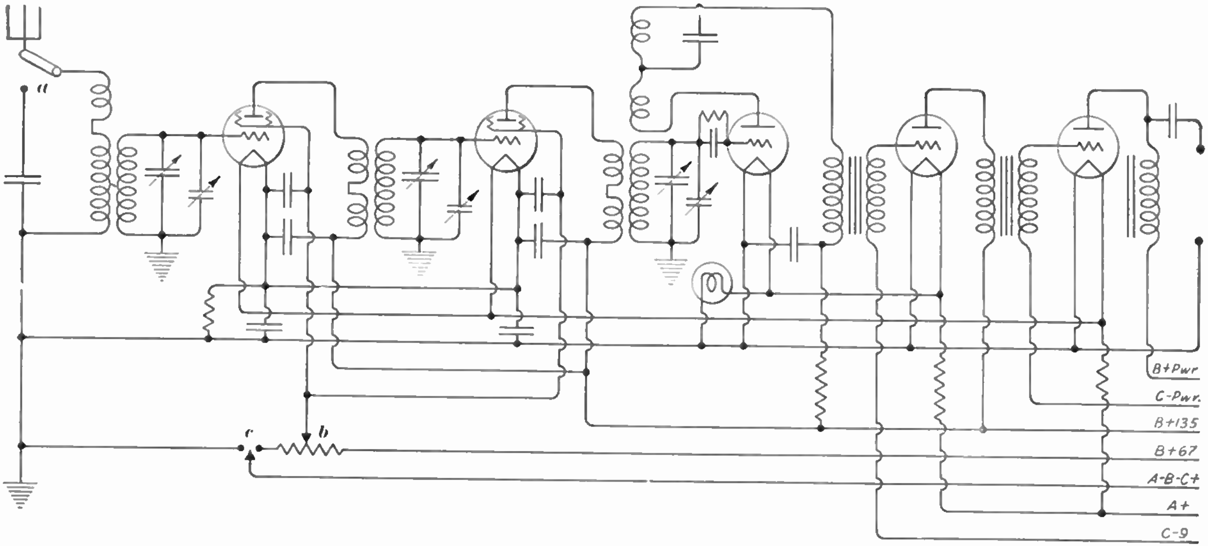


FIG. 12

20. Radiolas 21 and 22.—Radiolas 21 and 22 are battery-operated receiving sets with screen-grid tubes in the r-f stages. Radiola 21 is a table model with an external loud speaker, and Radiola 22 is a console model with a built-in loud speaker. The internal connections are the same in both models and are shown in Fig. 12.

The receiver consists of two tuned r-f stages with d-c screen-grid tubes (type 222), a tuned grid-leak type detector and two stages of transformer-coupled a-f amplification. A choice of power tubes may be had in the second a-f stage by simply providing suitable B and C voltages.

A local-distant switch *a* permits of the best tuning to local and distant stations. In the local position, the antenna is disconnected and a .00023-microfarad condenser is connected from the antenna connection to ground. This condenser across the primary of the first coil or the capacity of the antenna and ground when the switch *a* is on its upper contact tunes the antenna circuit to a low frequency, about 700 kilocycles, which increases the sensitivity of the set at the low-frequency end. Since the receiver is normally more sensitive at the high-frequency end, the use of the tuned circuit at the low frequency gives nearly equal sensitivity throughout the tuning range.

21. The volume control *b*, Fig. 12, is a 50,000-ohm potentiometer, which varies the screen-grid voltage of the r-f tubes. On the left of the volume control is shown the operating switch *c*. This switch not only disconnects the A battery, but also disconnects the B voltage from the volume control. This prevents unnecessary B-battery consumption when the set is not in use.

A fixed regenerative detector gives added sensitivity to the circuit with a resultant gain in overall sensitivity. This does not require any adjustment during operation.

SETS FOR D-C LINE OPERATION

22. Circuits of Neutralized Receiver.—There are a few factory-made sets that are much in demand in the large cities where the Edison three-wire d-c system prevails. They operate from 110 to 120 volts d-c, with all the filaments in series. Most

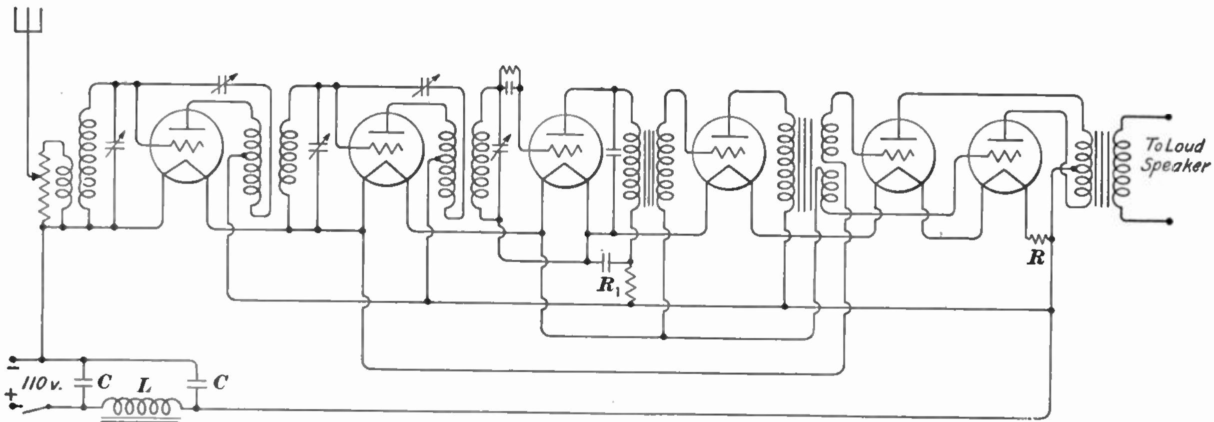


FIG. 13

of them are of either the neutralized or screen-grid tuned r-f type. Among them may be mentioned the Atwater Kent, the Freed-Eisman, the Kolster, the Sleeper and a few others. As they are all alike in circuit diagram except for the presence or absence of neutralizing condensers or grid suppressors, one of them will be described in detail.

The wiring diagram of the set is shown in Fig. 13. It will be seen that there are three tuned circuits the condensers of which are adjusted by means of the drum control and tune the grid circuits of the two r-f stages and of the detector. The volume is controlled by means of a potentiometer across the antenna coil, which has for its function to limit the radio-frequency voltage just before it reaches the grid of the first tube. The audio system is of standard design with a push-pull amplifier in the output stage.

23. All the tubes in Fig. 13 have the same filament requirements, namely, .25 ampere at 5 volts. The total voltage required for the six tubes, in series, is 30 volts. In order to reduce the line voltage to 30 volts, a series resistor R is employed, and this combined with the ohmic resistance of the inductance coil L gives the required voltage drop.

The plate voltage for all the amplifier tubes is taken directly from the line and corresponds, therefore, to the line voltage, except for the drop through the filter inductance L. The plate current of the detector tube passes through the resistor R_1, which produces the necessary voltage drop for the satisfactory operation of the detector tube.

24. The manner in which the grid bias is obtained is very simple to understand. In d-c sets the grid bias is always measured with reference to the negative-tube terminal. The r-f amplifier tubes have their grid-return leads connected directly to the negative-filament terminal, hence the grid bias is zero. The grid return of the detector tube is connected to the positive-filament terminal, hence a positive voltage is applied to the grid of the tube. The grid return of the first a-f tube is connected to the negative terminal of the detector tube so that the bias corresponds to the drop across the filament of this tube, or

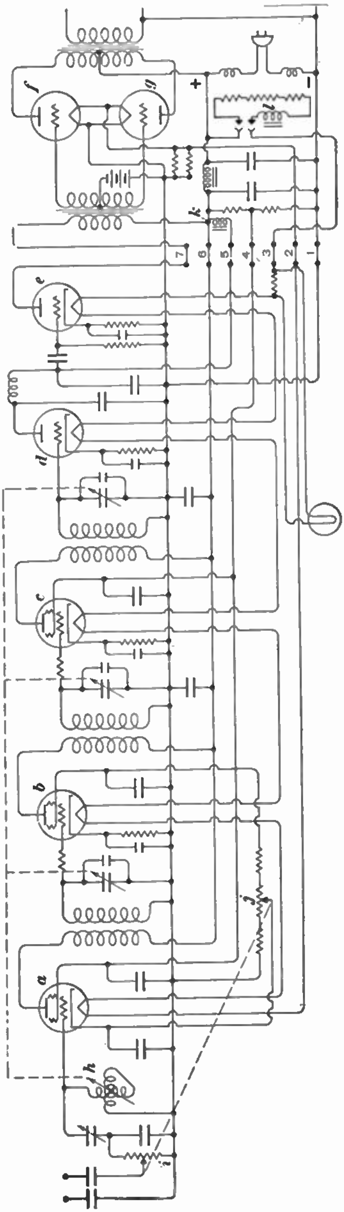


FIG. 14

5 volts. The first tube in the push-pull amplifier has its grid-return lead connected to the negative-filament terminal of the second r-f amplifier tube. The grid bias on this tube corresponds, therefore, to the drop across the filaments of the three tubes preceding it. Similarly, the grid bias on the second push-pull tube is equal to the voltage drop across the filaments of the three preceding tubes.

The filter in the power circuit consisting of the inductance coil *L* and the condenser *C* tends to smooth out any irregularities in the power supply.

25. Bosch Model 54 D-C Receiver.—The Bosch model 54 receiver for 110-volt d-c operation comprises three tuned r-f stages employing type 224 screen-grid tubes (separately heated cathode type) *a*, *b*, and *c*, Fig. 14; a power detector *d* with a type 227 tube; a first audio stage with a type 227 tube *c*; and a push-pull second a-f amplifier with type 171A tubes *f* and *g*.

The three r-f stages use the heater-type screen-grid tubes in preference to the d-c type, which results in an exclusion of line noises. Similarly, the detector and first a-f tubes are of the heater type, which, combined with the push-pull power amplifier, results in quiet operation with ample volume to operate a good loud speaker.

Variometer tuning of the first r-f stage is employed, thus assuring equal sensitivity on both high and low frequencies. The variometer *h* is geared directly to the condenser gang and needs no separate control. The small variable condenser across the variometer serves as the clarifier; its main purpose is to adapt the first tuning circuit to any length of antenna.

26. The volume control consists of two separate resistance units *i* and *j*, Fig. 14, operated by a single shaft. The resistance *i* is used as a potentiometer in the antenna circuit and the other variable resistance *j*, as a potentiometer to vary the grid bias of the first r-f tube *a*. This type of control gives smooth variation in volume on either distant or local stations and at the same time maintains a good quality of signal. The entire r-f amplifier is properly by-passed and thorough shielding is applied to permit of utilizing the large gain of which the screen-grid tubes are capable.

The detector *d* is of the biased type and is designed to handle without distortion the high output of the r-f amplifier. The required bias is furnished by the 40,000-ohm resistor in the cathode circuit.

The first audio tube *e* is choke-coil coupled to the detector stage, the choke coil being shown at *k*. The grid bias is furnished by the voltage drop across the 1,500-ohm resistor in the cathode circuit.

27. The push-pull power stage, Fig. 14, has two 171A-type tubes *f* and *g*, which receive the full line voltage for the plate supply. A separate C battery is employed, which permits of using all the available line voltage for the plates of the tubes.

The reduction of the line voltage for the series filament circuit is obtained by means of three 20-ohm resistors. The plate supply is carefully filtered and supplied with suitable resistors to reduce the line voltage to the desired operating value.

The field winding of the dynamic speaker that is used with this receiver is shown at *l*. A special type of field winding (4 ohms) is used. The three 20-ohm resistors in series with the field winding constitute the series filament resistance. The voice coil of the dynamic speaker is, obviously, connected in the secondary circuit of the output transformer.

A-C SETS

TUNED R-F CIRCUIT WITH GRID SUPPRESSORS

28. In Fig. 15 is shown a typical circuit diagram of a radio receiver using type-226 tubes in the r-f amplifier, a type-227 tube as a detector, a type-226 as the first a-f amplifier, and a type-250 in the power stage. The r-f circuits are maintained stable by the use of the 600-ohm grid resistors *R*. The volume control is a 2,000-ohm potentiometer across the plate coil of the first r-f amplifier tube.

The first three tubes as well as the first a-f amplifier are of the 226 type. The detector is type 227. The output tube is type 250. The rectifier tube in the power unit is type 281.

The filament voltages are obtained from separate low-voltage windings on the power transformer *a*. The plate and grid voltages are obtained from the output of the rectifier and filter. The choke coil *b* is really the field winding of the dynamic speaker which is used with this set, and this in conjunction with the two 2-microfarad condensers constitutes the filter circuit. The plate-supply circuits can be traced quite readily. The grid bias for the power tube is measured with reference to the center tap of the corresponding filament windings and the grid of the tube, which is at ground potential. In other words, this gives the drop across the 1,500-ohm resistor in the power unit. The other tubes are biased by the voltage drop across the 600-ohm resistor *c* in the set. The variable resistors *d* are the hum adjustors.

NEUTRALIZED A-C RECEIVERS

29. The neutralized receiver under discussion (Philco) consists of three stages of tuned r-f amplification, a grid condenser and leak detector, a first-stage a-f amplifier, and a push-

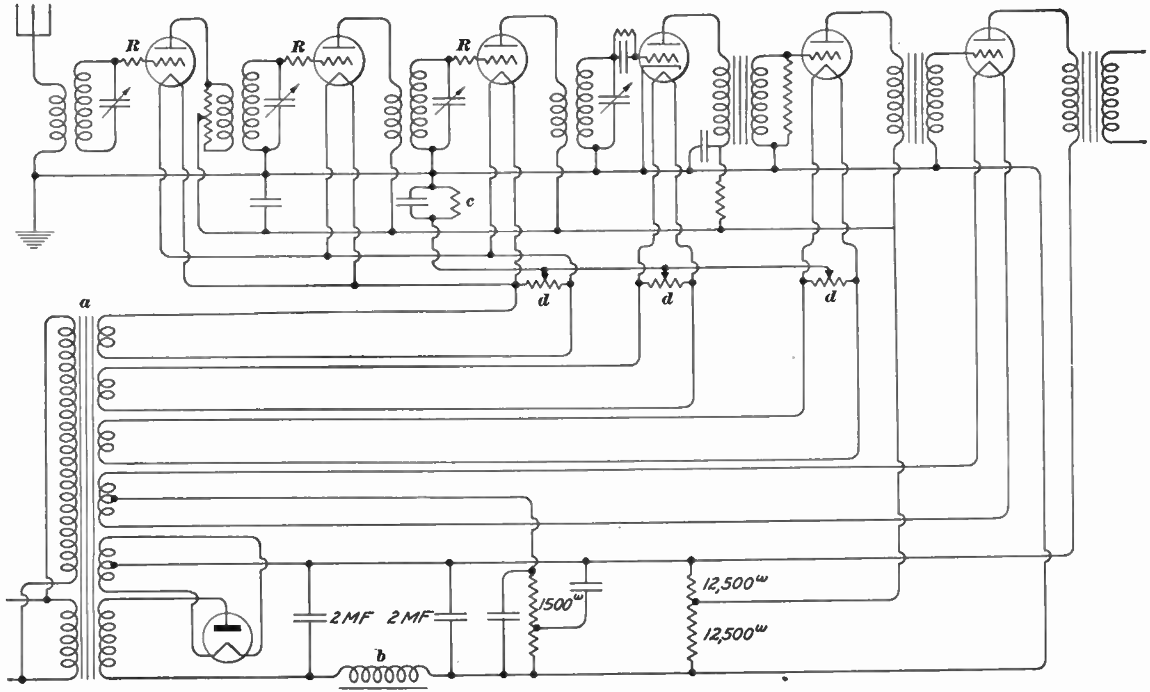


Fig. 15

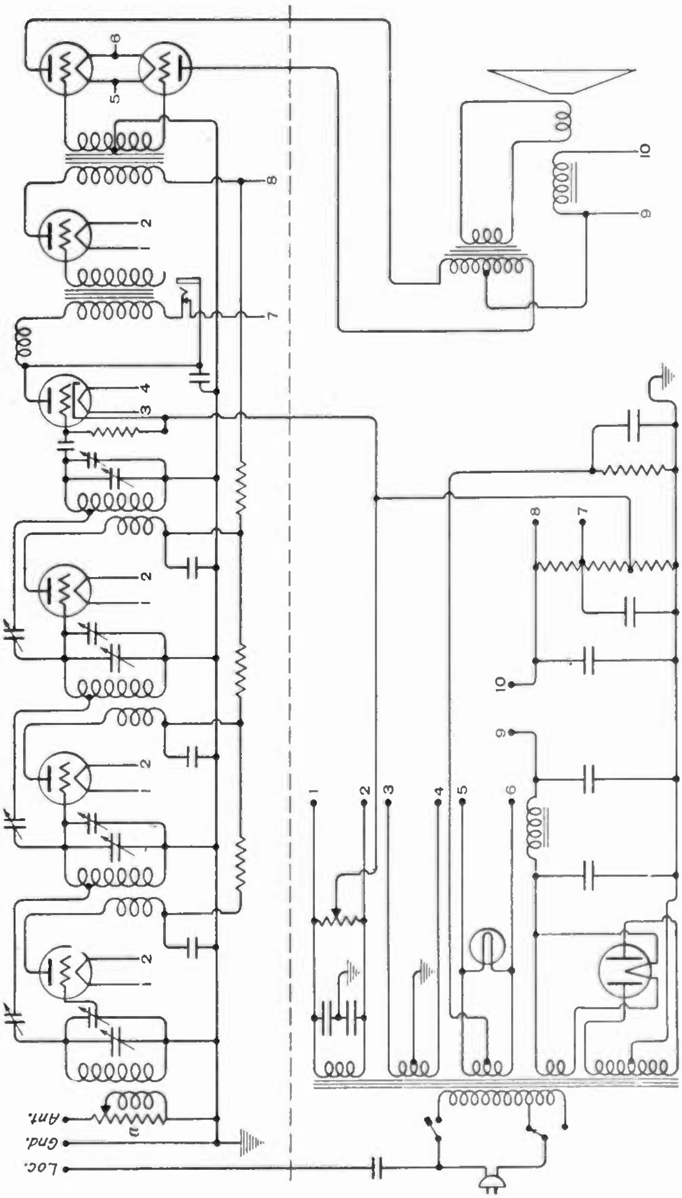


Fig. 16

pull power amplifier working into a dynamic speaker. The circuit diagram is shown in Fig. 16.

Very good selectivity is obtained from the four tuned circuits in the receiver. A further refinement is found in the range control, which is the small variable condenser across the first main tuning condenser. The range control is especially valuable when tuning in stations on the high-frequency channels. The other three variable condensers each have a compensating condenser shunted across them for equalizing all the tuned circuits.

There are three input terminals, marked *Loc.*, *Gnd.*, and *Ant.*, the meaning of which is obvious. The local connection is employed for nearby stations and where no outside antenna is available. This terminal is simply connected to the antenna terminal, thereby using the power line as an antenna with a small condenser in series. The ground terminal is connected to a water pipe or to some other good ground. The primary of the first r-f transformer is shunted by a variable resistor *a*, which serves as a volume control. The three r-f stages are well neutralized, the Hazletine system of neutralizing being used.

30. In order to avoid a large number of lines, the circuit, Fig. 16, has been simplified by the use of numbers to show the connections between the set and the power pack. For example, the filament terminals *1* and *2* in the set are connected to terminals *1* and *2* in the power unit; terminals *9* and *10* of the field winding of the speaker are connected to terminals *9* and *10* in the power unit, etc.

A phonograph jack is included in the plate circuit of the detector tube. When the plug is inserted into this jack, the phonograph reproducer is connected to the primary winding of the first audio transformer and the plate power is shut off.

In setting up sets having type-226 and 171A tubes, like the one under consideration, it is advisable to insert the 171A power tubes in their respective sockets first, so as to make sure that the 226-type tube would not be inserted therein by mistake, which would, of course, result in the burning out of the 226-type tubes. The set under consideration requires four 226-type tubes, one 227-type, two 171A-type, and one 280-type.

SCREEN-GRID TUBE SETS

31. Development.—With the advent of the alternating-current screen-grid tubes, the amount of r-f amplification that can be obtained without oscillations and with a reasonable degree of stability has been pushed to limits that were seldom reached except with extremely complicated circuits. The necessity of neutralization of the r-f circuits is eliminated, since the internal coupling by capacity between the grid and plate is suppressed by the screen grid.

The commercial sets containing screen-grid tubes take advantage of the large r-f amplification in two ways: first, they make possible the use of the so-called power detection, with or without the suppression of one of the audio stages; and second, with fewer tubes in the r-f system but with more tuning condensers, a band-pass filtering action may be secured from the tuning system, thereby improving considerably the quality of reception of both speech and music because all the higher audio frequencies are not reduced or suppressed as with the ordinary tuners in which the secondary only has a tuning condenser.

The general trend in shielded set construction is toward increased r-f amplification with a corresponding reduction in the audio system. It is claimed that better quality of reproduction will be secured due to the elimination of the distortion which accompanies multistage audio amplifiers. In some sets the shield grid tube is used as detector, on account of its greater detection coefficient as compared with that of the heater tube with three elements (227 type). As the shield grid tubes of the 224 type have a very high plate resistance, it is customary in some sets to couple the plate of such detector tube to the next audio stage by resistance and condenser or by choke and condenser rather than by transformer.

