1092

AMPLIFIERS *and* HETERODYNES

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The following publication, entitled "Amplifiers and Heterodynes, Radio Communication Pamphlet No. 9," is published for the information and guidance of all concerned.

[062.1, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

JOHN J. PERSHING,
General of the Armies,
Chief of Staff.

OFFICIAL:
P. C. HARRIS,
The Adjutant General.

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2. Care of apparatus.—All radio apparatus, including amplifiers and heterodynes, must be carefully handled. Rough treatment will surely cause trouble by dislodging or loosening parts of the apparatus, breaking electrical connections, either within the insulation or at the terminals, or, in the case of amplifiers, heterodynes, and other vacuum tube sets, breaking or changing the relative position of the elements of the tube. Therefore, it is necessary to handle radio apparatus with great care. Allowing the apparatus to become damp or wet will, in addition to causing rust and mold to form, nullify the insulating properties of the insulators used and in time destroy them. Radio apparatus should never be stored in a damp place. If unavoidably exposed to rain it should be carefully dried out by placing in a warm room, but never exposed to direct heat.

3. Care of telephones.—The telephones furnished with the amplifiers are type P–11 head sets. These should never be taken apart, as they are ground after assembly to get the exact clearance between the diaphragm and the pole pieces. If it becomes necessary to change the plug or cord, these should be connected in the exact way the old ones were. The connections can be identified by the colored tracer threads running through the insulation of the wires. To test the connection, connect the tip of the plug to the positive lead of a 20-volt dry battery and the ring of the plug to the negative lead. Unscrew the caps from the receivers, remove the diaphragm, and test the strength of the magnet in each ear piece with it. The magnets in both ear pieces should be stronger than the plug is connected to the dry battery than when it is not. If not stronger, proper connections of the cords and plugs have not been made.

4. Operation of heterodynes.—In operating a heterodyne there are two important factors to be considered. The one factor is the strength of the oscillation set up at the detector by the heterodyne. There is a definite though not critical strength, varying for different received signals, at which the reception is best. The strength of the oscillation set up at the detector by the heterodyne may be varied by changing the strength of the oscillations generated by the heterodyne or by changing the coupling between the heterodyne and the receiving circuits. The strength of the oscillations generated by the heterodyne may be controlled to some degree by control handles, usually rheostats, placed on the heterodyne for this purpose. Changing the coupling between the heterodyne and the receiving circuits may be done by means of a coupling control handle for this purpose, as in the set box type BC–104. If no such control is provided the coupling may be changed by varying the relative position of the heterodyne and the receiving circuits. Increasing the distance increases the coupling. The coupling may be also changed by changing the angle

between the coil of the heterodyne and the coil of the receiving set to which it is coupled. When the two coils are parallel the coupling is greatest; when at right angles the coupling is least.

The other important factor in the operation of the heterodyne is the frequency of the oscillations. The difference between the frequency of the received oscillations and those generated by the heterodyne determines the pitch of the note heard in the receiver and must be equal to an audio frequency. As the frequency of the received oscillations is determined at the transmitting station, these can not be changed at the receiving station. The frequency of the heterodyne, however, is under control and is varied so as to produce the desired audio frequency. The heterodyne frequency is varied by changing either the capacity or inductance in the circuit or by changing both of these. A heterodyne has control handles for this purpose. The setting of these handles is very sensitive. Thus, if the control handles were moved from a setting that gives oscillations whose wave lengths is 600 meters to a setting that gives oscillations whose wave length is 605 meters, the difference in frequency of the two wave lengths would be 4,300. This change in frequency is enough to make the note pass from audibility to inaudibility. So delicate is the apparatus, especially for short wave lengths, that in many heterodynes the approach of the operator's hand to the control handle gives capacity enough to change the note heard in the receivers. The set box type BC–104 is shielded so as to avoid as far as possible any such outside influences. In turning the control handles of a heterodyne a click is sometimes heard in the telephones of the receiving set. This click occurs at the point where the heterodyne oscillations and the received oscillations have the same frequency. It is just to either side of this point that the signals can be heard.

5. Operation of amplifiers.—By means of the rheostats on the set boxes the degree of amplification can be controlled. Use the minimum amount of current that will give readable signals. Interference from other stations may sometimes be eliminated by adjusting the rheostats. Interchanging the vacuum tubes, even in an amplifier, may give better results. If a tube does not light up, clean its contact points and try it again. It may be that the tube is burned out. If so, it must be replaced by a new tube. If the filaments of vacuum tubes are connected in series, the burning out of one tube will prevent the others from lighting. The defective tube can be found by trial and be replaced. A good test for a low-frequency amplifier is to gently tap the first tube. If the amplifier is working properly, a ringing sound will be heard in the telephone receivers.

6. Failure of amplifiers to operate.—Amplifiers may fail to operate even when the filament tubes are lighted. The trouble usually lies

in the high-volt battery. This should be examined for loose or broken connections, and should be tested as to voltage, which should not fall below 38 volts. A frequent cause of a high-volt battery running down is the storage of these batteries in such a way that their terminals are short-circuited. Short-circuiting a high-volt dry battery for only a few moments will make it worthless. High-volt batteries connected with wrong polarity will prevent the amplifiers from operating and hence should be checked up. If no trouble is found with the batteries, the other connections you have made should be checked up. If no faults are found, the trouble may be in a loose or broken connection within the set box.

7. "Howling" of amplifier.—Sometimes an amplifier "howls" or "sings." This drowns out the signals. There are numerous causes for this howling. A loose, broken, or dirty connection of the high-potential battery will cause it, as will also leakage or local action in that battery. The remedy lies in correcting the fault in the connections or battery. Another source of howling lies in a defective vacuum tube which, to the eye, is apparently in good condition. Such a tube must be replaced. It can be found by trial. Allowing the leads from the filament battery, the high-volt battery or to the telephones to touch each other is liable to cause howling, especially if these leads are free to move or swing against each other. The most frequent cause of howling, however, is too great a filament current. This can be controlled by the rheostat, usually placed on the amplifier. If there is none on the amplifier, an outside one can be connected in series with the filament battery. If the fault is not located among the above, grounding the negative terminal of the filament battery will often prevent howling. Insulating the amplifier from the ground has been found helpful in some cases. Sometimes reversing the input connections will eliminate the howling. It must be remembered that very often the foreign noises heard in the receivers of an amplifier are not caused by the amplifier but are due to other causes such as atmospherics, nearby electrical circuits or machinery, etc.

SECTION III.

AMPLIFIER SET BOX, TYPE BC–17 (Used in SCR–72 and SCR–147 sets).

8. Purpose of amplifier.—This set box is an audio frequency amplifier using VT–1 tubes, giving two stages of amplification. There is no detector and therefore the receiving set with which it is used must be provided with one, or a separate one must be used. The

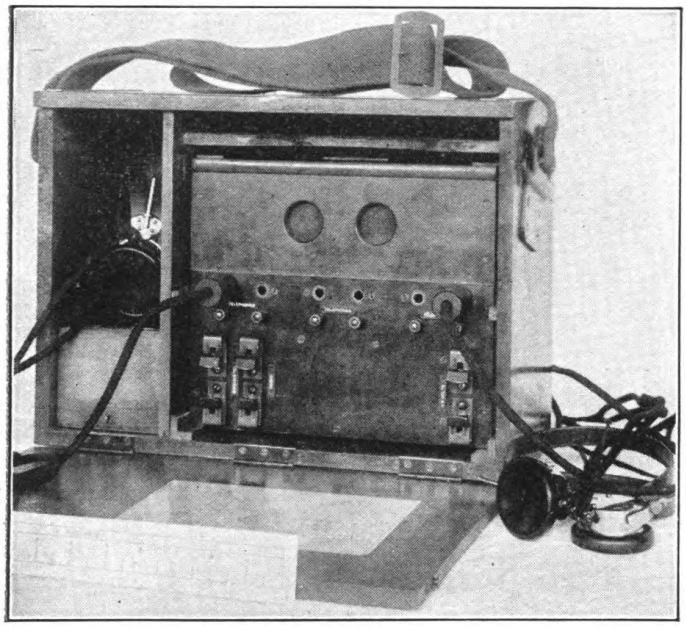


FIG. 1.—AMPLIFIER SET BOX, TYPE BC–17, IN ITS CARRYING CASE.

amplifier may be used for radio signals after detection, or for ground telegraphy signals. The latter use, however, is now obsolete. It was designed mainly for that use, and together with batteries and accessory equipment, was called set T. P. S. receiving, type SCR–72.

9. The amplifier set box.—The amplifier apparatus proper, together with the high-potential batteries, is contained in one box. This box measures 10½ by 6 by 10¼ inches high and weighs 13 pounds. It is carried in a carrying case having compartments for accessories and spares. A view of the amplifier in its carrying case is shown in figure 1. The front of the amplifier contains windows through which the two vacuum tubes can be seen. There is also a panel which bears telephone jacks and binding posts or Fahnestock clips. There are six telephone jacks arranged in pairs, which are in parallel. The pair to the left is used when it is not desired to use any amplification. The next pair is used for one stage of amplification, and the third pair for both stages. Beneath each pair of telephone jacks are two terminals to which a telephone head set may be connected if it is not provided with a plug to fit the jacks. On the lower left of the panel are two pairs of terminals or Fahnestock clips, suitably marked, to which the input to the amplifier is connected. The left pair is for ground telegraphy; the other pair for radio. On the lower right side of the panel are the terminals or Fahnestock clips to which to connect the 4-volt storage battery used for lighting the filament of the tubes.

10. The interior of the set box.—Access to the interior of the amplifier box is obtained by raising the cover of the box. On either side are compartments with Fahnestock clip terminals for carrying the high-potential batteries. Between these compartments is a space for the vacuum tubes, whose sockets are mounted on a shelf cushioned from mechanical vibration by being supported on a sponge rubber. Beneath this shelf are the intertube transformers, which are of the heavy iron-clad type, and other pieces of small apparatus.

11. Installing the BC–17.—(*a*) Connect the 4-volt storage battery leads to the terminals "+4 volt—" being sure to observe the proper polarity. If using the cord and battery provided with the set, do not plug into the battery until it is desired to receive signals. If using separate wires do not attach to battery until it is desired to receive signals.

(*b*) Open cover of the box and place a BA–2 battery in each compartment, face up and negative wire (black) to the rear. Connect the terminals to the clips provided, observing the proper polarity as marked on the edge of the compartment. (The rear terminal clips on each compartment are negative.)

(*c*) Place two VT–1 tubes in their sockets,

(*d*) Connect the output of the radio receiving set to the terminals marked "Radio." The polarity of the connection makes no difference in the working of the amplifier. (The output of a radio receiving set having a detector is where one would connect the telephone if no amplifier were being used.)

(*e*) Plug in the phones—preferably in one of the right-hand pairs of jacks. Finish the connection to the storage battery and the set is ready for operation.

12. Operating the BC–17.—There are no controls on the amplifier. sometimes better amplification can be obtained by interchanging the two tubes. If the amplifier "sings" or "howls" it can usually be stopped by grounding the negative terminal of the filament battery. When the amplifier is not in use, the filament battery should be disconnected from the set. Disconnect at the battery rather than at the set box.

SECTION IV.

AMPLIFIER SET BOXES TYPE BC–44 (used in SCR–72–B and SCR–148 sets) and TYPE BC–44–A (used in SCR–121 and SCR–121–B sets).

13. Purpose of amplifiers.—The amplifiers, type BC–44 and BC–44–A, are two stage audio frequency amplifiers, using VT–1 tubes. The BC–44 was designed to receive ground telegraphy signals as well as radio signals and has an extra terminal for this purpose. This is the only essential difference between the two set boxes. There is no detector in the amplifiers and hence an outside detector must be used in receiving radio signals before they can be amplified by these sets.

14. The amplifier set boxes.—All parts of the amplifier, except the 4-volt storage batteries, are carried in one box, which is divided into two compartments. The compartment to the left is to be used for storing the telephones and other accessories when they are not in use. The other compartment is closed by a bakelite panel. A cover, which can be clamped on a rubber gasket, protects the front of the set box. The set box, with its cover on, measures 16 by 8½ by 10 inches high, and with its spare parts and accessories weighs approximately 24 pounds. It is provided with a web carrying strap. Figure 2 shows a view of the BC–44 set box with its cover removed. The front panel of the set box bears terminals, marked "+B Batt—" for an external 40 volt battery, terminals marked "+4 volt—" for the filament storage

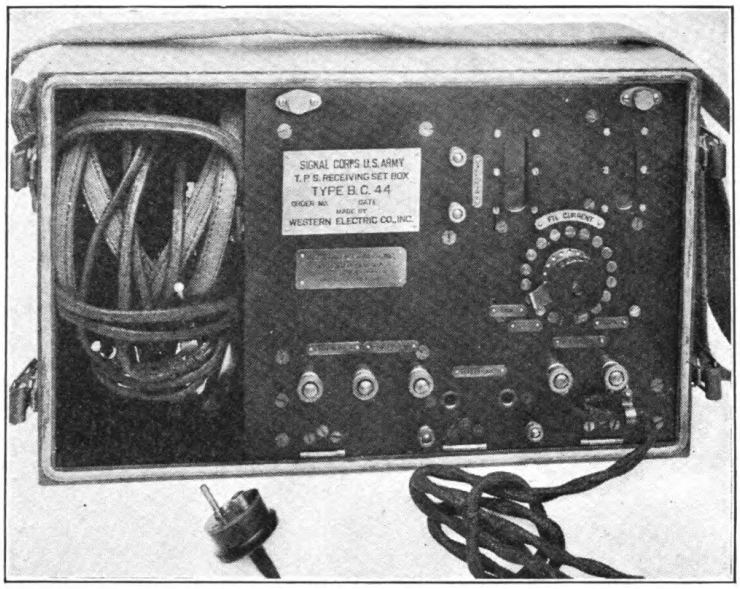


FIG. 2.—AMPLIFIER SET BOX, TYPE BC–44, FRONT VIEW.

