CHAPTER FIVE

OPERATION OF RECEIVING SETS AND THEIR ACCESSORIES

Selection of Receiving Sets—Manipulation of Receiving Sets—Preliminary Adjustments—Tuning of Single-Circuit Crystal Sets—Tuning of Two-Circuit Sets—Operation of Amplifiers—Adjustment of Regeneration—Tuning of Three-Circuit Set—Operation of Neutrodyne Set—Telephone Receivers—Loud Speakers—How to Remedy Receiving Set Troubles—Interference—Series and Parallel Condensers—Wave Traps—Use of Ammeters and Voltmeters in Receiving Sets—Batteries—Battery Chargers—Bulb Rectifiers—Mechanical Rectifiers—Motor Generators—Electrolytic Rectifiers

This chapter gives practical information on the handling of radio receiving sets by the man who simply wants to be able to operate a receiving set, while Chapter Four tells how to construct or assemble various types of sets.

Selection of Receiving Sets.—There are receiving sets of many kinds. They differ in respect to the range of frequencies or wave lengths they are good for, the distance from which they receive, and in many other respects. The simpler and cheaper sets which can be purchased for broadcast reception receive satisfactorily the music, etc., that is broadcast by medium power stations over an area the size of a large city. Anticipating the explanations below of the various parts of a receiving set, these very simple sets include a crystal detector and head phones, and cost $5 to $25. To receive over about 50 miles reliably, a set with an electron tube detector is required, which costs from $25 up. For greater distances, receiving sets with more electron tubes are necessary; some sets have as many as 10 tubes; the advantages, however, do not increase proportionally with the number of tubes used.

A loud speaker may be used instead of headphones with any receiving set, even the simplest. This requires replacing the headphones by a two-tube amplifier and a loud speaker, adding about $50 to the cost. It is then possible to fill the room with the sound received.

Receiving sets differ greatly in their ability to tune in a particular station without perceptible interference from other stations that are broadcasting at the same time. The ability to do this is called "selectivity," and is one of the most important characteristics to be sought in a receiving set. Information on this is given in "Manipulation of Receiving Sets" and "Wave Traps," below.

The most satisfactory day-after-day reception of broadcasting is from local stations, that is, stations within one hundred miles of the receiving station. Reception over greater distances, especially up to five hundred miles or more, is less regular and the signals received vary greatly in loudness. The long distance records of reception over distances of several thousand miles are comparatively infrequent and are almost always made by operators who are very experienced in the manipulation of their apparatus. A receiving set which accomplishes these results usually employs two or three stages of radio-frequency amplification, a detector, and two stages of audio-frequency amplification.

It is, however, entirely practical to secure regular broadcast service at a distance of one hundred miles from the broadcasting station. Loud-speaker reception with the production of sound which can be heard through an entire house is possible with a receiving set employing several electron tubes. For example, a regenerative receiving set with electron-tube detector, and two or three stages of audio-frequency amplification. The loud-speaking reproducer will usually accomplish this if the broadcasting station is one of the higher power stations. Such a station would, for example, be a Class B station putting 500 watts in the antenna. The most satisfactory loud-speaker reception is secured when the audio-frequency amplifier and the loud-speaking reproducer are designed and built to work with one another.

Loud-speaker reception of moderate intensity which can be heard satisfactorily through a single room can be secured with slightly less equipment than that indicated above. A regenerative receiving set with electron-tube detector and one or two stages of audio-frequency amplification will usually be sufficient for this purpose. A loud speaker can sometimes be made satisfactorily by using a single telephone receiver attached to a simple horn or fastened by a suitable attachment device to the horn of a phonograph. Instead of using a regenerative set it is possible to secure signals of practically the same intensity by the use of two stages of radio-frequency amplification between the receiving tuner and the detector tube.

If one is content to secure signals which can be heard only if the telephone receivers are worn on the head of the operator, it is possible to use equipment which is quite a little simpler than that suggested above. A one-tube regenerative set is very satisfactory in this case.

With each of the combinations suggested above it is possible on many occasions to receive signals over greater distances, though these times are not regular in occurrence and are less frequent in the summer than in the winter. The increasing number of the better broadcasting stations and the improving quality of the service which they transmit make it apparent that the dependance of the public will be placed upon the local stations, and that reception from distant stations, once in a while will serve to give added interest to the reception of regular local service.

If one expects to make the fullest use of his radio set he must plan to install one which will be sure to receive regularly the service which he desires. He will then receive as extra service the more distant stations which may be heard when transmission conditions are favorable. It must also be emphasized that radio carries much farther at night than in the daytime. This is especially noticeable at a distance of fifty miles or more from the transmitting station. For reliable radio service in the daytime one must, therefore, have much better radio receiving apparatus than is necessary for reliable service at night. While very much depends upon the design of the particular type of receiving set which is used, it is believed that the following table may be used as a guide in determining the general type of receiving set which should be purchased in order to get reliable service from certain distances in the daytime.

Table 1.—Showing approximate distances in miles for reliable daytime radio telephone receiving

Intensity of Signals	From Transmitting Station having 50 watts in antenna			From Transmitting Station having 500 watts in antenna		
	Crystal Detector	Regenerative receiving set and electron tube detector	Regenerative receiving set with 2-stage amplifier	Crystal Detector	Regenerative receiving set and electron tube detector	Regenerative receiving set with 2-stage amplifier
Readable signals in telephone receivers..	8	20	40	35	65	100
Loud signals in telephone receivers.....	1	8	20	5	35	65

It will be noted that one of the important factors affecting the receiving range is the power used at the transmitter. For this reason we have incorporated these values in the *Lefax* broadcasting station list.