32. The general type of construction conforms to the most recent practice of building the set with its electro-dynamic speaker in a console or cabinet. In such cases, the chassis containing the tuners and shielded grid tubes forms a unit. Another unit contains the power tubes with the a-c converting apparatus for the proper voltage supply to the tubes, and the third unit contains the dynamic speaker. Sometimes the first and second or the second and third units are combined in one chassis. Although there are some sets which are made in the table cabinet type and contain all the radio and power-supply apparatus, they are meant to be used with an external loud speaker and as a rule they have no means of energizing the electromagnet of the dynamic speakers. In some models such as the Atwater Kent, there is provision to energize the field of the reproducer from the set, but they are limited to the use of the speaker built for them. However, many power-amplifier chasses are made in such manner that the field of most dynamic speakers may be energized from the supply source of the power tubes by providing connections for such purpose.

The latest types of sets include a remote-control system to tune the set and regulate the volume. This is accomplished in some types in a manner very similar to the automatic elevator controls. At certain prearranged points in the dial where the favorite stations tune in very accurately, a set of stops is fastened, and when the remote-control button corresponding to each particular stop is pressed, the motor that turns the tuning-condenser shaft will rotate until the dial reaches the position corresponding to the particular stop selected, just as the automatic elevators will come to a stop opposite the floor level selected by pressing the suitable button in the control boards.

There is another system in which the rotation of the condenser shaft is accomplished by means of a special motor which follows the movements of the hand-operated dial at the remote-control end, much as the swell shutters of a pipe organ controlling the volume of the instrument follow the foot of the organist as he controls the swell pedal at the console, or as the indicators on steamships at the engine room follow the movements of the dials at the captain's observation cabin.

The following examples of shield-grid tube sets will serve to illustrate typical cases. The wiring diagrams with few modifications are sufficiently standardized and departures from them are only in the way of refinements or improvements for some particular purpose.

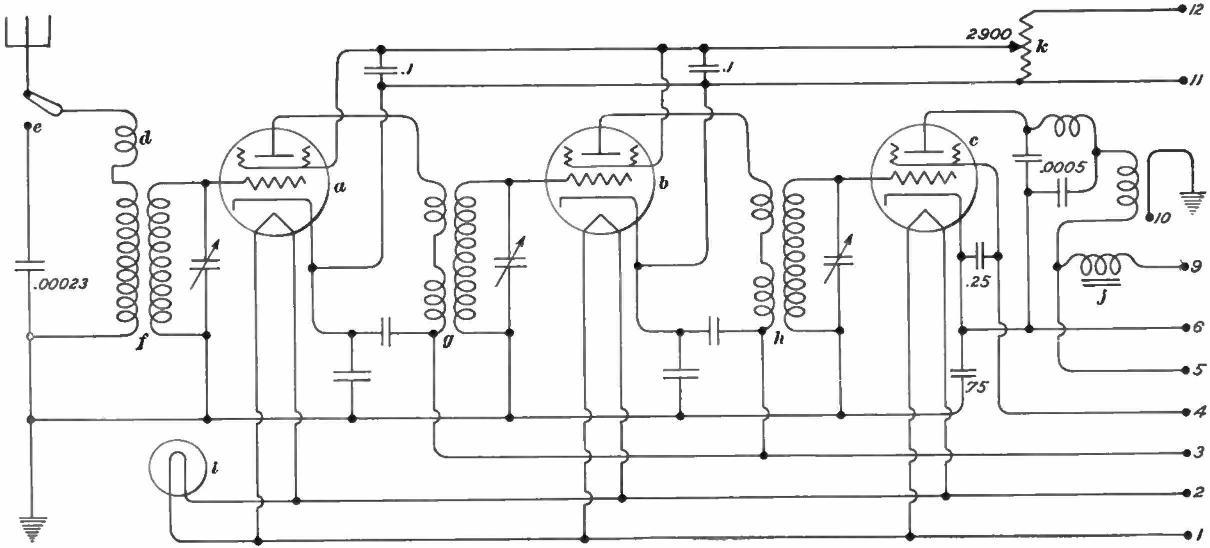


Fig. 17

33. Radiola 44.—The use of screen-grid tubes is well exemplified in Radiola 44 (also Radiola 46). The circuit diagram of the receiver is shown in Fig. 17 and of the power pack and power amplifier in Fig. 18. The receiving set, Fig. 17, consists of two stages of r-f amplification with a screen-grid tube *a* in the first stage and a similar tube *b* in the second stage. The detector tube *c* is of the same type and is operated on the principle of biased detection. The output of the detector is amplified by the power-amplifier tube in the power unit.

A high-inductance loading coil *d* is used in the antenna circuit so that variations in antenna constants have little effect on the tuning of the circuits. This eliminates the necessity for a coupling tube or an antenna trimmer. A "local-distance" switch *e* is included in this circuit for the purpose of disconnecting the antenna and closing the circuit with a .00023 microfarad fixed condenser when local reception is desired.

The tuning circuits consist of three r-f transformers *f*, *g*, and *h*, the secondaries of which are identical, and each is tuned by one unit of the three-gang condenser. The primaries of the transformers *g* and *h* consist of two sections; a high-inductance section loosely coupled to the secondary designed to supply the high impedance necessary to match the light impedance of the tube so that maximum amplification may be obtained, and a single turn in series with the former and closely coupled to the secondary so that a maximum amount of energy may be transferred without destroying selectivity.

The tubes *a*, *b*, and *c* in the receiving set, Fig. 17, have their filaments, or heaters, operated with alternating current. This is obtained from a special 2½-volt winding on the power transformer, Fig. 18, which is conducted from terminals *1* and *2* to the filaments of the tubes in Fig. 17. A pilot light *i*, which serves the double purpose of indicating that the set is on or off and at the same time illuminating the tuning scale is lighted from the same circuit.

The plate voltage to the r-f amplifier tubes comes from terminal *3*. The plate voltage to the detector tube comes from terminal *9*, through the coupling reactor *j* and filter. The filter consists of two r-f chokes and two .00005 microfarad condensers.

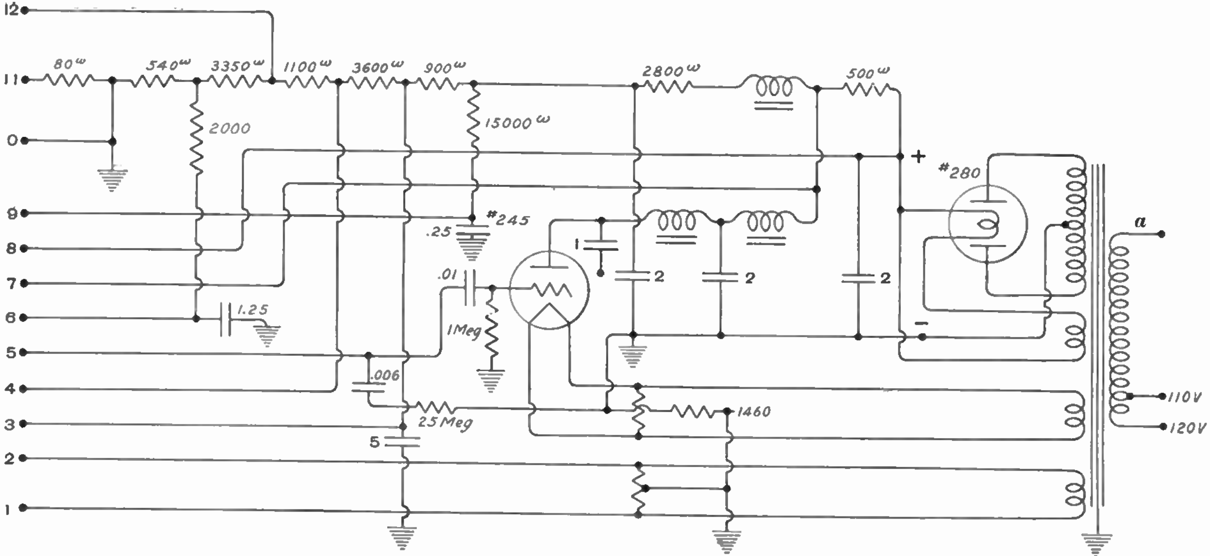

12
11
0
9
8
7
6
5
4
3
2
1
80ω
540ω
3350ω
1100ω
3600ω
900ω
2000
15000ω
2800ω
500ω
#245
.25
.01
1Meg
1.25
.006
25 Meg
5
1
2
2
2
+
−
#280
a
1460
110V
120V

Fig. 18

One of the condensers connects the plate side of the first choke to the cathode, and the second connects the high-voltage side of the same choke to the cathode. The coupling condenser and the necessary grid leak (1 megohm) are located in the power unit and may be traced by way of terminal *5*.

The positive voltage to the screen grids of the r-f amplifier tubes comes by the way of the 2,900-ohm potentiometer *k*, which acts as a volume control, the ends of which are connected to terminals *11* and *12*, and the slider to the screen grids. The screen grids are by-passed to the cathode by means of .1 microfarad condensers. The cathodes are maintained at a higher potential than the ground, as may be seen by reference to terminal *11*, Fig. 14.

The positive voltage to the screen grid of the detector tube comes from terminal *4* and this too is suitably by-passed to the cathode by means of a .25-microfarad condenser.

34. The cathodes of the r-f amplifier tubes *a* and *b*, Fig. 17, are positive with reference to the control grids and with reference to the filaments or heaters. The voltage for the cathodes is available from terminal *11*. The voltage for the cathode of the detector *c* is available from terminal *4*. The cathodes of the r-f tubes are by-passed to ground by means of .1 microfarad condensers and the cathode of the detector by means of a .75 microfarad condenser.

The grid bias is measured with reference to the cathode of the tube. One terminal of the voltmeter is connected to the grid and the other to the cathode. The tube *a*, for example, has its grid at ground potential. The cathode voltage is the drop of potential across the 80-ohm resistance from terminal *11*, Fig. 18, to ground. In other words, the plate current passing through the 80-ohm resistance gives the necessary grid bias to the r-f tubes *a* and *b*, Fig. 17. The grid of the detector tube is also at ground potential. However, the cathode connects through terminal *6* to the 2,000-ohm resistor through which the detector plate current must flow. The biasing circuit may be traced from point *9*, choke *j*, and filter, plate of tube *c*, cathode, terminal *6*, 2,000-ohm resistance, to supply.

35. The power unit is shown schematically in Fig. 18. The primary of the power transformer *a* is provided with a tap for 110- and 120-volt a-c supply. There are four secondaries, one of which is connected to terminals *1* and *2* as the filament supply to the tubes in the set. The one above it supplies the filament current to the power-amplifier tube (type 245). The third is used for the filament of the rectifier tube (type 280). The uppermost, or high-voltage, winding is connected in a double-rectifier circuit and supplies all the necessary plate and biasing voltages. The output of the rectifier, which may be considered as starting at points indicated + and −, continues from + through the 500-ohm resistor, choke, 2,800, 900, 3,600, 1,100, 3,350 and 540-ohm resistors to ground and from there to the − terminal of the rectifier output. The choke coils and condensers constitute the filter, and the resistors constitute the voltage divider.

The filter system is divided into two parts. The first 2-microfarad filter condenser shunts the total voltage supply. From here the audio plate voltage is filtered, another 2-microfarad condenser being connected across the junction between the filter choke and the output choke and ground. Instead of being taken from the output of this filter system, the voltage supply for the r-f tubes and the detector passes through the same 500-ohm resistor, separate choke, 2,800-ohm resistor, and is shunted with a third 2-microfarad condenser. At this point, the output again divides; to the detector through the 15,000-ohm resistor and terminal *9*; and to the r-f amplifier through an additional 900-ohm resistor and terminal *3*.

36. Some of these circuits are rather difficult to visualize and it will be of advantage to trace them completely. The plate circuit starts at the + point of the supply, Fig. 18, and continues through the 500-ohm resistor, choke, 2,800-ohm and 900-ohm resistors, terminal 3, Figs. 18 and 17, primary winding of transformer *g*, plate to cathode of tube *a*, to terminal *11*, 80-ohm resistor to ground and back to the − terminal of the supply. It should be remembered that all ground terminals constitute a common connection. The drop across the 80-ohm resistor from the cathode and terminal *11* to ground, makes the cathode so much more positive than ground, and hence makes the grid negative with reference to the cathode. The same circuit arrangement applies to the second r-f amplifier tube. The screen-grid voltages are obtained from a tap between the 1,100-ohm and 3,350-ohm resistors to terminal *12*, across part of the potentiometer *k*, to the screen grids.

Because of the great amplification that takes place within the screen-grid tube, it is necessary to protect the connections to the control grid from all stray electrical fields. In other words, it is necessary to shield a radio receiver, even though a screen-grid tube is employed. In fact, it is more necessary than in other types of receivers, because of the high amplification. All that is eliminated by the use of screen-grid tubes is the grid-plate capacity, and even this is appreciable. This means that in spite of all precautions taken against unwanted coupling, there is still some coupling between grid and plate and if the frequency is high enough and the voltage amplification is high enough, the tube will oscillate.

37. Atwater-Kent Model 55.—In Fig. 15 is given the wiring diagram of the Atwater-Kent model 55 screen-grid receiver using two 224, two 227, two 245, and one 280-type tubes. The novel features comprise means of energizing the electro-dynamic speaker from the C-voltage source; this is accomplished by using the resistance of the field winding, with another resistance in parallel, as a means of obtaining the necessary drop of potential due to the passage of the plate currents of the power tubes, to give them the proper negative grid voltage. If the wiring diagram of Fig. 19 is followed closely, it will be seen that the plate current of the power tubes follows the path through the mid-point of output push-pull transformer, through the supply network B+, B− through a divided path, one branch of which is made of the resistors R and R_1, the other the field winding of the electro-dynamic speaker to the ground, or chassis to which the mid-point of the filaments of the power tubes is connected. The resistors R and R_1 constitute a potentiometer or potential divider and the negative grid voltage may be made of the desired

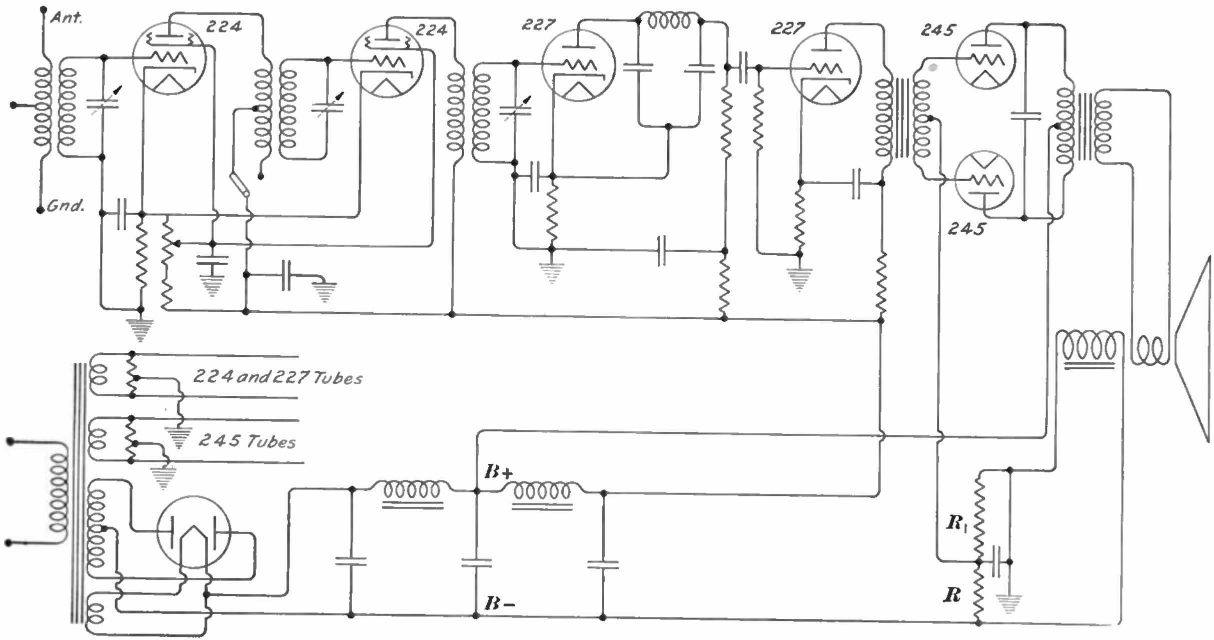
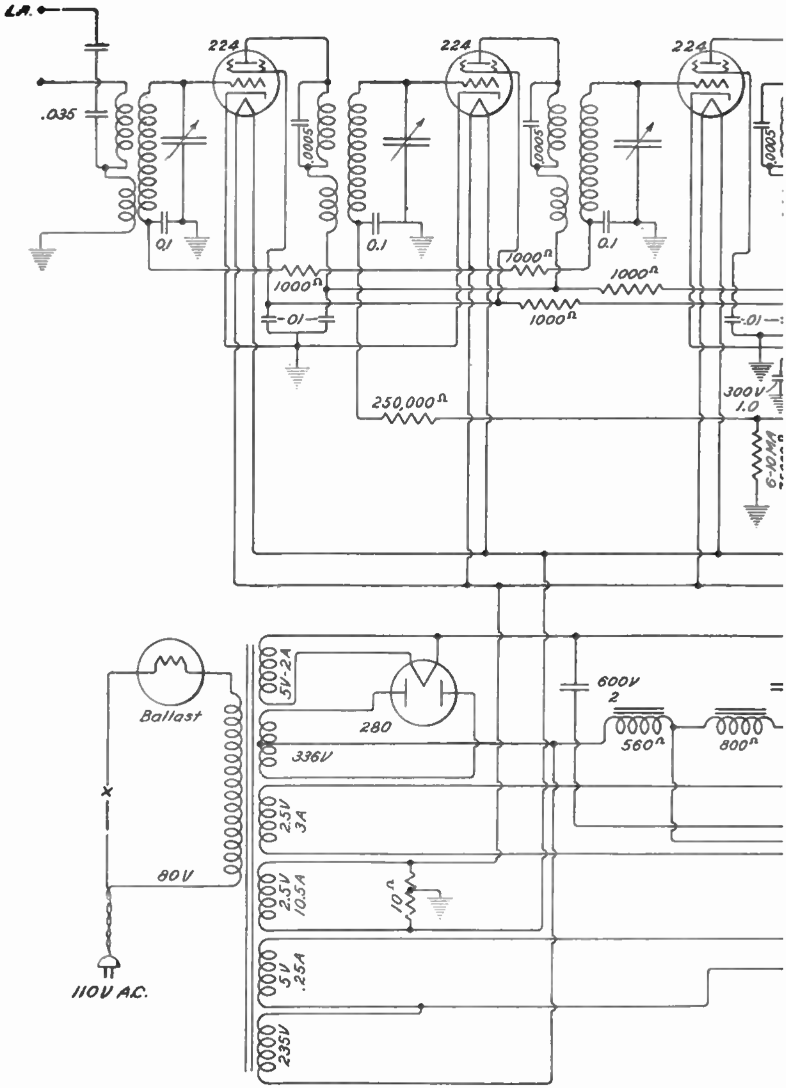

Ant.
Gnd.
224
224
227
227
245
245
224 and 227 Tubes
245 Tubes
B+
B−
R₁
R

Fig. 19



L.A.
.035
224
224
224
.0005
.0005
.0005
0.1
0.1
0.1
1000Ω
1000Ω
1000Ω
1000Ω
.01
.01
250,000Ω
300V
1.0
6-10MA
Ballast
5V-2A
280
336V
600V
2
560Ω
800Ω
2.5V
3A
2.5V
10.5A
10Ω
5V
.25A
235V
80V
110V AC.

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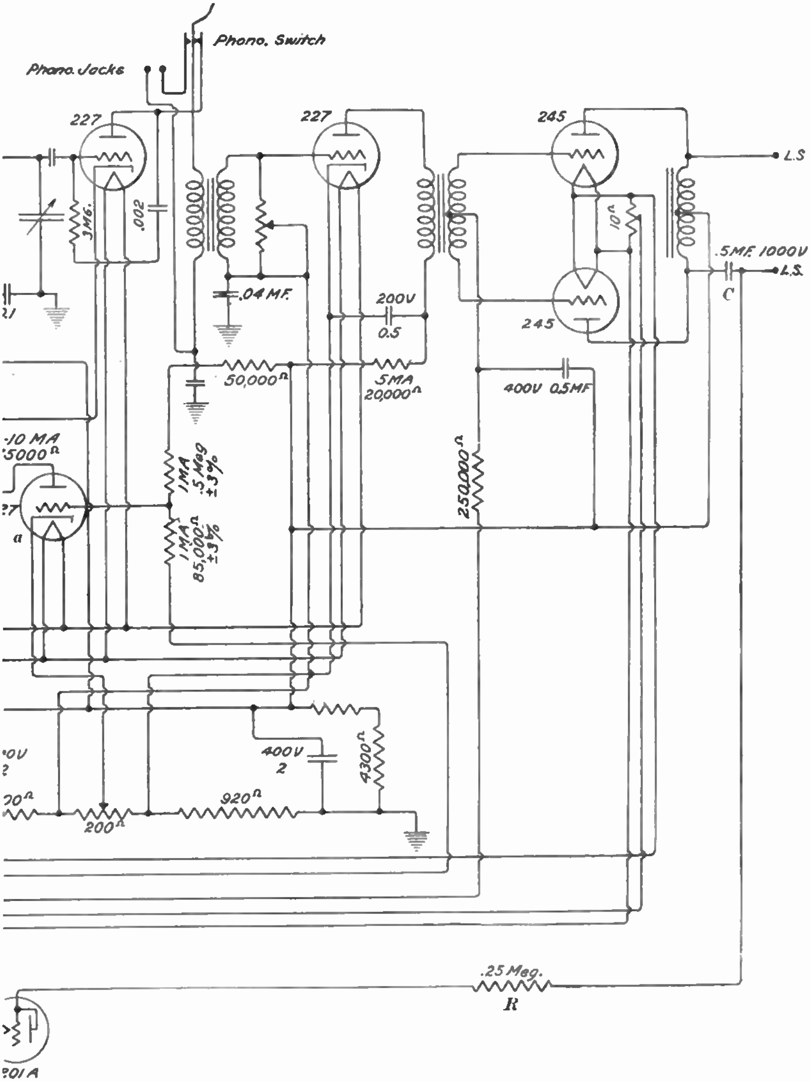

Phono. Switch
Phono. Jacks
227
227
245
L.S
.002
3M6.
.04 MF.
200V
0.5
.5MF. 1000V
L.S.
C
245
10Ω
50,000Ω
5MA
20,000Ω
400V 0.5MF
-10 MA
5000Ω
1MA
.5 Meg
±3%
1MA
85,000Ω
±3%
250,000Ω
a
400V
2
4300Ω
920Ω
200Ω
.25 Meg.
R
201 A

value by properly selecting their values. This scheme effects a saving in total voltage from the B source, since otherwise the drop across the dynamic speaker field would have to be taken at the expense of B voltage available. This way a good part of the necessary voltage for the excitation of the speaker field is available at the same time for C voltage drop, which is essential for the operation of the power tubes and which is derived from the B power pack.