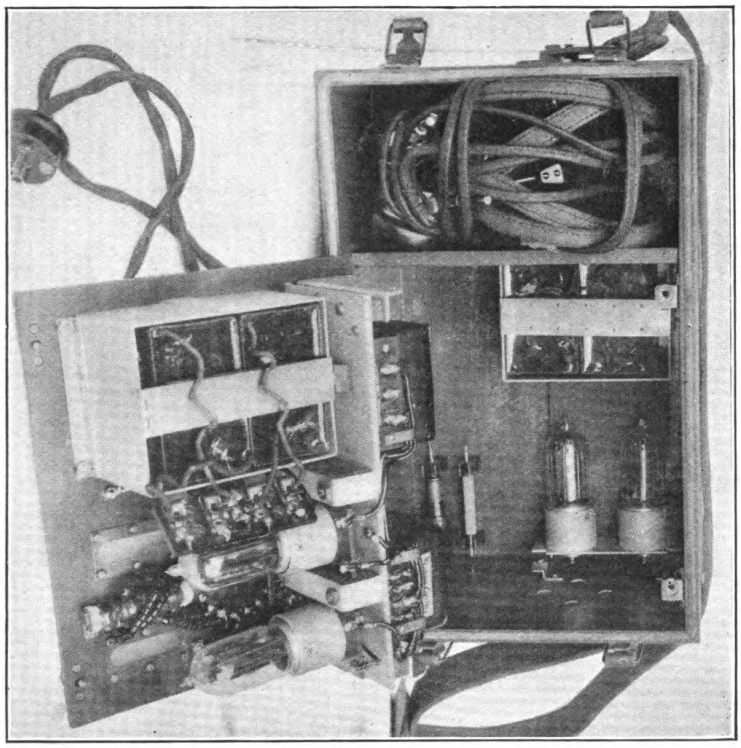


FIG. 3.—AMPLIFIER SET BOX, TYPE BC–44, INTERIOR VIEW.

battery, and terminals underneath two jacks marked "Phones" to which telephones may be connected if they are not provided with plugs to fit the jacks. There are also input terminals mounted on the panel. In the BC–44 these are three terminals, marked "Amplifier" and "Ground telegraphy." In the BC–44–A there is only one pair of terminals, marked "Amplifier." The panel also bears a clip under which the 4-volt battery leads may be fastened. A filament rheostat handle, marked "Fil current," is the only control on the amplifier.

15. The interior of the set boxes.—Access to the interior of the compartment carrying the radio equipment comprising the amplifier is gained by unscrewing a knurled knob in each upper corner and pulling forward the panel, which is hinged at its lower edge. The radio equipment in use, including a case for holding the high-volt batteries, is all mounted on the rear of the panel. A view of the interior of the BC–44 set box, with the vacuum tubes and high-volt batteries installed, is shown in figure 3. The transformers, which are of the iron-clad type, are mounted underneath the shelf carrying the vacuum tubes. The vacuum tubes are cushioned from jars by being mounted in sponge rubber. The small cylindrical objects with beaded insulated leads are resistances of the filament rheostat. Behind the apparatus mounted on the panel is a space containing suitable holders for the carrying of spare dry batteries, vacuum tubes, and resistances.

16. Installing the BC–44 or the BC–44–A.—(*a*) Turn "Fil current" rheostat to the "Off" position.

(*b*) Connect a 4-volt storage battery to the terminals marked "+ 4 volts —," being sure to observe proper polarity.

(*c*) Unscrew the knurled screw in each upper corner and pull the panel forward. Place in the holder mounted on the rear of the panel two BA–2 batteries with their faces up. Fasten the terminals of each battery to the Fahnestock clips, being sure to observe proper polarity. It is to be noted that the inner two clips are both positive and the outer two both negative. The rear pair of clips is to be used for the rear battery, the front pair for the front battery. Make all connections tight and clean.

(*d*) If the BA–2 batteries are not available, an external 40-volt battery should be connected to the terminals in the front of the panel marked "+ B Batt —." Observe the proper polarity as marked on the panel.

(*e*) Place a VT–1 tube in each of the two sockets, close and fasten the panel.

(*f*) Connect the two terminals of the output of the detector to the two binding posts marked "Amplifier." (The output terminals of the detector are where the telephones would be connected if no amplifier were used.)

(*g*) Plug in the telephones in the jack marked "Phones" or connect each lead of the telephone to one of the terminals immediately below the jack and the set is ready for operation.

17. Operating the BC–44 or the BC–44–A.—Turn the "Fil current" rheostat clockwise until the tubes burn a cherry red. There are no other controls on the amplifier. The receiving apparatus must be tuned and the detector adjusted in the usual manner. The amount of amplification can be controlled somewhat by the filament rheostat. Turning the handle of this rheostat to the right increases the amplification. It must be remembered that this increases the brilliancy of the tubes and shortens their life. If the amplifier howls the filament current should be reduced. If this does not eliminate the trouble, try grounding the negative terminal of the filament battery.

Section V.

AMPLIFIER SET BOX, TYPE BC–8–A (used in SCR–144 set).

18. Purpose of amplifier.—This set box is designed to amplify and detect damped wave signals. By the use of a separate heterodyne undamped waves may also be received and amplified. There are three stages of radio frequency amplification, followed by a detector tube and two stages of audio frequency amplification. Six VT–1 tubes are used. The amplification is greatest for waves whose length is 1,000 meters, but satisfactory amplification is obtained over wave length ranges of from 750 to 1,500 meters.

19. The amplifier set box.—The amplifying apparatus, except the batteries and certain accessories, is mounted in a box which measures 15½ by 6 by 8¼ inches high and weighs 10 pounds. The front of the box, shown in figure 4, is a bakelite panel on which are mounted the terminals and control handles. Along the lower edge of the panel are two pairs of terminals, the left-hand pair, properly marked, being for the 4-volt filament storage battery; the other pair, also properly marked, being for the 40-volt plate battery. The two terminals along the right edge of the panel are the input terminals, the upper one being marked "Grid" and the lower one "Fil." There is a telephone jack, marked "6 tubes," to plug in the telephone when it is desired to use the full amplification furnished by the set. Immediately below this is a telephone jack marked "5 tubes" for use when it is not desired to employ the second audio frequency amplify-

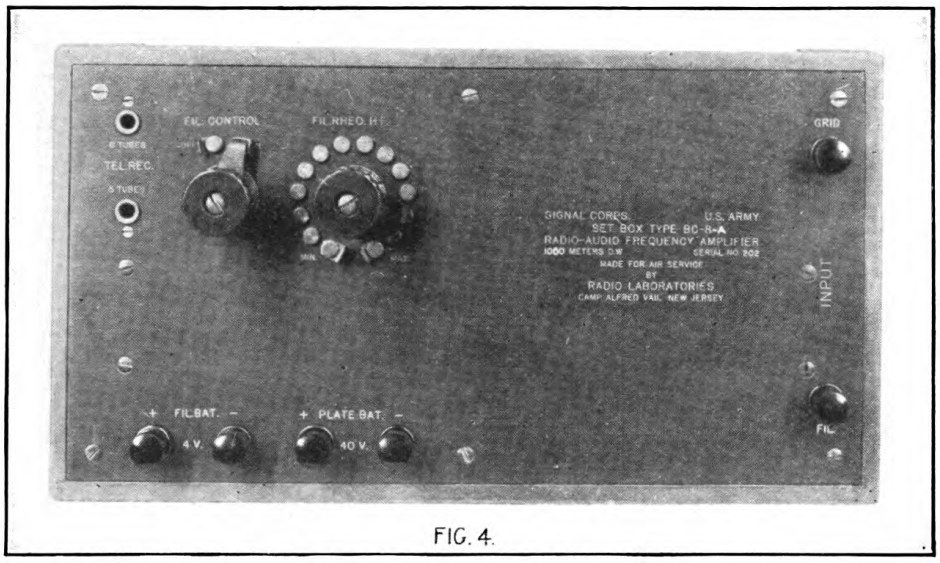


FIG. 4.

AMPLIFIER SET BOX, TYPE BC–8-A, FRONT VIEW.

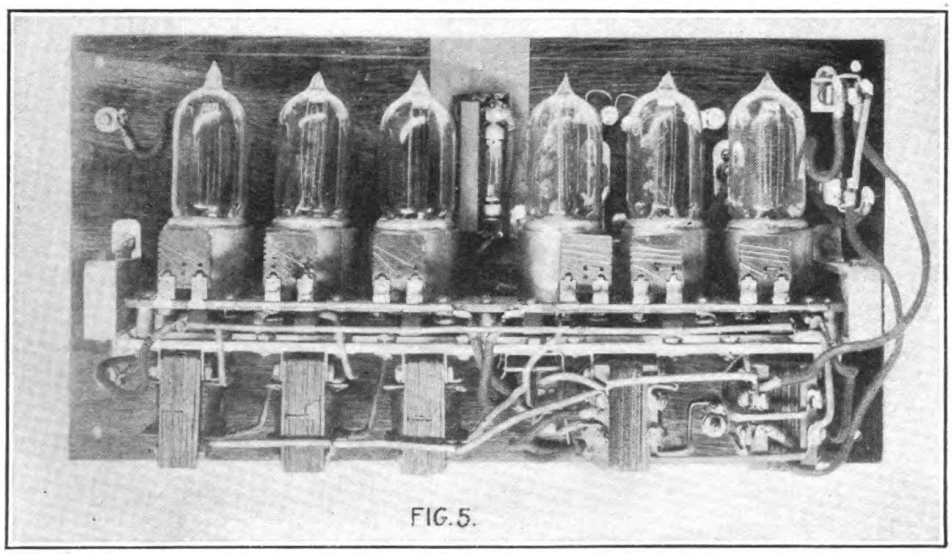


FIG. 5.

AMPLIFIER SET BOX, TYPE BC–8-A, INTERIOR VIEW.

ing tube. The panel bears two control handles; the one to the left marked "Fil control" turns on and off the filament battery. The other control varies the current passing through the filaments of the high frequency amplifying tubes. It is marked "Fil. Rheo H. F."

20. The interior of the set box.—Access to the interior of the set box is gained by raising the cover, which is hinged at the rear. A shelf, supported in sponge rubber pads, carries sockets for the six vacuum tubes. Viewing the box from the front, the three tubes to the right are used for radio frequency amplification; the fourth tube is used as a detector, and the remaining tubes for audio frequency amplification. A view of the interior of the set box is shown in figure 5. The radio frequency and the audio frequency transformers are mounted below the shelf. The filament resistance for each tube appears in front of the tube sockets. The narrow tube between the third and fourth vacuum tube is the grid leak resistance. It is to be noted that the whole apparatus is carried on the front panel.

21. Installing the BC–8–A.—(*a*) Place "Fil. control" switch to the "Off" position.

(*b*) Connect a 4-volt storage battery to the binding posts marked "+Fil Bat—, 4 V." Observe the correct polarity as marked.

(*c*) Connect two 20-volt batteries (BA–2 or BA–8) in series to the binding posts marked "+Plate Bat—, 40 V." It is very important that all connections be clean and tight and that the proper polarity is observed.

(*d*) Place six VT–1 tubes in their sockets, which are made accessible by opening the lid of the box. It may be found later that interchanging the tubes will give better results. Certain tubes are better amplifiers or detectors than others. This can be determined by trial.

(*e*) Connect the two terminals of the output of the receiving set to the two terminals on the right of the set box marked "Grid" and "Fil." If the radio receiving set has one side grounded, this side should be connected to the "Fil" binding post. If it is not known whether or not the receiving set has one side grounded, the proper connection can be found by trial. Use that connection which gives the best results. It is to be noted that this set box can be used only when the radio receiving set has no detector.

(*f*) Insert the telephone plug into whichever jack it is desired to use and the set is ready for operation.

22. Operating the BC–8–A.—Turn the "Fil Rheo H.F." control handle to the "Min" position. Turn the "Fil control" handle to the "On" position. Now turn the "Fil Rheo H. F." handle clockwise until the filaments of the three tubes to the right become a cherry red in color. The radio receiving set should be tuned in the

regular manner. Control of the amount of amplification is secured by the operation of the "Fil Rheo H. F." handle. In general this should be as close to the "Min" position as is possible, while maintaining signals of suitable strength. If there is a tendency for the amplifier to howl, the filament current must be reduced. Howling is more frequent when using the six tubes than when using only the five tubes.

SECTION VI.

AMPLIFIER SET BOX, TYPE BC–101 (used in SCR–149 set).

23. Purpose of amplifier.—The amplifier, type BC–101, is a vacuum tube amplifier, using either three VT–1 or three VT–5 tubes. There are two stages of audio frequency amplification in addition to a detector tube. A switch is provided to use the detector tube together with the amplifier tubes or to use the amplifier tubes alone. Thus the amplifier can be used with a receiving set that contains a detector or with one that does not contain a detector. As only audio frequencies are amplified, this apparatus, like all other audio frequency amplifiers, is independent of the wave length of the radio signals.

24. The amplifier set box.—The whole apparatus, except the storage batteries and certain accessories, is mounted in a box constructed of an aluminum frame which supports bakelite panels. The box is $8\frac{1}{2}$ inches by $6\frac{3}{4}$ inches by 10 inches high and weighs $10\frac{1}{2}$ pounds. The terminals and controls are all mounted so as to be nearly flush with the projecting sides of the box. The binding posts are all mounted on these extended sides; the two to the left marked "Grid" and "Fil" being the input terminals. At the bottom to the left are the terminals for the filament battery marked "Fil Bat 4 V or 2 V,— and +"; to the right of these are terminals for the 40-volt plate battery marked "Plate Bat, — and +." On the left are two terminals connected together by a copper strip which is removable. These terminals are for the insertion of a reactance coil when one is desired and are marked "Tickler." The front panel carries a double throw switch, one position of which, marked "Detector," throws the detector tube and the two amplifier tubes in circuit; the other position, marked "Amplifier," throws only the two amplifier tubes in circuit. To the right of this switch is a rheostat marked "Fil con-

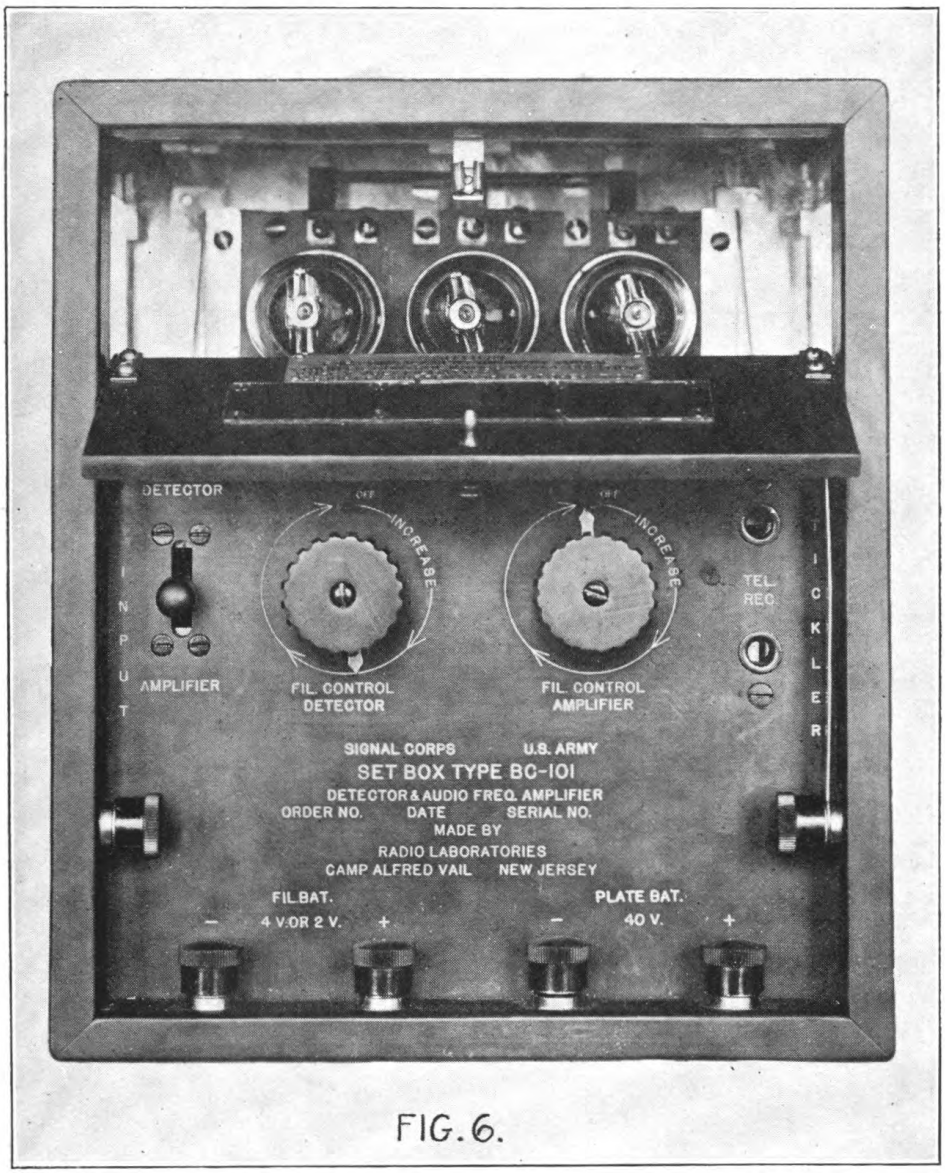


FIG. 6.