Manipulation of Receiving Sets.—In view of the differences of manipulation of the various types and makes of radio receiving sets, it is impossible to give

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a single general outline of procedure which can be followed with all sets, but a few suggestions will be given for the handling of three specific types: (1) the single-circuit; (2) the two-circuit; (3) the three-circuit receiving set. This classification is based on the number of elements of the receiving set that have to be adjusted to respond to the wave frequency that is received. For each tuning element there are one or more dials that must be tuned.

Generally speaking, a radio transmitting station cannot be heard unless the tuning dials are properly set to tune to that station. The tuning dials perform the double service of permitting the signals from the desired station to be received and excluding other signals. The importance of this latter service is appreciated as soon as one begins to use a receiving set, because there are so many radio stations transmitting at once.

Preliminary Adjustments.—It is first necessary to make sure that the antenna is properly connected to the receiving set and that the ground connection is thoroughly made (see chapter 6). If an antenna switch is used, this should be thrown to the receiving position. Next the detector must be adjusted to a sensitive condition. In a crystal detector this involves adjusting the contact of the fine wire or "cat whisker" until it touches a sensitive spot on the surface of the crystal. This can be determined by noting when the loudest sound is heard in the telephone receivers when the test buzzer is operated. If such a test buzzer is not included in the receiving set, a simple one can be connected as shown in Fig. 9, Chap. 4.

If the detector is an electron tube it is necessary to light the filament by closing the filament switch. In some receiving sets this is done by the mere insertion of the telephone plug. The filament rheostat knob is then turned in the direction which increased the brilliancy of the filament until the signal is loud enough or until a slight hissing sound is heard in the telephone receivers; then the rheostat handle is turned back very slightly to the point where this hissing is no longer heard. If an electron-tube amplifier is used, a slight adjustment of the current through the filaments of the amplifier tubes is also necessary. Filaments should be burned at as low a heat as possible, and always turned off when not in use.

Tuning of Single-Circuit Crystal Set.—Some single-circuit receiving sets have but a single tuning control in the form of a knob which is marked with a scale for reading its position. Other types of single-circuit tuners have in addition a switch which can be turned to any one of several contact points. In either case the usual procedure is to carefully turn one or both knobs until a position is found where the desired signals are heard. On account of the sharp tuning of the radio-telephone signals from distant stations it usually requires much more careful adjustment of the receiving circuits to receive speech or music than is required to receive signals from radio-telegraph stations using spark transmitting sets. It is therefore desirable to move the continuously variable control knob rather slowly and listen carefully for a desired broadcasting station. In some receiving sets there is provided an extra dial for a so-called "vernier" condenser, which is used for the clearest final adjustment of the tuner.

A "tickler" or regenerative control, if present, is operated as described below under "Adjustment of Regeneration."

Tuning of Two-Circuit Sets.—The ordinary "coupled-circuit" or "two-circuit" tuner has three knobs or control handles. These are the primary circuit tuning control, the secondary circuit tuning control, and the coupling control. In the first tuning of a receiving station it is advisable to turn the coupling control knob to a point near the position marked "maximum." Then an approximate adjustment may be made of the primary circuit, after which the secondary control is moved gradually over its entire range. If no signal is heard at any point, the primary control is moved slightly and the secondary control is again turned over its range. By repeating this process, a point on both primary and secondary controls will be found where the desired signal is heard most clearly. Then the coupling knob is turned slightly in the direction toward "minimum" and the primary and secondary controls readjusted slightly in order to secure a louder signal. It will be found that the farther the coupling knob can be turned in the minimum direction the less will undesired stations be heard. It will also be found possible to hear radio-telephone signals with a much smaller or looser coupling than spark signals from stations of equal power. It will make the tuning of a coupled-circuit receiving set much easier if one has a chart or table giving the frequency or wave length to which the secondary circuit is tuned at each position of the secondary control knob. It will then be possible to set this knob at the position corresponding to the wave length of the desired station, and further adjustment of the primary circuit to this same wave length can be made much more quickly. A chart giving this wave length calibration of the secondary circuit can be made when the receiving set is manufactured. A similar chart cannot be made for the primary circuit until after the receiving set is installed and connected to the antenna with which it is to be used, since the wave lengths corresponding to the various positions of the primary control knob depend to a great extent upon the size of the antenna employed.

If there is an additional control knob marked "tickler" or "regeneration" it should be kept in the minimum position until the tuning just described has been accomplished. It can then be adjusted as explained in the section on "Adjustment of Regeneration."

Operation of Amplifiers.—The amplifier is a device employing one or more electron tubes in order to make the received radio signals louder than they would be without it. Many amplifiers have two or three electron tubes and are called "audio-frequency" amplifiers. The "audio-frequency" currents which are thus amplified are those which pulsate at a frequency which can be heard by the human ear, *i. e.*, ordinarily between 16 and 10,000 cycles per second. They correspond to the frequencies of sound waves produced by the voice and by musical instruments. They are connected between the detector and telephone receivers or loud speaker. Radio-frequency amplifiers serve to amplify the currents of the tuner before they are connected to the detector. This type of amplifier is very similar in outward appearance to the audio-frequency amplifier. Since amplifiers employ electron tubes, it is necessary to use batteries to light the filaments of these tubes as in the case of the detector tube referred to above. It is also necessary to use the small blocks of dry batteries in the plate circuits of these tubes. The connections of the amplifier and detector are ordinarily arranged to make possible the use of a single battery for lighting the filaments of all of the tubes and a single "B" battery for connection to the plate circuits of all of the tubes of a single receiving set. The voltage of the "B" battery may be anything between 40 and 100 volts. Somewhat louder signals are secured by using the higher voltages suggested. The detector tube, however, rarely requires a voltage over 45.