The volume control is operated, as in most screen-grid sets, by adjusting the positive potential of the screen grid by means of a potentiometer. Another control which is provided for operating the set when local stations only are to be received, consists of a double switch which changes the number of turns in the primary winding of the first interstage transformer. Another control permits the use of long or short aerial by varying the number of turns of the primary of the antenna tuning coil. This set has therefore the minimum number of parts necessary to insure fairly good reception both for local and distant stations.

38. Peerless Receiver With Condenser-Type Speaker. The electrostatic reproducer is an excellent device for the clear rendition of distinctly articulated speech and the high overtones of musical instruments in the top end of the scale. It is, however, somewhat less sensitive than good dynamic speakers and it has not been much used in the past on this account as well as because it requires high voltage for its operation. With the advent of the high-gain r-f amplifiers with screen-grid tubes, sets have been made with the electrostatic speaker that are quite good for a clear reproduction of speech and even with considerable volume without sounding *boomy.* The Peerless set, Fig. 20, contains a tuned antenna, three screen-grid tubes, a detector (with condenser-and-leak) one stage of audio and a power stage made of two 245 tubes in push-pull. From this array of tubes and circuits, it may be seen that the total gain is enormous, since the high r-f gain is superimposed upon a powerful audio system and the detector is made of the most sensitive kind, namely, by the condenser-and-leak method.

The necessary high voltage required for the operation of the electrostatic speaker is obtained by adding in series to the B-voltage supply, another source of rectified electromotive force, which is called upon to develop very little power; because it merely charges the plates of the speaker condenser with very high potential, just as a magnetizing current is required to energize the magnetic field of a dynamic speaker. In both cases the sensitivity of the reproducer is proportional to the strength of the electric or magnetic field.

In order to secure this high voltage economically, an additional high-tension winding is provided in the power transformer, and a 5-volt winding to heat the filament of a 201-A tube the grid and plate of which are tied together, constituting a half-wave rectifier. A very simple filter made of the ¼-megohm resistor *R* and the ½-microfarad condenser *C* serve to take away the ripple of the pulsating rectified voltage. It will be noted that the negative terminal of this additional rectifier, instead of going to the ground, is connected to the positive plate-voltage terminal so that the two rectifier supplies are in series in order to furnish the high polarizing potential required by the speaker.

39. A unique feature in this set which is to be found in a few others is the automatic volume control which permits the reception of local or distant radio stations with equal intensity. This is accomplished by means of the auxiliary tube *a*, Fig. 20, which acts as a variable resistance and it is so connected that the cathode goes to the B+ terminal and the plate to the C voltage leads supplying the radio amplifiers through suitable resistors. It supplies negative voltage in the same manner as the regular rectifiers supply positive potential for the operation of the plate circuits of the tubes. The negative potential depends, however, upon the relative state of the grid of the rectifier tube *a* with respect to the cathode, and this is controlled by the amplitude of the carrier wave as obtained after being amplified. Thus, if the carrier is strong, the grid bias will be greater and therefore the amplification will be reduced and vice-versa. This automatic volume control may in turn be subjected to adjustment by hand so that the desired level of sound intensity may prevail at all times and for all stations. In other words, if it is desired that the set sound loud, it will do so no matter whether the station is near or far or how well or poorly it is received (up to the maximum limit of amplification available). If the volume required is soft, all stations will likewise, come soft. The amount of interfering noises will increase as the signal strength of a station diminishes, since the volume is automatically kept constant. In tuning in a station, the automatic volume control should be kept from operating, as otherwise it would be very difficult to tune it accurately and distorted reproduction may result; for that reason, some sets are now equipped with a meter that will enable the operator to tune always to the maximum response to the carrier wave.

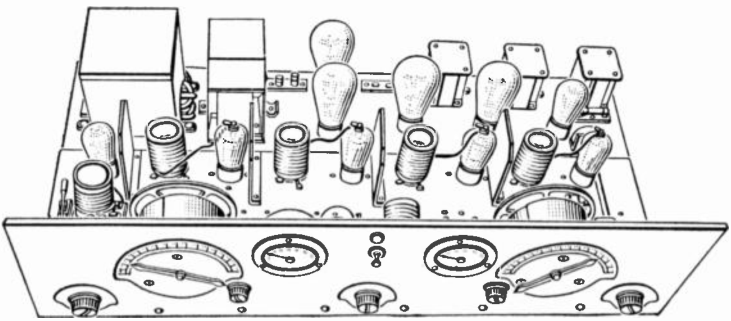


FIG. 21

40. Norden-Hauck Super 10.—The Norden-Hauck Super 10 radio receiver, the chassis of which is shown in Fig. 21 and the schematic circuit diagram in Fig. 22, is an a-c operated superheterodyne receiver using screen-grid tubes in the r-f and i-f stages. Ten radio tubes are employed in this model. These include five type-224 screen-grid tubes, three type-227 tubes, and two type-250 power tubes. In addition to these, two type-281 rectifier tubes are used, making the total twelve.

The receiver is arranged for broadcast and short-wave reception. This is obtained in an efficient manner by a removable-coil system. It is only necessary to change two coils to alter the wavelength range. The receiver comes regularly equipped to operate between 200 and 550 meters and between 18 and

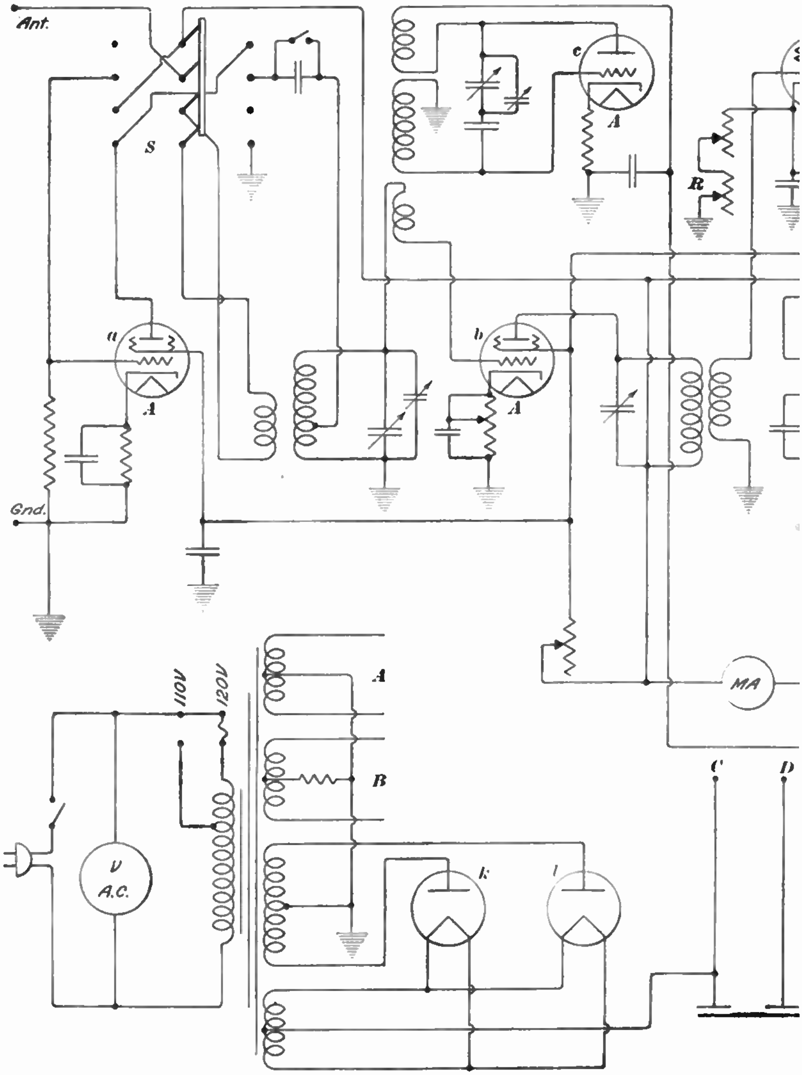
80 meters for experimental reception and television work if desired.

41. The chassis, Fig. 21, is extra-heavy aluminum, satin grain finish and lacquered. Heavy aluminum and copper shielding is used throughout. The panel is ¼-inch bakelite and is equipped with two major tuning controls, and two meters. The dial on the left controls the tuner of the first detector and that on the right controls the oscillator. The meter on the left reads the line voltage and the one on the right is the tuning indicator. In addition to these the panel contains a pilot light, the on-off switch, a sensitivity control, an auxiliary detector control and a volume control.

42. The circuit diagram, Fig. 22, is very interesting. Before going much farther into the theory of this circuit it may be well to mention that the letters *A* and *B* represent the connections from the filaments in the receiver to the corresponding terminals in the power unit. Similarly, the letters *C*, *D*, and *E* on the loud speaker represent connections to the filter circuit in the power unit.

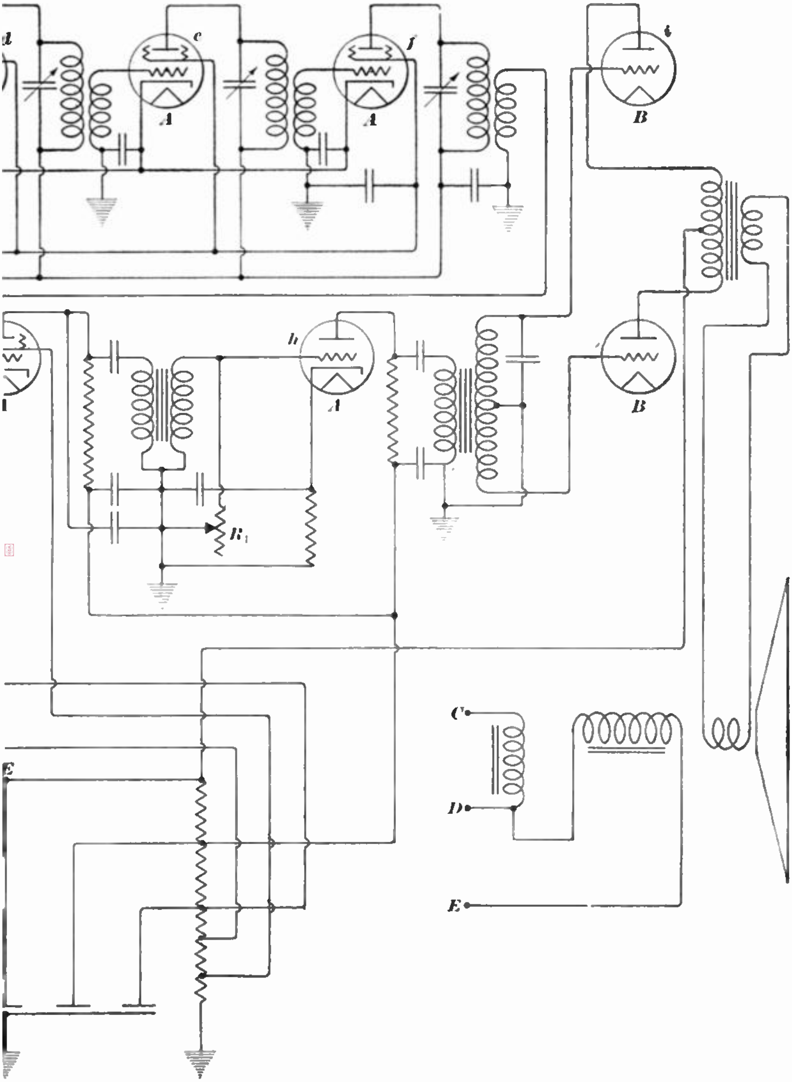
The switch *S*, when turned to the left, permits of using the tube *a* as the first r-f amplifier. When turned to the right, it disengages the first tube and connects the antenna system to the grid circuit of the first detector tube *b*. Both of these tubes are of the screen-grid type (224). The oscillator circuit with the tube *c* (type 227) is made to operate at a frequency that will produce a beat note of 475 kilocycles with the frequency of the incoming signal. The signal is then amplified at 475 kilocycles by the i-f amplifier tubes *d*, *e*, and *f*, then rectified by the second detector *g*, and finally amplified at audio frequency by the tubes *h*, *i*, and *j*, the last two being of the 250 type and connected in a push-pull circuit.

43. The first selector is the tuning element in the grid circuit of the first detector tube *b*, Fig. 22. The second selector is the tuning element in the grid circuit of the oscillator tube *c*. The sensitivity control is a double variable resistor *R* in the cathode circuit of the intermediate-frequency amplifier. This



BB N173 2484

F


d
c
f
t
A
A
B
h
A
B
R_1
C
D
E
E

control regulates the amplification of the three intermediate stages. The volume control is a variable resistor R_1 that shunts the secondary of the first audio transformer.

The power unit has an a-c voltmeter in the input circuit. This meter gives, at all times when the set is in operation, the correct reading of line voltage. The primary circuit has also an adjustment for line voltage which consists of a fuse and which is placed either in the 110- or 120-volt receptacle, depending on the line voltage. A milliammeter *MA* in the plate circuit of the r-f and i-f amplifier tubes serves as an indicator of resonance. The rectifier tubes *k* and *l* are type 281. The chokes of the filter system are incorporated in the dynamic-speaker unit. The connection is made at terminals *C*, *D*, and *E*.

SHORT-WAVE RECEIVERS

PILOT SHORT-WAVE RECEIVER

44. Battery-Operated Receiver.—The circuit diagram of the Pilot Super-Wasp, battery model, is shown in Fig. 23. It consists of one tuned r-f stage followed by a regenerative detector and a two-stage audio amplifier.

Two sets of plug-in coils are furnished for the Super-Wasp, one set acting as antenna coils in the r-f stage and the other as interstage coils between the plate of the screen-grid tube and the grid of the detector. The red, orange, yellow, and green ring coils for the antenna position contain only one winding apiece; the blue ring coil, covering the broadcast range, has two windings, a primary above a secondary.

These coils are thus easily distinguished from the detector stage coils, all of which have two windings apiece, a grid winding above a tickler. The coils are always used in pairs; that is, if an orange ring coil is in the first can (the r-f stage), the other orange ring coil must be used in the detector can.

The tuning ranges of the coils are as follows: Red, 14-27 meters (21,420 to 11,110 kilocycles); Orange, 26 to 50 meters (11,540 to 6,000 kilocycles); Yellow, 50 to 100 meters (6,000 to 3,000 kilocycles); Green, 100 to 200 meters (3,000 to 1,500 kilocycles); Blue, 200 to 500 meters (1,500 to 600 kilocycles).

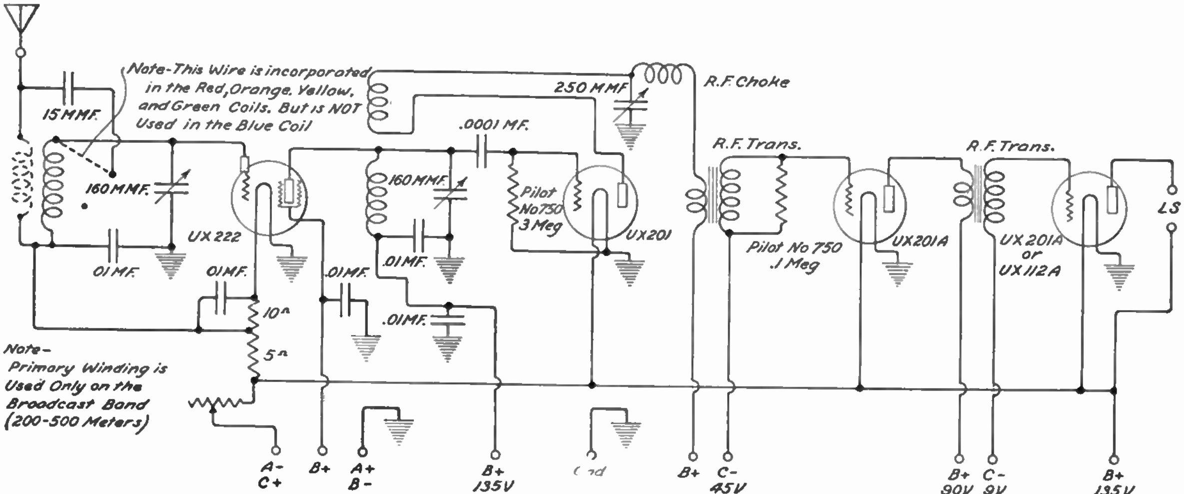

Note-This Wire is incorporated in the Red, Orange, Yellow, and Green Coils. But is NOT Used in the Blue Coil
15 MMF.
160 MMF.
.01 MF.
UX 222
.01 MF.
10 Ω
5 Ω
Note- Primary Winding is Used Only on the Broadcast Band (200-500 Meters)
.0001 MF.
160 MMF.
.01 MF.
.01 MF.
.01 MF.
250 MMF
Pilot No 750 3 Meg
UX 201
R.F. Choke
R.F. Trans.
Pilot No 750 .1 Meg
UX 201A
R.F. Trans.
UX 201A or UX 112A
LS
A- C+
B+
A+ B-
B+ 135 V
B+
C- 45 V
B+ 90 V
C- 9 V
B+ 135 V

FIG. 23

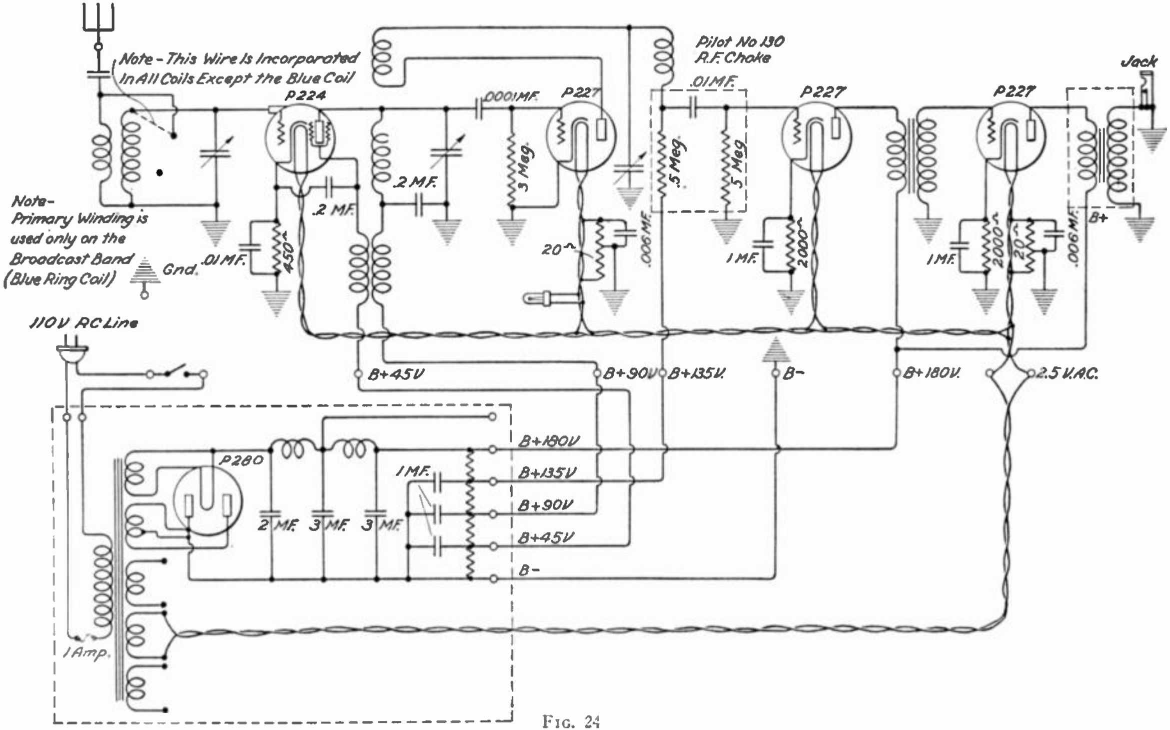

Note - This Wire Is Incorporated In All Coils Except the Blue Coil
P224
.0001MF.
P227
Pilot No 130 R.F. Choke
.01MF.
P227
P227
Jack
.2 MF.
.2 MF.
3 Meg
.5 Meg
.5 Meg
Note- Primary Winding is used only on the Broadcast Band (Blue Ring Coil)
Gnd.
.01 MF.
450Ω
20Ω
.006 MF.
1 MF.
2000Ω
1 MF.
2000Ω
20Ω
.006 MF.
B+
110V AC Line
B+45V
B+90V
B+135V.
B-
B+180V.
2.5 V.A.C.
P280
B+180V
B+135V
B+90V
B+45V
B-
1 MF.
2 MF.
3 MF.
3 MF.
1 Amp.