AMPLIFIER SET BOX, TYPE BC–101, FRONT VIEW.

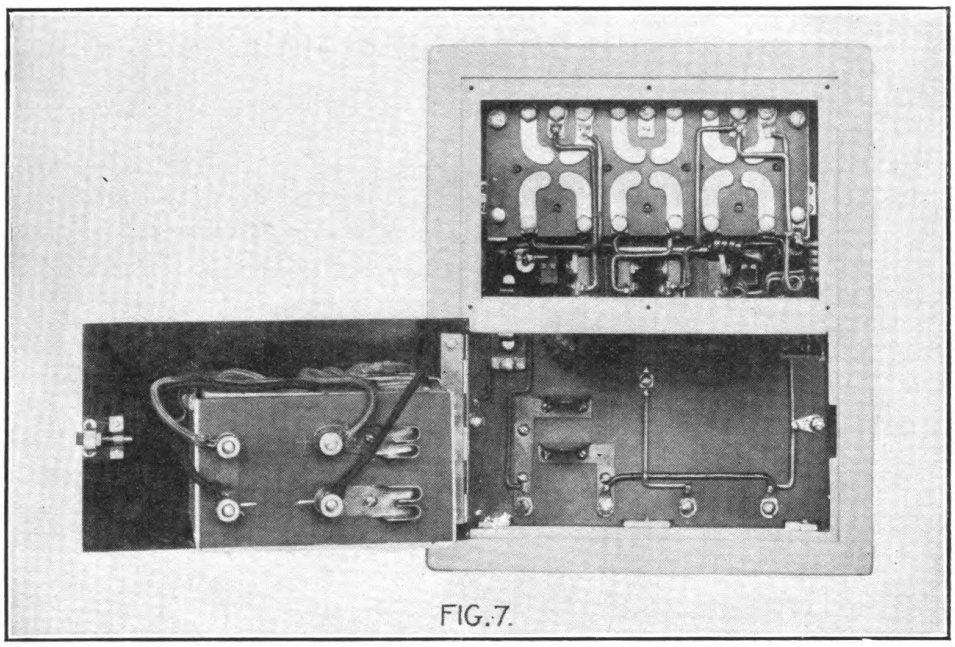


FIG. 7.

AMPLIFIER SET BOX, TYPE BC–101, INTERIOR VIEW.

trol detector" for controlling the filament current of the detector tube. To the right of this is another rheostat marked "Fil control amplifier" for controlling the filament current of the two amplifier tubes. There are also two telephone jacks, in parallel, so that two pairs of telephone receivers can be plugged in. The upper part of the front panel is a door, having three small windows. The door permits access to the interior of the set for putting in the vacuum tubes. Figure 6 shows a view of the set box with this door open.

25. The interior of the set box.—The aluminum frame of the box carries brackets which support a shelf mounted between sponge rubber pads to absorb mechanical vibration. This shelf carries the vacuum-tube sockets and attached to the underside of it are the transformers and various small pieces of apparatus. The lower half of the back of the set box is a door which has mounted on it a frame having terminals for the two BA–2 batteries used in the set. Connections of these batteries are completed inside the box by spring clips which engage when the door is closed. A view of the set box from the rear, with the upper panel removed and with the door open is shown in figure 7. It is to be noted that the BA–2 batteries are in place in their holders. The back of the vacuum-tube sockets are seen in the upper part of the view. The two audio frequency transformers can also be distinguished. Mounted on the inside of the right panel as viewed from the rear are supports which carry adapters (type FT–65) when these are not in use. Those adapters are to fit in the vacuum-tube sockets when VT–5 tubes are used. They can not be seen in the illustration.

26. Installing the BC–101—using VT–5 tubes.—(*a*) Turn "Fil control detector" counterclockwise to the "Off" position. Do same to the "Fil control amplifier."

(*b*) Connect a 2-volt storage battery or a closed circuit (ignition type) dry cell to binding post marked "Fil Bat, 4 V or 2 V." Be sure to observe correct polarity as marked on the set box.

(*c*) Open rear door and place in the holder mounted thereon two type BA–2 dry batteries. Place these batteries face up with their positive terminals (red wires) next to the door. Fasten the batteries in the holder by means of the copper strip spring provided, spreading the wires apart so that there are no wires between the spring and the face of the batteries. Obeying the following rule: "*Do not connect the terminals from the same BA–2 battery to the two terminals on the holder which are connected by a copper strip*," connect the four terminals of the two batteries to the four terminals provided on the holder, observing the proper polarity. Be sure to have all connections clean and tight. Press all the wires down so that they lie close to the batteries. After removing the adapters from their holders inside the box, close the door.

(*d*) If BA–2 batteries are not available a 40-volt battery must be connected to the terminals on the front of the box marked "Plate Bat 40 V." Be sure to observe correct polarity as marked in the set box.

(*e*) Open the door on the front panel and place an adapter in each vacuum-tube socket. Place VT–5 tubes in the adapters and close the door. It may be found later that interchanging the tubes will give better results. Certain tubes are better amplifiers or detectors than others. This can be determined by trial.

(*f*) Connect the two terminals of the output of the radio receiving set to the two terminals marked "Input, grid and fil" on the left of the amplifier. If the radio receiving set has one side grounded, this grounded side should be connected to the "Fil" terminal. If it is uncertain whether or not the radio receiving set is grounded, the proper connection can be found by trial. The connection which gives the best resulting signal should be used.

(*g*) Throw the double switch down to the "Amplifier" position if the receiving set has a detector that is being used; otherwise throw the double-throw switch up to the "Detector" position. Plug in the phones and the amplifier is now ready for operation.

27. Installing the BC–101— using VT–1 tubes.—(*a*) Follow directions given in subparagraph (*a*) of paragraph 26.

(*b*) Connect a 4-volt storage battery to the binding posts marked "Fil Bat, 4 V or 2 V." Be sure to observe correct polarity as marked in the set box.

(*c*) Follow directions of paragraph 26 (*c*) to 26 (*g*), inclusive, except that the adapters are not to be used.

28. Installing the BC–101— using a reactance coil.—(*a*) Follow directions either of paragraph 26 or 27, according to the type of vacuum tube to be used. The tickler terminals should be connected to the "tickler" or "feed back" or "reactance coil" in the receiving set, if there be any, when it is desired to receive undamped wave signals. It may be found necessary to reverse the connections to the amplifier tickler terminals to get the proper coupling. This can be determined by trial. When using a tickler the short-circuit strip between the two terminals on the amplifier should be disconnected at the upper terminals.

(*b*) If the receiving set has no tickler coil and there is no other method of receiving undamped waves, a method using this amplifier can be devised. The necessary conditions are that an inductance of the proper value connected to the tickler terminals be inductively coupled to the secondary receiving inductance of the receiving set. The amount of inductance to be used will vary with the type of receiving set, and also to some degree with the wave length of the incoming signals. The inductance to be used and its position may be

found by trial. Start by winding No. 24 silk-covered magnet wire in a single layer on a cylinder about 4 inches in diameter, leaving fairly long leads. The turns should be close together and there should be enough turns to make the coil about 1 inch wide. Attach the leads to the tickler terminals and place the coil near to and parallel with the secondary receiving inductance. If no results are obtained, turn over the coil you have made. If success is still lacking, try the coils in various positions with respect to the secondary receiving inductance, inverting the coil in each position. If still unsuccessful, change the number of turns on the coil and try again.

29. Operating the BC–101.—(*a*). Turn the "Fil control amplifier" switch clockwise until the two tubes to the right show a cherry red. If the detector tube is being used, do the same with the "Fil control detector." However, if the amplifying tubes only are used the detector tube is out of circuit and will not light up.

(*b*) Tune the receiving set in the usual method.

(*c*) Adjust the detector and amplifier tubes by means of their filament controls to give the most readable signals. It must be remembered, however, that burning the tubes too brightly greatly shortens their lives.

(*d*) If the amplifier howls or sings, try decreasing the brightness of the tubes, especially the amplifier tubes.

(*e*) When the amplifier is not in use, turn both filament-control switches counterclockwise to the "Off" position.

Caution.—If the BC–101 is used with other tube sets it should be furnished with a separate filament battery, otherwise the plate battery of the other set may be short-circuited.

SECTION VII.

AMPLIFIER SET BOX TYPE BC–103 (used in SCR–145 set).

30. Purpose of amplifier.—The amplifier, type BC–103, is designed to amplify, or detect and amplify, radio signals whose wave lengths are from 1,000 to 3,000 meters. It will amplify signals of other wave lengths, but the best amplification is produced within the above range. There are provisions made for three stages of radio frequency amplification, followed by detection, and two stages of audio frequency amplification. There are provisions made also for the use of the two audio frequency stages only. The amplification given by the latter is independent of the radio wave length of the signal. Six VT–1 tubes are used in the amplifier.

31. The amplifier set box.—The whole apparatus, except the batteries and certain accessories, is contained in a set box whose dimensions are 15½ by 6 by 8¼ inches high, and whose weight is approximately 10 pounds. The front of the box is shown in figure 8. There are terminals to which to connect the plate and filament batteries, and also two sets of terminals to which to connect the output of a radio receiving set. The terminals to the right marked "Grid" and "Fil" are to be used when the radio receiving set has no detector, or one which is not in use. The terminals at the lower center are to be used when the radio receiving set has a detector that is being used. In addition to these terminals the panel carries a filament control switch for turning off and on the current in the filament; a filament rheostat that controls the amount of current in the high frequency amplifying tubes; a two-way switch that must be thrown to the proper position when the amplifier is used for either of its two purposes; and an amplification switch which controls the amount of amplification produced by the high frequency amplifying tubes. There are two telephone jacks on the left of the panel. The lower one marked "5 tubes," uses only one stage of audio amplification; the upper one marked "6 tubes," uses both stages. All terminals and control switches are appropriately marked.

32. The interior of the set box.—The top of the set box is hinged so as to permit access to the six tube sockets. These sockets are for the VT–1 tubes used in the set and are mounted on a shelf. The three tubes to the right are the radio frequency amplifiers, the fourth tube from the right is the detector; the other tubes are audio frequency amplifiers. Mounted on the lower side of the tube shelf are transformers and other pieces of equipment. The tube shelf is cushioned against jars and vibration by sponge rubber, and is supported by brackets attached to the bakelite panel. Access to the apparatus for repairs can be had by removing the panel, which is held in place by machine screws. Fig. 9 shows how the apparatus is mounted on the back of the panel. In the figure, three radio frequency transformers are seen at the lower left and two audio frequency transformers at the lower right. The narrow tube between these two sets of transformers is the grid leak resistance.

33. Installing the BC–103.—(*a*) Place "Fil control" switch on "Off" position.

(*b*) Connect a 4-volt storage battery to the binding posts marked "4 V." Be sure to observe the correct polarity as marked on the set box panel.

(*c*) Connect two 20-volt batteries (BA–2 or BA–8) in series to the binding posts marked "40 V." Be sure to observe the correct polarity. It is especially important that all connections of these batteries be *clean* and *tight*.

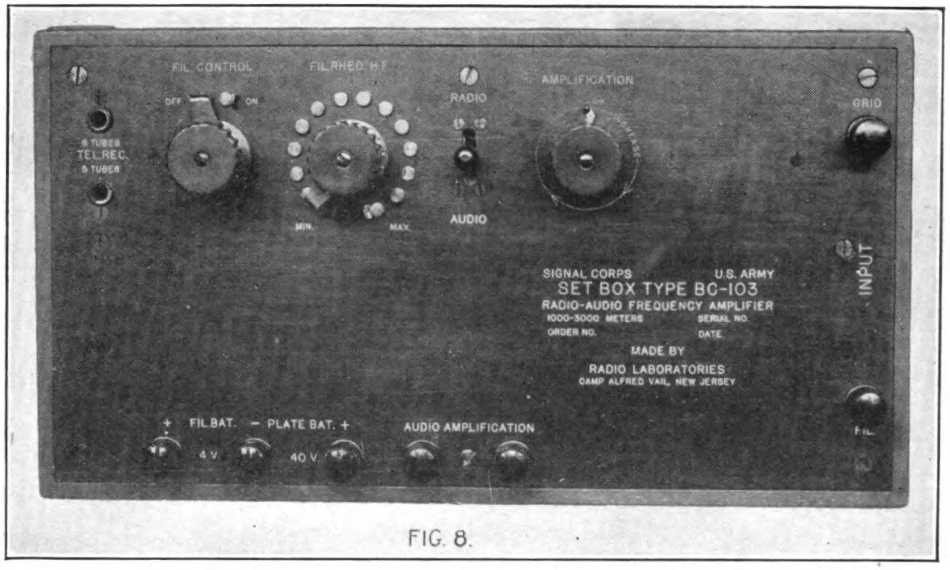


FIG. 8.