The adjustment of the potentiometer rheostat found on many radio-frequency amplifiers is similar to the regenerative adjustment described below.

Most receiving sets now utilize electron tubes requiring a comparatively small current to light the filaments. These tubes can be operated from dry batteries, unless there are several tubes in the same receiving set. In the latter case the total current required is great enough to make storage batteries more economical. Receiving sets have been developed in which the filaments of the tubes are lighted from the commercial lighting circuit, but no one should attempt to improvise such a connection without expert advice. Until further improvements are effected, the battery will remain the most satisfactory means of operating the vacuum tubes.

Adjustment of Regeneration.—In some receiving sets there is provided a control handle which is marked "regeneration" or "tickler." After the receiving set has been tuned to the desired signal, the sound can usually be increased by turning the tickler knob from its minimum position until the speech or music begins to be distorted or until a whistling or sizzing sound is heard. The tickler control should then be turned back just below this critical point. In order to economize in the use of the storage battery for lighting the filaments of the detector and amplifier tubes, the filament brilliancy may then be slightly reduced while the tickler or regeneration control is gradually turned toward the maximum position. Since the loudness of the received signals increases greatly as the tickler or grid and plate variometer controls are brought close to the position which gives the hissing sound, it is desirable that these adjustments be made very accurately in order that the loudest sound possible may be obtained without the undesirable noise. It should also be remembered that when the tickler adjustment is turned beyond the hissing or whistling point, the receiving set is usually acting as a weak transmitting set and will cause interference for other receiving sets nearby. This condition should therefore be avoided. By the proper use of a radio-frequency amplifier this undesirable feature of regenerative sets may be kept from causing trouble.

Time spent in indiscriminate tuning and manipulation of the various controls will not produce nearly as satisfactory results as equal time spent in systematically making the tuning, coupling, and regenerative adjustments outlined above. The controls described are the principal ones, though some additional controls, such as vernier condenser, are provided on certain receiving sets for use in obtaining closer tuning adjustment. Such additional adjustments need not be made until the signals from the station desired have first been tuned in.

Tuning of Three-Circuit Set.—The tuning of a three-circuit receiving set is somewhat more complicated than that outlined above for single-circuit and two-circuit receiving sets. In all there are five separate adjustments to be made. Adjustments of these must be changed in turn until the desired signals are received with the greatest intensity. These controls are as follows:

1. Primary circuit (marked on some sets "antenna inductance" or "antenna condenser").
2. Secondary circuit (sometimes marked "grid variometer").
3. Coupling.
4. Plate circuit (sometimes marked "plate variometer").
5. Detector (this is the same adjustment as the filament of the detector tube desribed under "Preliminary Adjustments").

In tuning this receiving set the coupling control should be turned to approximately the middle point. A first approximate adjustment should then be made of the antenna inductance or antenna condenser control, setting them somewhat above the middle of the scale if the recommended antenna length of 75 to 100 feet is used. Using both hands, rotate the grid variometer and plate variometer dials over their entire scales. These controls should be turned, one following the other, in such a way as to just keep the set from causing a slight hissing sound in the telephone receivers. When, by successive adjustments of the primary control, the desired signal has been located at a given position of the grid variometer and plate variometer controls, the coupling knob should be turned toward the minimum position until the signal is just barely audible. The primary antenna inductance or antenna condenser control should then be turned to a point which just causes the cessation of the hissing sound in the telephone receivers. The final adjustment to give the loudest signals should be made on the coupling knob.

Operation of Neutrodyne Set.—The manipulation of the tuning controls of the neutrodyne is similar to that described under the "two-circuit" set above, the procedure being extended to the three controls which are usually employed. The relative settings of the three dials ordinarily remain nearly the same throughout the tuning range of the set, so that after the proper settings for a single station have been determined, the set may be tuned to higher or lower frequencies by turning the dials approximately an equal number of scale divisions in the same direction.

Telephone Receivers.—Telephone receivers are mounted either singly or in pairs and are usually provided with a head band to hold them in place against the operator's ears. Telephone receivers designed for use with radio receiving sets usually have much more wire wound upon the magnets in order that a small current through the receiver may produce a louder sound from the diaphragm. As an indication of the amount of wire used in winding the telephone receiver magnets, the receivers are ordinarily rated by the resistance of this winding. Thus some receivers are 1000 ohms and others 2000 or 3000 ohms. It is impossible, however, to judge the performance of a telephone receiver by resistance alone, since many other factors enter into the determination of its efficiency. The two receivers of the head set are usually connected in series.

Two or three pairs of telephone receivers may be connected to a single receiving set by connecting them all in parallel or all in series. Telephone plugs may be purchased which are so constructed as to accommodate several pairs of telephone receiver terminals.

Loud Speakers.—Loud-speaking reproducers are on the market which can be substituted for the telephone

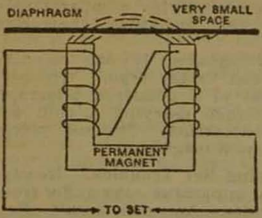

Fig. 1

receivers in any receiving set which employs an amplifier. The use of this loud speaker makes it possible to hear the radio signals throughout an ordinary room, though the volume of this sound varies with different types of reproducers.