Fig. 24

45. A-C Operated Receiver.—The circuit diagram of the a-c operated Pilot Super-Wasp is shown in Fig. 24. The circuit is essentially like that of the battery receiver with further modifications and refinements to permit of a-c operation. All the voltages are obtained from a specially designed power pack. The grid bias is obtained by means of a voltage drop in the negative lead of the high-voltage d-c supply. The biasing resistance in each case is by-passed with a large condenser so that no fluctuating feed-back will occur.

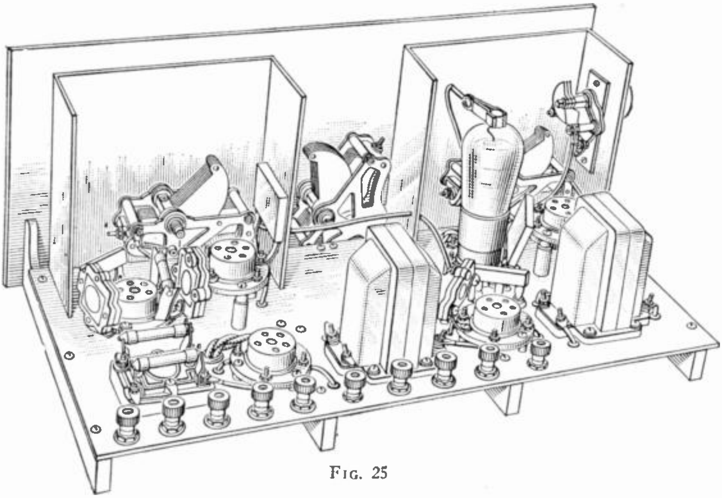


Fig. 25

46. Construction.—The parts of the Super-Wasp, a-c and d-c models, are laid out in such a way that the connections are very short and direct, as may be seen in Fig. 25. The figure shows the internal construction of the a-c model with the shield cans partly removed, but the same layout is used in the battery-operated model. The shield can on the right contains the r-f stage with screen-grid tube and the can on the left contains the detector equipment. The condenser between the two shields controls the regeneration. Each can contains two tube sockets. One of these is for the tube and the other for the coil. The coil socket is partly raised from the base. The two sets of plug-in coils are shown in Fig. 26. Those in the upper row are used in the r-f stage and those in the lower row in the detector stage.

The equipment directly behind the binding posts, Fig. 25, constitutes the audio amplifier. First comes the coupling resistor, then the first audio tube socket, audio transformer, second audio-tube socket, and finally the output transformer.

47. Tuning.—According to the instructions of the Pilot Radio and Tube Corporation, the success of the receiver will depend to a great extent on how smoothly the detector tube can be made to regenerate. Operating conditions are just right when the set goes into oscillation at the high end of any pair of coils with the regeneration condenser (the center one) all the way in.

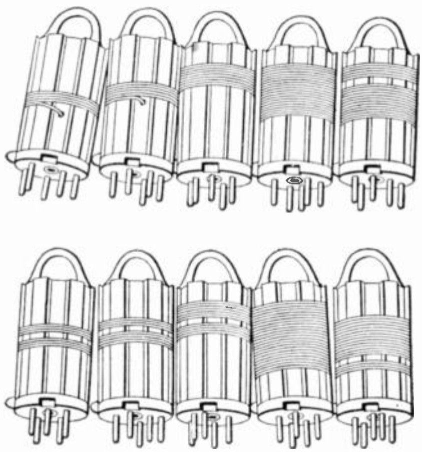


Fig. 26

The two tuning dials will run more or less alike, except at the very high and very low ends of the scales. For the full 0-100 range on the detector condenser (the right-hand one) the r-f condenser will usually run from 10 to 90 or 95. The size of the individual aerial affects this relationship. It is virtually impossible to make the dials read exactly alike, because of the different capacities and inductances associated with the r-f and the detector circuits.

The setting of the midget condenser (on the side of the shield can), Fig. 25, is a matter of experiment, and will be different for different aerials. It is also different for the different coils.

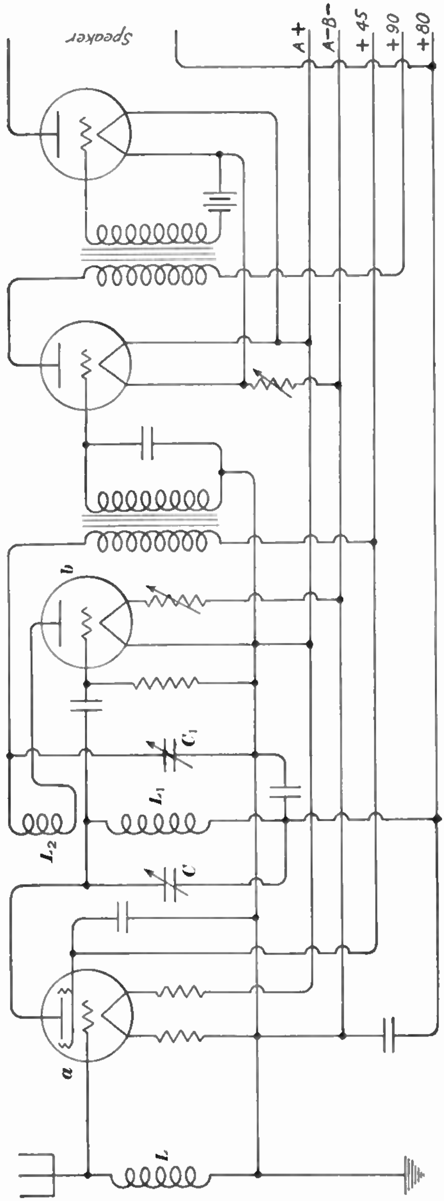


Fig. 27

The positions, found best by trial, can be marked right on the can with pencil lines.

In hunting for short-wave broadcasting stations, the tuning is going to be very sharp, and one will skip right by many powerful stations if one does not proceed carefully. The right-hand dial should be set at about 20, the left at about 25, and the regeneration condenser set up until the tell-tale rushing sound indicative of regeneration is heard. The dials may be moved up or down a degree at a time until a loud whistle is heard. The whistle is tuned in as loud as possible, and then the regeneration condenser is started back. The tuning dials should be juggled back and forth a trifle at the same time, and eventually one will be able to clear the whistle and hear the voice or music. If the

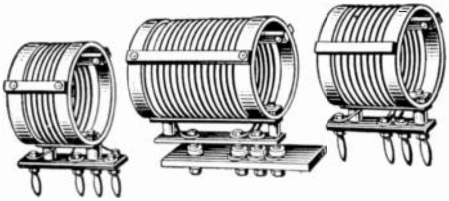


FIG. 28

signals are very weak, one may have to "zero beat" them. This is the operation of throwing the detector into oscillation, obtaining the whistle, and then tuning the set so carefully that the voice comes through just as the whistle disappears. It will reappear if the detector condenser is turned either up or down. Zero-beating is a very effective method of bringing in weak broadcasting stations, although it requires some experience in tuning. The trick can be mastered after a few evenings.

AERO SHORT-WAVE RECEIVER

48. The circuit diagram of Aero International Four receiver is shown in Fig. 27. An aperiodic input circuit is used, including a specially designed input impedance *L*. The shield-grid tube *a* contributes to the ease of operation by the elimination of the so-called *dead spots* in the tuning range. These are due to the fact that the antenna at the natural period, or multiple thereof, subtracts enough energy from the tuned circuit to stop the detector tube *b* from oscillating. The coil L_1 in conjunction with the condenser *C* constitutes the tuning circuit. The coil L_2 is the tickler coil and the amount of feed-back is regulated by means of the condenser C_1. The coils L_1 and L_2 are wound on one form and three such coils, as shown in Fig. 28, are supplied to cover the required wave-length range. The center coil in Fig. 28 is shown with a base. This base is used with all the coils.

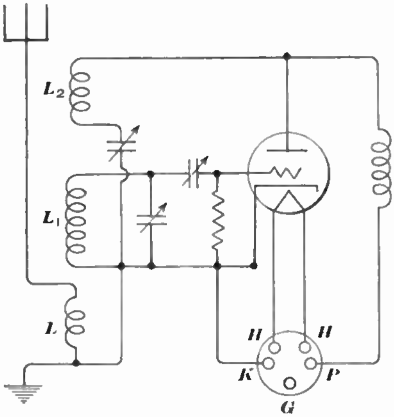


FIG. 29

HAMMARLUND SHORT-WAVE A-C ADAPTER

49. In Fig. 29 is shown the circuit diagram of the Hammarlund short-wave adapter for a-c operated broadcast receivers. The receiver is a simple regenerative detector, which is coupled to the audio amplifier of the

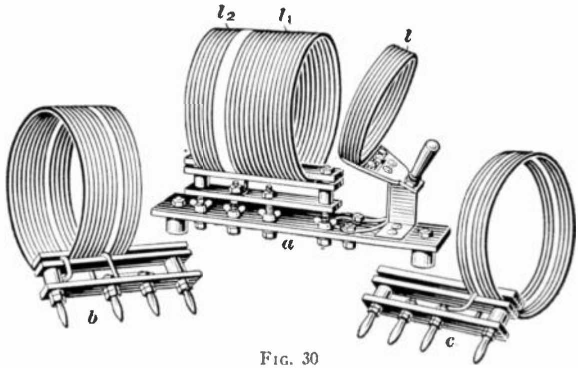


FIG. 30

broadcast receiver by means of an extension cable terminating in a tube socket. The tuning coils *L*, L_1, and L_2 are shown at *a*, Fig. 30. Three sets of coils are required as shown at *a*, *b*, and *c* to cover the short-wave band. The tuning and regeneration-control condensers, Fig. 29, are .00014 microfarad. The grid condenser is of the adjustable type having a maximum capacity of .0001 microfarad. The grid leak has a resistance of 2 to 9 megohms.

Extensions from the plate, filament, and cathode are brought to the base of a discarded tube and soldered to the pins. The tube from the detector circuit is placed in the adapter and the tube base with the extension cord is placed in the detector socket in the receiver. This adapter will work only in receivers that have the 227-type tube as a detector (second detector in superheterodyne sets) and whose plate voltage is suitable for grid-leak detection.

RADIO-TELEGRAPH RECEIVERS

TYPE IP-501 COMMERCIAL RECEIVER

50. Antenna Circuit.—The circuit diagram of type-IP-501 receiver is shown in Fig. 31. This receiver is used on board ships in conjunction with the ship transmitter. The antenna circuit extends from the antenna change-over switch *a* and continues through the tapped antenna coil *b*, the antenna tuning condenser *c*, to ground. In the actual transmitter the turns of the coil *b* that are not used are short-circuited by the arm of the switch. The purpose of this arrangement is to remove the possibility of the unused turns acting as an oscillating circuit and absorbing some of the energy from the used turns.

The buzzer circuit *d* serves mainly to energize the antenna circuit for the adjustment of the crystal detector if such is used in the installation. This circuit may also be used to test the operation of the vacuum-tube receiver.

51. Grid Circuit.—The grid circuit, Fig. 31, includes the coupling coil *e* in variable coupling with the antenna coil *b*, the main secondary inductance *f*, the tickler coupling coil *g*, and the tuning condenser *h*. The switch on the coil *f* is also equipped to short-circuit the unused turns. A grid condenser and leak are employed for detection.

The links *i*, *j*, and *k* join the circuits at these terminals. When the links are removed, additional inductance may be added to permit of operating the receiver at longer wavelengths.

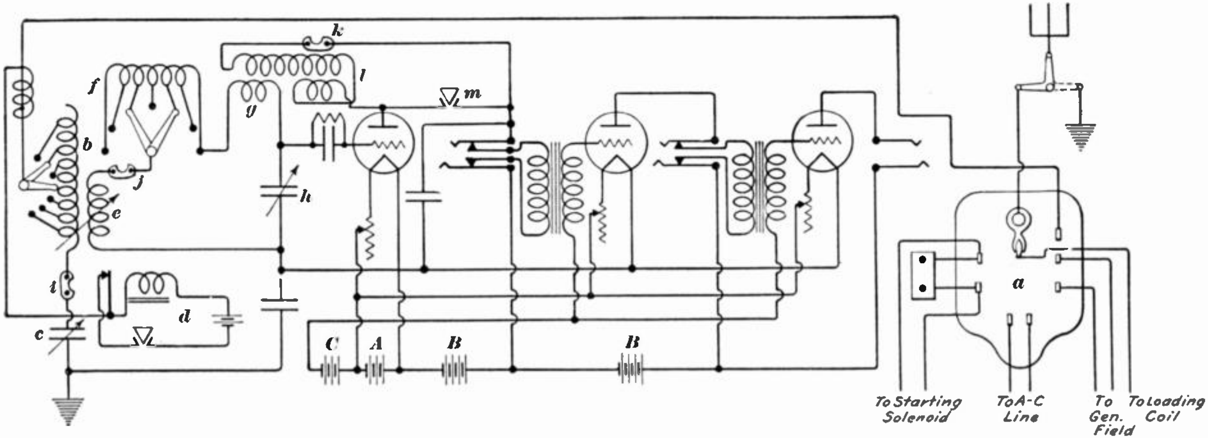

k
l
f
g
m
b
j
h
e
i
d
c
C
A
B
B
a
To Starting Solenoid
To A-C Line
To Gen. Field
To Loading Coil

FIG. 31

52. Plate Circuit.—The plate circuit of the detector tube, Fig. 31, starts from a tap on the *B* battery and continues through the primary of the first audio transformer, the tickler coil *l*, and to the plate of the tube. The function of the tickler arrangement is to strengthen the signals and also to permit the reception of cw. signals by making the detector oscillate. In order to determine whether the receiver is oscillating, it is only necessary to short out the tickler coil by depressing the button *m*.

If there is a distinct click and the hissing sound that is normally heard ceases, this is sufficient indication that the receiver was oscillating.

A jack is provided in the plate circuit of the detector for listening to signals that need no additional amplification. The two audio stages help in the reception of weak signals.

WESTERN ELECTRIC 600-METER RECEIVER

53. The Western Electric type-4-D radio receiver is of the superheterodyne type, as may be seen in Fig. 32. It will be noted that the antenna may be substituted by a loop. The beat frequency is about 45,000 cycles and is amplified by means of two stages. The first tube from left to right is the oscillator, the second the first detector, the third and fourth tubes are the i-f amplifiers and the sixth is the second detector.

There is only one stage of audio amplification, since the set is designed for operation with head phones only. All of the tubes are of the "peanut type No. 215-A." The set is designed for operation from dry B batteries and an 8-volt storage battery, such as is found on many installations on board of ships. This receiver is suitable for the reception of telephony with the carrier waves not suppressed.

SETS FOR TRANSOCEANIC TELEPHONY

54. These instruments are considerably different from the average receiving set, particularly because they are designed to operate without the carrier wave from the transmitting station. The progress of the voice currents as they are converted into single-side-band suppressed carrier wave that is eventually sent by the transmitting antenna, may be briefly explained as follows:

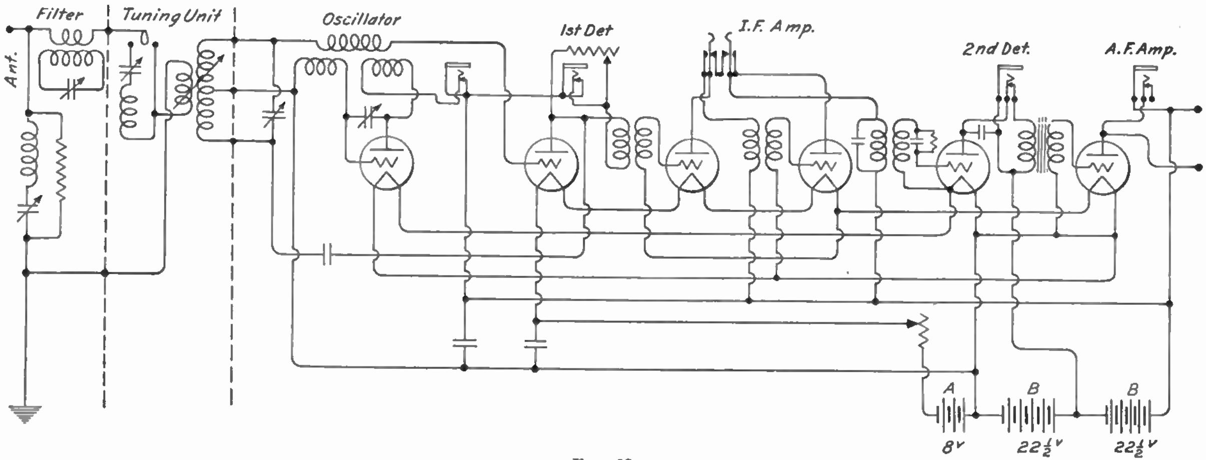

Filter
Tuning Unit
Oscillator
Ist Det
I.F. Amp.
2nd Det.
A.F. Amp.
Ant.
A
B
B
8v
22½v
22½v

FIG. 32

First the currents from the subscriber's telephone go through an amplifier to affect a balanced high-frequency amplifier the output of which, as it is balanced, is zero when no speech currents come from the amplifier, but as soon as there are voice currents, the balanced condition is disturbed and the result is a modulated r-f wave that does not contain the carrier, but just the two side bands. The band-pass filter that follows suppresses one of the bands and by so doing restricts the width of the bands to less than one-half of what would be the corresponding breadth if the ordinary broadcast methods were followed. Then the output is passed through high-powered amplifiers and thence to the antenna.

At the other side of the ocean, the highly directional receiving antenna collects the waves that reach the first detector. The detector, in conjunction with the local oscillator, sets up the frequencies which, when passed through a filter, will make the system highly selective. Then in the second detector these frequencies are mixed with a local source of a frequency nearly equal to the original carrier. With the introduction of the carrier that was suppressed at the transmitting station, it is possible to detect in the ordinary way the reconstructed signal, which, after being amplified by the audio system, can be sent to the subscriber's telephone.

55. It will be noted that it is not necessary to have both side bands in order to reconstruct the signal, and therefore the number of channels available can be more than doubled, as may be seen from the following example. Suppose that the highest audio frequency needed for intelligible transmission of speech is 3,000 cycles. Then, if ordinary methods of transmission were used, and with a range of from 20 to 100 kilocycles, there could be $100-20=80$ kilocycles available for all the channels. As each one would have a width of at least 7,000 cycles for safety, since twice 3,000 is 6,000 and 500 is allowed on each side to eliminate interference, there are $80\div 7=11$ channels available. Now, if the carrier and one of the side bands are suppressed, the width of each channel would be $3{,}000-300$ or 2,700 cycles, since 300 is the lowest frequency that must be passed for good transmission; but with the same 500-cycle safety factor on each side, the width would be $2{,}700+500=3{,}200$ cycles, and $80{,}000 \div 3{,}200=25$ channels instead of 11, which is more than twice the former number.

There is another advantage in the suppressed carrier system, which is that, when the carrier reaches the receiver in the ordinary systems, it comes mixed with a great deal of interference or static and the detector will demodulate it as in the ordinary receiving sets for broadcasting. When the carrier is suppressed at the transmitter and then put back at the receiving end, it comes pure from the vacuum-tube oscillator without static, and the only interference that is picked up comes from the side bands, which are as a rule much weaker than the carrier in the ordinary transmitters for broadcasting. Therefore, there is a gain in the signal-to-static ratio and greater distances can be covered without undue interference.

SERVICING OF D-C RADIO SETS

Serial 2485 Edition 1

LOCATION AND ELIMINATION OF TROUBLES IN RADIO SETS

ANTENNA INSTALLATION

INTRODUCTION

1. The installation of a radio receiving set, together with all the apparatus pertaining to it, the location of troubles whenever they appear, and the renewal of defective or worn-out parts are the tasks that concern the service man.

The troubles that a radio set may give to its owner are so varied and complex in nature that unless some systematic way of locating and correcting them is followed, it would be necessary at times to dismantle and reconstruct the radio set to find them. The service man should be well equipped with some simple testing instruments that will enable him to correct the majority of the troubles right on the spot.

The installation and repairs of a radio receiver will concern (*a*) the antenna, (*b*) the set itself, (*c*) the batteries or power units, and (*d*) the loud speaker.

OUTDOOR ANTENNA

2. The most efficient antenna system for the average radio set is one of about 100 feet or more in length. The antennas in congested districts should be as high as possible to eliminate interference from local sources, such as other receiving antennas and, most of all, they should be far from any electrical apparatus that is likely to spark or to emit radiations like X-ray machines.

An antenna stretched above the roof is usually the best form in any case. The length of the antenna should be measured from the far end to the ground connection. The lead-in should preferably be a continuation of the antenna wire itself, thus avoiding splices which will eventually introduce intermittent connections and high resistance by corrosion from the elements, and seriously impair reception. Intermittent make-and-breaks cause one of the most irritating and annoying interferences in radio reception.

3. If it is absolutely necessary to use a lead-in and to splice it to the antenna, it pays to solder it carefully to insure a permanent electrical connection. The excess flux should be wiped off and the joint should be covered with insulated tape to protect it from the corrosion caused by the rain and the air. If soldering is not used, a strong mechanical joint may suffice if it is well-wrapped first in tin foil, such as is found in cigarette boxes, and then covered with rubber-insulated tape.