AMPLIFIER SET BOX, TYPE BC–103, FRONT VIEW.

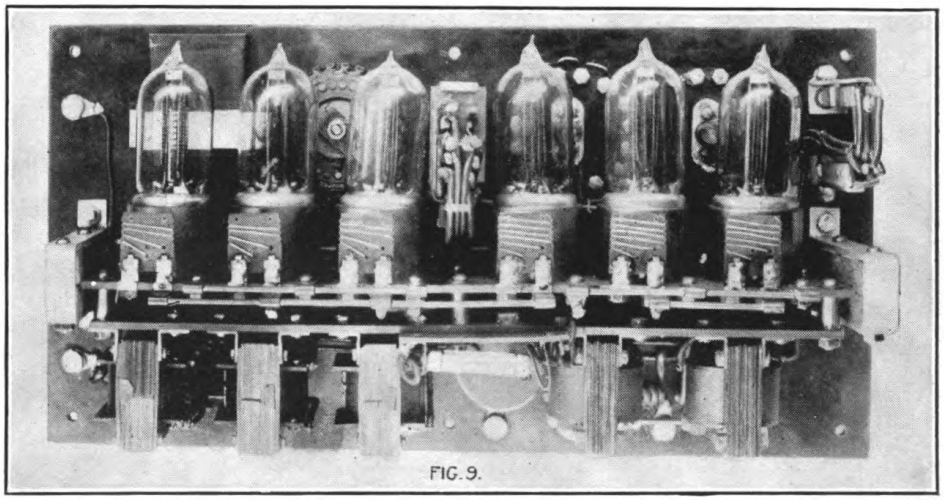


FIG. 9.

AMPLIFIER SET BOX, TYPE BC–103, INTERIOR VIEW.

(*d*) Place six VT-1 tubes in the sockets which are made accessible by opening the lid of the box. It may be found later that interchanging the tubes will give better results. Certain tubes are better amplifiers or detectors than others. This can be determined by trial.

(*e*) *For audio frequency amplification* (*used when the radio receiving set has a detector which is in use*).—Connect the two terminals of the output of the radio receiving set to the two terminals on the lower center of the box marked "Audio amplification." The polarity of the connection makes no difference in the working of the amplifier. (The output terminals of the radio receiving set are at the jack or binding posts to which the telephones would be connected if no amplifier were being used.)

Throw the double throw switch in the upper center of the panel *down* to the position marked "Audio."

(*f*) *For radio frequency amplification* (*used when the radio receiving set has no detector or one that is not in use*).—Connect the two terminals of the output of the radio receiver to the two terminals on the right of the amplifier marked "Input," one being labeled "Fil" and the other "Grid." If the radio receiving set has one side grounded, this grounded side should be connected to the "Fil" terminal. If it is uncertain whether or not the radio receiving set is grounded, the proper connection can be found by trial. The connection which gives the best resulting signals should be used.

Throw the double throw switch in the upper center of the panel *up* to the position marked "Radio."

(*g*) Insert the telephone plug into whichever of the jacks marked "5 tubes" or "6 tubes" it is desired to use. The amplifier is now ready to use.

34. Operating the BC–103.—(*a*) *For audio frequency amplification.*—There is only one control switch, the "Fil control" switch. When it is desired to receive signals this should be turned to the "On" position. The two vacuum tubes should light up. Nothing more need be done to the amplifier.

(*b*) *For high frequency amplification.*—There are three controls for the operation. The "Fil control" switch is thrown to the "On" position which causes all the tubes to light up. The other controls marked "Fil rheo H. F." and "Amplification" are for controlling the amount of amplification of the tubes. In general the "Fil rheo H. F." should be adjusted so that the high frequency amplifying tubes show the same brilliancy as the low frequency tubes. The degree of amplification can still further be controlled by turning the "Amplification" switch—turning in a clockwise direction gives greater amplification. If this switch does not give as great a control of the amplification as desired, the "Fil rheo H. F." may be used. Increasing the brilliancy of the tubes by this switch increases

the degree of amplification; decreasing the brilliancy decreases the amplification. In some cases the amplifier will "sing" or "howl," due to oscillations being set up in it. Such "singing" or "howling" prevents the reading of the signals. If they occur they can usually be stopped by moving the "Fil rheo H. F." switch one or two contacts toward "Min" and decreasing the degree of amplification by means of the "Amplification switch." Sometimes in addition to the above it is necessary to turn the "Fil control" to the "Off" position for an instant before the "howling" or "singing" will disappear. Howling is more frequent when using the six tubes than when using only the five tubes.

SECTION VIII.

HETERODYNE SET BOX TYPE BC–104 (used in SCR–146 set).

35. Purpose of the heterodyne.—The heterodyne, type BC–104, is a VT–1 oscillator designed to set up weak oscillations over a frequency range corresponding to wave lengths of between 800 and 3,400 meters. These weak oscillations are used in the reception of undamped waves of the same range of wave length by the heterodyne method. The heterodyne may be used as a wavemeter. (See Radio Communication Pamphlet No. 28.) It must be remembered that, when used for this purpose, the results may not be so strictly accurate as if obtained by an instrument designed primarily as a wavemeter.

36. The heterodyne set box.—The whole apparatus, except the batteries and certain accessories, is mounted in a box which measures 8 by 9 by 11½ inches high and weighs 12 pounds. The front of this box is shown in figure 10. On the lower edge of the front panel are binding posts for connecting the batteries, the pair to the left being for the 4-volt battery; the pair to the right for the 40-volt battery. In the upper left corner is a binding post for the antenna lead in wire, and in the upper right a binding post for connecting to the receiving set used. There is a "Fil control" switch for turning on and off the filament current; a "Coupling" control handle for varying the coupling between the circuits of the oscillator proper and the circuit which is a part of the antenna lead in wire. A double throw switch to the left controls the amount of inductance in the oscillating circuits, thus enabling the variable air condenser to have

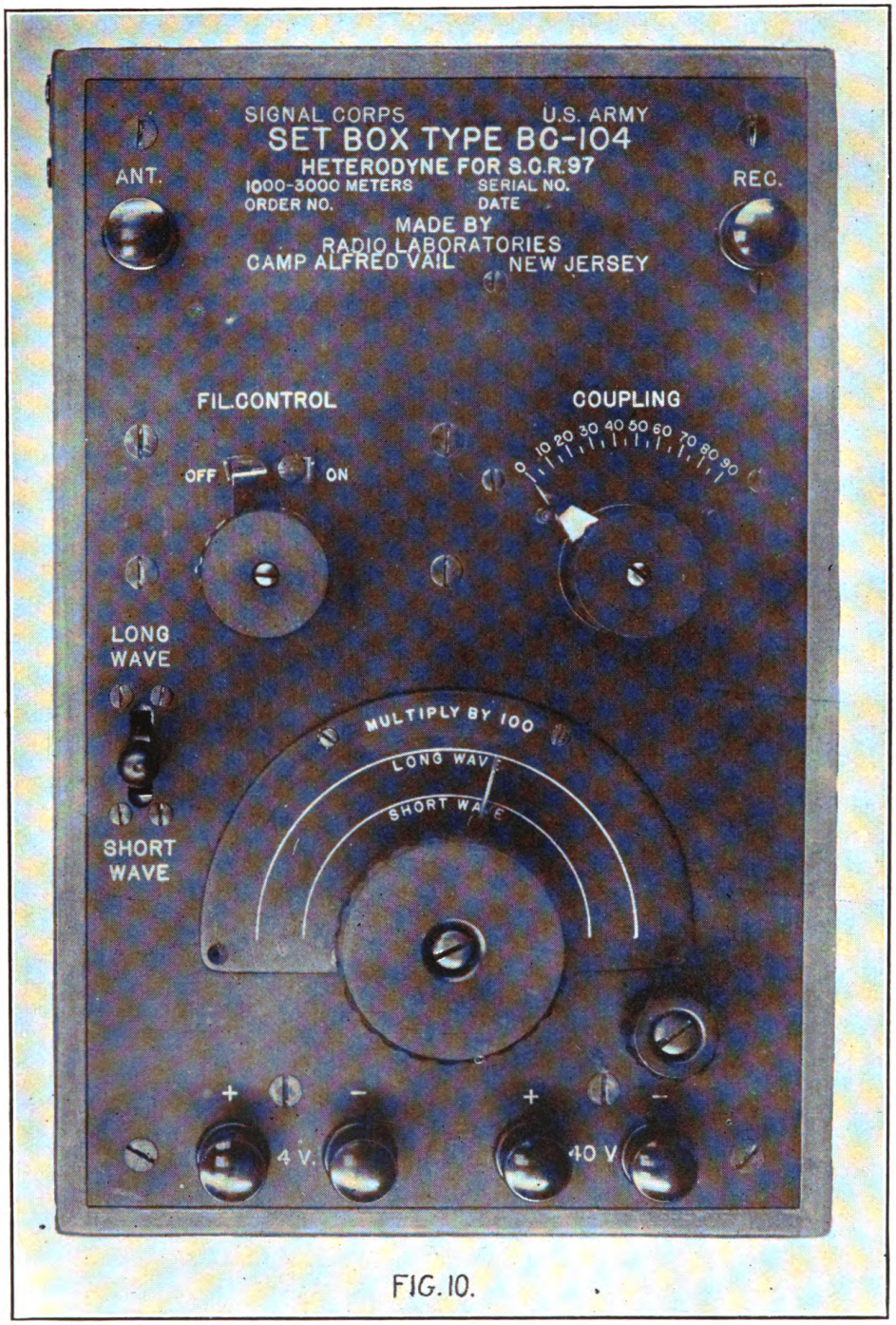


FIG. 10.

HETERODYNE SET BOX, TYPE BC-104, FRONT VIEW.

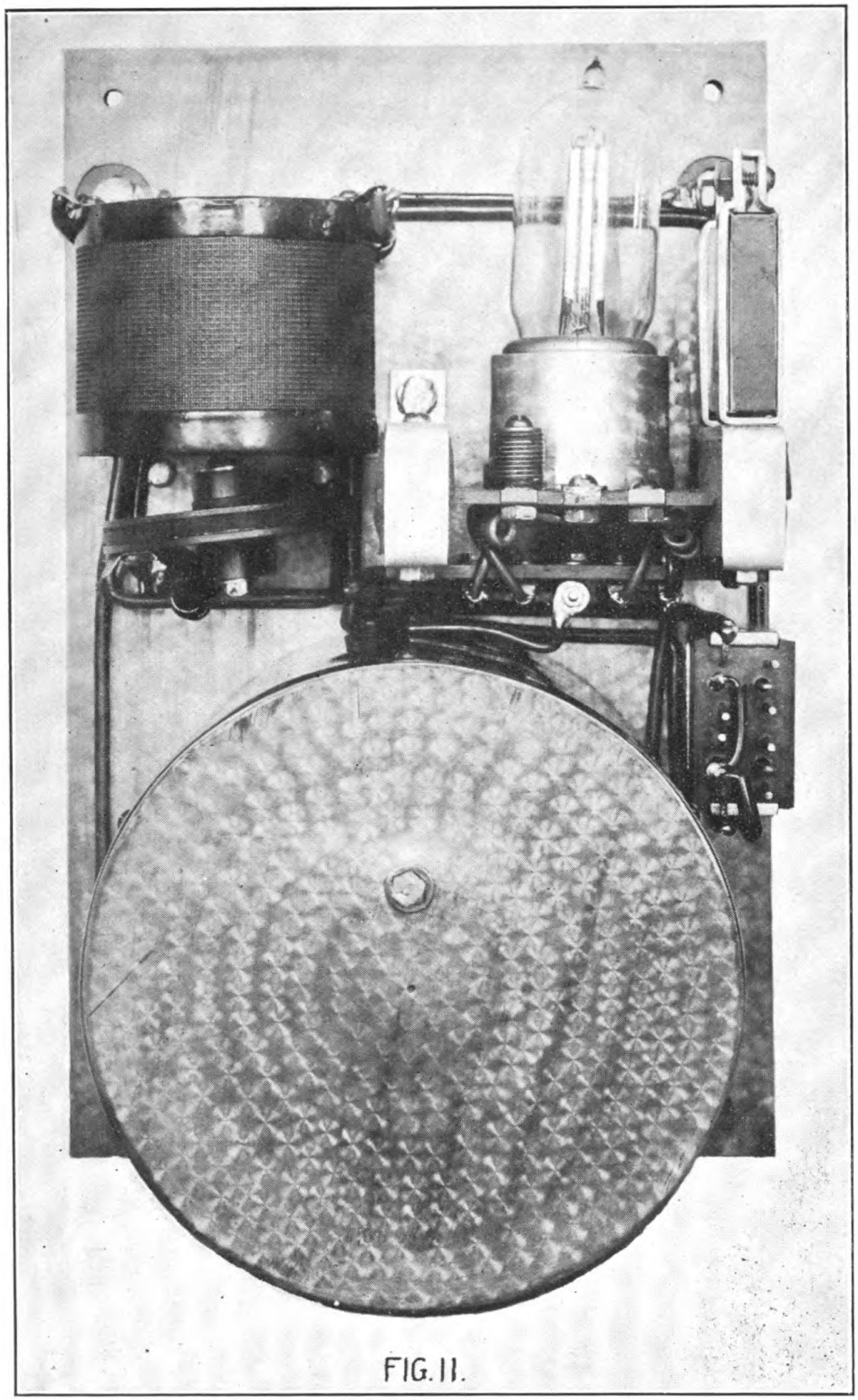


FIG. 11.

HETERODYNE SET BOX, TYPE BC–104, INTERIOR VIEW.

two ranges of wave length. The variable air condenser gives wave lengths of from 800 to 2,000 when the double throw switch is thrown down to the "Short-wave" position, and gives wave lengths of from 1,400 to 3,400 when the double throw switch is thrown up in the "Long-wave" position. The reading on the scale of the variable condenser should be multiplied by 100 to give the wave length. The air condenser is controlled for coarse adjustments by a large knob. For fine adjustments it is controlled by a small knob placed at the lower right of the large knob. When using the coarse-adjustment knob the smaller knob should have its gears disengaged. This is done by pulling the smaller knob slightly outward.