The most common type of loud-speaking reproducer is that operated on the **electro-magnetic** principle, in which a metallic diaphragm is placed over the poles of a permanent magnet. Two coils of very fine wire are arranged on the pole pieces of the magnet and are connected to the receiving set. (Fig. 1.)

The magnet in this reproducer is very strong, as can be seen by trying to lift the diaphragm from the pole pieces. The diaphragm is under a constant strain or tension, due to this magnetic pull. When electrical energy from the receiving set passes through the coils on the pole pieces, the magnetic pull on the diaphragm is varied in accordance with the strength of received signals.

Sound reproducers constructed on the **electro-dynamic** principle are capable of operating efficiently over a very wide range of electrical energy received. In this type of loud speaker there is no strain or tension on the diaphragm when no electrical energy is received from the plate circuit of the receiving set. Instead of a permanent magnet, an electro-magnet is used whose field coil is connected to a 6-volt battery which supplies a current of about 1 ampere for this electro-magnetic field. An armature, which is a small coil of wire the shape of a ring, attached to the metal diaphragm, moves up and down in the ring air gap of the electro-magnet, which is cylindrical in shape. Fig. 2 illustrates this type of reproducer.

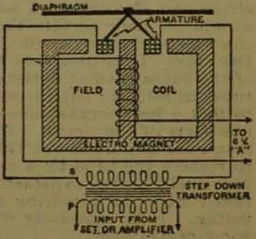

Fig. 2

Another type of efficient loud-speaking reproducer is that operated on what is known as the **balanced armature** principle. In this type the diaphragm and moving parts of the receiver unit respond to all frequencies in the broadcasting range without appreciable distortion. The better type of loud speakers on this principle have receivers sensitive to very weak currents and capable of carrying comparatively heavy currents without the armature chattering against the pole pieces.

Another type of loud speaker is one recently developed and known as the **"relay type."** Its construction is similar to that of a polarized telegraph relay. Four pole pieces, each carrying a coil, are grouped about a thin iron armature. The pole pieces receive their magnetism from a magnet.

How to Remedy Receiving Set Troubles.—Receiving sets, like other electrical apparatus, may suffer from short circuits or open circuits. An open circuit often makes itself known by a low-pitched hum in the telephone receivers. A simple way of testing for this trouble is by the use of a telephone receiver and dry cell. If no signals are received, either the filament or "B" battery may be wrongly connected. Try reversing one or both. On account of the small space which is allowed between the fixed and moving plates of the variable condensers it is possible for these condensers to become short circuited at certain positions on the scale. The telephone receiver and battery may also be used for locating this trouble. It may be remedied by giving the bent plate a slight push with a screwdriver while care is taken to avoid bending the adjacent condenser plates. In some condensers the position of the shaft carrying the movable plates is adjustable and may be changed by means of nuts located on the base of the condenser. Sometimes the telephone receiver cord becomes defective. This is noted by a rasping or scratching sound or a click when the telephone cord is moved. A new telephone cord can be obtained for a small sum from any radio supply store. In a regenerative receiving set if the adjustment of the grid and plate variometers or the tickler coil fails to produce regeneration, the filament current and plate voltage should be changed. If the filament of an electron tube fails to light or flickers, the tube should be removed from its socket and the ends of its four contact prongs should be cleaned with sandpaper or a fine file. It should be made certain that the spring connections in the tube socket make good contact with the prongs on the tube. It is desirable to try various combinations of the tubes used as detector and amplifier tubes, since tubes as sold are not entirely uniform and it is possible to find a best arrangement of these tubes in the various parts of the circuit. When the filament of an electron tube is burned out there is no remedy other than to replace the tube by a new one. Repaired tubes are not likely to be satisfactory unless as great care is taken with the repairing as in the original manufacturing. It is especially difficult to be sure that the vacuum will hold.

Grinding noises which persist when the antenna and ground wires are disconnected from the receiving set are not caused by atmospherics or "static" but may usually be remedied by tightening the connections to the binding posts at various parts of the circuit, by cleaning the contacts of the tubes, or by replacing old "B" batteries by new ones. Sometimes an electron tube is found which has a poor connection between the filament itself and the lead wire, which connects the filament with the prong on the base. Such a tube should be removed from the circuit and replaced by a new one.

If the signals which are usually loud from a certain station suddenly become weak, the trouble may be any of the following:

(*a*) The transmitting station may have reduced its power.

(*b*) If a crystal detector is used, the crystal may be out of adjustment or dirty. If dirty, the surface should be washed with soap and water, thoroughly rinsed and allowed to dry completely before using. The surface of the crystal should not be touched with the fingers. It may be worth while to file the metal point which touches the crystal.

(*c*) The receiving antenna or ground wire may have become disconnected. For further information on ground connections, see chapter 6.

(*d*) If an electron tube set, the plate or filament battery may be exhausted.

(*e*) The telephone plug may not be making good contact, or some other poor contact may have developed in the set wiring.

In case of difficulty in tuning out one broadcasting station in order to listen to another, it is often well worth while to utilize a wave trap.