ANTENNA INSULATION

4. The antenna should be supported in all places by high-grade glass or porcelain insulators and at no point should it be permitted to touch the building. It is well to have the lead-in wire far away from the walls so that the wind may not blow it against the building and touch it intermittently, as this will produce clicks in the loud speaker. The lead-in wire should come in through the wall or window frame through a porcelain tube. Window-strips are a good expedient in temporary installations but are not to be recommended for permanent use.

ANTENNA PROTECTION

5. The antenna should be protected from lightning and from other sources of high voltage. When an outdoor antenna is used, it should be protected by a lightning arrester of an approved type, and if it is located in a place where the electrical storms are unusually severe, a short-circuiting switch should be used to ground the antenna during a storm, or else the set should be disconnected from the aerial wire.

A double-throw single-pole switch of a substantial construction which may be used to advantage as a protection against lightning is shown in Fig. 1. The antenna should be connected to the middle point so that when the switch is thrown over to the right, it will connect the antenna to the set, and to the left to ground, disconnecting thereby the set from the antenna.

A lightning arrester of the gas-tube type is shown in Fig. 2. It consists essentially of two electrodes enclosed in a glass tube in an atmosphere of argon or neon, or other rarified gas. These gases act as insulators at low voltages, but at a certain critical voltage they ionize and become conductors when a surge of any kind occurs, discharging the antenna current to the ground.

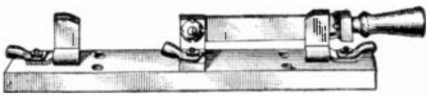


Fig. 1

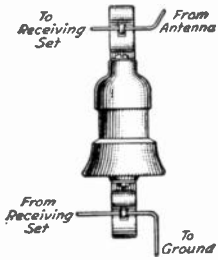


Fig. 2

They protect the set and the operators whenever there is no direct lightning discharge into the antenna. In the case of a direct lightning discharge there is little protection available, except perhaps by actually disconnecting the aerial from the radio receiving set.

INDOOR ANTENNAS

6. Where the installation of an outdoor antenna is not possible or practical, satisfactory results, at least for local broadcast reception, may be had by employing about fifty feet of insulated wire strung indoors following the picture molding or sometimes under the rugs or carpets. The size of wire is unimportant, although No. 18 B. & S. insulated standard bell wire will be satisfactory. In buildings where metal lathing is employed, indoor antennas do not always work properly, and under these conditions various systems of pick-ups should be tried. For example, a steam radiator in one room may be used for ground, another one in some other room for an antenna; an electric light fixture or gas pipes may be used for an antenna and the radiator for ground. In these suggested circuits, the collecting system

takes more the form of a huge loop rather than of an open antenna. It is also feasible to use the electric-light wires as a pick-up system by connecting the antenna binding post to one of the power wires through a small capacity condenser, or by using a standard socket-antenna. A metal disk placed under a desk telephone and connected to the antenna binding post will serve as an excellent pick-up in an emergency.

GROUND AND COUNTERPOISE

7. The ground connection is just as important as the antenna. As a rule, the cold-water system in apartments is as good a ground as can be found. In the country where no water-supply piping is installed in the house, a rod or metal plate buried in the ground several feet deep may act as a ground if there is enough moisture in the soil. A well or cistern may be used to place the rod or plate in good contact with earth.

In cases where these expedients are not practicable a counterpoise may be substituted for the ground connection. This is nothing else than a second antenna and should be about 5 or 6 feet above the ground and follow the antenna wire and be of the same length approximately.

The best way of securing electrical connection between the ground wire of the set and a water pipe, for instance, is by means of a ground clamp over a well-cleaned section of the pipe. In a few cases a wire may be soldered to a radiator cap and then the cap screwed tightly in its place.

LOOP AERIALS

8. Loop aerials are usually of substantial construction and give little trouble except at the connection between the terminals of the loop and the set. There are various types of sockets that permit the loop to rotate while connected to the set, and generally do not permit rotation over a complete revolution. Failures from such loops will be found, as a rule, in the contact prongs, which should be cleaned well, and, if the springs are weak, should be bent back to secure a good contact. Loop sets should be near windows to get the best results, and away from frames or other metallic structures, as they may shield the loop very effectively, diminishing considerably its power to pick up the radio waves. In some isolated instances if the loop is near a column or girder in a vertical position and the loop set is near it, an increase in wave reception may be noticed, and the directional effect of the loop somewhat less sharp. The signal in those cases comes mostly by the column and is induced electrostatically or magnetically into the loop. For this reason, it is well to move around a loop receiver while the loop is rotated in its axis, in order to find the best location for the radio set.

ANTENNA-SYSTEM FAILURES

9. Whenever grating or rasping noises in the telephone receiver or in the loud speaker are heard, the source may be traced to defective connections between the aerial and the set. In order to ascertain definitely whether the trouble is in the antenna, the antenna should be disconnected from the set while the set is turned on with full amplification. If the noises do not cease, it is good indication that the trouble comes from a loose connection either at the binding posts of the set or at the grounding point. It is well to make sure that the lead-in wire does not touch anything except through the insulators.

The most difficult trouble comes from the total absence of signals. This may be due entirely to a short-circuited antenna or a broken wire, when insulated antennas are used; or the fault may be in the set. At times, however, if the antenna wire is broken and it is held together only by the insulation, a very faint signal may be heard when the antenna is touched to the radio set. If absolutely nothing is heard when touching the antenna wire to the set, not even a click, it is an almost certain indication that the set is dead.

10. Poor insulation or a ground in the antenna may be detected sometimes, especially when the insulation is very poor, by connecting a 22½-volt B battery in series with a voltmeter or head phones and grounding one end of the B battery and with the free end of the phones or voltmeter touching the antenna after it has been disconnected from the radio set. If clicks are heard or the voltmeter deflects even a little, then there is a defective insulation in the aerial system. When a milliameter is used instead of a voltmeter, a protective resistance should be connected in series; otherwise, if the antenna is dead short-circuited, the instrument may be ruined. The head phones may be used as a protection. The short circuit may be in the lightning arrester, and, if this is suspected, it should be temporarily disconnected and the set tested for signals.

TROUBLES IN RADIO SET

DEFECTIVE RADIO TUBES

11. Methods of Testing.—It is safe to say that over three-quarters of the troubles with radio sets are traceable to defective tubes, or from not using the right kind of tubes. Therefore, the first thing to examine is the state of the tubes. In this connection, it is well to see that all of the filaments light at approximately normal brilliancy. If several tubes are of the same type, it is well to interchange them in various sockets, and note the effect upon reception. Old or worn-out tubes usually show the defect more when used as detectors. The best thing to do is to replace every tube, if possible, with a fresh or tested tube, and this may finish in many cases the investigation of trouble.

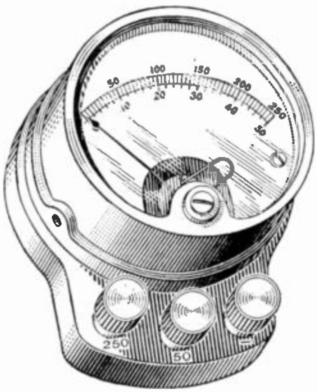


FIG. 3

Make sure that all the tubes in the set are receiving their normal operating voltages so that the new tubes may last the rated number of hours in service. A portable direct-current voltmeter of the high-resistance type, such as the Weston, Westinghouse, or Jewell, with several scale ranges is the most useful instrument to the service man. The Weston high-resistance portable voltmeter with a scale from 0 to 250 volts, and another from 0 to 50 is shown in Fig. 3. With this type of instrument all the B voltages supplied to all the tubes may be measured, and the A and C voltages may be tested with sufficient degree of accuracy to make sure that the tubes are getting their proper voltages. The way to make these measurements will be shown later in detail.

Sometimes an old tube in the detector socket will bring in distortion of the signals without reducing the volume appreciably. Other tubes may produce howls when the loud speaker is near or over the radio set. In many cases when the tubes are interchanged the trouble will vanish. Microphonic troubles may be due to other things besides bad tubes, and it may be to advantage to substitute the loud speaker for a pair of head phones temporarily. If the trouble does not disappear, it may be due to oscillations in either the radio- or the audio-frequency systems.

12. Intermittent Signals.—After the antenna system has been thoroughly inspected and properly connected, if there are any interruptions in the reception, or sudden changes in intensity, the trouble is likely to be found in bad contacts between the tube prongs and the springs in the sockets. At times the contacts are making a poor electrical connection without actually breaking the circuit, and, when there is sufficient voltage back of the contact, as in the plate connections, a poor contact will resolve itself into continuous noise like rocks falling down a chute. Low-voltage contacts like those in the grid circuits are likely to either make or break completely and, if the contacts are loose, there will be a series of clicks, sometimes very loud and irritating in character. The best thing to do is to clean the prongs thoroughly with a little piece of fine sandpaper. The use of emery cloth or steel wool is not to be recommended. Before reinserting the tubes in their sockets the prongs as well as the base of the socket should be wiped off, so that small particles of sand or dirt do not get between the prongs and the springs.

RADIO-FREQUENCY AMPLIFIER

13. Lack of Amplification.—Aside from bad contacts, open circuits, and short circuits, the main troubles that appear in connection with the radio-frequency system are two-fold, namely, lack of amplification and excessive amplification. The former may come from insufficient voltages applied to the tubes, from the fact that the several tuned circuits do not tune to the same frequency when a single control tunes the set, or by an open or a short circuit in the system. These last two sources of trouble, being common to all the radio-set departments, will be treated separately in the section relative to continuity tests.

After the voltages on all the tubes have been measured and found to be correct, if the set sounds weak, it is well to ascertain whether all the tuned circuits vary together at the same time; that is, whether all the condensers tune each stage to the same frequency. This may be accomplished by tuning the radio set to a powerful local station and disconnecting the antenna but turning on the full volume control. If all the circuits come into

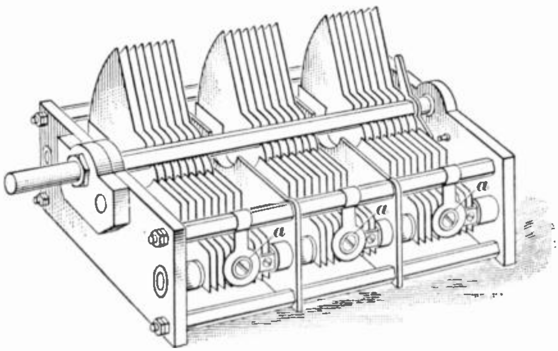


FIG. 4

resonance for that particular station at the same time, there will be only one point of maximum loudness as the controlling dial is turned past the tuning point for that station. If there are two or more distinct peaks, it is clear that some of the condensers do not tune simultaneously all the circuits to the same frequency and if the set is provided with vernier or equalizing condensers, the trouble may be corrected by adjusting them.

14. A typical three-gang tuning condenser is shown in Fig. 4. The individual condensers are provided with vernier or compensating units *a*, which are in parallel with their respective tuning condensers. In some sets the vernier controls are on the panel, but in most modern radio sets they are inside the set and are adjusted at the factory.

In some other sets, the rotors of the tuning condensers are mounted on a common shaft and fastened to it by means of setscrews. In this case the setscrews should be released in all but one of the condensers and the set tuned to a station close to the middle of the scale, say about 850 kilocycles, by moving each rotor by hand until the set gives a definite maximum response. If while the condensers are adjusted to resonance the signal strength becomes moderately loud, the volume control should be turned down because it is easier to detect accurately a maximum response with faint signals than with louder ones. When this is done, the setscrews are tightened and the fact is determined whether there is but one point of maximum response for that station with which the tests were made, to make sure that the condenser rotors did not get displaced during the tightening of the setscrews. The set is afterwards tuned to all the available stations, and, if the condenser plates have not been bent or damaged in any way, there should be only one maximum tuning point for every station.

15. Overamplification.—When some form of coupling exists between the circuits of the different tubes in a set, there is some interaction, usually overamplification, which manifests itself as oscillations and these, in turn, produce *singing* or *howling* at the loud speaker. Sometimes the frequency of the oscillations is beyond audibility but it is there just the same. It manifests itself in a choked and badly distorted speech or music and considerable diminution of volume. The elements of a vacuum tube contain enough internal capacity to introduce sufficient coupling between the plate and grid to produce oscillations and by means of neutralizing condensers or grid suppressors these oscillations are prevented. Again, in some sets the oscillations are stopped by reducing the filament or plate voltage or by the application of positive potentials or +C bias to the grid circuits, thereby introducing additional losses that overcome the oscillations. These last two expedients belong to sets of the past, but it is well to mention them as there are a few such sets in existence, usually of the home-made variety, and these, too, require frequent attention.

16. How to Neutralize Sets.—The method of neutralizing a radio receiving set will be given in connection with the circuit-diagram shown in Fig. 5. The set is first tuned to a powerful

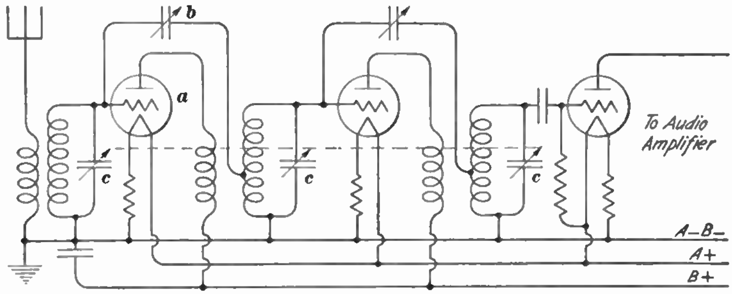


FIG. 5

local station with minimum volume control adjustment so as to secure an accurate setting on the dial that tunes the condensers *c*. The first tube *a* is then removed from its socket and replaced with a similar tube minus one of the filament pins. If one is not available, then the positive end of the filament circuit must be disconnected by inserting a piece of paper between the tube prong and the spring contact of the socket, an easy matter with the old Navy or UV-type bases. With the tube in the first socket but without filament current, the signal will probably not be heard until the volume control is turned on to almost full-tone position. This is accomplished either by increasing the filament current or by varying a shunt resistance, if such is provided for controlling the volume, in sets with the tube filaments wired in series. If there are no other interactions in the set except the tube capacity, the signal should vanish entirely when the neutralizing condenser *b* has the right balancing capacity, which is usually adjusted by means of a screwdriver.

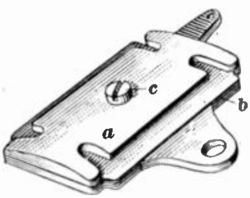


FIG. 6

A neutralizing condenser of the spring type is shown in Fig. 6. It contains a sheet of mica between two metallic clamps *a* and *b*, one of which is elastic and is tightened by means of the screw *c*, thereby increasing the capacity.

17. Imperfect Neutralization.—When there is mutual induction between the radio-frequency coils, even if it is very small, or there is no by-pass condenser across the B-battery leads, the neutralization can only be accomplished by reducing the signal to a minimum instead of making it disappear altogether. This is unsatisfactory because the oscillations particularly at the low wavelengths will not disappear when the filament circuit of the first tube is fully lighted. Unless the coils can be slightly displaced with respect to each other so that their mutual induction may be reduced as much as possible, there is nothing else to do but to get a minimum of signal with the circuit of the filament of the first tube open. A lower B voltage or filament current in the first tube should be used so that the oscillations that may occur at the low wavelengths will just disappear. A grid leak across the tuning condenser will be sufficient to stop the oscillations if the full B voltage must be used, but the sensitivity will suffer at the higher wavelength. If the tubes happen to be connected in series, as is the case with radio sets operated from a direct house current, the first tube should not be removed or the filament circuit opened, but it should be short-circuited instead, by wrapping a very thin wire around the two filament prongs as close to the base of the tube as possible, and the rest of the procedure is the same.

18. Neutralization of Multistage Amplifiers.—When there are several neutralized stages, as in Fig. 5, the process should be started with the tube next to the detector tube, and the antenna should be connected temporarily to the plate of the preceding tube and the other radio-frequency amplifier tubes removed (or short-circuited if their filaments are connected in series). This will bring matters to the same case as exemplified in the preceding paragraph. When the tube next to the detector has been well neutralized, then the tube ahead of it is adjusted in exactly the same way, connecting the antenna to the plate of the tube that is ahead of the one to be neutralized, until the beginning of the train of amplifiers is reached. If the set is shielded, the shields should not be removed when neutralizing the amplifiers, because the shield is there to avoid interactions other than those present internally in the tubes themselves. There is generally a screw hole in the shield through which a screwdriver, preferably one of non-conducting material, may be inserted. A small wooden rod sharpened with a penknife into the shape of a screwdriver can be easily made, and has the advantage that it does not bring in body-capacity effects or extraneous connections through the hands of the operator and thus disturbing thereby the operating conditions of the set.

SUPERHETERODYNE TROUBLES

19. General Suggestions.—The straight superheterodyne sets without reflex circuits are comparatively simple to tackle. There is, as a rule, one or even two stages of straight radio-frequency amplification before the first detector, and usually they are neutralized. All the considerations relating to neutralized receivers are applicable in this case. There are complications, however, and they come from the presence of the local oscillator, which may produce sufficiently powerful harmonics that, combined with some radio-station carrier waves, may at times produce sounds mistaken for oscillations in the radio-frequency amplifier. These cases are rare in straight superheterodynes, but are quite frequent in the reflexed types. The troubles with superheterodynes belong usually to two classes; failure of the oscillator and unsteadiness in the amplitude and frequency of the oscillations. Troubles arising from the radio-frequency tubes are assumed to have been corrected.

20. Failure of Oscillator.—Oscillations may fail to start if the oscillating tube is defective, if it does not receive any or insufficient B voltage, if there is an opening in the oscillator circuit, or if the coupling between the tickler coil and the grid coil is insufficient. First, a new tube is inserted in the oscillator socket and the result noted to determine if at least a murmur or sound like falling water is heard in the loud speaker when the full volume control is turned on, and the sound disappears upon the removal of the oscillating tube, or by short-circuiting its filament terminals if it is in a series circuit. The presence of the murmur is a reliable indication that the tube is oscillating. To make sure that the oscillations do not come from some other tube, it is well to note the difference in sound when the oscillating tube is removed. If the rest of the set is working properly, at least a station should be heard at once when the dials are revolved.

If a new tube does not produce any results, the B-battery voltage should be tested at the plate prong of the tube socket with a voltmeter. If a voltmeter is not available, a pair of head phones may be used. One terminal of the head phones is placed on the negative filament terminal and the other head-phone terminal on the plate contact. Plate voltage will be indicated by a very loud click. The loud speaker may be used also for this test in place of the head phones. If there is B voltage at the plate of the tube, and there are no oscillations, the tube is removed and the voltmeter or headphones connected to the plate and the grid terminals of the oscillator-tube socket. If there is a click or a voltage indication, there is no open circuit in the grid coil, and then the variable condenser should be inspected to ascertain whether the plates have been bent and there is a short circuit in the condenser. If the circuit is all right, it may be possible, in some commercial sets, but most commonly in home-made sets, that the coupling between the plate and the grid coils of the oscillator-tube circuit is insufficient, and therefore it should be strengthened by bringing the coils into closer inductive relation. Ordinarily this is accomplished either by turning the rotating coil or by adding a few turns to the plate coil, if the coils are fixed.

21. Unsteady oscillations are the result of variations in the voltage supply to the oscillator tube and are rarely present in battery-operated sets. They are more likely to occur in sets with tubes operated in series from the house current. The author knew of a superheterodyne with tubes that were fed in series from direct-current mains in a rather steady line in New York City where even the powerful local stations were fading continually, up and down. Upon close examination of the set, it was found that the oscillator changed in frequency with the line voltage variations and, as the intermediate frequency stages were sharply tuned, the beat frequency changed enough to affect the amplification for the intermediate stages to a tremendous degree. He suggested to connect a 3-volt dry-cell battery across the filament terminals of the oscillator tube to steady the voltage across the filament, but not requiring to supply any appreciable current, the line voltage furnishing the filament power. A switch was so connected that when the line voltage was interrupted, the 3-volt battery was disconnected. The expedient eliminated the fading completely.

22. Reflexed Superheterodyne Sets.—The superheterodynes that employ the first tube both as radio-frequency amplifier and intermediate-frequency amplifier, with the second tube acting both as detector and oscillator, are called reflex sets, as

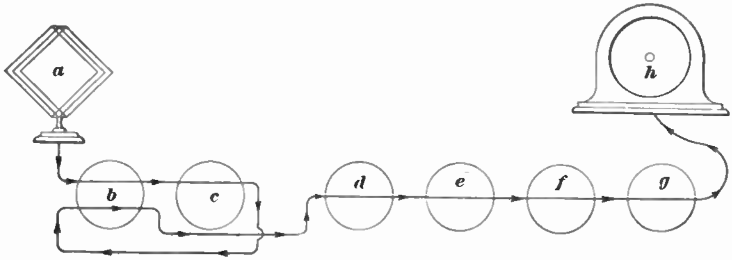


FIG. 7

the same tubes are used over again for another function. The second harmonic of the oscillating current supplies the local frequency that produces the beat or intermediate frequency. This circuit is shown schematically in Fig. 7. The loop *a* picks up the radio-frequency waves, which, after being amplified by the first tube *b*, are sent to the second tube *c*. The tube *c* is in an oscillating state at a frequency of one-half the value necessary to give a beat frequency of about 50 kilocycles. The second harmonic of the oscillating frequency will combine in the grid circuit of this tube *c*, giving rise to the intermediate-frequency currents and, by coupling back to the first tube *b*, this tube acts also as first intermediate-frequency amplifier. From the plate circuit of tube *b* the intermediate frequency currents go to the third tube *d*, which is a straight intermediate-frequency amplifier.