37. The interior of the set box.—The whole apparatus is mounted on the front panel of the box, which is lined throughout with copper to prevent any electrical field set up by the oscillator from being picked up by the antenna or other receiving apparatus. The variable air condenser is thoroughly shielded also so as to reduce to a minimum outside influences affecting the frequency of the oscillations. A view of the interior of the set box is shown in figure 11. On the large coil at the upper left is wound both the plate and the grid inductances, the latter having two taps. The small coil below contains the antenna inductance and rotates around a horizontal axis so as to provide different degrees of coupling with the coil above. The vacuum tube is mounted on a shelf supported by sponge rubber held in brackets on either side. The shelf also carries the filament resistance. The condenser shown at the right of the tube is the high-frequency by-pass condenser shunted across the 40-volt battery terminals. Below this condenser is a switch which is so designed that it has no appreciable electrical capacity. The large variable air condenser appears at the bottom of the illustration.

38. Installing the BC–104.—(*a*) Throw the "Fil control" switch to the "Off" position.

(*b*) Connect a 4-volt storage battery to the terminals marked "4 V," being sure to observe the proper polarity.

(*c*) Connect a 40-volt battery (two type BA–2 or two type BA–8 in series) to the terminals marked "40 volts." Be sure to have all connections tight and clean as well as observing the proper polarity.

(*d*) Raise the lid of the box and put a VT–1 tube in its socket.

(*e*) Connect the antenna lead-in wire to the binding post marked "Ant."

(*f*) Connect the binding post of the heterodyne marked "Rec" to the binding post of the receiving set marked "Ant" or other similar designation.

(*g*) Turn the "Fil control" to the "On" position and the set is ready for operation.

39. Operating the BC–104; receiving set calibrated—wave length known.—(*a*) Tune the receiving set to the wave length to be received.

(*b*) Place the double throw switch of the heterodyne either in the long wave or short wave position, depending upon the wave length to be received.

(*c*) Turn the "Coupling" handle until the pointer shows a coupling of 20 degrees.

(*d*) Pull outward the small fine adjustment knob of the variable condenser.

(*e*) Set the pointer of the variable condenser on the wave length to be received, using the large knob.

(*f*) Press in the fine adjustment knob so that its gears are meshed and turn *slowly* back and forth until the note is heard in the telephones and is of the proper pitch.

(*g*) Readjust the "Coupling" until the note heard in the telephones is of the proper intensity. The fact that the receiving set also needs final adjustment must not be overlooked.

40. Operating the BC-104; receiving set not calibrated—wave length known.—(*a*) Place the double throw switch of the heterodyne either in the long wave or short wave position, depending upon the wave length to be received.

(*b*) Turn the coupling handle until the pointer shows a coupling of 20 degrees.

(*c*) Pull outward the small fine adjustment knob of the variable condenser.

(*d*) Set the pointer of the variable condenser on the wave length to be received, using the large knob.

(*e*) Press in the small fine adjustment knob until the gears mesh.

(*f*) Put the secondary of the receiver on *aperiodic* if it has this arrangement.

(*g*) Adjust the coupling control in the receiver to give the maximum coupling.

(*h*) Vary the tuning of the primary of the receiver (and secondary also if there is no periodic arrangement) and at the same time turn the fine adjustment knob of the heterodyne slowly back and forth. It is not necessary to move the knob more than a third of a turn either side of its first position.

(*i*) After the signal has been picked up make final adjustments.

41. Operating the BC-104; receiving set calibrated—wave length unknown.—(*a*) Place the dcuble-throw switch of the heterodyne in short-wave position.

(*b*) Turn the coupling handle until pointer shows a coupling of 20°.

(*c*) Pull outward the small fine adjustment.

(*d*) Set the pointer of the variable condenser on the shortest marked wave length.

(*e*) Press in the fine-adjustment knob until the gears mesh.

(*f*) Tune the receiving set to the wave length to which the heterodyne has been set, using a close coupling.

(*g*) Turn the fine-adjustment knob of the heterodyne slightly back and forth, not moving it more than a third of a turn from its original position.

(*h*) If the signal is not picked up, turn the variable air condenser of the heterodyne to the next lowest wave length and repeat as above.

42. Operating the BC-104; receiving set not calibrated—wave length unknown.—This is a difficult task and requires much patience. It can be done by placing a variable condenser of the heterodyne on a definite wave length and tuning the primary and secondary of the receiving set. The receiving set should have the closest possible coupling between its primary and secondary. If there is an arrangement for making the secondary aperiodic, this should be done. The broadest kind of tuning should be used until the signal is picked up. The fine-adjustment knob of the heterodyne should be turned slightly back and forth with each setting of the receiver tuning elements. If the signals are not picked up, the heterodyne should be placed on another wave length and the process repeated. In order to receive the signal it is necessary that the frequency of the primary of the receiver, the secondary of the receiver, and the heterodyne be approximately the same. These conditions can be brought about by trial as described above.

SECTION IX.

PRINCIPLES OF AMPLIFIERS.

43. Definition of amplification constant.—A vacuum tube can be used as an amplifier because, under correct conditions, a voltage applied to the grid has a greater effect upon the plate current than the same voltage applied to the plate. This may be expressed more accurately as follows: A change in the grid potential produces μ' times as great a change in the plate current as an equal change in the plate voltage. The quantity, μ', is called the amplification constant of the tube, and is the maximum voltage amplification that can be obtained from the tube. Mathematically μ' can be expressed as $\frac{de_p}{de_g} = -\mu'$ where e_p and e_g are respectively the plate and grid potentials.

44. Value of amplification constant.—The amplification constant depends upon the structure and geometry of the tube. The mesh of the grid, the diameter of the grid wires, the distance between grid and plate, and between grid and filament are the more important factors which determine the value of this constant. The value of μ' may vary under extreme conditions of voltages applied to the tube but for ordinary operating ranges it may be considered as an unchanging value. μ' equals 6.5, very nearly, in the VT–1 tubes used in Signal Corps amplifiers.

45. Operating conditions for amplification.—In order to secure amplification certain conditions must be obtained. The filament must be hot enough to emit enough electrons so that the plate current is not limited by the number of electrons available. The plate voltage must be high enough to establish a strong electric field within the tube. The potential of the grid should at all times be sufficiently negative so that it will not absorb appreciable current and thus distort the grid voltage-plate current characteristic of the tube. The average potential of the grid with respect to the filament is designated by the term "biasing potential." In addition, for distortionless amplification, the voltage applied to the plate should be of such a value as to keep the dynamic characteristic of the tube as near a straight line as is possible with the external circuits used. The high impedance generally used in the plate circuit produces this condition.

46. Limit and control of amplification.—It has been shown (Thermionic Vacuum Tube, Van der Bij 1) that the voltage amplification of a tube as available across an external resistance is in the plate circuit expressed by:

$$\frac{e_p}{e_g} = -\frac{\mu'}{1+\frac{R_p}{R_e}}$$

where R_p and R_e are respectively the internal plate resistance of the tube and the external resistance, and where e_p and e_g are the effective alternating voltages of the plate and grid. An inspection of this equation shows that the ratio $\frac{e_p}{e_g}$ will increase with a *decrease* of the plate resistance and will also increase with an *increase* of the external resistance. If the external resistance becomes infinite, $\frac{R_p}{R_e}$ becomes zero, and the right-hand number of the equation becomes $-\mu'$. This means that the voltage amplification produced by a tube is limited to the amplification constant of the tube. The plate resistance of the tube depends mainly upon the geometry of the tube, but also depends upon the filament emission and average grid potential. The filament emission is changed with a change in temperature of the filament, and hence it is seen that an amplification produced by

a tube can be controlled to some degree by a rheostat placed in its filament circuit.

47. Low frequency amplifiers.—It is standard practice to have the output of one low frequency amplifier tube pass through the primary of a transformer, the secondary of which is connected to the grid and filament of the next tube. In this manner advantage is taken of the step up in voltage produced by the transformer as well as the amplification produced by the first tube. It can be shown that with an ideal transformer in which the coupling is tight and the load circuit is resistive only, the ratio of grid voltage between successive tubes is expressed by the following equation:

$$\frac{e_{g2}}{e_{g1}} = \frac{\mu' n \frac{R_{g2}}{R_{p1}}}{n^2 + \frac{R_{g2}}{R_{p1}}}$$

where e_{g2}=effective alternating voltage on grid of 2nd tube.
e_{g1}=effective alternating voltage on grid of first tube.
μ'=amplifying constant of 1st tube.
n=ratio of secondary to primary voltage in transformer.
R_{g2}=alternating current grid-filament resistance of 2nd tube.
R_{p1}=alternating current plate-filament resistance of 1st tube.

An inspection of this equation shows that if $\frac{R_{g2}}{R_{p1}}$ becomes infinite, the ratio of grid voltage becomes equal to $\mu' n$ which is the maximum possible value. The plate resistance of the tube is inherent in the design of the tube and can not be made equal to zero, but the grid resistance of the second tube can be made very large by placing the right biasing potential on it, although it can not be made infinite because of the residual gas in the tube and surface leakage in connections. If the finite ratio $\frac{R_{g2}}{R_{p1}}$ and the amplification constant, μ', are kept constant, it may be shown by plotting that $\frac{e_{g2}}{e_{g1}}$ is a maximum when $n^2 = \frac{R_{g2}}{R_{p1}}$. Substituting this ideal value of n in the basic equation, it is found that the maximum amplification, i. e. $\frac{e_{g2}}{e_{g1}}$ becomes equal to $\frac{1}{2}\mu' u$.

The above discussion is based upon an ideal transformer and takes no account of the no-load reactance, the leakage induction, and the core losses met with in a real transformer.

The effect of these is to reduce the value of the voltage ratio attainable. Considering only the no-load reactance of the transformer (the other quantities can be made small) it can be shown that the best ratio of transformation, n, is 4 or 5 to 1, that the ratio of grid voltages increases with an increase of the grid-filament resistance of

the second tube, that the ratio of grid voltages is not the same for all frequencies, and that the latter depends mainly upon the no-load reactance of the transformer primary. The effect of frequency upon the amplifying power of the tube is shown in figure 12, taken from "Principles of Radio Communication" (Morecroft) and upon which this presentation is based. The curves of the figure show the theoretical relation between the ratio of the potentials of two successive grids and the frequency. The plate-filament alternating current resistance is equal to 10,000 ohms; μ' equals 6, and n equals 4. In curves A, B, and C the grid-filament alternating current resistance

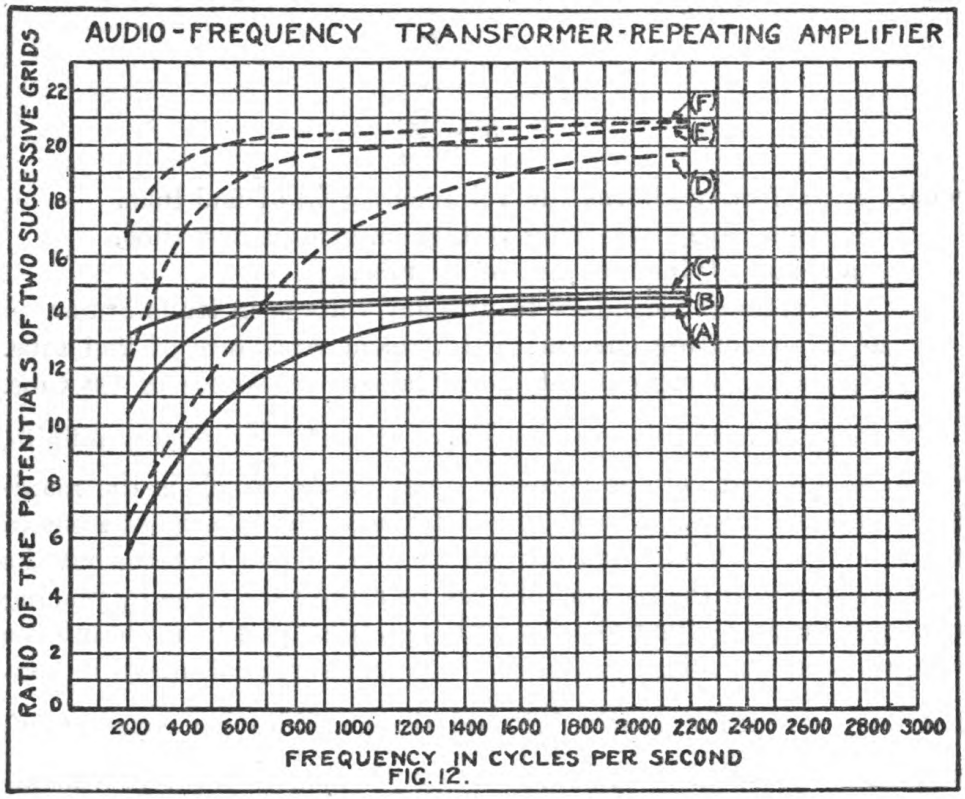


FIG. 12.

is equal to 250,000 ohms; the no-load inductance of the repeating transformer primary is equal to 2 henries in curve A, to 5 henries in curve B, and to 10 henries in curve C. In curves D, E, and F the grid-filament alternating current resistance is equal to 1,000,000 ohms; the no-load inductance of the repeating transformer primary is equal to 2 henries in curve D, to 5 henries in curve E, and to 10 henries in curve F.

If the amplifier is used in radio telephony it is important that the amplification be the same for all frequencies, otherwise speech distortion would result. The conditions upon which this can be obtained may be seen in the figure.

48. Comparison of low frequency and high frequency amplifier.—Because of the small effect at low frequencies it is unnecessary to take into account many phenomena that become important at high frequencies, and hence the designing of a low frequency amplifier is a much simpler task than that of a high frequency amplifier. With high frequency the small capacity of the tube and its leads become of prime importance. It is standard practice in the Signal Corps to use iron core intervalve transformers between high frequency amplifying tubes as well as between low frequency amplifying tubes. The iron core of the transformer adds to the difficulty of calculating the electrical constants. A high frequency transformer works best over a certain range of wave lengths if it possesses high efficiency.