Interference.—Irregular interfering noises heard in the telephone receivers are often caused by disturbances variously called "static," "strays," "atmospherics," "atmospheric disturbances." There are probably many other causes for these stray waves, but their sources have never been completely explained. They are more troublesome in the summer time than in the winter and are also more serious in tropical latitudes than in northern regions. The most satisfactory methods of reducing this atmospheric disturbance are the use of small antennas with very sensitive amplifiers and the use of very loosely coupled circuits. Radiotelephony has an advantage over radio-telegraphy when it is necessary to receive through this type of interference, since speech can often be understood by context even though some parts of it are lost. Some sources of interference which produce sounds very similar to atmospherics are the leaking of electric currents over the surface of faulty insulators of power lines, the sparking at commutators of electric motors, sparking at the contact of trolley wheels with the trolley wires, the irregular operation of arc lights and the operation of X-Ray machines. In some cases a continuous hum is heard on account of the antenna or ground wire being run parallel to an electric light or power circuit. This can be reduced by moving the antenna to a position at right angles to the power line. When it is desired to use a receiving station for continuous reliable reception of any radio service, it is advisable to investigate the possibility of such causes of interference in the immediate neighborhood as have just been mentioned. Interference from undesired radio stations or from atmospheric electricity is obtained only when the antenna and ground wires are connected to the receiving set. The interference from spark stations can be recognized by the long and short buzzing sounds constituting the dots and dashes of the radio-telegraph code. Such stations may be either commercial radio stations, such as operate between ship and shore, or may be amateur spark stations. Such interference can be minimized by reducing or loosening the coupling between the primary and secondary circuits or by reducing the tickler or regenerating action of the receiving set. Interference from continuous wave transmitting stations or from nearby receiving stations which are so adjusted as to act as weak transmitters is recognized by a whistling sound or continuous musical note. If it is found that the pitch of this musical note changes as the receiving set is detuned, this is an indication that the receiving set at hand is also generating and acting as a feeble transmitter. The tickler or regenerating action should therefore be reduced. When the adjustment passes this generating point a click will be heard in the telephone receivers.

Sometimes it is noticed that the strength of the signals received from distant stations varies rapidly for no apparent cause. This is particularly true at night, when the signals may fade in and out regularly or irregularly. While it is advisable to make sure that the connections to the receiving antenna are not loose, this difficulty is usually caused by changes in the condition of the space through which the radio waves travel between the transmitting and receiving stations. This difficulty is therefore obviously entirely out of the control of the receiving set manufacturer or user.

One of the best ways to reduce interference caused by alternating-current power lines, generators or motors having badly sparking commutators, arc lights, leaky insulators, sparking contacts at circuit breakers or on trolleys, etc., is the use of a small antenna. If the ordinary open type of antenna is used, its height and length may be reduced and the loss in signal strength recovered by employing a more sensitive receiving set. In case a coil antenna (see chapter 6) is used there is also some loss in signal intensity, but there is an added gain in freedom from interference on account of the directional characteristics of the coil. One of the simplest things to try, then, is the use of a coil antenna turned in such a direction as to reduce the interfernce to a minimum.

If an open antenna is used it is often helpful to turn it in a direction at right angles to that of power lines which may be passing near the house, or the antenna may be laid along the ground; in this case it should be covered with insulation or should be held a few inches above the ground with suitable insulators.

It is sometimes possible to balance out induction from neighboring power lines by using an auxiliary antenna which extends in a direction opposite to the antenna used with the receiving set. This auxiliary antenna can be connected through an inductance to the ground. The inductance should be coupled with a similar inductance in the regular antenna. The coupling must be in the proper direction to oppose rather than aid the two interfering effects in the antenna. A diagram illustrating this is given in Fig. 3. Sometimes merely using a counterpoise turned in the proper direction will accomplish the desired result without any special means of coupling.

If the antenna has been arranged to pick up a minimum of interference, it is worth while to use various means to improve the sharpness of tuning of the receiving set; then such interference as is picked up by the antenna will to some extent be filtered out before it reaches the telephone receivers. The receiving set itself should be thoroughly shielded to prevent the tuning coils and transformer windings from direct induction from the source of trouble. Inductively coupled receiving sets are preferable to single-circuit sets under these conditions. Radio-frequency amplification with sharply tuned amplifier transformers is also helpful. A well-designed regenerative set is also very selective. The coils, condensers and other parts forming the circuit should be designed to have minimum resistance. If the receiving set is one which has a series condenser in the antenna circuit, it is sometimes helpful to shunt the set with a high resistance (several thousand ohms) connected between the antenna and ground terminals.

Series and Parallel Condensers.—The series condenser shown in the antenna circuit of many diagrams is not always necessary if the antenna is short enough to enable one to tune to the desired wave length by the adjustment of the series inductance coil. The shorter the wave, the lower will be the setting of the series condenser. If the desired wave-length is longer than that to which the series inductance makes it possible to tune, the wave length of the antenna circuit may be increased somewhat by connecting the condenser

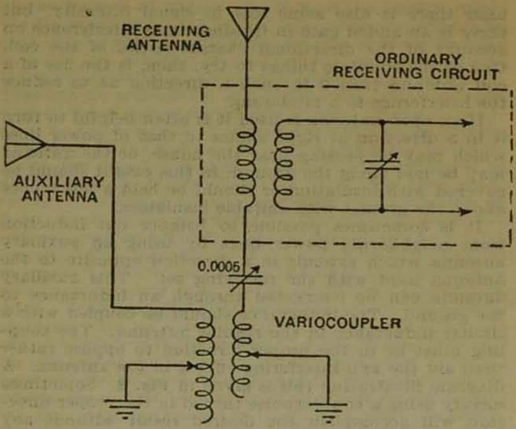

Fig. 3—Connections for Auxiliary Antenna

across the terminals of the series inductance. This condenser can conveniently be a variable condenser having a maximum capacity of 0.0005 microfarad. Either the series or the parallel condenser serve the added purpose of enabling one to tune more closely to the wave length desired by making finer adjustment of the tuning of the circuit than may be obtained by varying the number of turns of the coil only.