The fourth tube *c* is the second detector and the rest of the tubes are the same as on any regular set, the fifth *f* being an audio amplifier and the last *g* is the power tube. The output of the last tube operates the loud speaker *h*. In the oldest models, the power tube was like the rest of the tubes. The only thing to do in case of trouble with these sets is to make continuity tests and these tests apply in general to all systems and circuits.

23. Service Suggestions.—On account of the complexity of superheterodyne circuits and the fact that they are usually enclosed in a metal box, popularly known as the *catacomb*, it is not feasible to make any tests or replacements on the spot, and the whole catacomb should be detached and forwarded to the manufacturer's nearest representatives. There are, however, a few suggestions that may prove beneficial, but are not exhaustive. If the set reproduces the same station in many points on the dial that controls the oscillator labeled *Station Selector II* it may be advantageous to reduce the B voltage in the first detector and oscillator tube so that it is just about to stop oscillating. This may be done by means of a variable resistance such as a Clarostat inserted between the B voltage supply and the return of the plate of the tube. A $\frac{1}{2}$-microfarad condenser or one of larger capacity must be connected between the point of junction of the tube circuit to the Clarostat and the negative filament terminal.

If the intermediate frequency stages oscillate, a grid leak of some value between one-tenth and 1 megohm bridged from the grid of the second intermediate-frequency tube and the negative terminal of the C battery will usually stop the oscillations and at the same time improve the quality of reproduction, although broadening a trifle the tuning of the Station Selector II dial, Sometimes the oscillations and squeals come from old B and C batteries due to increased internal resistance of the cells, which will act as coupling resistances between tube circuits. The critical tubes are the second and fourth from left to right, which are the oscillator *c*, Fig. 7, and the second detector *e*, respectively, and it is well to insert fresh tubes in those sockets in case of failure to get signals, after making sure that all the batteries are alive.

DETECTOR CIRCUIT

24. Detector Troubles.—The most prolific source of trouble, especially from distortion, is the detector. The action of the detector, when a condenser and leak are used for detection, is so complex that no set of rules can be laid down to follow in case of trouble; only suggestions that will cover the great majority of the cases may be given. Aside from a defective tube, the detector may not operate properly from: (*a*) improper B voltage, too high or too low; (*b*) a bad leak or one of too low or too high resistance; (*c*) wrong connection of the grid return or improper bias; (*d*) excessive regeneration; (*e*) open circuits or short circuits.

25. Improper B Voltage.—The normal operating voltage on standard detecting tubes is between 20 and 50 volts when a grid condenser and leak are used. The actual value is not critical, except with some forms of gaseous detecting tubes, such as the UX-200A or UV-200, and even then a few volts variation on either side of the correct value, which has to be found by trial, will not make much difference. For local stations a value close to 50 volts should be used with a low resistance grid leak, and for faint distant stations about 30 volts may be better with a high resistance leak in order to gain in sensitivity. If the B voltage is obtained from a filter with high resistance, whether the source is the electric-light power or a B battery, nothing but a very high-resistance voltmeter should be used to measure the plate voltage in the detector. If the characteristics of the particular type of tube are known, it is preferable to insert a milliammeter in series with the B-voltage supply at the point where it is connected to the B+ Det. post of the radio set, which goes to the transformer or coupling resistance. From the reading of the milliammeter, the resistance of the transformer being negligible, the plate voltage may be obtained from the characteristic curve of the tube by giving the grid a definite voltage, for example, zero. This can readily be done by short-circuiting the grid terminal of the tube to the negative filament terminal. In practice, if a high-resistance voltmeter is not available, an ordinary instrument with a resistance unit in series such as a lavite or a low-resistance grid leak may be employed and can be calibrated by comparison with a standard B battery, and, although the reading for 45 volts may be at the lower end of the scale, it is sufficiently close for testing the plate voltage of the tube in actual conditions. The total resistance of the voltmeter should not be less than 50,000 ohms, approximately.

26. When great purity of tone is desired, the sets are made with detection by the grid-voltage-plate-current curved characteristic instead of the condenser-and-leak method. In such cases the B voltage should be of the full value used in the amplifier tubes, but the grid return should not be to the positive terminal of the filament battery, but to the negative through suitable C-battery bias, the value of which should be determined by trial, being usually about 10 per cent. of the plate voltage. The value of the B voltage in the detector tube, if too low, will result not only in diminished sensitivity, but worst of all, in discrimination against the bass tones. The plate internal resistance of a tube with very low B voltage becomes very great and therefore will not match the impedance of the coupling transformer together with its associated by-pass condenser. This will reduce excessively the high treble tones in comparison with the middle register on account of the fact that the lateral impedance of the resultant capacity will be too small in comparison with the large plate resistance of the detector tube with low B voltage.

There is another kind of distortion, and it manifests itself when strong local signals are desired and the amplification of the audio system is low. As these signals will frequently exceed the operating characteristic of the detector, the variation of the plate current with the rectified grid voltage will be very complex, and the result is a mushy and nasal tone, and, if pianoforte music is being reproduced, it will sound as if the sounding board were cracked. The same effect, but much worse, is heard when the detector tube is oscillating. High B voltage is not so bad as insufficient voltage from the standpoint of distortion, but it will tend to shorten the life of the tube. Sometimes the sensitivity goes down materially and when alloy-core audio transformers are used, there may be considerable distortion in the transformer on account of the large value of the steady current through the primary winding.

27. Bad Grid Leak.—If there is the proper plate voltage in the detector tube and yet the signals are distorted, it may be due to a bad grid leak. It is well to put in temporarily a new leak, of low resistance, a $\frac{1}{2}$ megohm, for example, and note the performance of the radio set when tuned to strong local stations. If this is satisfactory, then a high resistance leak, 2 megohms or more, is inserted, and if the set begins to distort again, the trouble may be due to excessive regeneration or even oscillations. Lack of sensitivity under original conditions may be due to the use of a $\frac{1}{2}$-megohm leak instead of a leak of 2 or more megohms or possibly to deterioration of the original leak. A new grid leak should be tried.

28. Grid-Bias Detection.—When the detection is accomplished by means of a condenser and leak, the grid tuning coil and condenser should be connected between the grid and the positive end of the filament so that the tube will get a positive C voltage. To make sure that such is the case, a voltmeter is connected between the negative terminal of the A battery and the end of the tuning coil next to the grid condenser. The voltmeter should read the A-battery voltage. If the detection is without condenser and leak, the C voltage is tested by means of the voltmeter between the same points and the instrument should indicate the C-battery voltage. Improper bias voltage will result, as a rule, in diminution of the sensitivity, but not necessarily in much distortion; in fact, without condenser and leak, almost any tube will detect even a little because of the natural curvature of its characteristic even at the portion that approaches most a straight line.

29. Excessive Regeneration.—Regeneration is a very general defect of most radio sets, whether they are ostensibly regenerative or not. For good quality of reproduction it is necessary to amplify, besides the carrier wave, the two side bands to the extent of 5,000 cycles on each side of the carrier. When the resistance of some of the various tuned circuits is made very low by the regeneration effect, the side bands will not receive uniform amplification. The lower tones, because their corresponding side-band waves are nearer to the carrier, will be amplified considerably more than the higher tones, and the result will be a muffled and drummy reproduction. Also, if it is necessary to depend on regeneration to get enough volume, the limits on the detection curve will be exceeded on strong transient tones such as occur in pianoforte music, with the same effects as described in connection with insufficient plate voltage. If the regeneration is under control, as, for example, in sets provided with a tickler coil, the remedy is obvious. If, after the regeneration has been reduced to such value as to insure good quality, the signal is not loud enough, it will be imperative to extend the length of the antenna or to increase the amplification in some other way; for example, by putting in tubes of higher amplification factor with the same plate resistance, or tubes of the same amplification constant but of lower plate resistance. Thus, 201A tubes may be replaced advantageously by those of the 112 type.

When the set is ostensibly non-regenerative, regeneration may be present nevertheless, and it may be reduced, if excessive, by reneutralizing the set, by lowering the B voltage in the radio-frequency tubes, by using a lower resistance grid leak, or by inserting higher resistance grid suppressors (500 to 1,000 ohms) if the set is of this type.

It may be possible that the angle made by two or more radio-frequency coils is such that there is some magnetic coupling between them. For example, in a neutrodyne where the coils are inclined about 57 degrees, unless they are accurately placed with their axes in this position, there will be mutual induction between two or more of them with consequent inductive regeneration. When the neutralization cannot be carried out completely, it is a rather certain indication that such is the case.

AUDIO AMPLIFIER

30. Audio-Amplifier Troubles.—Aside from open circuits, which will be treated as part of the continuity tests, the most general causes of trouble come from: (*a*) Low voltage in the plates of the audio-frequency tubes, particularly the power tube; (*b*) improper C voltage in the grid of the power tube; (*c*) plate current passing through the loud speaker; and (*d*) regeneration.

31. Improper Voltages in Audio System.—Low plate voltage in the intermediate audio amplifying tube is not so harmful as in the last, or power tube. A low voltage in the plate circuit of the power tube will have the effect of weakening the lower tones and sometimes also the very high ones by the same action by which low plate voltage in the detector tube would cause these troubles. As a rule, there is no need of a C battery in the first audio tube; the voltages impressed to the grid of that tube are small and are not sufficient to make the grid to take appreciable current and distort the signal. In the last tube, however, it is imperative to have C voltage of such value as will be required by the plate voltage of that tube. It is recommended to use as high B voltage as the tube will stand according to the manufacturer, because high quality of reproduction for moderately loud signals goes hand in hand with maximum power output of the last tube, and this is practically proportional to the square of the B voltage. If the C voltage is not sufficient, the power tube will not last long and will soon begin to distort; therefore, it is of the utmost importance to make sure that the B and C voltages in the power tube are correct.

32. Direct Current in Loud Speaker.—Whenever a tube of the power type is placed in the last audio stage, it is essential to interpose a coupling circuit between the plate of the tube and the loud speaker so that the steady plate current will be kept out of the speaker. In some old sets the plate current is allowed to go through the speaker, an ordinary amplifying tube taking the place of the power tube, or the latter is run at low voltage. Then care must be taken to give the grid a smaller C voltage than required by the B battery e.m.f. because there is a drop in the loud-speaker windings which, in the case of low-resistance tubes like the UX-120 or UX-171A, will reduce the available voltage in the plate by a fair percentage. A high-resistance voltmeter should be employed to measure the actual plate voltage, the test being made between the plate terminal and the negative filament end. The UX-171A type tube may be used without coupling device when the B voltage is below 100 at low volume of reproduction, and under those conditions it will still improve the tone with respect to what it would be if a UX-201A tube took its place. With the latter type tubes, the drop in the speaker windings is small enough to be ignored.

33. To determine whether the steady component of the plate current flows through the speaker when it should not, the set is operated with the volume control down to a minimum so that there is no sound from the speaker. Then one of the tips of the cord of the speaker is pulled out from the plug, and if no appreciable click is heard, no direct current is passing through. With direct current passing, a small spark and click will surely indicate it. If the power tube operates on more than 300 volts, the test should be carefully made to prevent a good electric shock from injuring the operator while disconnecting the speaker terminal from the set. The passage of current ordinarily is due to a short-circuited condenser in series with the speaker. A break-down in the transformer windings when the latter takes the place of the condenser-and-choke coupling is hard to detect because the secondary is ordinarily insulated from the radio set, and it is possible that the secondary touches the primary or other point at high direct-current potential at one point, thereby not passing any direct current through, but if a person should touch the loud-speaker circuit and at the same time touch anything that is grounded, such as a radiator or the A or B battery, he will receive a shock. If the insulation looks doubtful, one end of the loud speaker cord is touched to ground while connected to the set; a spark at the point of contact will indicate broken-down insulation.

34. Regeneration in Audio Amplifier.—Regeneration in an audio amplifier can take place both electrically and acoustically. In the former case the coupling between the grid or plate of the detector and the plate circuit of the last tube introduces regeneration, and comes principally from bad wiring of the set. It is due principally to bringing close together the grid and plate leads.

Sometimes the audio-frequency transformers have sufficient magnetic leakage to produce audio-frequency oscillations, but oftener oscillations are produced by the leakage reactance of the transformers. The leakage reactance may be considered as being tuned with the distributed capacity and the regenerative coupling of the tube and this will start oscillations, which ordinarily are of a high pitch. A grid leak or high resistance across the secondary of one of the audio transformers, preferably the second, will stop the audio-frequency whistle.

35. Regeneration or feedback through the battery circuits is often the cause of loud low-frequency squeals. Referring to

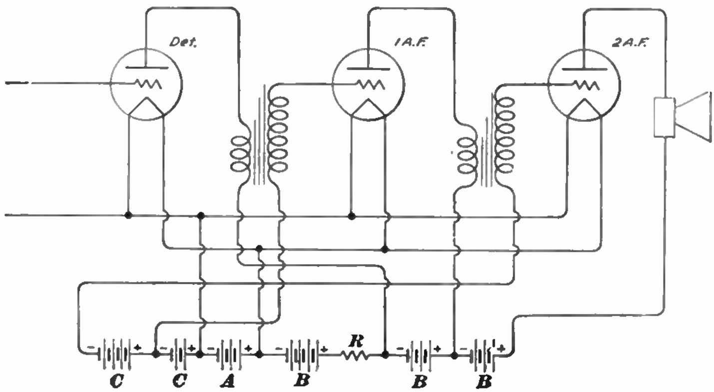


Fig. 8

Fig. 8, it will be noted that the plate current from the detector tube returns to the filament through the B battery. The resistance *R* represents the internal resistance of the B battery, if it is old. Then the voltage drop due to the current from the first audio tube and the power tube, which continues through the detector B-battery block, will combine with the voltage drop due to the detector current. These two currents may be sometimes in phase, and sometimes in opposition at the various frequencies. If the detector and amplifier currents are in phase, the regeneration will make the amplifier squeal; and if in opposition, it will reduce the amplification. It may be that the voltage drops come at some other phase angle, in which case they may be decomposed theoretically into two components, one of which is in phase or in opposition to the voltage drop due to the detector current, and will produce one or the other of the above-mentioned disturbances for the various frequencies. For this reason it is well to have a coupling circuit made of a choke and a condenser to keep the strong audio-frequency currents from the B batteries as shown in Fig. 9, and this holds, particularly in the case of electric-light operated radio sets. In battery sets, new B batteries have sufficiently low resistance to insure against this form of coupling. In direct-current sets operated from the 110-volt lines, if the sets are of the home-made variety and

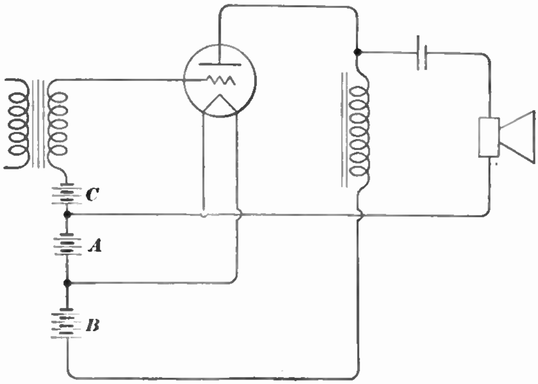


FIG. 9

squeal badly at low pitches or distort when low-pitch tones are present, the coupling circuit of Fig. 9 is strongly recommended. It is well to put a large condenser across the B voltage supply, as, for example, 4 or more microfarads, if the trouble persists. Intermediate-frequency squeals, of the order of 150 to 500 cycles, may come from any of the sources mentioned, but they are most likely to come from acoustic regeneration.

36. When the loud speaker is near the set and the audio amplification is considerable, the vibrations of the speaker may be communicated to the elements of the detector tube, producing thereby a relative displacement between grid, filament, and plate, which will in turn vary the plate current accordingly. These current variations will pass through the audio transformer and through the amplifier up to the loud speaker, which will sound correspondingly louder, and as its mechanical vibrations are communicated back again to the detector-tube elements the process will go on, again and again building up sustained vibrations just as in an electrical regeneration system. The pitch of the tone usually depends on the natural frequency of the loud speaker or that of the elements of the detector tube. It is obvious that by placing the speaker away from the set, the oscillations will stop. At times it is only necessary not to place the speaker on top of the radio set. If the oscillations or howls continue a rubber or metal cap on top of the detector will kill them.

37. The real danger of distortion occurs when there are no howls or continuous oscillations but regeneration is present just the same, causing distortion due to reinforcement of certain tones and producing a peculiar effect upon speech that will resemble the voice of a man talking into a pitcher, the so-called *rain-barrel effect*. These are the result of one or more peaks in the audio-frequency response curve of the set and speaker together, due to acoustic regeneration. The only thing to do is either to reduce the total audio-frequency amplification or put the speaker as far as convenient from the set. On the other hand, rain-barrel effects may be due to the construction or location of the loud speaker, or both, irrespective of the radio set. To effect the reduction in audio-frequency amplification, nothing is better than to shunt a resistance across either the primary or secondary windings of one or both audio transformers until the quality of reproduction improves.

Care must be exercised in distinguishing the regeneration effects from those very same effects coming only from natural frequencies of the loud speaker. To make sure that the speaker is not to blame, the audio system may be operated at reduced B voltage in all tubes but the last one and the quality of reproduction noted. If it improves perceptibly, the distortion is coming from acoustic regeneration. A still better test is to take the loud speaker to an adjoining room and operate the set in its own place. If the distorted reproduction still persists, it surely does not come from acoustic regeneration. It is assumed that in examining the troubles due to acoustic regeneration, one has made sure that all the tubes are all right, because worn-out tubes will produce rain-barrel and similar effects when in the audio system and a fair volume is desired from the set.

It is well to repeat that the first thing to do when a set is not properly reproducing is to examine the tubes, and best of all, to put in fresh tubes everywhere, if possible, before going any farther. Then all the battery voltages should be checked and, if the trouble persists, it can be traced to any one of the causes discussed.

POWER-SUPPLY UNITS

THE A BATTERY

38. **Storage Batteries.**—There are three kinds of batteries in the average radio set. The A battery is usually a storage battery, although some portable and semiportable sets employ dry cells to light the filaments of the tubes. B and C batteries are generally of the dry-cell type.

If the storage battery does not give enough voltage to light the tubes to normal brilliancy, it may require charging. There are some special types of voltmeters or indicators in the market that tell whether a battery is well discharged or is in good condition. The use of the hydrometer, however, is more reliable, as the specific gravity of the electrolyte is a sure indication of the amount of charge in the battery. On the other hand, it is not as convenient to use where the storage battery is located in a place hard to reach without inconvenience and there is always the danger of soiling something with the electrolyte dripping out of the hydrometer. The readings of 1,280, 1,200, 1,160 correspond to a fully charged, half-discharged and discharged battery. A completely discharged battery gives a reading of 1,150 on the hydrometer. It is never a good thing to let a battery go as low as that and leave it in that state for a length of time because it will get sulphated, the plates will get short-circuited, and the battery will have to be repaired at considerable expense or a new one secured.

39. **Charging Precautions.**—There is little danger of overcharging a battery in the average house, as the charging outfits

rarely charge the batteries at an excessive rate, and unless the owners are very careless to let the charger go on indefinitely there is little to be feared in this respect. There is, however, a very common occurrence with chargers. A great majority of the radio sets are grounded and so are the electric-light lines to which the chargers are connected. Certain types of chargers that are in use in alternating-current circuits have an auto-transformer, with the result that the electric-light circuit is actually connected to the storage battery through the charger. In this case if the battery is not completely disconnected from the set and from the ground, there is apt to be a short circuit in the electric-light lines and fuses will be blown. In some cases the tubes of the radio set have been burned out by a cross-connec-

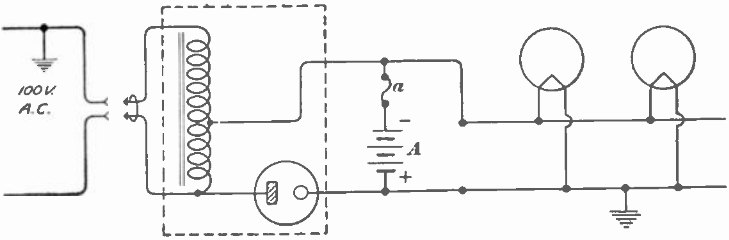


FIG. 10

tion resulting from the charger being connected to the battery during an attempt to operate the radio set. This will be made clear by referring to Fig. 10. The alternating-current line supplying the charger is grounded and the negative terminal of the A battery is also grounded. During the peak of the alternating-current wave, which is about 150 volts above or below ground, a tremendous current will be sent through the battery circuit. If the battery has a fuse in series with it like that shown at *a*, it will blow, and the next instant the current will go through the set, burning every tube in the set. The moral is: Never charge a storage battery without completely disconnecting it from the radio set. This can be accomplished conveniently by means of a double-pole double-throw switch as shown in Fig. 11.