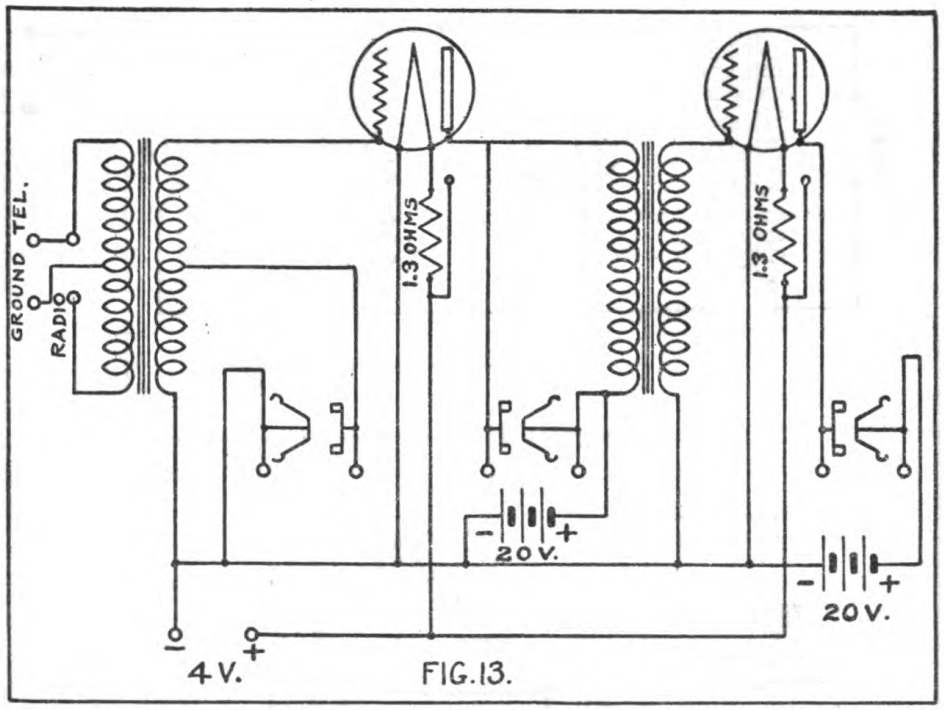


FIG. 13.

SECTION X.

PRINCIPLES EMBODIED IN THE SET BOXES AND THEIR CIRCUIT DIAGRAMS.

49. Amplifier Set Box Type BC–17.—This amplifier is a low frequency amplifier using iron core transformers. The circuit diagram is shown in figure 13. It is to be noted that connections are provided for tele-

phones so as to use one, two, or no stages of amplification. The plate voltage is 20 volts, there being one battery for each tube. The filaments are connected in parallel and no filament rheostat is provided. The grid is connected to the negative side of the filament. The drop in potential through the secondary of the transformers is sufficient to keep the grid at the negative potential that insures good operation. There are four input terminals arranged in two pairs. One pair uses the whole of the primary of the transformer, while the other pair uses only a part of it. Certain vacuum tubes require a greater filament voltage than others. In these tubes the positive terminal of the filament is permanently connected to the metal base of the

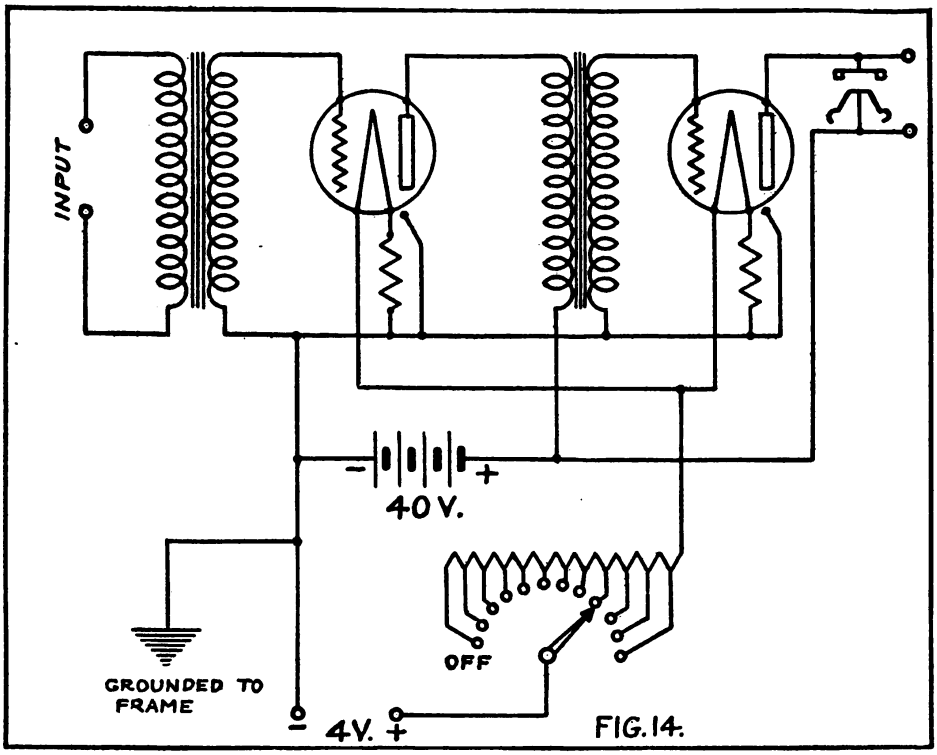


FIG. 14.

tube, and connection is installed in the amplifier from the metal socket to the positive side of the filament resistance whereby the resistance is thus automatically short circuited when a tube of this type is inserted. These tubes are, however, no longer standard Signal Corps equipment.

50. Amplifier set boxes type BC–44 and BC–44–A.—These amplifiers are identical except that the BC–44–A, whose circuit, as shown in figure 14, is provided with only one pair of input terminals, whereas the BC–44 is provided with two pairs similar to the BC–17 set box. These amplifiers are similar to the BC–17 amplifier, except that a rheostat is provided in the filament circuit; no provision is made to

use any except the total amplification that can be produced by the set, and the plate voltage is 40 volts instead of 20 volts.

51. Amplifier set box type BC–8–A.—This is an amplifier having three stages of radio frequency amplification followed by detection and two stages of audio frequency amplification. The circuits are shown in figure 15.

The radio frequency signal impressed on the grid of the first tube appears in amplified form as a radio frequency component of the direct current in the plate circuit. The plate direct current is supplied by the 40-volt battery through the primary of a radio frequency iron core transformer. The impedance of the primary causes a radio frequency voltage to be set up across it by the radio frequency current. This voltage is stepped up by the secondary winding because of its larger number of turns, and this increased voltage is then impressed on the grid. The second and third radio frequency amplifier tubes and the third radio frequency amplifier tube and the detector tube are coupled together in the same manner by radio frequency iron core transformers.

Radio frequency transformers operate best over a certain range of wave length. The transformers used in this amplifier operate well between 750 and 1,500 meters. Due to the fact that stray coupling always exists between the plate and grid circuits of an amplifier, the amplifier tends to generate oscillations. Such oscillations occur at that frequency at which the total losses of the amplifier are a minimum. This condition is also that at which maximum amplification is obtained. As the quality of the signal received is very poor when the amplifier is oscillating, it is desirable to operate the amplifier at the point just short of that at which oscillations occur, as it is at this point that the best readable signals are obtained. One of the factors that determines whether or not a tube will generate oscillations is the plate resistance. By adjusting the plate resistance the tube may, if other conditions permit, be brought to the point just short of oscillating. In order to secure this critical adjustment a rheostat is placed in series with the filaments of the radio frequency amplifier tubes. By varying the filament current the electron emission is varied. This changes the plate resistance and hence gives a control over one of the factors producing oscillations. The filament circuits of the three radio frequency amplifier tubes each contain a 0.5-ohm resistance, the common filament rheostat furnishing the balance of the resistance necessary in the filament circuits.

The transformers in the plate circuit of the third radio frequency amplifier tube has its secondary connected in series with the grid circuit of the detector tube. The detector tube circuit is of the type using a gridleak resistance and a condenser. The grid circuit is connected to the filament circuit so that the voltage drop across the

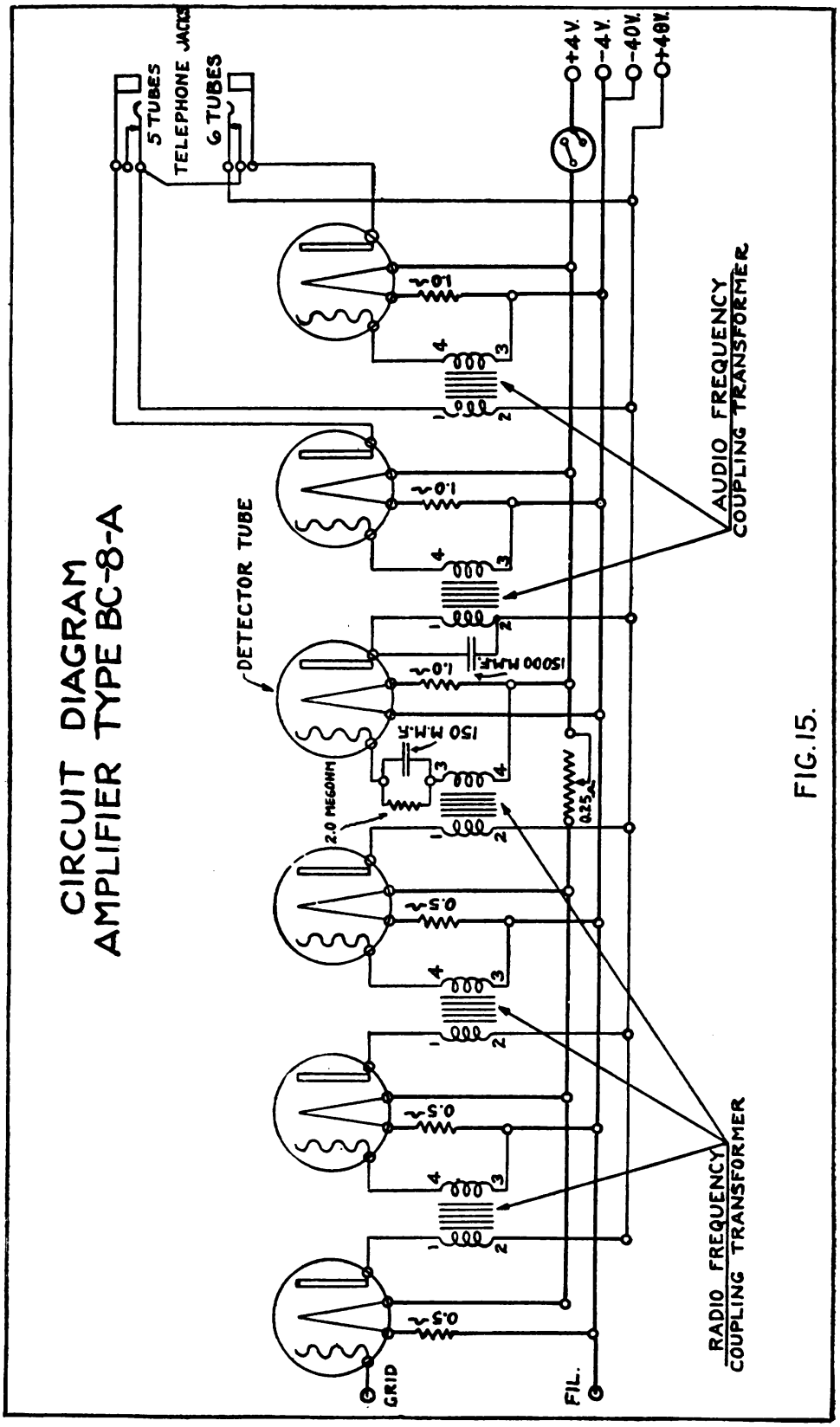


FIG. 15.

1.0-ohm resistance in the filament circuit places a positive biasing potential upon the grid. This potential is supplied through a 2-megohm gridleak resistance. The positive biasing potential causes a steady grid current to flow, the value of the current being such that the operation is located at the greatest bend of the *grid* current-*grid* voltage curve (using proper plate voltage). The incoming radio frequency signal then undergoes an effective rectification in the grid circuit. Because of the bend in the curve, the positive half of the cycle causes an increase in current that is greater than the decrease in current caused by the negative half of the cycle. The radio frequency voltage therefore causes a pulsating direct current to flow through the grid condenser. The action of the condenser is to store up these radio frequency pulsations. The condenser is charged so that the side connected to the grid becomes negative. The only way the negative charge can be dissipated is by a current passing through the 2-megohm resistance. As the voltage across the condenser is very small, an appreciable length of time is required to discharge the condenser energy. This time lag causes the radio frequency charges to build up so that the condenser charges and discharges at the group or spark frequency. The plate voltage is sufficient to make available the full amplification of the tube. The negative voltages appearing on the grid at the group of spark frequency are reproduced as an alternating current component of the direct current in the plate circuit. The plate current is supplied from the 40-volt battery, the primary of an audio frequency transformer being included in series with the battery. A radio frequency by-pass condenser of 0.0015 m. f. capacity is provided across the transformer primary.

The audio frequency current in the detector tube plate circuit has its potential stepped up by means of the audio frequency transformer, so that the largest possible potential is impressed on the grid of the first audio frequency amplifier tube. The amplifier audio frequency current obtained in the plate circuit of that tube is again amplified in a similar manner by the second audio frequency amplifier tube. Telephone jacks are provided in the plate circuits of both tubes so that either one or two stages of audio frequency amplification can be used as desired. When only one stage is used the telephone head set is connected in series with the plate circuit of the first audio frequency amplifier tube, and the audio frequency transformer primary in that circuit is shorted.

Provision is made for the use of only one stage of audio frequency amplification, because while increased amplification strengthens the signal, it also strengthens all interfering noises due to static, mechanical vibrations, audio frequency induction from near-by electrical apparatus, etc. Often, therefore, a weaker signal can be read more easily because of the reduction of intensity of interfering noises.

The current in the filament circuits of the two audio frequency tubes is limited to the proper value by 1 ohm resistances placed in each circuit. The potential drop across the resistance in the filament circuit of the tubes is used to furnish a negative biasing potential, which is applied to the grids of both audio frequency amplifier tubes.

52. Amplifier set box type BC–101.—This detector-amplifier is a vacuum tube detector and two-stage audio frequency amplifier. The circuit diagram is shown in figure 16. A switch is provided to enable the detector tube to be disconnected, if desired, in order to use the detector tube which may be included in the radio-receiving set. When the switch is thrown to "Detector" the input binding post marked "Grid" is connected to the grid of the detector tube. When the switch is thrown to "Amplifier" the input binding post marked "Grid" is connected to one terminal of the primary of the first audio frequency transformer. The other side of the primary of this transformer is then connected to the input binding post marked "Fil." The input binding posts are connected to the grid and filament of the detector tube when the switch is thrown to "Detector," and are connected to the primary of the first audio frequency transformer when the switch is thrown to "Amplifier." When the switch is thrown to "Amplifier" the filament circuit of the detector tube is opened.

When the switch is thrown to "Detector" the radio frequency voltages developed across the secondary circuit of the radio receiving set are impressed directly between the grid and filament of the detector tube. The 1.05-ohm resistance in the detector tube filament circuit is used to place a proper negative biasing potential on the grid. The plate current for the detector tube is furnished from the 40-volt battery through the primary of an audio frequency transformer and a 0.5 megohm resistance. The resistance is by-passed for both audio and radio frequency currents by a 0.15 m. f. condenser. The primary of the audio frequency transformer is by-passed for radio frequencies by a 0.005 m. f. condenser. The effective value of plate voltage and the value of negative biasing potential on the grid are such that the value of plate current obtained is located on the greatest bend of the *grid* voltage *plate* current curve. This causes one-half of the radio frequency cycle to be amplified more than the other half of the cycle. An audio frequency current is thereby set up having the frequency of the spark signal or the heterodyne beat note signal.