Wave Traps.—It is sometimes impossible to tune out a powerful nearby station when trying to receive a distant station on nearly the same frequency. The interfering station can be cut out by means of a wave trap. It is connected as shown in Fig. 4. The antenna is connected to the receiving set as shown, but the wave trap is inserted between the ground terminal of the set and the wire which leads to the actual ground. The wave trap is merely a coil connected in parallel with a condenser. The wave trap is most effective in cutting down the signals to which, as a series circuit, it is tuned. For example, if the coil and condenser are of a size suitable for use as the tuned secondary of a two-circuit receiving set, they will be effective in absorbing the current in the antenna of the frequency or wave length at which they would give loudest signals if used in the secondary. Therefore, the effective wave length of this wave trap can be changed by changing the number of turns on the coil or the setting of the variable condenser. For wave lengths in the broadcasting range, a coil having about 50 turns on a tube about 3 to 4 inches in diameter with a variable air condenser of 0.0005 microfarad capacity is suitable. By connecting the wave trap in the ground circuit as shown, it is possible to greatly decrease the strength of signals from the transmitting station to which the filter is tuned while maintaining at nearly the original intensity the signals from a station of a different wave length for which the regular antenna, tuning inductance and condenser are adjusted. If the two wave lengths in question are very close together, this separation is extremely difficult and in fact impossible with the coils and condensers which one can ordinarily buy. The effectiveness of the wave trap in stopping signals of a given wave length is greater if the resistance of the coil and condenser composing it are small.

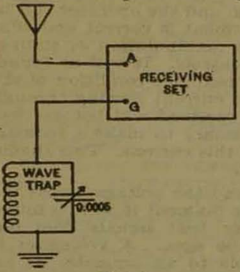

Fig. 4

Use of Ammeters and Voltmeters in Receiving Sets.—The use of measuring instruments to determine the condition of the batteries and to make it easy to re-establish a given adjustment of the filament circuit helps greatly to do away with much guesswork in the operation of radio receiving sets. The two batteries with which voltmeters or ammeters can be used in radio receiving sets are the "B" battery in the plate circuit and the "A" battery which furnishes power to the filament.

The exact voltage of the "B" battery is not ordinarily important, the signal intensity or the amplification secured remaining nearly the same, even though the battery decreases slightly in its voltage during the course of its use. However, when the battery is nearly discharged, the voltage drops rather rapidly and the signals then decrease noticeably in intensity. To determine whether the difficulty in the reception of signals is caused by a worn-out or discharged "B" battery, it is convenient to have a voltmeter with which the voltage of the "B" battery can be measured. Since the voltages used in ordinary receiving sets are of the order of 20 volts for the detector tube and 40 to 90 volts for the amplifier tube, a direct-current voltmeter having a maximum reading of about 100 volts is useful.

In the filament circuit either a voltmeter or an ammeter may be used. An ammeter connected in series with the filament of a tube reads the current flowing through it and through the filament from the "A" battery. When the filament rheostat has been adjusted so that the signals are received most satisfactorily, the reading of the ammeter is noted; then at a subsequent time when the receiving set is being used, the filament rheostat can be brought to the position corresponding to this same ammeter reading, and the operator can be quite certain that this adjustment is correct and thus give attention to the careful manipulation of tuning, coupling, and regenerative controls. It will be found, however, that as the tube is used, the condition of the filament changes, so that the current flowing through it when the best signals are received will become less and less. It is therefore necessary to make a redetermination of the best value of this current. This should be done perhaps once a week.

If a voltmeter is used to read the voltage across the terminals of the electron tube filament it will be found that this voltage reading for best signals does not change noticeably as the tube ages. A voltmeter is therefore somewhat preferable to an ammeter as an aid in reproducing the proper conditions in the filament circuit. The voltmeter should be connected across the terminals of the filament itself rather than across the battery to which the filament is connected; that is, the voltmeter readings should not include the voltage across both the filament and the filament rheostat, but should read the filament voltage alone. The maximum scale reading of the voltmeter should, however, be slightly greater than the normal voltage of the "A" battery when it is fully charged. This voltmeter will, then, be useful in determining whether this battery is becoming discharged, as will appear from a definite decrease in the voltage across its terminals.

In using direct-current voltmeters care should be taken to connect the plus terminal of the meter to the positive (plus) terminal of the battery. In many batteries the positive terminal is marked with red. In order to avoid the necessity of having separate voltmeters for each of the tubes used in a receiving set, one may provide jack and plug connections with which the voltmeter can be plugged into each of the filament circuits in turn. The jack used for a voltmeter connection must be an open-circuit jack; that is, the circuit must not be closed when the plug is removed. The jack used for making connection to an ammeter should on the contrary be a closed circuit jack. That is, the circuit should close when the plug is removed, the insertion of the plug making a connection of the ammeter in series in the circuit.

Batteries.—When fully charged, the specific gravity of the electrolyte (of the usual storage battery) is between 1.210 and 1.300. The exact figure for a particular battery is given by the manufacturer.

To fully charge a battery after discharge, it is necessary to pass through the cells in the proper direction (opposite to that of discharge) an amount of current equal in ampere-hours to that taken out on discharge, plus some excess to make up for losses. If the charging rate is not too high, all the current is useful in charging the battery. If the rate is increased, a point is reached where gassing occurs, due to decomposition of the water in the electrolyte. Charging rates sufficiently high to produce gassing are not only wasteful of electric energy, but tend to dislodge the active material from the plates and produce excessive temperature rise.