40. In case the electric-light lines carry direct current, the short circuits arising from attempts to charge the batteries while connected to a grounded radio set may be more severe. If it happens that the positive pole of the direct-current line is not grounded, but the negative is, it is possible to charge the batteries while connected to the radio set, provided the set is not grounded elsewhere except to the negative pole of the line, and in this case, the negative terminals of both the battery and the set should be permanently connected together. Then, by a suitable resistance

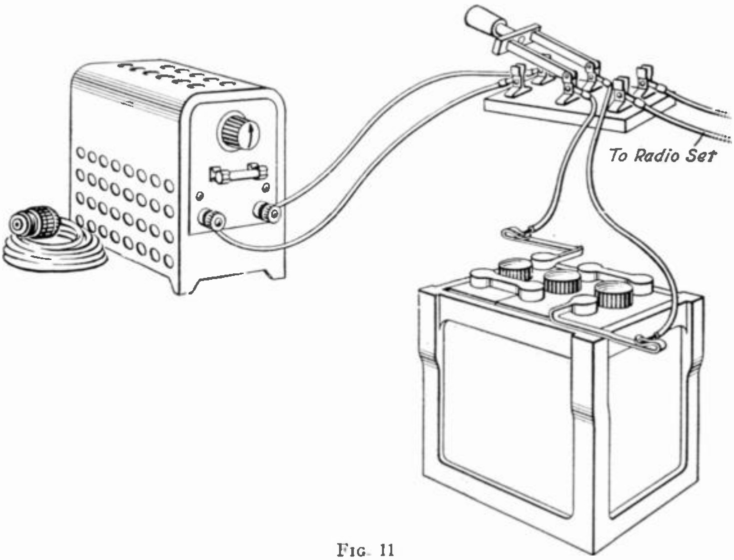


FIG. 11

for charging the battery from direct-current mains it may be possible to charge the battery only while the set is running, care being taken to put a slightly greater current from the mains into the system than the current required to light all the filaments, so as to make up for the leakages.

BATTERY CHARGERS

41. Types of A-Battery Chargers.—There are two kinds of chargers; for direct-current and for alternating-current lines. The direct-current chargers are made of a resistance coil in series with an ammeter, and sometimes they have taps in the resistance unit so that the batteries may be charged at different rates. The only thing that may give trouble from them is that the wrong polarity has been used when charging the battery and this can easily be checked by the meter. If the current fails to pass into the battery, the leads that serve to connect the charger to the battery are short-circuited and the indication of the meter noted. If it fails to read, there is an open either in the leads that go to the battery or in those that connect the charger to the line;

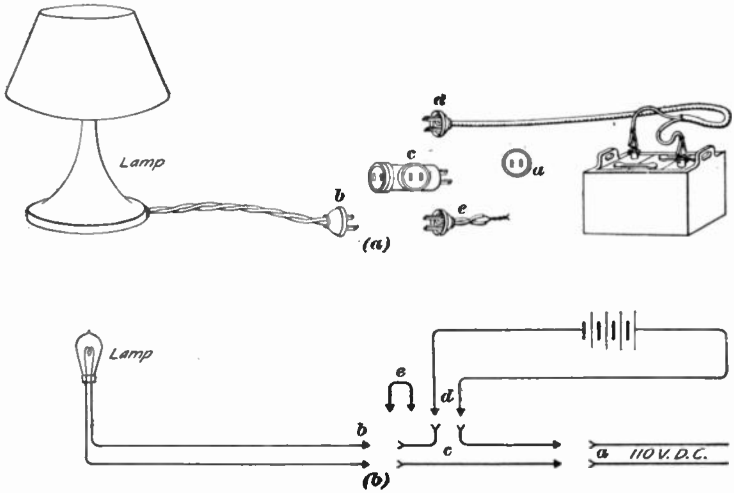


FIG. 12

quite likely at the connecting posts. If the connections are all right, the resistance coil may be damaged, although this is not likely.

A very simple and economic direct-current charger may be made by inserting a series socket in the line of a reading lamp of high candle power as illustrated in Fig. 12 views, (*a*) and (*b*), where *a* is the wall socket, *b* the lamp plug, *c* the series socket, *d* the battery plug, and *e* an auxiliary plug with its prongs short-circuited. This last item serves to complete the circuit of the reading lamp when the battery is not to be charged. The polarity can be easily ascertained by noting the brilliancy of the lamp. When the lamp is dimmer the polarity is correct, as the line voltage is slightly diminished by the battery voltage. Thus, the battery may be charged without expense, the current from the reading lamp being utilized.

42. Alternating-Current Chargers.—Alternating - current chargers consist, in general, of a step-down transformer, a rectifier, and suitable protective devices like fuses and resistors. In the old-type mechanical rectifiers operating on the synchronous relay principle, there is very little that can go out of adjustment. When the contacts are perfectly adjusted, the servicing is practically reduced to the adjustment of the points and the tension of the spring. If the armature is not tuned to the frequency of the line current it will not vibrate sufficiently to insure good contact between the points. Moreover, it may be that if the natural frequency of the vibrating element is just a bit off 60 cycles, beats may be produced and a tremendous amount of sparking and burning of the contacts will follow periodically. The sound produced by the vibrating element will tell when it is vibrating the most and is more regular. Then, the points are adjusted by screwing in or out the fixed one until the sparks disappear or become a minimum. The battery must always be connected to the charger while making the preceding adjustments.

The chargers containing a tube rectifier, like the Tungar and the Rectigon, have only stationary apparatus not likely to go out of order. The main trouble may be an exhausted tube or a broken wire if the instrument has been tampered with. These rectifiers have to be connected only one way to the battery, as otherwise they will discharge the battery (if of sufficient voltage) or not charge it at all. The only danger that may be feared is that of a short circuit of the electric-light line to the ground through the radio set while the battery is being charged.

43. Trickle Chargers.—During the last few years the problem of securing continuous power for the filaments, without the necessity of taking the storage battery to the service station for charging, was solved by means of a charger that is in operation continually, night and day, except when the set is working, and charging the battery at a very low rate. There are separate trickle chargers from the battery, but most commonly a low-capacity storage battery is incorporated with the trickle charger and the combination constitutes what is called an A-battery eliminator. Trickle chargers are subject to the same troubles as the regular chargers and the suggestions given for solving troubles on other types apply also to trickle chargers.

In the dry-disk rectifier the most common troubles met with arise from the copper-sulphide rectifier breaking down, and sparking across. Sometimes in case of a severe breakdown the transformer may burn out also. If the unit takes an abnormal current from the alternating-current lines, as manifested by a good-sized spark when making-and-breaking the alternating-current supply at the socket contacts or even by adjacent lights growing slightly dim, it is a sure sign of a short circuit. The

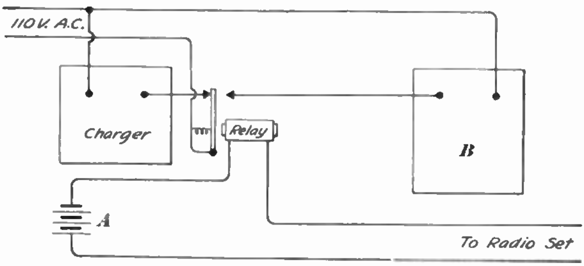


FIG. 13

rectifier should be immediately disconnected from the transformer and the fact ascertained whether the heavy current is still drawn from the line. If so, the transformer is short-circuited, and it is no good any more, as the repairs rarely cost less than a new one. Otherwise, the short may be in the rectifier and may manifest itself by sparking across the radiator plates.

If the battery has been permitted to run down very badly, the trickle charger will have to supply too much current at first, which may be sufficient in some cases to burn it out. If the A-eliminator does not furnish any voltage at all, this may have been the case, and it will be necessary to charge the storage battery by some other source and replace the burned-out rectifier.

44. In many installations there is a small relay in the A-supply circuit which automatically completes the line-circuit connections to the trickle charger or to the B eliminator. This is shown schematically in Fig. 13. The winding of the relay is connected in the filament circuit so that when the filament switch in the radio set is closed, the relay becomes magnetized, by the current flowing through its winding. When magnetized, the relay attracts its armature, which immediately comes in contact with its front stop. When the relay is demagnetized, the armature is pulled to its back stop by a retractile spring.

From the illustration, it will be noted that when the armature of the relay is against its back stop, as shown, the 110-volt alternating-current supply is connected to the input of the charger. As soon as the filament switch in the radio set is closed, the relay becomes magnetized and brings the armature to the front stop. The armature, leaving its back stop, disconnects the line circuit from the charger. The armature in contact with its front stop connects the 110-volt line circuit to the input of the B eliminator. Thus, the operation of the filament switch in the radio controls the switching of the alternating-current supply.

B AND C BATTERIES

45. When a dry-cell battery goes down to a full-load voltage below 75 per cent. of its rating, it should be discarded and replaced. The voltage measurement should be made with the set working and with a high-resistance voltmeter. The B batteries will go down much quicker than the C batteries because the former are required to furnish considerable current while the latter only furnish voltage. When the B battery is run down but not below 75 per cent. of its rated voltage, the C voltage should be reduced to the value corresponding to the lower B voltage, this particularly applying to the power tube, otherwise distortion may result. The C voltage reduction can be accomplished by using the proper taps in the C battery provided by the manufacturer, but 3 volts too much or too little will not affect the results.

CONTINUITY TESTS

BATTERY CONNECTIONS

46. A-Battery Connections.—Whenever a radio set fails to give any sound in the loud speaker, a systematic check-up of all the connections should be started from the sources of power. The switch controlling the filaments should be turned on and if the filaments fail to light, the battery should be tested with a voltmeter to see whether it is alive. If the battery is alive, then the voltmeter is connected to the A-battery terminals of the radio set and, if the voltmeter registers the battery voltage, then the open may be in the filament rheostat. A voltmeter test from the negative A terminal to the two terminals of the filament rheostat will locate the open.

In some old-fashioned sets the filaments of certain tubes are controlled from the loud-speaker jacks so that, when the plug is inserted, the filament circuit is completed and certain tubes light and others go out. If the loud speaker is connected to the last audio stage, all the tubes are supposed to be lighted, and it is well to have it so connected for the continuity tests in the A-battery lines.

In some sets, the radio-frequency tubes are fed through a separate rheostat from the rest; in other sets, the detector tube has its own filament rheostat. It is well to turn all the rheostats full so that any break may be detected. If an individual tube fails to light, it may be that the socket terminals do not make good contact or that the wires have become detached from the socket terminals.

47. Practically every vacuum tube has circuits and voltages like those shown in Fig. 14. The power supply, which includes the *A*, *B*, and *C* units, is generally connected to the receiving set by means of a cable. In the illustration terminal *1* represents the $-C$ terminal in the receiving set; terminal *2*, $+C\ -A\ -B$; terminal *3*, $+A$; terminal *4*, $+B$. A voltmeter *V*, like the one shown previously in Fig. 3, is drawn on the right of the vacuum-tube circuits, Fig. 14. Leads and contact points form part of the voltmeter test set. The leads are connected to suitable terminals on the voltmeter, depending on the values of the voltages to be tested in the receiving set. The insulation on the test points of the voltmeter has sometimes distinct color designation. The positive point is painted red and the negative test point, black. This is to enable the service man readily to distinguish between the test points.

The A-battery circuit is tested on the low scale of the voltmeter. The test points are first placed on the terminals of the *A* battery, then on terminals *2* and *3* in the receiving set. Then, with the negative point on terminal *2*, the positive point is suc-

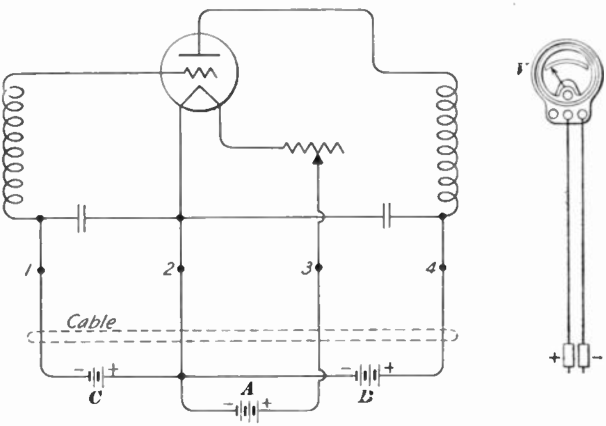


FIG. 14

cessively touched to the pointer of the rheostat, rheostat terminal, socket contacts, and through the filament of the tube. This tests the entire filament circuit of a tube, and if there is a break in the circuit, it will be discovered in this test.

48. B- and C-Battery Connections.—B- and C-battery circuits should be tested with the tubes out of the sockets, as a precaution against a cross of the B supply with the A supply. The negative point of the voltmeter, Fig. 14, is first placed on the negative terminal of the *B* battery, and the positive point on the positive terminal of the *B* battery, to determine whether the *B* battery is alive. Then the voltmeter points are touched to terminals *2* and *4* in the receiving set to determine whether there is a break in the cable connections. Then with the negative point of the voltmeter on terminal *2*, the positive point is successively touched to the terminals of the coupling unit and to the plate terminal and connections in the tube socket. This test explores the entire plate circuit. The different voltages in the receiving set should be as follows: Detector, 22½ to 45 volts; amplifier, 67½ to 90 volts; power tube, 135 to 180 volts. The battery leads should be well connected in the receiving set. If the leads come in a cable, they generally follow the standard color code, which is as follows:

Negative A	Black with yellow tracer
Positive A	Yellow
Negative B, positive C	Green with red and blue tracers
Positive B (Det.)	Maroon
Positive B (Amp.)	Maroon and red
Positive B (Power)	Red
Negative C	Black with green tracer

49. If one or more cells of the *B*-battery block, Fig. 14, are found dead, it may be possible that there is a short circuit in the cable or in the set. When a fresh battery is about to be connected, the negative terminal of the *B* battery should be connected at once to the negative lead from the cable and the positive point of the voltmeter to the positive terminal of the *B* battery. Then the negative point of the voltmeter is touched to all the positive terminals coming from the cable, such as the 45-, 90-, 180-volt leads and, with all the tubes out, there should be no indication in the voltmeter. If a kick is registered but with no permanent deflection of the needle of the voltmeter, the circuit is clear, and the kick is due to the charging current to a by-pass condenser across the *B*-battery wire in the radio set.

If a voltmeter is not at hand, a 10-watt lamp may be used instead and it will answer the purpose insofar as the detection of dead short circuits is concerned, because high-resistance leaks will not draw sufficient current from the *B* battery through the lamp to light it even dull red. The head phones are not very reliable for this test, as they are likely to give a strong click when charging a condenser as well as when current passes permanently through them. With a little practice, however, the click due to the charging of a condenser can be distinguished from that due to passage of steady current if the contact is repeated quickly several times; since the condenser will not have time to discharge itself sufficiently while performing the test, the succeeding clicks will be much fainter, perhaps inaudible.

50. With all the *B*-battery blocks connected properly and the negative point of the voltmeter, Fig. 14, attached to the negative *B* or negative *A*, the positive point of the voltmeter is touched to the plate terminals of the vacuum-tube sockets to determine whether the correct voltage is applied to them. This test will reveal any open or broken lead in the cable or poor contact in the sockets.

Exactly the same procedure should be followed in testing for C voltage, except that the positive instead of the negative point of the voltmeter should be connected to the negative *A*, which is common to the negative *B* and positive *C*. The grids of the amplifier tubes should have negative *C* voltage in most radio sets, although there are quite a few that have no *C* voltage in the radio stages, but only in the audio tubes, the detector having in the majority of cases a positive *C* voltage coming from the return of the grid circuit to the positive *A* wire. In this case the voltmeter will not indicate anything because of the high resistance of the leak in comparison with that of the instrument itself, and for this reason it is better to test from the terminals of the grid coil rather than from the grid prong of the socket of the detector tube.

CONTINUITY TESTS IN SETS OPERATED FROM D-C MAINS

51. The usual circuit for the A, B, and C supply to a radio set operated from the 110-volt direct-current line, is shown in Fig. 15. It will be noted that all the filaments are connected in series with each other, and with several resistances that reduce the line voltage to the proper value and at the same time the drop across them due to the filament current is utilized for *B* and *C* voltage sources.

The first thing to determine is whether all the tubes are lighted to the proper voltage and this can only be ascertained by testing with the voltmeter across each of the tube-socket filament terminals, or measure the voltage from the first negative filament terminal to the last positive terminal and divide by the number of tubes in series. As a rule, if there is an open circuit all the tubes go out like in a Christmas tree light circuit. There are cases, however, where the tubes are shunted by compensating resistances and then a burned-out tube may not cause a complete interruption of the filament circuit.

The method of procedure when the tubes do not light is to test first for line voltage across the supply, and then to connect the negative point of the voltmeter to the negative terminal *a*

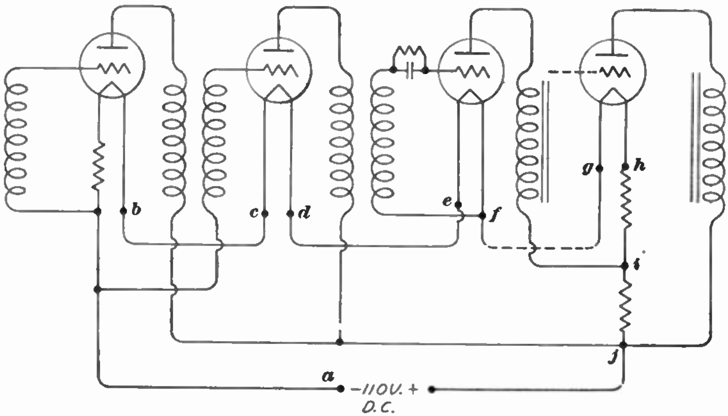


Fig. 15

of the line, which is also the negative of the first tube of the series, and from there on keep on testing with the positive terminal of the voltmeter to points *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, and *j*. As soon as the full 110 volts is registered on any intermediate point in the circuit, the open is located on that spot.

52. The C voltage has to be measured from the negative terminal of each tube, Fig. 15, to the coil or transformer attached to the grid circuit, or to the grid prong itself in all cases except the detector on account of the high-resistance grid leak. A 10-watt lamp may be used conveniently in place of the voltmeter to locate an open, but not to measure or determine the correct voltage applied to each tube. An excellent precaution when testing an electric-light set, is to insert in series with the supply line a 100-watt lamp so that, if any short-circuits may occur during the test, the fuses will not be blown, and the operator is protected. No accurate voltmeter measurements should be made, or any A, B, or C voltage permanent adjustments should be made with this 100-watt lamp in series, as the line voltage will be lower.

In connecting a d–c set to the electric-light lines, the proper polarity may be determined just by the fact that the set will remain absolutely silent if the polarity is wrong, and it will make some sort of noise, even just a murmur if right. So if a set refuses to operate, the first thing to do is to reverse the polarity at the socket by pulling out the top of the plug and replacing it with the prongs reversed, and this simple thing will probably be all that is required to make the set work.

TESTING OF COILS AND TRANSFORMERS

53. If there are B and C voltages at all the plate and grid prongs of all the sockets as determined by the tests previously outlined, there is no open circuit in the coils and transformers, and the next thing to determine is the presence of short circuits. To this end, it is best to start with the radio-frequency system. The antenna should be connected to a fixed condenser of any value, as for example .005, and the other end of the condenser should be connected by means of an exploring wire to the grids of the detector, second radio, first radio, and antenna post.

If there is a faint signal when the antenna extension is touched to the grid of the detector tube, the set is tuned a little to determine whether a station may be heard. If so, the antenna is connected through the .005 condenser to the plate of the preceding tube, and the set retuned. If the signal is a little louder, the circuit is all right. Then the grid of the same tube is touched with the exploring wire and if the set has individual tuning dials, the dial controlling the grid of this tube is turned to see whether the signal can be made a little louder than before. If so, the service man goes to the plate of the preceding tube, and so on, until the antenna coil (or resistance) is reached. If, during the process, the signal loses strength materially or disappears, the place where a short circuit occurred will be located. It is assumed that by the continuity test on the B and C voltages it is certain that there are no opens, since there could be no voltage at the prongs of the socket unless the circuit was completed.

54. The simplest way of reaching at the prongs of tubes of the "UX" type while they are in place is to lift them slightly from the base and insert a hooked wire, No. 18 size (more or less), with rubber insulation such as is used for outdoor connections of electric-light installations. This short piece, about 10 inches long, is spliced to a piece of flexible wire that connects the exploring terminal to a condenser and to the antenna or to a voltmeter for other tests.

The short circuit may be either in the coil or in the associated tuning condenser. If it is in the condenser it is ordinarily caused by bent plates that touch each other at some or at all the positions of the rotor plates. This is often discovered by the intermitancy of the signals and even of the soft purring caused by the carrier waves when the dials are turned, and is generally accompanied by clicks and scratchy noises in the loud speaker.

55. Short circuits in the windings of the audio-frequency transformers may be found quickly if the set has jacks to connect the loud speaker or the head pieces to the detector, first audio and second audio. With the phones attached to the detector tube, if a signal is heard, it should become considerably louder when the phones are plugged to the first audio. If not, the transformer or the by-pass condenser or condensers across the windings are short-circuited. Then a little resistance measurement may help considerably. This may be done in the easiest way by means of an ohmmeter. The terminals of the ohmmeter are connected to the terminals of the winding. The ohmmeter shows the resistance of the winding, which may be used as a guide in determining whether the winding is shorted or open. When making resistance measurement with this instrument, all the batteries should be disconnected from the set, otherwise erroneous results or injury to the ohmmeter may follow. The resistance of the average audio-frequency transformer windings varies considerably, but the primary seldom has less than 100 ohms and seldom more than 800; the secondary resistance may vary between 2,000 and 10,000 ohms.

If either winding has short-circuited turns but the whole winding is not short-circuited, it will work after a fashion, and it will be difficult to the service man to determine how badly short-circuited the windings may be without resorting to amplification measurements or to more complicated measuring apparatus. The best thing will be to replace the transformer with a new one.

56. Before assuming that the windings of the transformer are short-circuited, the by-passing condenser (if any) should be disconnected or unsoldered and the test repeated. If after the condenser is disconnected, the B or C voltage is still in the plate or grid of the tube to which the transformer is attached, the short circuit is elsewhere on the leads that join the transformer to the socket prongs. Sometimes the windings get short-circuited to the frame of the transformer and consequently to that of the whole set if constructed on a metal chassis, and then there will be a drain in the B batteries without making a dead short circuit in all the cases. The tests indicated for continuity in the battery leads will show it, since at the moment that the B battery is attached to the negative terminal and the positive is touched to the proper cable lead through the voltmeter, there will be an indication of the instrument, and the more the reading approaches the full voltage of the cell, the closer is the short circuit to the battery lead in the windings of the transformer.