Two binding posts are provided in series with the plate circuit of the detector tube. The binding posts are normally connected together, but the connecting strap may be removed and a tickler coil forming part of the radio receiving set connected between the bind-

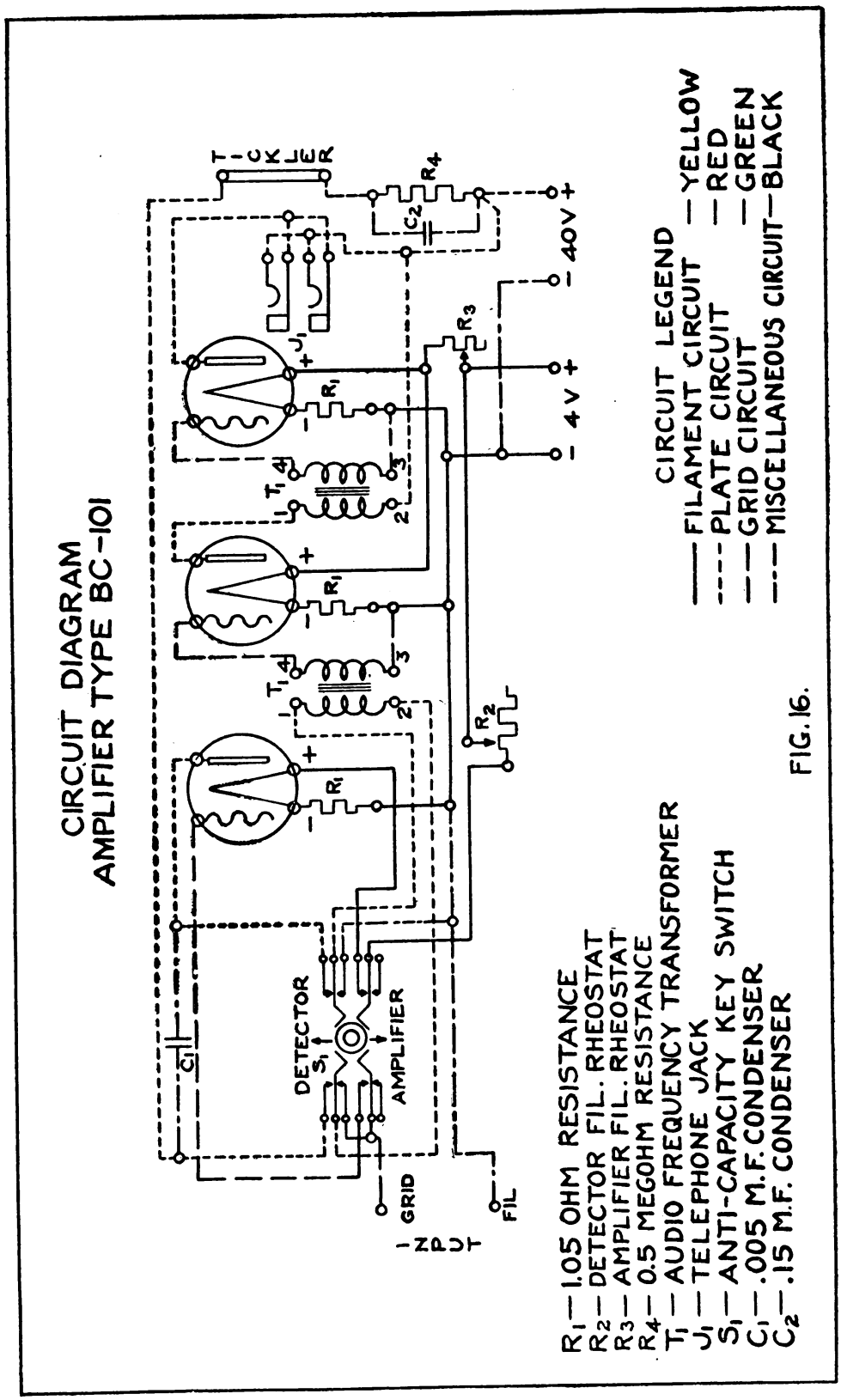


FIG. 16.

ing posts. By means of the tickler coil the detector tube circuit can be made regenerative for the purpose of strengthening spark or other damped wave signals, or can be made to oscillate for the purpose of heterodyning undamped wave signals.

When the switch is thrown to "Amplifier" the audio frequency voltages developed in the plate circuit of the detector tube forming part of the radio receiving set are impressed across the primary of the audio frequency transformer connected to the first audio frequency amplifier tube.

The operation of the audio frequency amplifier tube is the same whether the detector circuit forming part of BC–101 or a separate detector is used, and is analogous to the low-frequency stages of the BC–8–A amplifier. The current in the filament circuits of the three tubes is limited to the proper value for the VT–1 tube operated from a 4-volt battery by means of a 1.05-ohm resistance placed in each circuit. The potential drop across this fixed resistance in the filament circuit of each tube is used to furnish a negative grid biasing potential. It will be noted that the normal operating current for VT–1 tube filaments is determined by the 1.05-ohm fixed resistance in the circuit of each tube, with the filament control rheostats turned clockwise until the resistance is all cut out.

Type VT–5 tubes require 0.25 ampere at 1.1 volts. When VT–5 tubes are used in the BC–101, a 2-volt storage battery or one closed circuit (ignition) type dry cell (1.4 volts) is connected to the filament battery binding posts. The detector tube filament circuit contains a rheostat providing a maximum resistance of 10 ohms. The two amplifier tube filament circuits are supplied through a common rheostat providing a maximum resistance of 5 ohms. The rheostats provide ample resistance range for operating the VT–5 tubes from the battery sources mentioned above. The detector tube and amplifier tubes are supplied through separate rheostats because the detector tube may require a slightly different value of current for best operation than the value required for amplifier tubes. A control of amplification, using either VT–1 or VT–5 tubes, is obtained by varying the filament control rheostat in the circuit of the amplifier tubes.

53. Amplifier set box, type BC–103.—This is an amplifier having 3 stages of radio frequency amplification, followed by a detector and 2 stages of audio frequency amplification. By means of a switch and separate terminals provision is made for the use of only the audio frequency amplification when desired. When thrown to the audio amplification position, the switch opens the filament circuit of the four tubes that are not in use. The circuit diagram is shown in Fig. 17. The amplifier resembles the BC–8–A amplifier. It differs mainly in that a control in addition to the filament control is

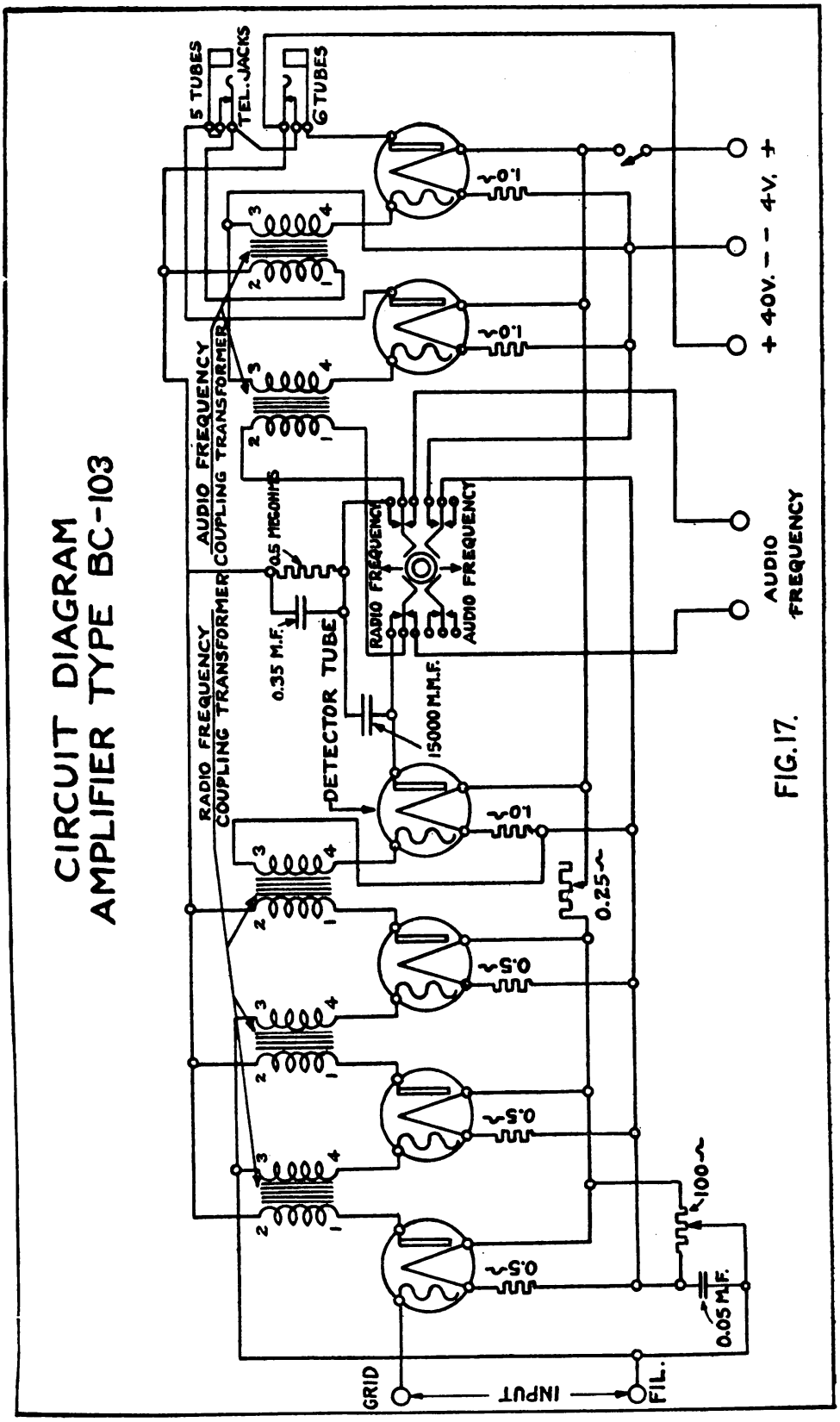


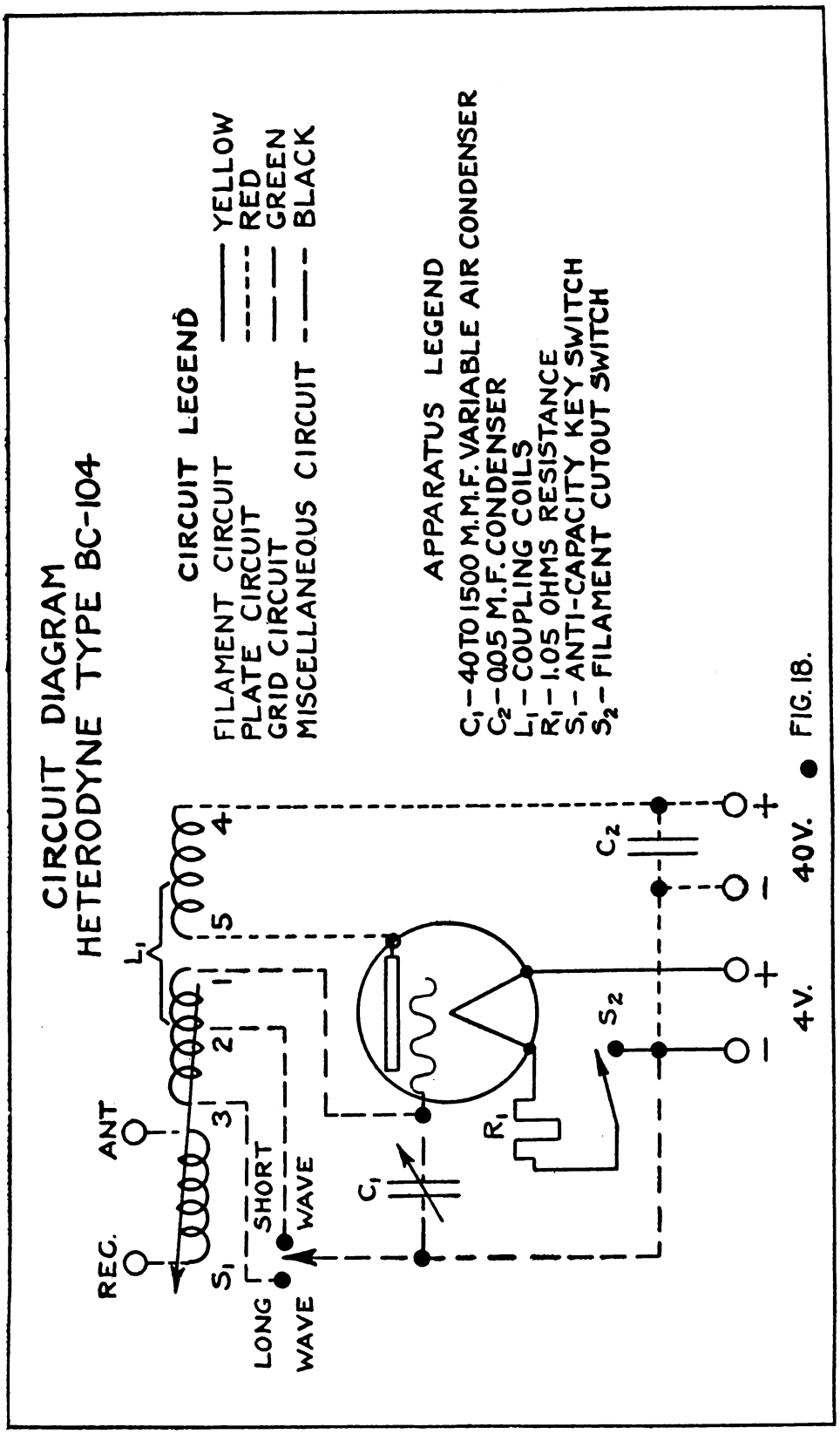
FIG. 17.

given to the high frequency amplifiers, and in that no grid-leak and condenser are used in the grid circuit of the detector tube.

As has been stated greatest amplification is obtained when the amplifier is oscillating, but as this gives signal of poor quality, it is desirable to arrange the amplifier constants so that the amplifier is just at the point of oscillating, at which point the best readable signals are obtained. These constants will vary with different wave lengths and hence controls are necessary. In addition to the filament rheostat control found in the BC–8–A, there is a voltage divider (potentiometer) which is controlled from the panel. By means of this voltage divider, the average potential of the grid may be varied. Varying the potential of the grid varies the plate resistance of the tubes and hence, within limits, it is possible by this means to bring the amplifier to the point of oscillating.