In general, any charging rate is permissible which does not produce excessive gassing or a cell temperature exceeding 110° F. The value of the charging current at which gassing begins depends upon the factors mentioned above, but the principal factor is the state of charge of the battery. When a battery is fully charged, any rate, however small, will produce gassing, but this rate may be reduced so that the small amount of gassing that results is practically harmless. This safe rate is called the "finishing rate." The more completely the battery has been discharged, the greater may be the initial rate. The method of diminishing the rate toward the finish of the charge is called "tapering" the charge. A battery may be charged at any time when a charge will be useful; it is not necessary to wait until it has been completely discharged. A general rule for determining the maximum permissible rate of charging is: The charging rate in amperes must never exceed the ampere-hours out of the battery. Any method of charging that keeps the charging current within this limit will not overheat the battery or cause it to gas. If 34 ampere-hours have been removed from a battery, the charge may be started at 34 amperes. In a quarter of an hour the rate must be decreased ¼ x 34 or 8.5 amperes, giving a rate of 25.5 amperes, and so on. The intervals may be chosen to suit the convenience of the operator. Since the average output current of commercial battery charging devices rarely exceeds 6 amperes, there is little danger of harming a battery by an excess charging rate with such equipment. In addition, most chargers automatically give a tapering charge, so that when the battery is fully charged, the current output is reduced to a safe value.

The characteristics shown by this method will be approximated if the constant-voltage method is followed, provided the proper voltage can be chosen. A value of 2.3 volts per cell is usually considered as a good average value, although some adjustment may be necessary between summer and winter. This method requires a minimum amount of attention of the operator and lessens trouble that may follow from any excessive overcharge.

Dry batteries used for lighting the filaments of tubes gradually deteriorate during use until they are unable to supply the required current. The "B" batteries also become exhausted in the course of use. Exhausted dry batteries cannot be recharged and new ones must be secured to replace them.

A storage battery can be used with a radio receiving set for only a limited time without recharging. In order to recharge the battery and put it in condition to supply further current to the receiving apparatus, it is necessary to connect it through special apparatus with the power or lighting circuit or send it to an electrical shop to be charged.

Battery Chargers.—A number of devices are made for use in charging a small storage battery from the house-lighting circuit. Some of these can be connected to an ordinary electric light socket and require very little attention. One must be sure to know by inquiring of his electric light company whether the lighting power is alternating or direct current. This makes an important difference in the type of battery charger which is suitable. When the battery is connected to the electric light circuit through the charger and the necessary initial adjustment of the charging current is made, it can ordinarily be left in this condition, that is, "on charge," for a number of hours without attention. The time of charge depends upon the capacity of the battery and the amount which has been used since it was last charged. It is advisable to use a hydrometer as a tester in order to determine whether the battery needs recharging. It is not desirable to permit the battery to become so greatly discharged as to fail to light the filaments of the electron tubes to their normal brilliancy. Storage batteries need to have distilled water added to them at intervals. This can be secured at any automobile or battery service station. Detailed instructions for care and operation are furnished with each battery by the manufacturer.

Bulb Rectifiers.—There are several types of bulb rectifiers on the market which operate on the same principle and have similar characteristics. When making a choice, the following things should be taken into consideration: First is the selection of the proper size of outfit. The choice of a 2-ampere or a 5-ampere rectifier is not, as it might at first appear to be, simply a question of the relative fatness or slimness of one's pocketbook. Each of these machines has its own field of usefulness.

In general, if the battery to be charged is of low capacity—as, for example, not over 40 ampere-hours—the 2-ampere size should be selected. For larger batteries the 5-ampere size is preferable, as it will charge the battery in a much shorter period of time.

Another point that should be considered is the load on the battery; that is, the extent to which it will be discharged when operating the receiving set. If only a single-tube outfit is used, the discharge rate may be about 0.25 ampere. Figuring roughly that the receiving outfit is in operation an average of three hours per day, then the total discharge would be 0.75 ampere-hours. In this case the 2-ampere size would be entirely large enough, regardless of the size of the battery. Operating the rectifier for one and one-half to two hours per day would keep the battery in a fully charged condition.

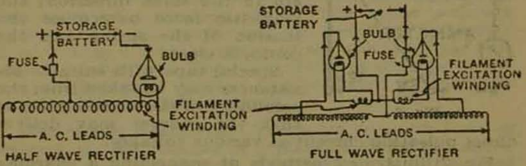

Fig. 5—Bulb Rectifiers

On the other hand, if a 3-tube receiving set is used, and each tube takes one ampere, the total discharge of the battery will be nine ampere-hours per day on the basis of operating the set three hours per day. To keep the battery charged with a 2-ampere rectifier will require a charging period of five or six hours per day, whereas with the five-ampere size, a two-hour charge per day would be sufficient.

Mechanical Rectifiers.—These rectifiers employ a mechanism for interchanging the connections to the alternating current circuit at the end of every half-cycle and thereby deliver a pulsating direct current, the voltage of the supply being reduced to the proper value for battery charging by means of a transformer. The general principles of operation may be had from a study of Fig. 6, which is typical of all types. The rectifier shown is called a half-wave charger, only one-half of the alternating cycle being delivered to the battery. There is very little energy lost during the half-cycle that is not rectified, as no energy is taken from the line excepting that utilized in producing eddy-current losses, heating and hysteresis in the transformer. This is very small in the average well-designed transformer.