LOUD-SPEAKER TESTS

57. Polarity of Loud Speaker.—When there is no coupling circuit between the plate of the power tube and the loud speaker, it is imperative to connect certain loud speakers so that the plate current of the last tube will strengthen the permanent magnetic field of the telephone magnets, otherwise the speaker will not only lose sensitivity but will distort loud signals. The proper polarity may be determined by adjusting the diaphragm so that the speaker just begins to emit a clattering noise. The polarity is then reversed and, if the clattering increases, the polarity is correct, as the diaphragm will be closer to the pole pieces. Then the air gap is adjusted so that the speaker does not clatter even with the strongest signals. If a cone speaker like the No. 540 Western Electric or a similar one has an adjustment at the apex, it is loosened and the air-gap in the driving unit is allowed to take its own position when the plate current is passing through; then the rod is again secured to the cone by means of the setscrew.

58. Continuity Test in Loud-Speaker Circuit.—There are two general methods of connecting a loud speaker to a receiving set. If the loud speaker is connected directly in the plate circuit of the power tube and if one of the tips of the loud-speaker cord is pulled out of the plug and touched to it again several times, there ought to be heard a series of loud clicks, the absence of which will be an indication that the circuit is open either in the cord or in the windings of the speaker. To determine which it is, the terminals of the driving unit of the loud speaker are short-circuited to see whether there is a very minute spark upon breaking the circuit, or a voltmeter may be used if one is handy. If the open is not in the cord, the loud speaker will have to be sent to the repair shop, or perhaps it will be better to secure a new one of an improved type. Speaker units are so rugged that unless high voltages are applied to the windings or they are mechanically tampered with, they are good for a lifetime, or as long as the permanent magnets hold their strength.

59. If a coupling circuit is used between the set and loud speaker, it may be either an output transformer or a condenser-and-choke coupling. In the former case, the speaker should be completely insulated from the battery terminals and if the speaker fails to give any sound, it should be tested first with a B battery of 22½ volts to see whether any current passes through and there is no break in the circuit from the end of the tips of the cord. It ought to click loudly. Being satisfied that the circuit is continuous, the service man tests the transformer by means of the voltmeter to be sure that there is no B voltage in the secondary and that there is between the A minus and the plate terminal. If there is a B voltage at the B terminal of the transformer and none at the plate terminal, the winding is open or burned out, and a new transformer should be put in. If there is B voltage in the secondary, then the insulation is broken down.

With the condenser and choke-coil coupling there is the possibility of an open between the plate and the condenser or between the condenser and the jack. A short-circuited condenser would have been revealed by the continuity tests when connecting the B batteries, provided the speaker was attached to the set at the time of the tests. If there is B voltage at the B end of the choke coil, but none at the plate end, the coil is open and should be replaced.

There are two ways of connecting the speaker to the set through the coupling choke-and-condenser, one is the proper way, and the other, while it will give results, is not correct and distortion may follow due to feed-back through the battery circuit. The correct way is to connect the loudspeaker between the plate and the filament of the power tube, with the condenser in series. In this connection the condenser will have to stand the full B voltage plus the peaks of the signal voltage and therefore should be of substantial dielectric strength. If the speaker is connected in the incorrect way; that is, across the choke coil only, there is no need of a condenser, since the only d.-c. potential applied across the loud-speaker windings is the drop across the choke coil, which is very small. The objection to this connection is that the signal currents are obliged to traverse the B batteries before they return to the filament of the last tube, and unless the B batteries are new, they will have internal resistance and there will be a drop due to the passage of the signal currents through that resistance, and this is in common with some of the weak signal currents from the detector. Consequently there is a feed-back with its accompanying distortion. This effect while slightly noticeable in sets with a low-power output tube, is very important where a tube like the UX-171A or a more powerful one is operated at high plate voltages.

SERVICE-MAN'S TOOL KIT

60. From the standpoint of efficient service, it is usually advisable to make all repairs on receiving sets directly on the owner's premises. In order to do this, the service man must have a well-equipped tool kit, so that he may be able to make all tests and repairs with as little delay as possible. A well-stocked tool kit should have the following items:

Test points and leads
Headset
C battery, 4½ volts
Pliers, long nose, 5 inch
Combination pliers, 5 inch
Diagonal cutting pliers, 5 inch
Roll of friction tape
Screwdriver, 3-inch blade
Screwdriver, 6-inch blade
Screwdriver, 6-inch blade, heavy duty
Pocket knife
Crescent wrench, 4 inch
Small dust brush
Socket wrenches
Socket-contact adjusting tool
Non-metallic screwdriver
Small hammer
Electric soldering iron and stand
Rosin-core solder
Memorandum book
Circuit diagrams and other essential data

61. The most important tools are: one or two screwdrivers, a pair of combination pliers and cutters, a knife, a roll of insulation tape, and a few pieces of insulated wire, preferably of flexible lamp cord, and a few feet of magnet wire. The electric soldering iron with solder and paste are quite necessary in most cases even for simple inspection tests. A small fixed condenser of about .005 microfarad capacity with leads attached is very handy to explore the radio-frequency end of the set, since it will permit coupling the antenna to any point of the circuit and at the same time insulating it from the plate voltage.

MEASURING INSTRUMENTS

GENERAL CLASSIFICATION

62. Instruments are available for the measurement of practically all electric quantities. These instruments may be classified according to (1) the kind of current in the circuits on which they are used, as direct-current or alternating-current instruments; (2) the service for which they are intended, as switchboard or portable instruments; (3) their principle of operation, as D'Arsonval, electrodynamic, electrostatic, hot-wire, or thermoelectric instruments; (4) the methods of showing the results of measurements, as indicating, or recording.

DIFFERENCE BETWEEN AMMETERS AND VOLTMETERS

63. The principal difference between most voltmeters and ammeters for use on either d.-c. or a.-c. circuits is as follows: The coil of a voltmeter consists of many turns of wire and is connected across the circuit with or without a resistance in series with it. The total resistance of the instrument circuit is large and the current very small, compared with that flowing through the main circuit.

The coil of an ammeter consists of a few turns of comparatively large conductor, and, for the measurement of small currents, is usually connected directly in series with one of the line wires of a circuit. For measuring larger currents the ammeter coil is connected in parallel with a much smaller resistance, called a *shunt*, which is connected directly in series in the circuit in which the current is to be measured. The resistance of the ammeter coil and the shunt, if one is used, is small and the entire current flowing in the circuit passes through the ammeter including the shunt.

In order that stray magnetic fluxes from neighboring conductors may not affect the inductions of electric instruments, the working parts are often enclosed in an iron case.

HOW TO INCREASE RANGE OF VOLTMETER

64. A voltmeter can be used to measure voltages much higher than its maximum scale reading by connecting a suitable resistance in series with the instrument. Such a resistance is called a *multiplier*. Multipliers are made of such resistances that the scale reading must be multiplied by a certain number such as 2, 5, 10, etc., to obtain the voltage under test.

Let R be the resistance of the voltmeter, R_1 the resistance connected in series with it, E the highest reading of the voltmeter, and E_1 the highest reading desired, then

$$R_1 = R\left(\frac{E_1 - E}{E}\right)$$

When the resistance R_1 is connected in series with the voltmeter, the scale reading must be multiplied by $(E_1 \div E)$ to give the difference of potential across both the added resistance and the voltmeter, that is, across the circuit whose difference of potential is being measured.

EXAMPLE.—(*a*) What resistance must be connected in series with a voltmeter whose highest reading is 150 volts and whose resistance is 150,000 ohms in order to use it to measure up to 600 volts? (*b*) By what constant must its scale readings be multiplied to give the potential difference across both the voltmeter and added resistance?

SOLUTION.—(*a*) By substituting in the foregoing formula, $R_1 = 150{,}000 \times \left(\frac{600-150}{150}\right) = 450{,}000$ ohms. Ans. (*b*) The scale reading must be multiplied by $600 \div 150 = 4$. Ans.

HOW TO INCREASE RANGE OF AMMETER

65. The range of an ammeter may be increased by connecting a shunt across its terminals. Let R be the resistance of an ammeter, S the resistance of a shunt connected across the ammeter terminals, I the original highest reading of the ammeter, and I_1 the current range desired. To produce the same reading, the current and fall of potential through the ammeter itself must be the same with as without the shunt, the drop through the shunt will be exactly the same as that through the ammeter, and the current I_1 in the main circuit minus the current I in the ammeter, will be equal to the current (I_1-I) in the shunt.

To produce the same reading I with and without a shunt it is necessary that $S(I_1-I)=RI$; hence

$$S=\frac{RI}{I_1-I}$$

Therefore, to increase the range of an ammeter, having a resistance of R ohms, from I to I_1 amperes, a shunt S whose resis-

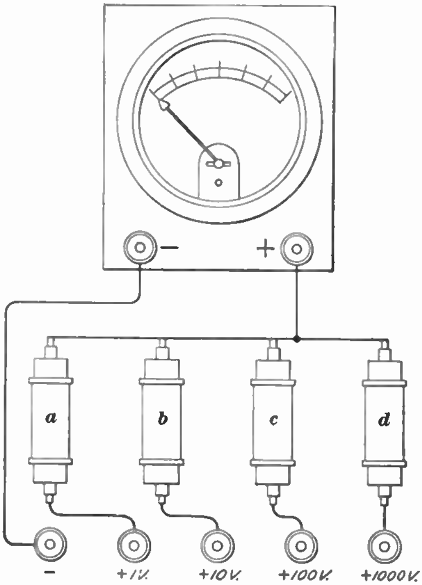


FIG. 16

tance may be calculated by the formula just given must be connected across the ammeter terminals. When shunted, the indicated reading must be multiplied by $(I_1 \div I)$ to give the total current flowing in the main circuit.

USE OF MILLIAMMETER AS VOLTMETER

66. Many laboratories have available a number of millivoltmeters and milliammeters which, with a number of different multipliers, would permit the application of the instruments on hand to many other uses. For example, a standard milliammeter like that shown in Fig. 16 having a scale of 0 to 1 milliamperes can be used as a very efficient voltmeter having convenient ranges from 1 to 1,000 or more volts by simply connecting in series with it multipliers of suitable resistance and calibrating or simply reading the scale in volts instead of in fractions of a milliampere. With a resistance *a* of 1,000 ohms in series, the range will be from 0 to 1 volt; with a resistance *b* of 10,000 ohms, 0 to 10 volts; with a resistance *c* of 100,000 ohms, 0 to 100 volts; with a resistance *d* of 1,000,000 ohms, 0 to 1,000 volts, etc. With similar multipliers, a milliammeter having a range of 0 to 1.5 milliamperes may be used as a voltmeter with a range of 0 to 1,500 volts, and higher. The resistors must, of course, be designed to carry safely the currents indicated on the milliammeter.

RESISTANCE MEASUREMENTS

67. Resistance in General.—Electrical resistance plays a dominating role in nearly all radio and electrical circuits. The resistance is usually considered a detrimental factor in wasting power; in many cases, however, the resistance effect is employed to give the desired operating conditions. Electric resistance is broadly applied to the factor offering opposition to the passage of a continuous direct current, and to an alternating current, provided other factors, such as inductance and capacity, may be considered as negligible.

68. Ohm's Law.—In case the voltage drop in the resistance and the current through the resistance are known, the value of the resistance may be calculated by Ohm's law. Briefly, the resistance in ohms equals the voltage drop, as measured by a voltmeter, divided by the current, as measured by an ammeter. This forms a convenient method of resistance measurement where the necessary apparatus is available.

69. Measurement of Resistance with Voltmeter.—A resistance can be measured by means of another resistance of known value, and a voltmeter. The known and unknown resistances are connected in series and to the terminals of a battery or other source of potential. The voltmeter is connected across the unknown resistance and across the known resistance in succession. The value of the unknown resistance is then equal to

$$R=\frac{R_1E}{E_1}$$

in which R = unknown resistance in ohms;
R_1 = known resistance, in ohms;
E = voltmeter reading across unknown resistance, in volts;
E_1 = voltmeter reading across known resistance, in volts.

For example, if the voltage reading E across the unknown resistance is 36.9 volts, E_1 across the known resistance is 26 volts, and the known resistance is 2.6 ohms, then the value of the unknown resistance $R=\frac{2.6\times 36.9}{26}=3.69$ ohms.

70. High-Resistance Measurement with Voltmeter.—High-reading voltmeters may be used to measure very high resistances. The voltmeter, the battery, and the high resistance are all connected in series. The voltage of the battery may be as high as convenient, as long as it is within the range of the voltmeter. The resistance may then be calculated by the following formula:

$$R=r\left(\frac{e}{e_1}-1\right)$$

in which R = unknown high resistance, in ohms;
r = resistance of voltmeter, in ohms;
e = battery voltage, or reading of voltmeter with resistance short-circuited;
e_1 = reading of voltmeter with unknown resistance in the circuit.

EXAMPLE.—If the electromotive force of the battery, as measured by the voltmeter, is 100 volts, and the deflection, when the resistance to be measured is in circuit, is 40 volts, what is the value of that resistance in ohms if the resistance of the voltmeter is 18,000 ohms?

SOLUTION.—In this case $e=100$, $e_1=40$, $r=18{,}000$, then $R=18{,}000\times\left(\frac{100}{40}-1\right)=18{,}000\times 1.5=27{,}000$ ohms. Ans.

71. Ohmmeter.—An ohmmeter is an instrument that indicates the resistance of a circuit directly in ohms. A commercial type of this instrument is shown in Fig. 17. The circuit the resistance of which is to be measured is connected in series with the terminals of the ohmmeter. The pointer will show directly the resistance of the circuit. The principle of the ohmmeter is best understood with reference to Fig. 18, where a dry cell *a* sends a current through an adjustable resistance *b* and a galvanometer *c*, the dial of which is marked directly in ohms. If an unknown resistance is connected across the terminals of the instrument the deflection will be proportional to the current. The scale of the instrument is graduated so that the value of the resistance is obtained directly. As the dry-cell voltage may diminish owing to the age of the cell, a compensating adjusting screw is provided so that the value of the instrument resistance *b* may be corrected; the instrument should read zero when the terminals are short-circuited together and infinite when

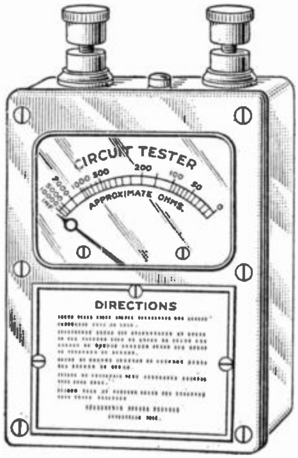


FIG. 17

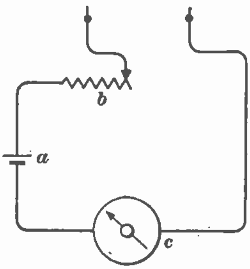


FIG. 18

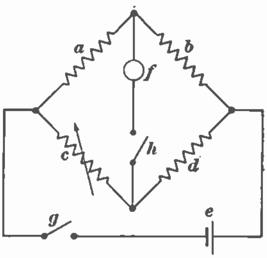


FIG. 19

open. It will be noted that the smaller the resistance the more the needle will deflect owing to the passage of a stronger current through the galvanometer, and consequently on a short circuit, the deflection will be that of the full scale, and the dial reading will be zero. On an open circuit the deflection will be to *infinite,* that is, the pointer will not move from its initial position.

72. Wheatstone Bridge.—Another method of resistance measurement makes use of a balanced circuit, or Wheatstone bridge. Essentially, the Wheatstone bridge consists of an input signal, a method of observing the signal intensity, and a set of resistances that may be varied to balance the resistance combination. The resistances shown at *a*, *b*, *c*, and *d*, in Fig. 19, form the bridge part proper, and may be adjusted to give the proper settings. In place of the battery *e* alone, a buzzer may be added to the battery circuit and the combination utilized as a signal source. In that event the galvanometer *f* would be replaced by a pair of telephone receivers. The key *g* is necessary to open and close the circuit while adjustments are being made. An additional key at *h* closes the galvanometer circuit to test for a condition of balance and should be closed each time after *g* is closed.

The circuit from the battery through the Wheatstone bridge comprises two parallel branches; namely, that through the resistances *a* and *b* in series, and that through the resistances *c* and *d* in series. The voltage drop through both paths must be the same, since they are connected together at their ends. The galvanometer will give a reading if there is a difference of potential between its terminals. Suppose the resistances *a* and *b* are equal, and that *d* is the resistance of unknown value. Resistance *c* may be varied until the galvanometer gives no deflection when keys *g* and *h* are pressed, which will mean that the resistances *c* and *d* must likewise be equal. If *c* is a calibrated decade resistance box, its reading under these conditions will be the resistance of the unit or device inserted at *d*.

73. Sometimes the resistance *c*, Fig. 19, is fixed and has a known value, and the arms *a* and *b* are formed of a continuous wire with the galvanometer connection adjustable along its entire length. When balance is secured, the ratio or relationship between *a* and *b* is used to determine the value of *d*, since this same ratio exists between *c* and *d*. Explained as a formula this would be

$$d = c \times \frac{b}{a}$$

The accuracy of results obtained with the Wheatstone bridge depends mainly on the care with which readings are taken. With suitable apparatus, this is one of the best ways of making resistance measurements, and also one of the most practical.

CAPACITY MEASUREMENTS

74. Capacity Bridge.—The capacitance, or capacity, as it is more commonly called, of a condenser may be measured by means of a modified Wheatstone bridge. One of the arms of the bridge would have a variable condenser so that the bridge could be properly balanced with the unknown condenser in another arm. As shown by Fig. 20, the capacity bridge includes the two equal resistance arms *a* and *b*. The arm *c* now includes a variable condenser *c* which is used to secure a balance in the bridge both when only condenser *d* is connected in the circuit without the condenser *e* of unknown capacity, and when condensers *d* and *e* are connected in parallel. A small fixed condenser *d* is necessary so that a balance may be obtained and the reading of *c* noted without the unknown condenser *e* in circuit. After the unknown condenser *e* is added, the capacity of that branch is increased by the exact value of capacity of condenser *e*. When the circuit or bridge is again balanced, the reading of condenser *c* should be taken. The difference between the two readings of condenser *c* will be the capacity value of condenser *e*.

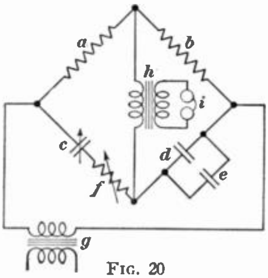


FIG. 20

75. In order to secure an accurate balance with the bridge, it is necessary to connect a resistance, as *f*, Fig. 20, in one or the other of the condenser arms, as may be found by trial. This will compensate for any resistance effect introduced by the condenser in the other condenser arm. The readings of this resistance, with and without the condenser *e*, are indicative of the losses in the condenser under test. The input circuit or signal source may consist of a buzzer, which should have a pure tone, at some convenient audio frequency. The buzzer is coupled with the bridge by a transformer *g*, and another transformer *h* serves to connect the bridge with a pair of head phones *i*.

76. Substitution Method.—The capacity of a condenser may be determined quite closely merely by comparison or substitution. A circuit containing an inductance and standard variable condenser is tuned to resonance with a suitable radio-frequency source, as indicated by a meter or other device. The condenser setting is noted and recorded. The unknown condenser is then connected across the calibrated condenser and the circuit retuned to resonance with the same signal as before. The difference between the two readings of the standard variable condenser gives the value of the unknown condenser capacity.

INDUCTANCE MEASUREMENTS

77. An inductance may be measured by placing it in a circuit tuned by a variable standard condenser. The circuit should be tuned to resonance with a meter or lamp to indicate when the resonance condition is reached. The signal may be secured by loose coupling with a wave meter energized by a vacuum tube or other oscillator. The condenser setting at resonance should be recorded as C_1, and the unknown inductance may be called L_1. The unknown inductance should be replaced by a known standard inductance L_2. Next the circuit should be retuned to resonance, the condenser setting being called C_2. The unknown inductance may be calculated from the formula

$$L_1 = \frac{L_2 C_2}{C_1}$$

SUGGESTIONS TO SERVICE MEN

78. Most Important Instrument.—The most important instrument for checking present-day receiving sets is a high-resistance direct-current voltmeter having at least two voltage scales. With it the service man can check all the voltages in the receiving set, test the continuity of the circuits, determine resistance values, check short circuits in tuning and by-pass condensers, determine the polarity of direct-current sources, and perform many other useful tests.

The next instruments in importance and utility is a pair of head telephones and a fixed condenser of about 1 microfarad. With the telephones in series with condenser, and one of the terminals of the condenser connected to the negative A lead, and the free terminal of the telephones attached to an exploring lead, the performance of all the apparatus pertaining to the audio system may be very easily tested. It is advisable to have in addition to the condenser, a resistance of about 100,000 ohms in series with the telephones and the condenser so that the load introduced in the various circuits under test will be a light one and the conditions may not be materially disturbed while attaching the instrument.

79. Set Testers.—There are on the market a number of complete set testers. These combine two or more instruments and are provided with extension cords, plugs, switches, terminal posts, etc., for making rapid tests on all types of receiving sets. Such test sets are extremely useful in diagnosing troubles in sets, checking tubes, and testing the supply. In most of these sets, the direct-current instrument is 0 to 1 milliammeter provided with shunts and multipliers to read several current and voltage values. The alternating-current instrument is generally a voltmeter. This is used to check the line voltage and the a.-c. filament voltages in the receiving set.