The transformer in the plate circuit of the third radio frequency amplifier tube has its secondary connected directly between the grid and filament of the detector tube. The 1.0 ohm resistance in the detector tube filament circuit is used to place a proper negative biasing potential on the grid. The plate current for the detector tube is furnished from the 40-volt battery through the primary of an audio frequency transformer and a 0.5 megohm resistance. The resistance is by-passed for both audio and radio frequency currents by a 0.35 m. f. condenser. The primary of the audio frequency transformer is by-passed for radio frequencies by a 0.015 m. f. condenser. The effective value of plate voltages and the value of negative biasing potential on the grid are such that the value of plate current obtained is located on the greatest bend of the grid voltage-plate current curve. This causes one-half of the radio frequency cycle to be amplified more than the other half of the cycle. An audio frequency current is thereby set up having the frequency of the spark signal or the heterodyne beat note signal.

54. Heterodyne set box, type BC–104.—In order to cause a tube to oscillate it is necessary to couple the grid and plate circuit in such a manner that the transfer of energy from the plate to the grid circuit will compensate for all losses in the grid circuit. Inductive coupling is used for this purpose in the BC–104, whose circuit diagram is shown in figure 18. Frequency of oscillation is determined in the heterodyne by the grid circuit, which contains a variable air condenser, C_1, and an inductance variable in two steps. The condenser, C_2, is placed across the terminals of the plate battery and furnishes a by-pass for the oscillations in the plate circuit. It is to be noted that the coil transferring energy to the output circuit is the grid coil. The heterodyne is so designed that oscillation will be started as soon as the filament current is turned on. The oscillations are



strong enough to persist under any operating conditions that may occur in the receiving antenna circuit.

As is well known, the heterodyne method of reception consists of generating local oscillations, which, added to the incoming signal oscillation, produces a beat note which may be made of audible frequency. The local oscillation added to the incoming oscillation has the effect of amplifying it. The amplitude of the local amplification which produces the greatest effective amplification depends upon the amplitude of the incoming signal and to some extent upon the design of the receiving and detecting apparatus. The amplitude of the local oscillation which is added to the received oscillation may be varied by varying the coupling between the heterodyne and receiving circuits. A control handle is provided for this purpose.

In addition to the many advantages possessed by the beat method of reception, the method of using a heterodyne for this purpose has the following advantages over the method which uses an autodyne: In using an autodyne there must be a close reactance coupling between the grid and plate circuits of the autodyne tube, and hence interfering signals, especially spark, will be amplified. In using an autodyne it must be slightly detuned in order to produce beats of desired frequency; this weakens the incoming oscillations. A heterodyne can also be calibrated and used as a wave meter.

SECTION XI.

PARTS LIST OF SETS.

55. Equipments in complete sets.—The equipments forming the complete sets of the amplifiers and heterodynes described in this pamphlet are as follows:

Set T. P. S. receiving, type SCR–72:
- Equipment, type GD–3.
- Equipment, type PE–12.
- Equipment, type RC–3.

Set T. P. S. receiving, type SCR–72–B:
- Equipment, type GD–3–A.
- Equipment, type PE–10.
- Equipment, type RC–3–B.

Set low frequency amplifier, type SCR–121:
- Equipment, type PE–10.
- Equipment, type RC–11.

Set low frequency amplifier, type SCR–121–B:
- Power equipment, type PE–38.
- Amplifier equipment, type RC–11–B.

Amplifier set, type SCR–144:
- Power equipment, type PE–38.
- Amplifier equipment, type RE–24.

Amplifier set, type SCR–145:
    Power equipment, type PE–38.
    Amplifier equipment, type RE–25.
Heterodyne set, type SCR–146:
    Power equipment, type PE–38.
    Heterodyne equipment, type RE–26.
Amplifier set, type SCR–147:
    Power equipment, type PE–38.
    Amplifier equipment, type RC–3–A.
Amplifier set, type SCR–148:
    Power equipment, type PE–38.
    Amplifier equipment, type RE–27.
Amplifier set, type SCR–149:
    Power equipment, type PE–38.
    Amplifier equipment, type RE–28.

56. Parts list of equipments.—The equipments listed in the paragraph above comprise parts as follows:

Power equipment, type PE–10:
    Battery, type BB–14 (3)—1 in use, 2 spare.
Power equipment, type PE–12:
    Battery, type BB–2 (2)—1 in use, 1 spare.
Power equipment, type PE–38:
    Battery, type BB–28 (2)—1 in use, 1 spare.
Radio equipment, type RC–3:
    Battery, type BA–2 (4)—2 in use, 2 spare.
    Case, type CS–2 (1).
    Cord, type CD–22 (1).
    Headset, type P–11 (2).
    Radio Communication Pamphlet No. 9 (1).
    Set box, type BC–17 (1).
    Tube, type VT–1 (4)—2 in use, 2 spare.
Amplifier equipment, type RC–3–A:
    Battery, type BA–2 (4)—2 in use, 2 spare.
    Case, type CS–2 (1).
    Cord, type CD–50 (1). (Equipped with terminal type TM–12–A instead of TM–12.)
    Cord, type CD–56 (1).
    Headset, type P–11 (2).
    Radio Communication Pamphlet No. 9 (1).
    Set box, type BC–17 (1).
    Tube, type VT–1 (4)—2 in use, 2 spare.
Radio equipment, type RC–3–B:
    Bag, type BG–13 (1).
    Battery, type BA–2 (4)—2 in use, 2 spare.
    Compass, watch, luminous dial (1).
    Cord, type CD–40 (2)—1 in use, 1 spare.
    Cord, type CD–56 (1).
    Headset, type P–11 (2).
    Pliers, 6-inch combination (1).
    Radio Communication Pamphlet No. 9 (1).
    Screwdriver, 1½-inch blade, ⅛-inch tip (1).

Radio equipment, type RC–3–B—Continued.
Set box, type BC–44 (1).
Tape, friction (½ pound).
Tube, type VT–1 (4)—2 in use, 2 spare.
Voltmeter, type I–10 (1).
Radio equipment, type RC–11:
Battery, type BA–2 (4)—2 in use, 2 spare.
Cord, type CD–40 (2)—1 in use, 1 spare.
Cord, type CD–56 (1).
Headset, type P–11 (2).
Radio Communication Pamphlet No. 9 (1).
Set box, amplifier, type BC–44–A (1).
Tube, type VT–1 (4)—2 in use, 2 spare.
Amplifier equipment, type RC–11–B:
Battery, type BA–2 (4)—2 in use, 2 spare.
Cord, type CD–50 (2)—1 in use, 1 spare. (Equipped with terminal, type TM–12–A instead of TM–12.)
Cord, type CD–56 (1).
Headset, type P–11 (2).
Radio Communication Pamphlet No. 9 (1).
Set box, amplifier, type BC–44–A (1).
Tube, type VT–1 (4)—2 in use, 2 spare.
Amplifier equipment, type RE–24:
Battery, type BA–2 or BA–8 (4)—2 in use, 2 spare.
Cord, type CD–50 (1). (Equipped with terminal, type TM–12–A instead of TM–12.)
Headset, type P–11 (2).
Radio Communication Pamphlet No. 9 (1).
Set box, amplifier, type BC–8–A (1).
Tubes, type VT–1 (12)—6 in use, 6 spare.
Amplifier equipment, type RE–25:
Battery, type BA–2 or BA–8 (4)—2 in use, 2 spare.
Cord, type CD–42 (1).
Cord, type CD–50 (1). (Equipped with terminal, type TM–12–A instead of TM–12.)
Headset, type P–11 (2).
Radio Communication Pamphlet No. 9 (1).
Set box, amplifier, type BC–103 (1).
Tubes, type VT–1 (12)—6 in use, 6 spare.
Heterodyne equipment, type RE–26:
Battery, type BA–2 or BA–8 (4)—2 in use, 2 spare.
Cord, type CD–50 (1). (Equipped with terminal, type TM–12–A instead of TM–12.)
Radio Communication Pamphlet No. 9 (1).
Set box, heterodyne, type BC–104 (1).
Tubes, type VT–1 (2)—1 in use, 1 spare.
Amplifier equipment, type RE–27:
Bag, type BG–13 (1).
Battery, type BA–2 (4)—2 in use, 2 spare.
Cord, type CD–50 (1). (Equipped with terminal, type TM–12–A instead of TM–12.)
Cord, type CD–56 (1).
Headset, type P–11 (2).

Amplifier equipment, type RE–27—Continued.
Radio Communication Pamphlet No. 9 (1).
Set box, amplifier, type BC–44 (1).
Tubes, type VT–1 (4)—2 in use, 2 spare.
Amplifier equipment, type RE–28:
Bag, type BG–45 (1).
Battery, type BA–2 (4)—2 in use, 2 spare.
Case, type CS–20 (1).
Cord, type CD–50 (1). (Equipped with terminal, type TM–12–A instead of TM–12.)
Cord, type CD–56 (1).
Headset, type P–11 (2).
Radio Communication Pamphlet No. 9 (1).
Set box, amplifier, type BC–101 (1).
Tubes, type VT–1 (6)—3 in use, 3 spare.
Ground equipment, type GD–3 (used in T. P. S. sets):
Bag, type BG–3 (1).
Drum, type DR–3 (2).
Hammer, 2 lb. cross-peen (1).
Reel, type RL–6 (1).
Stake, type GP–4, or GP–6, or GP–14 (12).
Wire, type W–4 (1,000 feet).
Wire, type W–5 (60 feet).
Ground equipment, type GD–3–A (used in T. P. S. sets):
Bag, type BG–8 (1).
Drum, type DR–3 (2).
Hammer, 2 lb. cross-peen (1).
Reel, type RL–6 (1).
Stake, type GP–6 (12).
Wire, type W–4 (1,000 feet).
Wire, type W–5 (60 feet).

SIGNAL CORPS PAMPHLETS.

(Corrected to February, 1922.)

RADIO COMMUNICATION PAMPHLETS.

(Formerly designated Radio Pamphlets.)

No.

1. Elementary Principles of Radio Telegraphy and Telephony (edition of 4–28–21) (W. D. D. No. 1064).
2. Antenna Systems.
3. Radio Receiving Sets (SCR–54 and SCR–54–A) and Vacuum Tube Detector Equipment (Type DT–3–A).
5. Airplane Radio Telegraph Transmitting Sets (SCR–65 and SCR–65–A).
9. Amplifiers and Heterodynes (W. D. D. 1092).
11. Radio Telegraph Transmitting Sets (SCR–74; SCR–74–A).
13. Airplane Radio Telegraph Transmitting Set (Type SCR–73).
14. Radio Telegraph Transmitting Set (Type SCR–69).
17. Sets, U. W. Radio Telegraph (Types SCR–79–A and SCR–99) (W. D. D. 1084).
20. Airplane Radio Telephone Sets (Types SCR–68; SCR–68–A; SCR–114; SCR–116; SCR–59; SCR–59–A; SCR–75; SCR–115).
22. Ground Radio Telephone Sets (Types SCR–67; SCR–67–A) (W. D. D. 1091).
23. U. W. Airplane Radio Telegraph Set (Type SCR–80).
24. Tank Radio Telegraph Set (Type SCR–78–A).
25. Set, Radio Telegraph (Type SCR–105) (W. D. D. 1077).
26. Sets, U. W. Radio Telegraph (Types SCR–127 and SCR–130) (W. D. D. 1056) (edition of Nov., 1921).
28. Wavemeters and Decremeters (W. D. D. 1094).
30. The Radio Mechanic and the Airplane.
40. The Principles Underlying Radio Communication (edition of May, 1921) (W. D. D. 1069).

WIRE COMMUNICATION PAMPHLETS.

(Formerly designated Electrical Engineering Pamphlets.)

1. The Buzzerphone (Type EE–1).
2. Monocord Switchboards of Units Type EE–2 and EE–2–A and Monocord Switchboard Operator's Set Type EE–64 (W. D. D. 1081).
3. Field Telephones (Types EE–3; EE–4; EE–5).
4. Laying Cable in the Forward Area (formerly designated Training Pamphlet No. 3).
6. Trench Line Construction (formerly designated Training Pamphlet No. 6–a).
7. Signal Corps Universal Test Set Type EE–65 (edition of Dec., 1921) (W. D. D. 1020).
10. Wire Axis Installation and Maintenance Within the Division (W. D. D. 1068).
11. Elements of the Automatic Telephone System (W. D. D. 1096).

TRAINING PAMPHLETS.

1. Elementary Electricity (edition of 1–1–21) (W. D. D. 1055).
2. Instructions for using the cipher device Type M–94. (W. D. D. 1097.) (For official use only.)
4. Visual Signaling.
7. Primary Batteries (formerly designated Radio Pamphlet No. 7).
8. Storage Batteries (formerly designated Radio Pamphlet No. 8).

FIELD PAMPHLETS.

1. Directions for Using the 24–CM. Signal Lamp (Type EE–7).
2. Directions for Using the 14–CM. Signal Lamp (Type EE–6).

AMPLIFIERS AND HETERODYNES.

RADIO COMMUNICATION PAMPHLET NO. 9.

SECTION I.

APPARATUS DESCRIBED IN PAMPHLET.

1. Apparatus described in pamphlet.—A radio set comprises two or more equipments, which together form a set and are given an SCR type number. Each equipment is given a type number, different type numbers being assigned to equipments that vary even in only one particular. The radio equipment, proper, described in this pamphlet varies mainly in the set boxes. It is to be noted that some of these are the same for different SCR numbers; this is because the auxiliary equipment is different, thus necessitating a different SCR number. Receiving T. P. S. sets have been included because they can be used for low frequency amplification, although ground telegraphy itself is no longer used in army communications.

It is the set boxes that are described in detail in this pamphlet. The following data will enable one to find the description desired:

Set box BC–17 is the amplifier of the SCR–72 and SCR–147 sets.

Set box BC–44 is the amplifier of the SCR–72–B and SCR–148 sets.

Set box BC–44–A is the amplifier of the SCR–121 and SCR–121–B sets.

Set box BC–8–A is the amplifier of the SCR–144 set.

Set box BC–101 is the amplifier of the SCR–149 set.

Set box BC–103 is the amplifier of the SCR–145 set.

Set box BC–104 is the heterodyne of the SCR–146 set.

Full parts lists of each set are given in Section XI.

SECTION II.

NOTES ON CARE AND OPERATION OF AMPLIFIERS AND HETERODYNES.