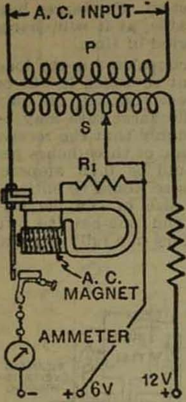

Fig. 6

The vibrating element, carrying one of the contacts, is attached to a spring in such a manner that its tension may be adjusted. The value of the current flowing through the a.-c. magnet is adjusted by R_1 to such a value that when the magnetic field set up by this magnet is opposed in polarity to that of the permanent magnet it is also equal to it. There is, therefore, at this instant, no force in the direction which closes the contacts, and the spring opens them. When the current in the a.-c. magnet reverses, the fields are in the same direction; the magnetic force overcomes the tension of the spring and the contacts close.

Special taps with suitable resistances may be taken from the secondary of the transformer, so that the charger may deliver direct pulsating current at various voltages.

Fig. 7 illustrates methods of connecting a charging outfit so that the operator may switch it on or off conveniently. Convenience of operation means a great deal, as the success obtained with any storage battery depends upon its condition, and this is maintained at its best when its charge is never left to run down. It is better to charge too much than not enough. No harm can come to the apparatus, as the charger is designed to furnish a voltage but slightly in excess of the full-charge voltage of the battery. The characteristics of the battery are such that it takes a tapering charge, *i. e.*, as its voltage rises it takes a smaller and smaller current.

The terminals of the chargers are generally marked the same as the battery terminals to which they are to

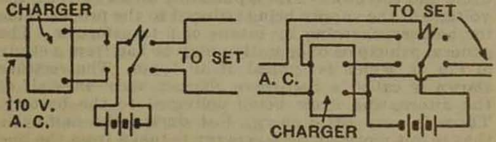

Fig. 7—Wiring Diagram for Switch Control

be connected; thus, + on charger to be connected to + on battery. In many cases no switch is needed for switching the battery over from the set to the charger, or vice versa, as when the a.-c. supply is cut off, the charging circuit is automatically opened. In these cases the charger and battery may be connected permanently in parallel, at the same time maintaining the connections to the set. As a matter of protection, however, it is best to install a switch, to change over either one or both of the lines to the battery.

Motor-Generators.—The use of motor-generators for charging purposes is not very extensive, for as a rule the cost of these outfits is somewhat higher than the cost of a bulb or vibrating rectifier. They are used chiefly where several batteries are charged. They are more flexible in operation than bulb or vibrating rectifiers, and can be controlled at will without any trouble or inconvenience.

A motor-generator is simply a motor and a generator connected by a common shaft. The motor is driven by the 110 v.-a.c. supply and the generator delivers a d.-c. voltage a little in excess of the voltage of the battery to be charged. The set operates at constant speed and the generator voltage can be varied by insertion of a rheostat in its field circuit.

Electrolytic Rectifiers.—The most common form of electrolytic cell consists of a plate of aluminum and a plate of lead or carbon immersed in a solution of ammonium phosphate or borate, dilute sulphuric acid or ordinary borax. Cells of this type are commonly used by radio amateurs for obtaining high voltage direct current for plate voltages in transmission. The rectification is not perfect, for as the voltage across the electrode is increased, leakage through the gas film on the surface of the aluminum takes place, until at a certain voltage the film breaks down completely and a large flow of current results. In the case of an aluminum cell using sulphuric acid as the electrolyte this critical voltage is about 25 volts. With ammonium borate it is about 500 volts; with ammonium phosphate it is 360 volts. In the case of a tantalum rectifier using

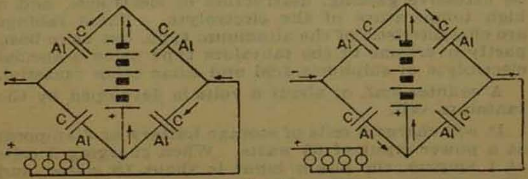

Fig. 8

sulphuric acid, the critical voltage is 430 volts. The tantalum rectifier uses electrodes of tantalum in place of aluminum.

Fig. 8 shows the method of connecting four of these cells so as to rectify both half-waves of an alternating current. The direction of flow is indicated by the arrows, and is shown for both halves of the cycle. The current through the battery which is being charged is in the same direction in each case. The lamp bank indicated is for regulating the current through the cells, and hence regulating the charging rate of the battery.

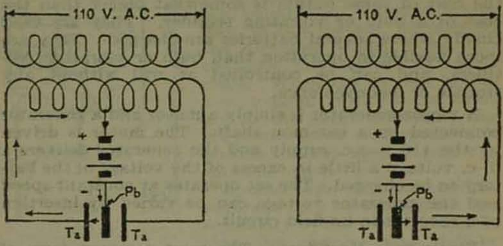

Fig. 9

Fig. 9 shows the connection for rectifying both half-waves of the cycle, using a cell with two tantalum electrodes and one lead electrode. The voltage to be rectified is stepped down from the line voltage by means of a step-down transformer. Diagrams for both halves of the cycle are shown.

Electrolytic cells can cause little electrical disturbance in the line, since there are no circuits to be opened and closed or to oscillate. They require a minimum amount of attention on the part of the operator, requiring only water occasionally. They are able to handle currents large enough to charge small storage batteries satisfactorily, but attempts must not be made to use them to rectify heavy currents. The result would be excessive gassing, destruction of electrodes, and a high temperature of the electrolyte. These failings are characteristic of the aluminum type, but have been partly overcome in the tantalum type using a special electrolyte of sulphuric acid and some other material.

A counter-emf. of about 3 volts is developed by the tantalum cell.

It will charge 3 cells of storage battery at 3 amperes at a power input of 65 watts. When charging 2 cells at 1 ampere, the power input is about 18 watts, and when charging 1 cell at 2 amperes it is about 29 watts.